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Abstract Summaries

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High-Power Lasers and Applications V

7843-01, Session 1

Narrow linewidth and widely tunable operation of Tm:fiber laser with volume Bragg gratings

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Volume Bragg gratings (VBGs) recorded in photo-thermal refractive (PTR) glass combine the advantages of high diffraction efficiency (>99%), narrow spectral width (<20pm), low insertion losses, high damage threshold and good thermal stability. In this work, we demonstrate narrow spectral width and widely tunable operation of cladding pumped high power Tm:fiber laser using volume Bragg grating for wavelength selection and spectrum narrowing. The operating wavelength was continuously tunable from 1930 to 1821 nm, with > 52 W output power over a tuning range of 104 nm from 1930 to 1826 nm, which is, to the best of our knowledge, the most wide tuning range demonstrated to date using a volume Bragg grating. Over 60.8 W of diffraction limited (M2 ~ 1.5) CW output power was generated at 1930 nm for 137 W of launched pump power, corresponding to a slope efficiency with respect to launched pump power of 46%. Output spectral widths (FWHM) were measured to be < 12 pm over the whole tuning range. The VBG-locked laser had almost identical performance in terms of slope efficiency, threshold and output power with that of a free running laser using a broadband dielectric end mirror. More over, output power shows a nearly linear dependence on the pump power, even at the highest pump power, suggesting that there is scope for further power scaling by simply increasing the input pump power. Prospects for further spectral narrowing using novel VBG paring technique are discussed.

7843-02, Session 1

High-power Tm3+-doped fiber amplifier with 100-W pulsed laser output

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By the combination of a Q-switched Tm:LuLiF crystal laser and double-clad Tm fiber amplifiers, 100-W power level ~2-μm pulsed laser output has been achieved. This is believed to be the first time to demonstrate a high average-power pulsed ~2 μm fiber laser source. Pumped by diode modules at 793 nm, the master oscillator fiber power amplifier system provided a slope efficiency of ~52%. By using an acousto-optic modulator, the laser pulse width can be tuned between 80 ns and ~1 μs, and the pulse repetition rate can be changed from 500 Hz to 50 kHz. The maximum pulse energy can be as high as ~10 mJ. With increasing signal output power, the pulse evolution and spectral variation were also investigated. Limitation of amplified pulse energy and peak power with the current specialty Tm fiber, and how to improve these values were discussed.

7843-03, Session 1

Amplification of spontaneous emission in 2μm single frequency master oscillator and fiber power amplifier

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2 micron solid-state lasers have attracted a great deal of attentions in recent years. 2 micron lasers have many potential applications, such as remote sensing, medical applications, laser radars, and optical communications in free space. 2 micron lasers are also useful for pumping solid-state lasers and optical parametric oscillators which operate in the mid-infrared region. In some of the applications, high output power or energy as well as narrow linewidth and good beam quality are required, e.g. coherent wind sensing lidar or coherent beam combination. A master-oscillator power-amplifier (MOPA) system is ideal to obtain narrow linewidth and at the same time, high output power. We reported a single frequency laser source consisting of a Tm:YAP coupled-cavity master-oscillator and a Tm-doped fiber power amplifier. The single frequency seed was a Tm:YAP coupled-cavity laser. The maximum single frequency output power was 721mW, the slope efficiency of single-frequency laser operation was 46%. The seed beam was coupled into a 4-meter-long double-cladding LMA Tm3+ and Al3+ co-doped fiber core which was cladding-pumped by a 793nm laser diode. The MOFPA yielded 5W of single frequency output at 1990nm. A strong amplification of spontaneous emission (ASE) was observed when higher pumping power was applied. We studied the influence of the input signal power and pumping power to the ASE. We found the input signal power was crucial to the efficiency of the MOPA system. In order to extract the high gain in the active fiber when it was pumped by high power laser diode, substantially high input signal was needed.

7843-04, Session 1

Analysis and suppression of modal noise in single mode large mode area double cladding fiber amplifier

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Up-to-date continuouse single mode fiber laser produe level of kW output power, and fiber lasers have been extensive used in many areas. An increase of the core size and decrease of the NA in large mode area (LMA) doubel cladding fibers can substantially reduce the power density still with single transverse mode, which is benificial to high power fiber laser systems. But when the coupling from the seed laser to the amplifier is not goog, the model noise of the output amplifed laser will be found. The mechanism of the modal noise in single mode large mode area double cladding amplifier was described at first. It was mainly because of the two modes'mismatch, then the signal light partially coupled into the clad of the LMA-DCF and was amplified together with the signal light which propagated in the fiber core. The suppression of the modal noise was also given at the same time. And the experimental result show good agreement with the theoretical.

7843-05, Session 1

The slope efficiency of 2μm thulium doped fiber laser

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In order to obtain high slope efficiency of 2 μm laser output, it is essential to design operating parameters of fiber laser prior to the experiment. Based on the rate equations, the pump and signal power equations of the thulium doped fiber laser have been built. The effects of the cross relaxation coefficient K3101, the pump power filling factor p, the laser reflectivity of input mirror R3, the laser reflectivity of output mirror R4, and the Tm3+ concentration N of kilowatt level thulium doped fiber laser on the slope efficiency have been theoretically analyzed by

the numerical method. In this paper, the high slope efficiency has been obtained and optimized. Besides, the slope efficiency is decreased by 67% with the increasing of laser reflectivity of output mirror and 22% with the increasing of pump power filling factor when the pump power is 1000 W, the doping concentration is 8×1026 m-3 and the cross relaxation coefficient is 1×10-22 m-3s-1. Meanwhile, the slope efficiency increases with increasing the laser reflectivity of input mirror, the doping concentration and the cross relaxation coefficient, but the doping concentration and the cross relaxation coefficient have more obvious influence on the slope efficient compared with the laser reflectivity of input mirror.

7843-06, Session 2

Active and passive coherent beam combining of thulium-doped fiber lasers

P. Zhou, X. Wang, Y. Ma, K. Han, Z. Liu, National Univ. of Defense Technology (China)

Recently, thulium-doped fiber laser (TFL), which emitted near 2 um laser beam, has become the latest revolution in high-power fiber laser technology. TFL can find wide application in medicine, lidar, materials processing, and nonlinear frequency conversion to mid-infrared wavelength regime. Nevertheless, further increasing the output power will face great challenges induced by nonlinear effects such as SBS and SRS.

Coherent beam combining of lasers beams can increase laser output power while simultaneously maintaining beam quality. Several approaches have been proposed and robust coherent combining of a small number of fiber lasers/amplifiers have been demonstrated. All those demonstration focused on Yb-doped or Er-doped fiber lasers. As the increasing requirement of high brightness TFLs is many application fields, coherent beam combining of TFL is also a key technology deserves to be investigated.

In this manuscript, we will present our investigation on coherent beam combining of TFLs. Three different approaches, i.e., interferometric array, mutual injection locking and active phasing based on frequency-dithering technique, are employed.

In the interferometric array scheme, coherent combining is realized by using an intracavity fiber coupler in an all-fiber laser array configuration. Efficient coherent combining can be achieved by providing sufficient loss discrimination. High combining efficiency of 85% for two fiber laser has been obtained.

In mutual injection locking scheme, mutual coherence between the two fiber lasers is established by means of mutual coupling through two 3dB couplers. High combining efficiency of 99% for two fiber laser has been obtained, and the fringe contrast of the intensity pattern at the receiving plane is as high as 93%.

In active phasing scheme, when the phase control system is in the closed loop, the fringe contrast of far-field intensity pattern is improved by more than 90 % from 10 % in open loop, and the residual phase error is less than /15.

7843-07, Session 2

Coherent beam combining of stimulated Brillion scattering based multiwavelength lasers

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Coherent beam combining of fiber lasers is an efficient way to get high power laser with good beam quality as the fiber laser power scaling is restricted in terms of thermal load, fiber damage and nonlinear effect. In two main configuration of coherent beam combining, including passive phasingand active phasing configuration master oscillator power amplifier (MOPA) based on active phase control is the most effective way for coherent beam combining. In active phasing MOPA configuration, signal frequency seed laser is often considered to be necessary to improve the spatial coherence property and obtain high brightness in the far-field. Nevertheless, the output power of the single frequency amplifier is about hundreds watts level as restrict of nonlinear effects, especially the stimulated Brillouin scattering (SBS), and this is a great challenge to increase the total power of coherent beam combining. Multi-wavelength seed laser can suppress SBS and improve the ultimate output power of the fiber laser amplifier. According to Dajani et al, if the amplifier seeded by multi-wavelength with wavelength separation is equal to or greater than the twice of the Brillouin shift, the output power can be about N times of a single-wavelength amplifier at SBS threshold with no signs of four-wave mixing. Where N is the number of the seed laser. In this we will demonstrate coherent beam combining of stimulated Brillouin scattering based multiwavelength fiber lasers for the first time. Multiwavelength laser is generated using stimulated Brillouin scattering by seeded a 10 kilometer single mode fiber with a single frequency laser. Multiwavelength lasers more than 8 wavelengths are generated and phase locking of is achieved using stochastic parallel gradient descent (SPGD) algorithm. The mean power of the main-lobe in close-loop is 1.5 times of that value in open-loop. As multiwavelength seeded fiber amplifiers can reach a higher ultimate powers than single frequency seeded amplifiers, this architecture is easily scalable to higher power with the MOPA configuration.

7843-08, Session 2

Mutual injection phase-locked and coherent combined of inter-related fiber lasers

M. Zhu, Y. Chen, H. Wang, Y. Liu, C. Mi, C. Lu, Wuhan Mechanical Technology College (China)

Mutual Injection Phase-Locked coherent laser array seems to be a important method for coherent combining fiber lasers. A novel fiber laser is designed to realize high power and high quality beam fiber laser coherent beam combining output. The two fiber lasers share fiber bragg grating(R=0.85@1085nm)as preceding mirror,so they are associated with each other.

Based on a corner-cube,the mutual injected energy is enhanced. And by a polarizer, coherent beam combining output is realized.Through experiments: steady interference stripes with high contrast ratio (about 0.92)are observed and about 9.4 W output power is achieved which indicates that the power combining efficiency is approximately 90%,line width is almost 530GHz. Mutual injection-locking theory is analyzed.

The combining method can be scaled to combine more lasers. Successful attempts of phase-locked show that this method may provide a promising way in the field of fiber laser coherent.

7843-09, Session 2

Thulium-doped silica fibers with enhanced 3H4 level lifetime: modelling the devices for 800-820 nm band

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Silica-based thulium-doped fiber (TDF) devices operating around 810 nm would extend the spectral range covered by single-transverse mode, high-power fiber devices. These devices can be used for fiber sensors, instrument testing, health care and medicine and for

pumping of special types of lasers and amplifiers. Particularly, bismuth-doped fibers pumped around 800 nm may shift their gain to 1300 nm telecommunication band, where highly reliable silica-based fiber amplifiers are still unavailable. Broadband sources based on TDFs would offer advantages of unpolarized and high power output that are weak points of superluminescent diodes used in fiber sensors. A high-power amplifier in the 800 nm band would be useful in short-haul free-space and optical fiber communications.

Using a comprehensive numerical model of the fiber we have shown that efficient lasing at 810 nm can be achieved for specific ranges of the laser cavity parameters and enhanced 3H4 lifetime. The 3H4 lifetime of 58 μs was measured in our highly alumina-codoped fibers that represents a significant improvement compared to pure or weakly modified silica glass (14 μs). We have predicted more than the 30 dB of gain of the amplifier and more than 500 mW output power of the ASE source with FWHM of 5 nm at 3 W of pump power. Two upconversion pumping schemes enabling compact all-fiber setup are investigated: single-wavelength pumping at around 1060 nm and dual-wavelength pumping scheme at 1455 and 1560 nm. Dual-wavelength pumping scheme would avoid populating of 1G4 and higher levels and can mitigate the color center formation.

7843-10, Session 3

High power high stability green laser based on LD pumped composite ceramic Nd:YAG rod

D. Xu, Tianjin Univ. (China)

We report a 153 W average power green laser employing intracavity frequency doubling of a diode-side-pumped double Q-switched composite Nd:YAG ceramic laser. The two synchronized acousto-optic modulators are placed orthogonally to hold off the very high pump gain for efficiently Q-switching operation. Type II high gray track resistance KTP (HGTR KTP) crystal is used as double frequency nonlinear crystal in order to avoid the gray-track problem. The diode-to-green optical conversion efficiency is 14.27%. To the best of our knowledge, it is the highest green power and efficiency obtained by intracavity frequency doubling of this novel composite ceramic Nd:YAG laser. Both efficiency and output power have been improved greatly compared to the previous reports. The measured green laser pulse width is 162 ns with repetition rate of 25 kHz. The fluctuation measured is less than 0.6% at around 150 W average output power.

7843-11, Session 3

Microstructure and NIR to VIS upconversion luminescence of Y2O3:Er translucent ceramics

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Y2O3:5%Er nanocrystalline powder was prepared by low temperature combustion method. The crystal structure and morphology were analyzed by means of XRD and HRTEM. The resultant powders were sintered into translucent ceramics at 1570 degree in vacuum for 6 hours. The micrograph of unpolished surface and fracture surfaces showed that the sintered Y2O3:Er ceramics with average grain size at about 10 m had homogeneous micro-structure and low pore volume. Under the excitation of 980nm, 808nm and 785nm diode laser, respectively, very strong green and red upconversion emissions from Er3+ ions were observed, the power dependence of upconversion emission intensity was measured to deduce the upconversion mechanism. A trend of upconversion intensity increase first and then decrease with the excitation time was also found for the first time.

7843-13, Session 3

Investigation of thermal effects in a diode end-pumped Tm,Ho:YLF solid state laser

Y. Peng, X. Zhang, L. Li, B. Jiang, Harbin Engineering Univ. (China)

The laser diode (LD) end-pumped solid-state laser has been always investigating recently for its advantages, such as compact and simple instruction, high efficiency, stable performance and so on. The spectrum region around 2μm which can be emitted from Tm,Ho:YLF plays an important role in the field of laser radar, remote sensing and high-resolution molecular spectroscopy for the good air transmission and eye-safety. The investigation in the LD end-pumped solid-state laser is focused on how to improve the output laser power and output laser efficiency. But thermal effects limit the improvement of the laser performance and even make the resonator unstable by reducing the population of laser upper level and changing physical properties of the crystal.

In this paper, thermal effects are investigated by numerical and experimental methods. Considering Gaussian field distribution of pump light and output laser, a set of 8-level continuous wave rate equations of Tm,Ho:YLF laser is given. The rate equations are solved in the steady state, and the fractional thermal loading and the thermal focal length of the Tm,Ho:YLF laser are theoretically obtained. The M2 factor and thermal focal length as a function of the pump power are measured by the knife edge method. M2 factors are less than 1.2 for various pump powers which shows that the laser beam is TEM00 mode. Then the focal length as a function of pump power is obtained by measuring the far-field divergent angle, and it is found that the theoretical results agree well with the experimental results.

7843-14, Session 3

Study on second harmonic generation output in pulsed TEA CO2 laser

R. Guo, D. Li, Changchun Institute of Optics, Fine Mechanics and Physics (China)

Firstly, through the second method the comparison between two nonlinear crystals ZnGeP2 and AgGaSe2 is conducted for their nonlinear coefficient and damage threshold in theory. The theoretical results show that the crystal AgGaSe2 is more suitable for the SHG of pulsed TEA CO2 laser. When using pulsed TEA CO2 laser with wavelength of 9.3μm to pumping AgGaSe2 SHG crystal, the wavelength of 4.65 m is obtained. In the condition of repetition rate 100Hz, the upmost output power of single pulse is up to level of 1W, which corresponding efficiency of SHG is about 6%. The experimental results show that the polarization of laser beam has greatly influence on the SHG output of the crystal. Under the radiation of 3MW/cm2 from fundamental wave and the right position for maximal SHG output in the crystal, when polarization of laser beam rotates plus/minus 4.5 degree, the SHG output of energy decrease about 30%. The research of this paper will make a foundation for further development of mid-infrared laser.

7843-15, Session 3

Evolution of shock wave in TEA gas laser

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and Technology (China); L. Miao, Wuhan National Lab. for Optoelectronics (China)

The evolution of shock wave generated by discharge in the laser chamber is one of the key factors which affect laser beam quality, discharge stability, and repetition rate of TEA gas laser. In this paper, Mach-Zehnder interferometer is applied to observe the gas density distribution evolution after discharge. And both the longitudinal and transversal shock waves between electrodes as well as the acoustic wave originating from the preionization in the discharge pumping zone of a TEA gas laser are observed by using the shadowgraph method. A He-Ne laser is used as the parallel light source, and all the photographs imaged on the ground glass are recorded by ICCD camera. By changing the discharge voltage, gas pressure and gas composition, the developing processes in different conditions are compared and analyzed. It is observed that the shock wave originating from cathode is different from the anode's one even in the symmetric construction. And the waveform and amplitude of the shock wave are affected by the gas composition, gas pressure and discharge voltage. Furthermore, the gas composition and pressure can affect the speed of the wave obviously. In addition, the transversal shock is more obvious than the longitudinal shock wave. What's more, the shock wave is more obvious in high CO2 concentration than the high N2 concentration and less obvious in pure He gas.

7843-16, Session 3

Optimization algorithm for compact slab lasers

C. Cao, Xidian Univ. (China)

A novel design of an efficient, highly reliable, and good beam quality diode side-pumped solid-state laser is presented. Effort has been done to obtain a highly uniform pumping intensity in the active area, which simultaneously reduces the effects of thermal gradient. We report a compact, conduction-cooled, highly efficient, continuous wave slab laser in diode-side-pumped geometry. To achieve high efficiency and near-diffraction-limited beam quality, a novel laser head has been developed. In a close-coupled resonator, a novel pumping geometry is demonstrated.

7843-17, Session 3

Mechanism analysis and numerical investigation of optical bistability in 2μm Tm,Ho:YLF solid laser

B. Jiang, X. Zhang, L. Li, Y. Peng, Harbin Engineering Univ. (China)

A self-saturated absorption mechanism is proposed to theoretically investigate the optical bistability of Tm,Ho:YLF laser. Based on this bistability mechanism, the rate equation model of the bistability is established. The optical bistability behaviors of Tm,Ho:YLF laser are obtained by numerical simulating. We also analyzed the relation between laser gain and loss to confirm the rationality of the bistability mechanism. Furthermore, the time character of the optical bistability is investigated. It is found that the positive pulse power and the duration of the pre-pump are two major factors that affect the laser turn-on delay time and their influences on the turn-on delay are analyzed.

7843-18, Session 3

Coupled finite element simulation of laser ultrasonic

W. Liao, D. Yang, Northwestern Polytechnical Univ. (China)

The finite element models for laser ultrasonic in metal film were built in thermoelastic and ablation mechanism, respectively. The generation and propagation of ultrasonic in a copper foil irradiated by a pulsed laser with nanosecond and subnanosecond durations were simulated.

Under thermoelastic condition, we obtain the off-plane displacement results of longitudinal and shear wave by pulsed laser with different beam radius, intensity and pulse width. It is confirmed that short pulse gets clear waveform of ultrasonic.

For ablation model, we use an equivalent force instead of the vapor pressure during gasification process. The results show that the amplitude of ultrasonic in ablation model is about tenfold to hundredfold higher than that in thermoelastic model. The longitudinal wave and shear wave is easy to be resolved in the direction of 30º that deflected from the incident point. The ultrasonic waveform is sharper while the sample is clamped between the solid windows.

7843-19, Session 3

Effect of variable oxygen partial pressure for SrTiO3 thin films preparation with pulsed laser deposition

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In recent years, SrTiO3 (STO) ferroelectric thin film has given rise to many concerns, and a pulsed laser deposition (PLD) is one of the most widely used and attractive deposition methods for the growth of thin films developed. It also shows an unique advantage for the deposition of ferroelectric thin film. In this paper, STO thin films on MgO (100) substrate were manufactured by PLD using the triple-frequency harmonics of pulsed laser Nd YAG. The thickness of the STO thin films was measured using a stylus profiler. Their microstructure and surface morphology were analyzed using X-ray diffraction (XRD) and atomic force microscopy (AFM). Additionally, their optical character and electrical character were characterized using optical transmission spectrum and impedance analyzer. In accordance with the above text results, the oxygen partial pressure is a highly important parameter to influence the film morphology and films grown. These tasks that we have done will bring experimental results to the fabrication of STO thin films for further researches.

7843-20, Session 4

One new quality of the maximum-likelihood estimation of laser pointing system by use of return photon counts

L. Zhou, Institute of Optics and Electronics (China)

In all laser pointing systems, boresight and jitter are two fundamental pointing errors arising from vibrations and atmospheric turbulence. In order to estimate these errors, the papers presented before have developed a series of estimators, which are based on Gaussian jitter model and use Gaussian far-field irradiance profile and the statistics of return photons from the target. One of them is maximum-likelihood estimation, which can simultaneously estimate jitter and boresight with high precision and speediness. Besides these traditional qualities, a new quality of the maximum-likelihood estimation is found in this paper that the estimator has different performance with different boresight and

jitter errors. Furthermore,both Monte Carlo simulations and experimental results demonstrate that the maximum-likelihood estimation has a higher degree of precision when boresight is bigger than jitter. And this paper gives a careful analysis of the new quality of the maximum-likelihood estimation. In addition, a reasonable deduction is made after a further analysis of the estimator model that not only the maximum-likelihood estimation but also other estimation has this new quality. In other words, the errors of laser pointing system had better be estimated when boresight is bigger than jitter or jitter is very small. It will be very useful for the people who wish to obtain high precise results.

7843-21, Session 4

Adaptive inverse control of a fast steering mirror for electro-optical fine tracking

Y. X. Xia, Institute of Optics and Electronics (China)

Fast steering mirror is the most important part of the electro-optical fine tracking system. At the beginning of this paper several reasons which affect the precision and bandwidth of the control system were discussed. Compared with the ground based platform, the performance of the movement based platform electro-optical fine tracking system will be affected by the movement of the platform, moreover, the disturbances that cause beam jitter include narrowband mechanical vibrations and broadband atmospheric disturbances. So, all of these require the control system is a wide bandwidth and a robustness system. A novel controller for an electro-optical fine tracking system is designed based on Adaptive Inverse Control principle. The adaptive inverse control is an advanced algorithm, theoretically, it can eliminate disturbance completely, moreover, it separate processing to the system dynamic characteristic and the object perturbation but does not affect mutually. Compared with the PID controller, this controller is simpler and the parameter regulation is more convenient, but the control effect is better and the robustness is stronger. The experiment includes two FSM, one is used as a controlling FSM and the other is used as a disturbance FSM, the controlling FSM is mounted on a rotating platform, the rotating platform simulating the mechanical vibrations. The simulation and the experiment results indicated that the FSM control system based on the adaptive inverse control algorithm is very effective. It has a high performance on the tracing precision and the disturbance suppresses. Thus a new method is provided for the high-performance electro-optical fine tracking system.

7843-22, Session 4

The spatial and temporal evolution of the broadband chirped pulse with small-scale self-focusing

Y. Hou, X. Fu, H. Liu, L. Zhang, Hunan Univ. (China)

Self-focusing is a fundamental physical phenomenon in nonlinear optical. In the design considerations for solid-state laser facilities, it is must to be paid more special attention to the phenomena of small-scale self-focusing (SSSF) or filamentation. The beam will become more unstable with high optical powers because of SSSF of the small phase or amplitude modulation, which resulting in splitting of the laser beam. This is an important factor that limits the useful power of a solid-state laser. By experiments and simulations, the spatial and temporal evolutions of the broadband chirped pulse with SSSF in nonlinear medium have been investigated. Firstly, we studied the spatial modulation growth of broadband pulse by experiment in CS2 and the laser will produce many small peaks from perturbation modulation. It is found that modulation growth of chirped optical pulses is delayed with the pulse chirp increasing. And then we investigate the temporal evolution of the pulse at the modulation peak and bottom during the SSSF by numerical simulation. The numerical simulation is based on the spatial-temporal nonlinear Schrödinger equation and the split-step Fourier method. We found that pulse width at modulation peak is decreasing with the increasing of modulation peak intensity. But the pulse at modulation peak will broaden when the peak intensity reaches the maximum and then the pulse began to splitting into two parts. However, the pulse width at modulation bottom always broaden and finally reach to a constant value. The simulation results are in agreement with the experimental results.

7843-23, Session 4

Control of high power laser in nonlinear media by lens-focusing and beam self-focusing

H. Liu, X. Fu, Y. Hou, J. Deng, Hunan Univ. (China)

Many of the scholars devote themselves to research the propagation of laser beam. They considered the propagation of laser beam which is affected by diffraction, nonlinear effects and other physical affects. The appropriate focal spot is useful in uniform irradiation on target plane. But they didn't pay more attention to how to control the focal distance and beam quality of high-power laser at focusing spot in nonlinear media. In this paper, based on the theory of lens-focusing and laser self-focusing in nonlinear media, we firstly preliminary analyzed how to control the collapse position of beam when intensity and beam waist have been varied by the laser self-focusing in nonlinear media and lens-focusing. The changing of beam waist by lens affects intensity, and then the nonlinear propagation will be affected by intensity and nonlinear refractive index. We obtain the relations of the focusing position with input power and focal length of lens. The length of focusing is inversely proportional to the input power and directly proportional to focal length of lens. Secondly, we investigate how to control the focal distance and beam quality of high-power laser at focusing spot in nonlinear media by nonlinear propagation equation and split-step Fourier method. We demonstrate that focal distance shorten with the increasing of input power if we keep beam waist and the focal length of lens unchanged, and it lengthen with the increasing of focal length of lens when the input power unchanged. We can control the focusing spot at any position by changed power and lens. The numerical simulations is good consistent with theoretical analysis.

7843-24, Session 4

The beam propagation factor of nonparaxial truncated Hermite-Gaussian beams

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The issue of the M2 factor used for characterizing the laser beam quality within the paraxial approximation has been widely studied. In some practical applications, when the beam width is comparable with or less than the wavelength or when the far-field divergence angle becomes large, the paraxial approximation fails. In recent years with the rapid development of microcavities and photonic band gap crystals etc., the characterization and propagation of nonparaxial beams become more and more interesting. On the other hand, in practice the beam propagation is subject to some extent to the aperture effect. In this paper, by taking the nonparaxial Hermite-Gaussian (H-G) beam diffracted by a hard-edged aperture, namely, the nonparaxial truncated H-G beam as an example, the expression for the M2 factor of nonparaxial truncated H-G beams is derived and illustrated with numerical examples. It is shown that the M2 factor of nonparaxial truncated H-G beams depends not only on the truncation parameter and beam order N but also on the initial waist-width to wavelength ratio w0/ The far-field divergence angle approaches an asymptotic value when the truncation parameter 0. Furthermore, the M2 factors of nonparaxial truncated Gaussian beams and nonparaxial untruncated H-G beams are treated as the special cases of our general result.

7843-25, Session 4

Adaptive conversion of a wavefront-distortion beam to near-diffraction-limited flattop beam based on stochastic parallel gradient descent algorithm

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The typical intensity distribution of the laser beam is often undesirable for practical applications, especially for requiring uniform intensity distribution over the cross section of the beam. Examples include micromachining, laser welding, isotope separation, laser printing, optical processing, laser radars, efficient power extraction in laser amplifiers, and etc. In many laser systems, wave-front aberrations (WFAs) that result in deterioration of beam quality are common. These wave front may originate from imperfections in the many optical components. In this paper, a system of containing dual deformable mirrors (DMs) is designed, which can efficiently convert a wavefront distortion beam to a near-diffraction-limited beam. The DMs are controlled by stochastic parallel gradient descent algorithm. The first DM adaptively redistributes the intensity of the input beam and the other adaptively compensates the wavefront of the output beam. The whole system is controlled by SPGD algorithm. The circle and square flattop beam can be easily realized by this technique. The design consideration is analyzed in detail. Compared with the conventional beam shaping system, such as refractive, reflective and resonator mode controller, the dynamic phase distortion of the input beam can be compensated by this technique. The technique, which eliminates the requirement of measuring the intensity and phase distributions of the input beam, can be used in the applications of conversion of input beam with various shape to output beam with various shape. The intensity distribution of the output beam can be maintained for a certain distance in the near field. This technique provides a new method for generating near-diffraction-limited flattop beam.

7843-26, Session 4

Optimization of apodized Bragg gratings for spectral beam combining

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It is an effective approach to get high-power laser output by spectral beam combining (SBC). Volume Bragg grating (VBG) recorded in Photo-Thermo-Refractive (PTR) glass is the common combining elements in SBC. Reflecting VBG used at near-normal incidence is much more advantageous for high density SBC. But the side-lobe of diffraction efficiency of reflecting VBG greatly limits both the spectral separation of combining beams and the number of wavelength channel in a given spectral range, which are the critical parameters that determine high combining efficiency and high power laser output, and also the side-lobe causes diffraction losses. In order to suppress the side-lobe of diffraction efficiency, in this paper, an innovative method-apodized reflection VBG for SBC is proposed. We first analyze and compare the spectral diffraction efficiency with different apodized profiles (raise-cosine, sine, and quadratic-sine) using Chain-Matrix analysis, and calculate the effects of index modulation amplitude and grating thickness on diffraction efficiency. Then, we study the impact of various apodized VBG on the performance of spectral beam combining and make a comparison. The results show that using the apodized VBG gratings, the side-lobe of diffraction efficiency is suppressed very well; the quadratic-sine apodized profile is the best candidate for suppressing the side-lobe of diffraction efficiency but it decreases the maximum diffraction efficiency of the VBG grating; the raise-cosine apodized profile does not cause markedly diffraction efficiency decreasing but the effects of side-lobe is larger than quadratic-sine apodized profile at the same incident condition and grating parameters. Take into account the effects of grating thickness, incident beam's spectral width and beam divergence,the combining efficiency based on the apodized VBG is given.

7843-27, Session 4

Detection of sulfur dioxide in air by laser induced breakdown spectroscopy

Q. Xu, X. Ma, H. Zhao, Tsinghua Univ. (China)

A study of the detection of gaseous sulfur dioxide in air by Laser Induced Breakdown Spectroscopy(LIBS) is reported. Plasmas were formed in the sulfur dioxide gas, and three lines of sulfur at 560.61nm, 567.77nm and 565.99nm were observed. We found that the most appropriate experimental conditions for LIBS detection on sulfur dioxide gas are: Laser Pulse Energy =100mJ, Gate Time Delay = 2us. A further study was made in detecting sulfur dioxide gas of different concentrations by LIBS. Finally we calculated the detection limit of sulfur dioxide gas is 330ppm.

7843-12, Poster Session

The influence of the shape of ultrathin foils on the generation of attosecond pulses by femtosecond pulses

J. Zhu, Y. Song, L. Wang, P. Zhang, Beijing Univ. of Technology (China)

Thomson scattering offers the possibility to gain the higher frequencies of the scattering electomagnetic waves(wave) than that(ones) of the incident light, which opens a new way to produce attosecond pulses comparing with the traditional methods such as high-order harmonic generation in intense laser-atom interactions and self-amplified sponteneous emission from a free electron laser. Furthermore, coherent Thomson scattering makes the way more efficient with radiating electromagnetic pulses with higher energy density.

In this paper, we analysed the influence of the shape of the ultra-thin foils driven by femtosecond pulses on the generation of attosecond pulses. In these processes, the relativistic electron layers, which produced from the ultra-thin foils for coherent Thomson backscattering, are used for generating attosecond pulses. We investigated thoroughly the influence above in the processes applying the methods of an analytic model and one-dimentional partical-in-cell simulation(1D-PIC). The results of this paper are valuable for designing attosecond pulses in the future.

7843-38, Poster Session

High beam quality 400W practical all-solid-state laser for laser beam texture

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A high-average-power and high-beam-quality diode-side-pumped solid-state laser was designed carefully for laser beam texture. By using of low concentration Nd:YAG crystals with thermally near-unstable resonator design and two-rod birefringence compensation technology, the 1064 nm cw output power of 400 W at pump power of 1170 W was achieved with the beam quality factor M2 ~ 15, corresponding to an optical-to-optical conversion efficiency of 34.2%.

7843-39, Poster Session

Analysis of light propagation in a circular double clad fiber using coupled mode method

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Fiber technology has attracted significant interest during the last decades. The appearance of double clad fibers (DCFs) provides an efficient way to generate high power fiber laser. In comparison with other types of fiber, DCFs benefit from their inner cladding which results in a large effective mode area and a high numerical-aperture. Currently, light propagation in DCFs has been theoretically studied by using the methods of ray tracing, wave-optical approach and eigenmode expansion. Especially for the eigenmode expansion method, the light propagation in a perfect circular DCF is explained by the propagation of a complete set of guided mode and the field distribution in the cross section are unchanged along the DCFs.

In this paper, instead of the eigenmode expansion method, we use the coupled mode theory to study the light propagation in the perfect circular DCF. Firstly, we use an equivalent model: two coupled fibers, i.e., a single mode fiber (SMF) and an annular core fiber (ACF) to replace the DCF. We obtain the LP01 mode (fundamental mode) of the SMF and the guided modes of the ACF at different wavelengths by using weakly guiding approximation, and then calculate the coupling coefficients between the LP01 mode and these guided modes. The results show that the modes between the two fibers can be strongly coupled when they have the same symmetry and the coupling coefficient for the high-order mode of the ACF is larger than that for the low-order mode. With considering all the guided modes of the ACF, the field distributions in the DCF's core are calculated at different wavelengths by using the coupled mode equations. From the calculated results we find that the power in the core shows a quasi-periodic distribution along the DCF. The average period of the distribution increases with increasing wavelength for different DCF parameters, but the average power in the core is closely related to the chosen parameters of the DCF.

7843-40, Poster Session

Build-up time of the random laser in R6G dye solution with TiO2 scatters

S. Fan, X. Zhang, Q. Wang, Z. Chen, Z. Wang, R. Lan, Shandong Univ. (China)

The dynamic properties of the laser emission are very important in studying the characteristics of the laser and may reveal the underlying operating mechanism. Random laser is a newly developed type of laser that is important in the study of the physical mechanism of the laser. Here we report a more precise measurement of the build-up time of random laser pumped by picosecond pulse laser. The build-up time is defined as the time delay from the peak of the pumping pulse to that of the emission. The random laser is R6G dye solutions with nanometer size TiO2 as the scatterer. Various dye concentrations and scatterer density are tried and measured. A specially customized fiber and a streak camera with a spectrometer are employed to make the simultaneous measurement. The fiber has two branches and the lengths of both branch are made equal. The difference of the lengths is proved to be less than 1 mm in the experiment. The dispersion of the fiber, which introduces much error in the results, is also measured and later compensated in the following data processing. The streak camera with spectrometer can catch the random laser pulse and the pumping pulse signal in one shot with a resolution of less than 1 picosecond. The results for various samples are given and compared, which will be useful in the study of the physical mechanism of the random laser.

7843-41, Poster Session

Broadly tunable ytterbium-doped photonic crystal fibre laser and high power superfluorescent fibre source

B. Wang, S. Chen, CangZhou Normal Univ. (China); J. Wang, Beijing Univ. of Technology (China); Y. Li, Nankai Univ. (China)

Fibre lasers have attracted much attention especially in recent years, for its convenience of heat dissipation and simplicity to reach good beam quality. Ytterbium-doped fibre is mostly preferred in high power fibre lasers for its simple energy level structure, high conversion efficiency, and commercially achievable laser diode pumping sources at 975 nm. By utilizing ytterbium-doped fibre as the gain medium associated with the clad pumping technique [1], the output powers of fibre laser systems have exceeded 1 kW.

In this paper, By utilizing an ytterbium-doped photonic crystal fibre (PCF) as the gain medium, a 2.5 W superfluorescent fibre source (SFS) and a tunable PCF laser with 74.4 nm tuning range and 5.5 W output power are experimentally demonstrated. The tunable operation of the laser is realized by rotating a diffraction grating. Effects of the degrees of the cleaved angle at the anti-reflection fibre end on the output characteristics of the laser and the SFS are investigated. A large cleaved angle is beneficial to realize a broad laser tuning range and beneficial to obtain a high power superfluorescent fibre source without parasitic lasing.

7843-42, Poster Session

Supermode analysis in multi-core photonic crystal fiber laser

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In recent years, much attention has been paid to fiber lasers because of their ability to provide high-power and excellent beam quality compared with conventional laser systems. However, the scalability of output power is limited by mode area and nonlinear effects in single-mode fiber laser and photonic crystal fiber (PCF) are introduced to overcome these limitations. The multi-core photonic crystal fiber (MPCF) laser is particularly interesting because it can support a more large effective mode area and many theoretical and experimental results have been reported. Because of distributed nature of the cores, thermo mechanical effects could be mitigated compared with those of single-core lasers. Based on the desirable features of the MPCFs, the multi-core photonic fiber laser with in-phase supermodes seems to be a natural way to scale up the power of fiber lasers while keeping their good beam quality.

In this paper, we report on the laser properties of multi-core photonic crystal fiber lasers. The supermode selection of photonic crystal fibers with linearly and circularly distributed multi-cores is observed. The supermode properties are investigated by using full-vector finite-element method (FEM). The mode operations of our 16-core rectangular-array and 18-core circular-array photonic crystal fiber lasers are simulated by the COMSOL Multiphysics software. The near-field distribution and the far-field diffraction pattern of in-phase mode are presented. Effective supermode selection is obtained by using the Talbot effect and a perfect in-phase supermode is obtained.

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7843-43, Poster Session

Numerical optimization of Yb-signal assisted high power Er/Yb codoped double-clad fiber amplifier

Q. Han, J. Ning, W. Zhang, B. Chen, X. Wang, Tianjin Univ. (China)

Co-seeding an Er/Yb codoped fiber amplifier(EYDFA) with a signal in the emission band of Yb3+ has been shown to be a promising way to improve both the power conversion efficiency(PCE) and stability of high power double-clad EYDFAs. In this paper high power EYDFAs assisted by an Yb-signal in the wavelength range from 1000-1100 nm are numerically investigated. The results show that the selection of the Yb-signal wavelength and the optimization of the fiber length are vital to the performance of an EYDFA. As demonstrated in this paper, if these parameters are optimized, PCE improvement as high as >85% is even possible. However, if these parameters are chosen improperly, the co-seeding of an Yb-signal may detrimental to the performance of the amplifier. Optimized Yb-signal assisted EYDFA provides a simple but effective way to improve the available power in the 1.5 um range for eye-safe applications.

7843-44, Poster Session

Pulsed Nd:YAG laser cutting of silicon wafer by controlled fracture technique

J. Liu, J. Lu, X. Ni, G. Dai, L. Zhang, Nanjing Univ. of Science and Technology (China)

The traditional mechanical cutting technique for brittle materials with the help of a metal or diamond point tool has been used for decades. Therefore, chip formation and uncertain fracture of the cut edge are the intractable problems in the conventional mechanical cutting process especially for thin brittle wafer. Controlled fracture technique has great potential in laser cutting brittle materials. This technique uses less laser power and enables high cutting speeds compared to other laser cutting methods. During the laser cutting of brittle material using controlled fracture technique, thermal stress is used to induce the crack and the material is separated along the moving direction of the laser beam. In order to investigated the process of pulsed Nd:YAG laser cutting brittle silicon wafer, a three-dimensional mathematical thermoelastic calculational model which contains a pre-existing crack was established in this paper. The temperature field and thermal stress field in the silicon wafer were obtained by using the finite element method. During the pulse duration, the changes of stress intensity factor around crack tip were analyzed. The stress intensity factor keeps increasing during the laser irradiation time, when it becomes larger than the fracture toughness of the silicon, the crack extension will occur. Meanwhile the mechanism of crack propagation was investigated by analyzing the development of the tensile stress induced at the crack tip. The maximum tensile stress is always at the crack tip because of the concentration of stress by the crack, and the tensile stress at the crack tip keeps increasing during the pulse duration. When the tensile stress induced by the laser becomes large enough, the crack will propagate along the cutting line. The next pulse duration, the maximum tensile stress is also induced at the new crack tip because of the concentration of stress, the crack will go on propagate by the end of the process. The calculational results in this paper are in agreement with the reported experiment results.

7843-45, Poster Session

Study on the supermode and in-phase locking in multicore fiber lasers

Y. Wang, J. Yao, Y. Zheng, W. Wen, R. Zhou, Tianjin Univ. (China)

Multicore fiber lasers have larger mode areas, resulting in higher power thresholds for nonlinear processes such as stimulated Raman scattering and stimulated Brillouin scattering. Because of longer distributed distance of the cores, thermal mechanical effects are decreased compared with those of single-core lasers. Therefore, multicore fiber lasers are proposed as a candidate for the power scaling. The progress of multicore fiber lasers is simply introduced. Optical fields propagating in multicore fibers are coupled evanescently, resulting in what are called supermodes. In this article, the coupled-mode theory for analyzing supermode of fiber transmission is introduced. By mean of the theory, assuming under weak-coupling conditions, the supermodes are approximated as linear superposition of modes of individual cores with appropriate coefficients. The near-field and the far-field mode distributions of the fundamental in-phase supermode are numerically calculated, and the corresponding mode distribution patterns are drawn. According to the mode distribution in multicore fiber laser, the transverse supermode competition between supermodes is discussed based on rate equations extended to fiber with multiple cores.

For making the multicore fiber laser preferentially operate in a particular supermode so that improving beam quality, an in-phase locking method based on self-imaging Talbot external cavity is presented, and by using the method, a properly Talbot distance is given. The result shows Talbot external cavity can efficiently achieve in-phase locking.

7843-46, Poster Session

A potential approach to ~10fs, >2 petawatt pulses by hybrid laser based on Ti:chrysoberyl and Ti:sapphire

B. Cao, X. Lu, D. Fan, Shanghai Institute of Optics and Fine Mechanics (China)

A hybrid laser composed of Ti:chrysoberyl and Ti:sapphire is proposed in this letter. The laser has the similar structure to ordinary Ti:sapphire based lasers except that the host material of the regenerative amplifier is replaced by Ti:chrysoberyl. The Ti:chrysoberyl is employed in this system with the polarization parallel to a axis since then its photoluminescence spectrum has two peaks. A simplified theoretical model for numerical simulation is presented here. The ability of the hybrid amplifier chain to compensate the gain narrowing is obviously demonstrated and the laser is potential to generate ~10fs, >2petawatt pulses according to the numerical simulation.

7843-47, Poster Session

Detection of surface breaking on cylinder material using surface acoustic wave generated by scanning laser source

Y. Shi, L. Zhang, L. Cai, China Aero-Polytechnology Establishment (China)

Laser ultrasonics, a nondestructive test method (NDT), is more and more applied in industrial fields such as crack detection in metal and nonmetallic materials, and size measurement and welded joint examination. According to the thermoelastic theory, a finite element model for laser-generated surface waves on the elastic cylinder material is built and an experimental installation using laser interferometer as the ultrasonic wave receiver is set up to verify the numerical results.

By changing the relative distance between the laser source and the surface notch in the computation, the scanning procedure is simulated. The corresponding varieties of amplitudes of the surface waves, which propagate circumferentially on the cylinder material, are presented and the physical mechanisms are analyzed. The influence of the depth of the surface notch is also discussed. The results demonstrate the SLS technique can be applied to detect tiny crack whose depth is smaller than the wavelength of the SAW.

7843-48, Poster Session

Optical-mechatronics high peak power ultrashort pulse UV laser system

J. Chen, Chung-Hua Univ. (Taiwan)

We have developed an Optical-Mechatronics high peak power ultra-short pulse UV laser system. This multi-functional diversified UV laser system havs many sub-systems that can be employ separately. It can be a tunable femto-second laser seed source, medium power ultra-short pulses laser system, single amplified medium power ultra-short pulse laser system, multi-frequencies single amplified medium power ultra-short pulse laser system, medium power ultra-short pulses UV laser system, and concluding the high peak power ultra-short pulse UV laser system. The complete laser system layout together with synchronization controls of all the laser system will be present in detail.

7843-49, Poster Session

Femtosecond optical parametric oscillator based on periodically poled potassium titanium phosphate

X. Ma, J. Tian, X. Zhang, Beijing Univ. of Technology (China)

We describe a synchronously-pumped optical parametric oscillator (OPO) based on periodically poled potassium titanium phosphate (PPKTP). The OPO was pumped by a self-mode-locked Ti:sapphire laser. Its signal wave covers from 1070 nm to 1375 nm, and could be tuned freely by cavity-length tuning, the corresponding idler wave covering from 1.9um to 3.2um in the mid-infrared region, and the red, green and blue visible light was also generated by intra-cavity sum frequency and frequency doubling. The threshold was measured to be about 250 mW at 810 nm pump. A thin glass substrate was inserted to the cavity for output coupling, and the maximal output power was measured to be 26 mW. We adopted ring cavity and linear cavity experimentally. After optimizing the OPO's operation parameters, the output characteristics of the ring cavity and linear cavity were investigated respectively. The approach to improve the output efficiency was also discussed.

7843-50, Poster Session

Signal-to-noise ratio of airborne lidar system

H. Hao, Beijing Institute of Technology (China)

Abstract: Laser light detection and ranging(Lidar) system is a useful tool for range determination in various applications, particularly if it provides compact and robust set-ups with suitable light source, efficient sensors and adequate signal processing. This article gives an overview of airborne Lidar system and its application. By analyzing the transmission and reception process of laser signal, the article constructs a model of backscatter signal of the Lidar system, and gives some basic formulas which make up the relationship of signal-to-noise ratio, for example, the received power, the dark noise power and so on. And this article carefully studies and analyzes the impact of some important parameters in the equation on the signal-to-noise ratio, such as the atmospheric transmittance coefficient, the work distance. And the matlab software is used to simulate the detection environment, and obtains a series values of signal-to-noise(SNR)ratio under different circumstances such as sunny day, cloudy day, day, night. And the figures which describe how the SNR of Lidar system is influenced by the critical factors are showed in the article. Finally according to the series values of signal-to-noise ratio and the figures, the SNR of Lidar system decreases as the distance increases, and the atmospheric transmittance coefficient caused by bad weather decreases, and also high work temperature drops the SNR. Depending on these conclusions, the Lidar system will work even better.

7843-52, Poster Session

Nonlinear images of gain defects

Y. Hu, H. Wu, Q. Zheng, J. Xu, Hunan Univ. of Science and Technology (China)

The nonlinear image of optical defect is a threat for the safe running of high-power solid-state laser systems. The nonlinear image effect for small-scale scatterers with gain defect, which may be caused by the uneven gain in gain media, is investigated by numerically solving the propagation with the standard split-step fast-Fourier-transform algorithm. Two cases, i.e. the scatterers only caussing gain and the scatterers causing gain and phase modulation simultaneously, are mainly considered. It is proved that nonlinear images can also be formed for scatterers with gain. However, when compared to the nonlinear image effect for scatterers with attenuation, the following significant differences are found: firstly, the intensity at the point corresponding to the center of the scatterer experiences an obvious decreasing just before the nonlinear image is formed, contrary to the case that the scatterer without gain; secondly, this decreasing is enhanced as the scatterer's gain increases; thirdly, there is a distance several centimenters, even more than ten centimeters, between the nonlinear images of scatterers with gain and those with attenuation. For scatterers which cause gain and phase modulation, above differences are ignorable, but the nonlinear image effect has some new properties: firstly, the peak beam intensity on the exit surface of the nonliear medium is higher than the case the scatterer with phase modulation only; secondly, the second-order nonlinear image is increased obviously, but the effect of the scatterer's gain on the image's peak intensity is relatively limited. Besides, the effect of the distance between the scatterer and the nonlinear image and that of the power of the incident beam are discussed.

7843-53, Poster Session

High power widely tunable all solid state pulsed titanium-doped sapphire laser

Q. Sheng, X. Ding, J. Yao, N. Chen, B. Li, Tianjin Univ. (China); X. Yu, Nankai Univ. (China); X. Li, W. Wen, R. Zhou, Tianjin Univ. (China)

We report a pulsed, widely tunable Ti:sapphire laser pumped by an all-solid-state Q-switched intra-cavity frequency-doubled Nd:YAG laser. To realize high conversion efficiency, the laser cavity was designed for well mode matching between 532 nm pump beam and Ti:sapphire laser beam in the sapphire crystal based on measured thermal focal length of the Ti:sapphire crystal. The 220 mm flat-flat cavity and 195 mm thermal focal length at the maximum pump power brought a 220 m TEM00 mode spot radius of 780 nm Ti:sapphire laser beam, when the pump beam radius was focused to 200 m in the Ti:sapphire crystal. Meanwhile, the Ti:sapphire laser was also operating at the stable-power point of U-shaped curve indicating change of spot radius versus thermal lens focal power.

Using two dense flint glass prisms as dispersion elements, the output could be continuously tuned over 675-970 nm, with spectral line width of less than 2 nm. Due to gain-switched characteristics of Ti:sapphire

laser, the pulse width can be as short as 17.6 ns. At the optimized repetition rate of 7 KHz, the maximum output power was 6.2 W at 780 nm when the 532 nm pump power was 22 W, with laser threshold of 8.2 W; corresponding conversion efficiency was 28.2%.

7843-54, Poster Session

A new fluid state laser system realizes laser output

L. Gui, Shanghai Institute of Optics and Fine Mechanics (China)

This article demonstrates a diode-pumped pulse laser operation in a flowing fluid host containing Nd-glass particles, transversely pumped by 810nm laser diodes. A series of Laser pulse as the output are observed. The repetition frequency is 1Hz, and the pulse width is about 100, and the peak pulse energy is up to 2.93mJ, and the average pulse energy is 0.84mJ. Given that fluid circulation offers improved heat management, the realization of laser output of this new fluid state laser verifies a practical way to solve the heat-induced problems in high energy laser systems.

7843-55, Poster Session

Fiber laser intensity noise suppression through optoelectronic feedback

F. Zhang, J. Zhu, Y. Ke, L. Jing, X. Shi, C. Li, B. Yu, Anhui Univ. (China)

In this paper,we demonstrate a technique for suppressing the intensity noise of the erbium doped fiber lasers(EDFL) at low frequency (about 10KHz). We show that by using negative feedback into the pump drive,the relaxation oscillation noise could be suppressed.and we also through negative feedback into the LiNbO3 intensity modulator which inserted into the cavity.Compared with previous negative feedback methods of suppressing the intensity noise.In order to suppression the intensity noise at low frequency and prevent the relaxation oscillation frequency move to the higher frequency, we both feedback into the cavity and the pump drive .

7843-56, Poster Session

Optical frequency comb generation based on stimulated Brillouin scattering in highly nonlinear fibers

X. Zhang, Z. Cao, F. Ai, B. Yu, Anhui Univ. (China)

In this paper, a simple and all-fiber frequency comb generator by stimulated Brillouin scattering (SBS) in highly nonlinear fiber (HNLF) is demonstrated. The optical resonator is composed of a segment of highly nonlinear fiber and two optical loop mirrors. A tunable laser is used as the pump. When the wavelength and the power of pump laser are adjusted correctly, dozens of comb lines with comb spacing in the 10 GHz range are obtained, while a series of longitudinal modes spacing in 100 kHz are also appeared. Besides these, an erbium-doped fiber amplifier (EDFA) and a polarization controller will be used to amplify the power of pump and adjust the polarization state of the light in the resonator respectively. It can be expected that more comb lines would be achieved.

7843-57, Poster Session

Mode competition in concentric-type multicore fiber lasers combined with large mode area single mode fiber

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The mode competition mechanism in concentric 4-core and 7-core fiber lasers with large mode area single mode (SM) fiber as in-phase supermode selection component is presented. The coupling coefficient between the fundamental mode in large mode area SM fiber and each supermode in mutlicore fiber is discussed. For individual supermode in multicore fiber, the coupling coefficient is optimized as a function of the core radius of SM fiber as well as the distance between multicore fiber and SM fiber. The optimization results demonstrate that only two supermodes are involved in concentric-type fiber lasing - in-phase and anti-phase supermode, owing to the negligible coupling coefficients of the other supermodes. Furthermore, to achieve the best in-phase supermode selection, the core radius of SM fiber will be optimized for maximum coupling coefficient difference between in-phase supermode and anti-phase supermodes. In this case, the anti-phase mode seems noncompetitive regardless of the distance. The numerical results illustrate that in-phase supermode always dominate the output and is highest competitive when the distance equals zero. Compared to conventional multicore fiber lasers with Talbot cavity, this all-fiber configuration based on large mode area SM fiber has higher-order supermodes more efficiently suppressed, consequently high-brightness output is obtained.

7843-58, Poster Session

Effect of process parameters on the growth of dendrite in laser clad bead

Q. Li, Hunan Univ. (China)

Laser cladding was performed on the surface of ductile cast iron substrate with Fe-base allay under different process parameters. The microstructure of cladding layer was analyzed using SEM and Metallurgical Microscope.The secondary dendrite arm spacing was measured. The results showed that, within a certain range of laser energy density, with increase in the energy density, the secondary dendrite arm spacing as well as the size of the grain rises.The microhardness of the cladding layer becomes lower and lower.

7843-59, Poster Session

Laser surface hardening of ductile cast iron for vehicle die

Y. Xu, Hunan Univ. (China)

High-power laser transformation hardening improves the surface properties of metallic materials. Laser surface hardening treatment has many advantages over conventional hardening treatments, such as outstanding wear resistance, high fatigue strength, small dimensional deviation and so on, thus it is developed for many industrial applications in recent years. Ductile cast iron, which is popular in industry, especially in automobile industry, are often used after surface treatments. In this paper, laser transformation hardening is carried out on the ductile cast iron blocks by using circular CO2 laser beam with variations in laser power, spot size and scanning speed. Different patterns of the laser scan path is also studied, including a single-pass hardening pattern, a multi-pass hardening pattern with overlapping and that without overlapping. The distribution of microhardness along cross and

longitudinal directions and the variation of microstructure of hardened layer are investigated. It is seen that the surface hardness of ductile cast iron blocks increases greatly at suitable values of process parameters in laser transformation hardening, which satisfies the automotive dies with an increase in service life.

7843-60, Poster Session

Beam cleanup of a 5mJ-200μs pulsed green solid state laser using a bimorph mirror

X. Lei, N. Yu, P. Yang, L. Dong, W. Liu, Y. Hu, B. Xu, Institute of Optics and Electronics (China)

It is well known that in applications of the pulsed solid-state laser, high beam quality is one of the most important orientations for physicists. However, the wave-front distortions within the lasers cause it hard to realize. There are several sources of wave-front distortions in a pulsed solid-state laser, for instance, the non-linear effects of materials, thermal lensing etc. All contribute to the degradation of the beam quality. To get high beam quality by beam cleanup, scientists have developed many ways. In such methods, adaptive optics (AO) systems using deformable mirrors have been applied for laser beam cleanup and proved to be effective.

Conventional AO systems used for laser beam cleanup mainly include three parts: a wave-front sensor (WFS, most of them are Hartmann-Shack sensors), an active correction element and a control strategy. When these AO systems are applied to correct wave-front aberrations, firstly, the aberrations are measured by the WFS directly. Then, based on the wave-front information, the wave-front aberrations are compensated. However in the strong scintillation regime or when the intensity of laser beam is rather non-uniform, conventional AO systems based on gradient wave-front sensors may not obtain very good results. To get an alternative, optimization-based AO control systems have been developed for improving laser beam quality. In this paper, we present an AO system for beam cleanup of a pulsed solid-state laser whose wavelength is 532nm. The repetition rate of this pulsed laser is 20Hz and 100Hz. The AO system is wave-front sensor-less which is based on Stochastic Parallel Gradient Descent (SPGD) algorithm and a 20-element bimorph mirror (BM for short). The results are presented and discussed.

7843-61, Poster Session

Fresnel diffraction by circular aperture illuminated with a phase modulated and spectral dispersed laser beams

J. Deng, X. Fu, L. Zhang, Z. Jin, S. Wen, Hunan Univ. (China)

Uniform illumination on target plane and a focal pattern with sharp-edge and flat-top profile is essential in the direct-drive approach to inertial confinement fusion (ICF). A number of beams smoothing methods have been suggested to improve laser irradiation uniformity on the target plane. Smoothing by spectral dispersion (SSD) is a temporal smoothing technique that is suitable for glass laser system (e.g. OMEGA laser in University of Rochester), and have proven that SSD can effective smooth the high-frequency intensity modulation in the target plane. In practice, SSD device is usually located before the main amplifier, which means that the beams phase modulated and spectrally dispersed by the SSD device will be transmitted through the entire amplifier system. However, almost all research of SSD concentrated on the focal spot smoothing, and obviously SSD installation also will significantly change the near-field diffraction characteristics of the beams after the SSD device. In this paper, the Fresnel diffraction characteristics of a phase modulated and spectral dispersed beam (the beam after SSD device, termed PM-SD beam) which passed a circular aperture is investigated detail using numerical simulation. We compared the diffraction patterns of PM-SD beam and monochromatic beam illuminations, and found that PM-SD beam can significantly change the distribution of the near-field diffraction intensity. We also discussed the effects of the main parameters of the SSD installation such as frequency and amplitude of the electro-optic modulator and coefficient of the grating dispersion, and found that when choosing appropriate parameters, we can obtain a smoothing near-field diffraction pattern. This implies that PM-SD beam can reduce the source of small-scale focusing, because the spatial intensity modulation generated by diffraction and interference is the main reason of spatial small-scale focusing.

7843-62, Poster Session

Optimum design of DBR Er/Yb co-doped double cladding fiber laser

H. Su, Y. Geng, Z. Guan, Q. Guo, Hebei Univ. (China)

Er3+/Yb3+ co-doped double cladding fiber lasers (EY-DCFL), as a kind of high efficiency and high power level laser source operating in the eye-safe wavelength region around 1.55 μm, have been paid great attention and developed rapidly in recent years. Distributed Bragg reflection (DBR) configuration which uses fiber Bragg gratings (FBG) as the reflector to form the resonator has been applied in EY-DCFL for the sake of compactness and wavelength stability. To optimize the performance of DBR EY-DCFL, in this work the output characteristics of DBR EY-DCFLs with different parameters are investigated theoretically and experimentally. Numerical simulation on the output characteristics of DBR EY-DCFL is performed based on rate equations and power propagation equations of the Er3+/Yb3+ co-doped system. The output powers as functions of the launched pump power, the gain fiber length, the reflectivity of the output mirror, as well as the concentration of the rare-earth ions in the fiber are presented. Comparative experimental study on the output power, spectral properties and time-domain stability of DBR EY-DCFLs formed by fiber Bragg gratings with different reflectivity are carried out. In the optimum condition, the maximum output power of the fiber laser is 2W with a slope-efficiency of 53.8%, and the lasing center wavelength and 3dB bandwidth are 1550.8nm and about 0.02nm, respectively. The experiment results demonstrate the correctness of the theoretical study.

7843-63, Poster Session

An efficient algorithm based on propagation equations of Tm-doped double-clad fiber laser

J. Liu, C. Zhao, X. Fu, S. Wen, Hunan Univ. (China)

In the theoretical analysis of double-clad fiber lasers, they are analyzed using the numerical algorithm of two-point boundary value problems. Among these algorithms, the shooting is commonly used. But the input pump power is known, the boundary conditions of laser power are only given in the double-clad fiber laser, and the iteration progress of the initial laser power is quite complex. So, the shooting algorithm for double-clad fiber laser is relatively complicated. In this paper, an efficient, simple and fast algorithm based on the propagation equations of Tm-doped double-clad fiber laser is proposed, in which the initial guessed value is directly corrected based on the relation of the two-end boundary values of laser power, and it is not necessary to know the initial or terminal laser power. Then, the evolutions of the pump and laser powers along the fiber are analyzed. It is proved that the initial guessed laser power can be fast convergent to the truth value regardless of the magnitude of the initial guessed laser power, and this algorithm can be effective even if the pump power is up to kilowatt level. Finally, compared with the shooting algorithm, the iteration progress of this algorithm is easier, and the running time is 17 times as fast as that of the shooting algorithm, so this algorithm can be more quickly and simpler convergent to the truth value. So, this algorithm can be used in the Tm-doped double-clad fiber laser efficiently.

7843-64, Poster Session

Effects of the gas flow and the defocusing distance from laser beam focus on powder-feed laser cladding

Y. Li, Hunan Univ. (China)

In this paper, the effects of the gas flow and defocusing distance from laser beam focus on powder-feed laser cladding are investigated, and a numerical model to simulate the free surface of the molten pool is developed. The effect of transporting gas flow on the powder feed rate, and those of the transporting and shielding gas flow on the divergent angle of the gas-powder flow and the characteristics of the formed clad bead (height, width, surface smoothness, pore and crack) are worked out, respectively, while the other process variables being constant. Suitable values of the transporting gas flow and shielding gas flow can be obtained from the experiments. Provided that there is no heat exchange in powder-gas flow, the equations of mass and momentum conservation are established while the effect of gas-powder flow on the molten pool is presented as a boundary condition equation for developing the numerical model of the molten pool. The experimental results obtained at variable defocusing amount show that the negative defocusing amount rather than the positive one is suitable for laser cladding and that the defocusing amount influences the molten height below the substrate surface.

7843-65, Poster Session

Experimental measured for the effects of broadband pulse on the B-integral of small-scale self-focusing

Z. Jin, X. Fu, L. Zhang, J. Deng, S. Wen, D. Fan, Hunan Univ. (China)

In high-power solid-state lasers, small-scale self-focusing is one of the major factors for degradation of laser beam and limiting the maximum laser power available. It leads to the damage of the elements of laser systems due to a drastic increase in the peak intensity and energy density. With the rapid advances of laser driver technology, in particular the emergence of chirped pulse amplification, the broadband femtosecond laser was applied in high power laser system gradually. It is very important to reveal the characteristic of nonlinear small-scale self-focusing of broadband laser experimentally. In high-power laser system, B-integral is used to measure the severity extent of small-scale self-focusing and the typical value of B-integral is less than 1.8 by Beamlet, as the prototype of NIF architecture, which the non-linear intensity growth is slow.

In this paper, we perform an experimental setup for the analysis of modulation growth, and focus on the feature of modulation growth of the broadband pulse laser. The spatial contrast of broadband pulse with increasing B-integral in nonlinear medium is discussed. In the case of the different pulse width, comparison of the fastest growing frequency modulation and random noise modulation case, spatial contrast with the curve of B-integral is obtained experimentally. It was found that the value of B-integral corresponding to that the spatial contrast increases sharply is greater than that of narrowband laser in both cases. Thereby we can believe that broadband laser can extend the value of B-integral, and then improve the system loading.

7843-66, Poster Session

Time-resolved digital holographic diagnosis of the shock wave in water induced by femtosecond laser pulses

X. Wang, P. Wang, Nankai Univ. (China)

Nowadays the dynamic processes in water induced by femtosecond laser pulses become more and more attractive research topics due to their potential applications in biology and medical fields. It is believed that the phase distributions will be of more advantage to precise and intuitive characterizations of the shock wave behavior, compared to shadowgraphs. In this paper, time-resolved digital holography is used to record and investigate the breakdown area in water induced by a 50 fs, 76 MW laser pulse and two-dimensional phase distributions are reported. Experiment results show that when the plasma reaches a certain length, the profile of the shock wave produced by the central part of the plasma is similar to a cylindrical wave, while that produced by the two ends of the plasma will be more like a spherical wave. Furthermore, the changes of the refractive index caused by the former are greater than that by the latter, which indicates that the energy of the shock wave is different in different propagation directions. In addition, the plasma region increases and the profile of the overall shock wave approaches to a cylindrical wave when the laser power increases, while the length of the plasma zone decreases and the profile of the overall shock wave approaches to a spherical wave when the laser power decreases. This further indicates that the shock wave front is definitively dependent on the shape of the plasma. These results are consistent with our simulations based on the shock wave transmission theory. The work provides an important experimental basis for femtosecond laser applications in biological and medical fields.

7843-67, Poster Session

Study on laser cladding of Ni-based alloy on aluminum

Y. Wang, N. Liu, Tianjin Polytechnic Univ. (China)

In order to improve the surface Performance of Aluminum work piece, A Ni- Cr alloy coating metallurgically bonded onto thick Aluminum plate is performed by YAG laser remelting plasma spraying coating process. In laser cladding processing, it is difficult to get good metallurgical bonding between the layer and Aluminum. Plasma spraying technology is used to get a alloy layer on the surface of thick Aluminum plate, and then using YAG laser cladding method to make a coating. The results of micro organization analysis indicate that the cladding layer and substrate form favorable metallurgical bonding, as a narrow metallurgical bonding zone, about 3mm in thickness. The structure of cladding layer is more compact compared with witch of plasma spraying coating, and the crystal grains are refined grain.

7843-68, Poster Session

Optimization of reflector design for diode-pumped Nd:YAG laser with single-side pumping geometry

K. Lee, Y. Kim, Yeungnam Univ. (Korea, Republic of); H. C. Lee, J. Lee, J. Cho, Hanwha Corp. (Korea, Republic of); Y. G. Jeon, Agency for Defense Development (Korea, Republic of); J. Yi, Yeungnam Univ. (Korea, Republic of)

We tried various designs of reflector and reflector material to get uniform and efficient pumping of Nd:YAG rod even with single-side pumping geometry. We used commercial software ZEMAX and LASCAD

for design. The combined application of the software enabled us to evaluate numerically the laser performance and absorbed pump diode profile. We tried various shape of reflector such as semi-circular, square, elliptical reflectors, and cusp-shape to get uniform pumping. In the calculation, four diodes bar with emission area of 3.2 mm x 10 mm were considered to simulate the experimental result. For Nd:YAG laser crystal, experimentally measured absorption coefficient - was used in calculation. In the design, water flows inside the cooling tube which surrounds the Nd:YAG rod. For further improvement a planar-concave window was placed in front of the diode to enlarge pump beam divergence angle. The window improved uniformity of pump beam distribution inside the crystal. In experiment, absorbed pump beam distribution was measured by observing florescence using a CCD. Through several trial and error, we found best pumping chamber design for single-side pumping, which gives reasonably uniform and efficient pumping of Nd:YAG rod. Q-switched laser output characteristic was calculated for various laser cavity designs. The output power and pulsewidth were optimized by varying the laser cavity length and the output coupler reflectivity.

7843-69, Poster Session

Research on laser atmospheric transmittance in the slant path on the sea

Y. Liu, Shandong Institute of Business and Technology (China)

In order to determine laser transmit power, laser atmospheric transmittance in the slant path on the sea is researched. First, laser atmospheric attenuation on the sea was analyzed. Then 1.06μm laser atmospheric transmittance formula in the slant path was approximatively concluded. 1.06μm laser atmospheric transmittance on the sea was calculated. And then 10.6μm laser atmospheric transmittance curve was described. The curve is changed by visibility and propagation distance. Finally, some data and conclusions about 1.06μm laser and 10.6μm laser atmospheric propagation in the slant path on the sea were presented. It has some extent reference value for research on laser weapon.

7843-70, Poster Session

Fast axis coupling and phase-locking of semiconductor laser by external-cavity feedback

H. Pi, Shanghai Institute of Optics and Fine Mechanics (China)

Since the structure limitation, the beam divergence of semiconductor laser is very large, especially at the fast axis direction, which results in a significant restriction to the high light beam quality applications. The divergence angle at the fast axis direction could be collimated to tens of milliradian just by using cylindrical micro-lens. For high-power laser-diode stacks, the method of external-cavity feedback could be applied to realize cross-injection between the arrays, and phase-locking could be achieved at proper condition. In that case, the output divergence angle could be narrowed to a few milliradians. In this paper, we experimentally achieved cross-injection between two collimated broad-stripe diode-lasers (LDs) by employing a common external cavity mirror. It showed that the fast axis divergence angles for each laser were compressed to some extent, and the center wavelengths tended to unanimity. The theoretical discussion was also given, showing good agreement with the experimental results. Our research would benefit to enhance the beam quality of the high-power laser diode bar stacks.

7843-71, Poster Session

Laser doping of phosphorous in grooved silicone surface

K. Lee, S. Bae, Y. Kim, Y. Joh, J. Yi, Yeungnam Univ. (Korea, Republic of); M. Jeon, J. Lee, J. Hong, Millinet Solar (Korea, Republic of)

Among various trials on improving energy conversion efficiency of silicone based photo-voltaic cell, laser doping casts promising future. Several research groups are suggesting their own methods for laser doping. Usually, doping laser is injected inside of narrow phosphoric acid jet. The injected beam propagates through the jet and it grooves surface of silicone cell. The laser energy also heats the silicone surface and phosphorous is penetrated through the surface. In this work, we separate the grooving laser and heating laser. The silicone surface was grooved by a pulsed fiber laser. The spot size of the laser was 50 m. For surface measurement, grooved with of 200 m was needed. To have the groove width, we scanned the laser several times. SEM image of the grooved surface showed ripple of the surface. The phosphoric acid was sprayed on the grooved surface. A fiber coupled cw diode laser heated the sprayed Si surface. After heating, the Si was washed thoroughly by deionized water. The depth profile of penetrated phosphorous was examined by using SIMS. The profile indicated that phosphorous was penetrated about 50 nm. Four point measurement of surface resistance also indicated successful laser doping.

7843-72, Poster Session

Analysis and simulation of stimulated Brillouin scattering in all-fiber single-frequency fiber amplifiers with delivery fibers

J. Leng, National Univ. of Defense Technology (China)

The pump combiner is one of the key components in the all-fiber single-frequency fiber amplifiers, which couples the pump power into the inner clad of the double clad fiber. At the same time, delivery fibers are drawn in by the pump combiner. In this paper, the influence of the delivery fibers on stimulated Brillouin scattering (SBS), which mitigates the signal power into reverse direction and limits the maximal output power and even causes potential damage to optical components, is discussed, based on the rate-equations combining with SBS. The impacts of pump schemes are simulated, together with lengths and geometrical structures of delivery fiber. The results indicate that the amplifier performance is considerable undermine by the delivery fiber in a backward pumped amplifier, in which the lengths and core diameter of the delivery fiber make great impacts on the performance. On the other hand, the performance is almost not confined a forward pumped amplifier. The impacts of the temperature and strain gradients along the fiber, which can broaden the SBS gain profile and thereby suppress SBS, on the amplifier performances are discussed. Suitable suppression scheme is proposed to overcome the influences of delivery fiber on the amplifier performance.

7843-73, Poster Session

Microstructure and high-temperature oxidation resistance of TiN/Ti3Al intermetallic matrix composite coatings on Ti6Al4V alloy surface by laser cladding

H. Liu, Kunming Univ. of Science and Technology (China)

A high-temperature oxidation resistant TiN embedded in Ti3Al intermetallic matrix composite coating was fabricated on titanium alloy

Ti6Al4V surface by 6kW transverse-flow CO2 laser apparatus. The composition, morphology and microstructure of the laser clad TiN/Ti3Al intermetallic matrix composite coating were characterized by optical microscopy(OM), scanning electron microscopy(SEM), X-ray diffraction(XRD) and energy-dispersive spectrometer(EDS). In order to evaluate the high-temperature oxidation resistance of the composite coatings and the titanium alloy substrate, isothermal oxidation test was performed in a conventional high-temperature resistance furnace at 600° and 800°, respectively. The weight gains were measured using a high accuracy photoelectric balance and the relative high-temperature oxidation resistance was also used to characterize the oxidation resistance of the laser clad TiN/Ti3Al intermetallic matrix composite coating.

The result show that the laser clad intermetallic composite coating has a rapidly solidified fine microstructure consisting of TiN primary phase (granular-like, flake-like, and dendrites), and uniformly distributed in the Ti3Al matrix. It indicates that a physical and chemical reaction between the Ti powder and AlN powder occurred completely under the laser irradiation. In addition, the microhardness of the TiN/Ti3Al intermetallic matrix composite coating is about 900HV, 4 times higher than that of the titanium alloy substrate. The high-temperature oxidation resistance test reveals that TiN/Ti3Al intermetallic matrix composite coating results in the better modification of high-temperature oxidation behavior than the titanium substrate. The excellent high-temperature oxidation resistance of the laser clad is attributed to the formation of the reinforced phase TiN and Al2O3, TiO2 hybrid oxide. Therefore, the laser clad TiN/Ti3Al intermetallic matrix composite coating is anticipated to be a promising oxidation-resisting surface modification technique for Ti6Al4V alloy.

7843-74, Poster Session

Study on temperature filed of nodular cast iron in laser transformation hardening

S. Hu, Hunan Univ. (China)

In this paper, the temperature field of nodular cast iron in laser transformation hardening was investigated. The temperature field was modelled and calculated with an ANSYS software. In the presented experiments, colorimetric temperature measurement method with CCD was applied to obtain the temperature field. The calculated results agreed well to the experimental ones. The model would help predict the width and depth of the hardened track and its micostructure and properties.

7843-75, Poster Session

Approximate calculation of pulse laser heat treatment

Y. Wu, The Academy of Equipment Command & Technology (China); J. Li, Y. Fu, Kunming Univ. of Science and Technology (China)

During the research of the laser surface heat treatment of a material, the temperature field is an important parameter to determine the thermal effect. Due to the complexity of heat interaction between the laser beam and the material, the irradiated workpiece is regarded as the homogeneous medium with constant thermophysical properties and the intensity distribution of laser beam is considered as an ideal distribution so as to simplify the calculation. But laser beam intensity is, in fact, not always ideal distribution. Therefore, it is a crucial task to study the calculation method of time-dependent temperature fields by using real beam intensity distribution. In our study, the laser beam intensity is regarded as superimposition of TEM00 and TEM01 in term of the certain proportion. Through the superimposition factor's adjustment, we can well express the laser beam intensity distribution with the low-order mode output. The semi-analytical calculation formula of pulse laser heating is also re-deduced, which is suitable for this kind of laser device. And the heat treatment experiments of steel were done so as to prove the feasibility of the theoretical study. In order to let our investigation results be adapted for laser beam with arbitrary intensity distribution, the approximate expressions of arbitrary distribution of laser beam and the method of determining the thermophysical parameters of the material through the experiments are discussed.

The paper is organized as follows: Section describes the present researches about the calculation of laser heat treatment, and provides our method. Section proposes the calculation model of pulse laser heat treatment. The experimental verification based on the phase transformation model AC1 is given in section . The approximate expressions of arbitrary distribution of laser beam and the method of determining the thermophysical parameters of the material through the experiments are discussed in Section . Section is our conclusion.

7843-76, Poster Session

Simulation and measurement of temperature field of nodular cast iron in laser transformation hardening

S. Hu, Hunan Univ. (China)

On the basis of considering the thermal physical parameters of material,the latent heat and the effect of convection radiation,ANSYS parametric design language is used to estabish a three-dimension computing model of transient moving temperature field of nodular cast iron in laser transformation hardening.The temperature field change in the laser transformation hardening process was analyzed.Then the trichromatric(RGB) image in the process was acquired by color-CCD and the strength value of monochromatric radiation was calculated.The test specimen of nodular cast iron was assumed to be the greybody. According to the principle of colorimetric temperature measurement,the temperature was obtained and shown. The relation of simulated results and the experimental results was found by compareing with them.Then the width of the hardened track can be predicted by the experimental results.This would help analyse the effect of process parameters and carry out real-time measure and control in laser transformation hardening process.

7843-77, Poster Session

Experimental Investigation on multiwavelength Raman fiber laser based on chirped FBG and sagnac filter

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It is extremely useful to fabricate multiwavelength lasers based on stimulated Raman scattering in optical fibers since the Raman fibers have several advantages such as stable operation at room temperature and large gain bandwidth. A broadband chirped fiber Bragg grating and a sagnac loop have been utilized to form a linear Raman cavity to generate a multiwavelength fiber laser. To explore the impacts of four-wave mixing processes on the Raman fiber laser, a length of dispersion-shifted fiber (DSF) is incorporated into the laser oscillator. The integrating Raman gain of DSF is small in comparison with the Raman gain media for the purpose of limiting its Raman contribution on Stokes waves. Experimental results show that for a given pump level four-wave mixing interactions induced by DSF play a role of broadening the Stokes spectrum and outputing more wavelengths than the case without DSF.

7843-78, Poster Session

PMMA transmission welding with fiber lasers

J. Jiao, Institute of Industry Technology (China); X. Wang, Huazhong Univ. of Science and Technology (China); X. Bai, C. Peng, Institute of Industry Technology (China)

Nowadays, plastic is widely used in areas of autos, medical devices, electronic devices, et al. Welding plastic with lasers become more and more popular, especially the plastic transmission welding with near-infrared lasers. In previous studies, the laser beam was always treated as a surface source, which not agrees well with the practical exactly. In this paper, the laser source was treated as a voluminal source in the transmission part and a surface source in the absorption part. The mathematical model of plastic laser transmission welding (LTW) was proposed, and the thermal behavior of the welding process was simulated by using finite element method (FEM) software ANSYS. The wide of the welding path and the temperature of the heated zone for different parameters were predicted by numerical method. Under the direction of the numerical results, PMMA material was welded with fiber lasers. The welding quality was tested by microscope, which agrees well with the numerical predicting.

7843-79, Poster Session

Aberrations correction of a Nd:YAG slab amplifier using a compact adaptive optics system

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Zigzag slab laser amplifier is promising laser architecture for achieving high power and high quality beam output. Compared with its counterparts such as rod lasers, disc lasers, the distortions generated in the zigzag slab are much smaller at the same power level due to its better cooling means and convenient thermal management. However, it is should also be noted that many detrimental factors such as thermally induced strain and distortions, static aberrations from the optical components and so on would induce wave-front distortions in the laser field and reduce the output beam quality. Therefore, many researchers have been engaging in developing techniques to improve the performance of zigzag slab amplifiers to the best of their ability. Generally, it is difficult to compensate for all the wave-front distortions that generated in the slab laser just through passive methods, especially for those dynamic thermal distortions. To offer a promising alternative, we employ the active method based on adaptive optics (AO) to correct the distortions in a zigzag slab amplifier. This AO system mainly includes a 39-element rectangular deformable mirror (DM), a far-field detector, and a stochastic parallel gradient descent (SPGD) optimization algorithm. What is different from those conventional AO systems used in many fields is that this wave-front sensor-less SPGD AO system does not need any wave-front sensors to measure wave-front information, but use the far-field metric which is mainly determined by the beam quality to control the DM and achieve distortions correction. This strategy is low cost and compact to implement in the zigzag slab amplifier system.

7843-80, Poster Session

Different types of sideband generation in a passively mode-locked soliton fiber laser

H. Li, Z. Jing, J. Liao, X. Tang, R. Lu, Y. Liu, Univ. of Electronic Science and Technology of China (China)

Femtosecond mode-locked fiber lasers have attracted a great deal of interest both as advanced photonic devices with a range of research and industrial applications and also as an interesting nonlinear physical system to study. Here we report on the experimental observation of sideband generation in a passively mode-locked soliton fiber laser. The laser used in this study has a cavity configuration typical for Er-doped fiber ring lasers using the nonlinear polarization rotation technique for mode locking. Self-starting and stable mode-locking operation is easily achieved in the laser. The output soliton pulses have a duration of about 300 fs and a repetition rate of 13.7 MHz at 1560-nm wavelength. Detailed spectral and transient dynamics of the laser are measured at different pumping levels. As the pump power is increased and the polarization controller is adjusted, the soliton peak power increases, and the sidebands of the soliton spectrum change from the Kelly sidebands with spectral peaks to the parametric sidebands with spectral dips. The dip-type sidebands have clearly different characteristics to those of the Kelly sidebands. We numerically simulated the soliton operation of the fiber laser based on the coupled Ginzburg-Landau equations. The simulation results are consistent with the experimental observations, which confirm that dip-type spectral sidebands can appear on the soliton spectrum of a uniform soliton-emission fiber laser.

7843-82, Poster Session

Far field irradiance profile control with high spatial frequency deformable mirror

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A novel method based on diffraction theory to control the far-field irradiance profile by deformable mirror is presented. Special near-field phase which determines the contour of the focal spot is obtained by a high spatial frequency deformable mirror. Numerical simulations show that, we can control the far-field intensity envelope as CPP by adopting adaptive optics technique when the spatial resolution of deformable mirror is high enough, here 16×16 actuators in 320mm×320mm aperture. The coupling coefficient is an important factor influencing control effect, and its best value range is round 0.6.

7843-83, Poster Session

Suppression of transverse stimulated Raman scattering or transverse stimulated Brillouin scattering

Y. Zhang, H. Ye, X. Yan, M. Wang, J. Zheng, M. Li, F. Jing, X. Wei, Chinese Academy of Engineering Physics (China)

A novel method, by which the edge of the frequency convector is processed into arris, has been proposed to suppress the reflection of transverse stimulated Raman scattering or transverse stimulated Brillouin scattering at the edge. The mode analysis indicates that the residual reflection decreases exponentially with the angle of the arris by this method and the direction of the light finally reflected back has an angle with the surface of convector.

7843-28, Session 5

Experimental study of monitoring plasma light in laser cladding

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Laser cladding monitoring is one of the cladding layer quality controlling methods. At present, cladding monitoring usually monitor the temperature or the shape of melting pool. The height deviation between melted and unmelted point is also considered. In this paper, optical

signal of plasma which is one of the characteristic signal of plasma has been detected by phototube in cladding. The relationship between blue-violet light intensity and laser power scan velocity has been discussed, and the relevance between quality of layer and intensity has been analysed as well. The results indicate that while laser power growed the intensity increased just at a low rate, and the intensity decreased as scan velocity increased when the power is lower than a definite value. But when the power is greater than this value the intensity will rise as velocity increase. The quality of layer is improved greatly when the intensity value rang from 1.7 to 2.5 with a slight fluctuation.

7843-30, Session 5

Numerical simulation of curved surface of gear in laser cladding

Z. Hu, L. Hong, G. Wu, Shanghai Maritime Univ. (China)

Most of the temperature and stress fields simulations in laser cladding were based on flat surface, while actually cladding may occur on any curved surface. The difference between cladding on flat surface and curved surface is that the latter will result in uneven distribution of laser power. Experiments of laser cladding have been done on different material gears under various technical conditions, and crackles have been observed by SEM. Some factors that affect laser power actually, such as laser shielding, the incident angle of laser and curved surface of gear are all considered. Based the analysis of the shape of layer after cladding and the phase transformaion during cladding, temperature and stress fields of gear surface laser cladding have been simulated by ANSYS in this article. The results indicate that appropriate material matching and base preheating can decrease the likelihood of crackles, even eliminate it.

7843-31, Session 5

Shock induced phenomena in high fluence femtosecond laser ablation of silica glass

X. Wang, Nankai Univ. (China)

Shadowgraphs of dynamic processes outside and inside the target during the intense femtosecond laser ablation of silica glass at different energy fluences are recorded. Two material ejections outside the target and two corresponding stress waves inside the target are observed. In particular, a third stress wave can be observed at energy fluence as high as 40 J/cm2. The pressure, the temperature, the free electron density, and the ionic components at the laser pulse end are estimated, based on which the mechanical reaction of the laser heated material is investigated. According to our analysis, the first wave is a thermoelastic wave, while the second and the third may be generated subsequently by the mechanical expansions. Besides, it is found that the first stress wave propagates with a velocity greater than the sound velocity, while the second stress wave propagates with a velocity less than the sound velocity. Therefore, the first wave is a supersonic shockwave with a high stress magnitude, while the second may be the plastic stress wave or subsonic shockwave with a lower stress magnitude. Further more, the temporal evolution the second stress wave is investigated, and its velocity is speculated to decreases from a high value initially, which could be due to the interaction between the first and second stress waves at small delay times. These results can provide a further support to the theory of highpressure shock phenomena in femtosecond laser ablations.

7843-32, Session 5

Investigation on femtosecond laser-assisted microfabrication in silica glasses

F. Chen, H. Liu, X. Niu, Q. Yang, X. Wang, J. Si, X. Hou, Xi'an Jiaotong Univ. (China)

Femtosecond (fs) laser-assisted microfabrication is proved to be a cost-efficient method to fabricate three-dimensional microstructures in transparent materials. When focused into the targets, fs pulses will modify the materials in the focal point due to the multiphoton absorption, where the chemical etching is significantly accelerated, resulting in selective removal of the materials. In this paper, using an 800-nm, 30-fs and 1 kHz laser direct writing followed by 5% HF aqueous solution treatments, straight microchannels and three-dimensional (3D) microstructures with fine appearances are manufactured in the silica glasses. Additionally, the influence of the chemical etching velocity on the processing parameters, such as the laser power, scanning velocities, scanning times and laser polarizations, is detailed investigated. The results indicate that the etching velocity of the microchannels is proportional to the laser power and reciprocal proportion to the scanning velocities, but is independent with the scanning times; circular or elliptical polarized lasers will greatly increase the chemical etching velocity and the surface smoothness of the fabricated microchannels compared to the linear polarizations. Our works will provide insights into the 3D microfabrication of transparent materials, which have great potential applications in biochips, micro-total analysis systems, integrate optical devices and etc.

7843-33, Session 5

The state-of-the-art laser bio-cladding technology

J. Liu, Hunan Univ. (China)

Musculoskeletal disorders are recognized as one of the most significant human health problems that exist today. Biomaterials are synthetic materials intended to replace part of a human body or function appropriately in contact with a living tissue. Laser bio-cladding is one of main current processes for fabrication of implants to replace part of a human body. In this article,the current state and future trend of laser bio-cladding technology are discussed. Since laser cladding technique appeared, its applications has been developing from coatings through repair and rapid fabrication of tools and components to bio-cladding. Application of laser cladding in implants include fabrication of metal scaffolds and bio-coating on the scaffolds. Stainless steel scaffolds and Ti alloy ones have been developed, and calcium phosphate bioceramic coatings have been deposited on Ti alloys. The types of biomaterial devices currently available in the market include replacement heart valve prosthesis, dental implants, hip/knee implants, catheters, pacemakers, oxygenators and vascular grafts. Some tasks are envolved in laser bio-cladding process now, such as customization of implants and optimization of the characteristics of the scaffolds and coatings, and the efforts are being put to figure out how to solve the existing problems. Patient-customisable implants with improved performance and biocompatibility may be commercially produced using laser bio-cladding. This process is attracting more and more attentions of people.

7843-34, Session 5

Effect of laser cladding variables on the microstructure and crack of laser cladded Ni-alloy on ductile cast iron

Q. Li, Hunan Univ. (China)

In this paper, the effects of the process variables on the microstructure and cracks in laser clad track on ductile cast iron were investigated by simulation of the thermal and stress field and performation of experiments. Firstly, the ductile cast iron substrate was laser cladded with Ni-base alloy under different process conditions. The microstructure and crack were observed by metallographic microscope. Then, the temperature and residual stress fields in laser cladding with near Guass heat source were calculated by ANSYS software, while APDL(ANSYS Parameter Design Language) being used to control the density of thermal flow, scanning velocity and path. In establishing three-dimensional(3D) models of the distributions of temperature and stress, the influences of heat of conduction, convection and radiation and latent heat of phase transformation were taken into account, and the powder addition was computed by killing and activating element. The relationship between the cracks and residual stress and that between the microstructure of cladding layer and thermal field were expressed numerically. The variation of the microstructure and the cracks of the cladding layer was interpreted theoretically. It was found that the microstructure and crack were influenced by process variables. In comparison with the presented experiment, the simulation with ANSYS finite element software could help to predict, to some extent, the microstructure and crack of laser cladded Ni-alloy on ductile cast iron.

7843-35, Session 5

Effect of laser power and heat treatment process on microstructure and property of multi-pass Ni based alloy laser cladding coating

H. Liu, Kunming Univ. of Science and Technology (China)

Ni60CuMoW alloy power was cladded on 45 steel substrate using an synchronization powder feeding method by 6kW transverse-flow CO2 laser apparatus.The effect of laser power and heat treatment process on the corrosion resistance and wear behavior of the cladding layer was discussed. The microstructure and mechanical property were analyzed by optical microscopy (OM), X-ray diffractometer (XRD), scanning electron microscope (SEM), energy depressive X-ray spectroscopy (EDX), microhardness meter and PS-268A electrochemical test equipment. Results show that the cladding layer is mainly consist of (Ni, Fe), NiCu, Cr5B3, Ni31Si12 and a small amount of WC. With the increase of the laser power, corrosion resistance and microhardness has been improved. When the laser power is 3.2kW, the corrosion resistance of single-pass cladding layers in 3.5%NaCl saturated solution is improved significantly, the maximum self-corrosion potential increased by 136.2mV and corrosion current density decreased by 2 orders of magnitude. Compared with the substrate, the wear resistance and microhardness of treated sample is increased 4 times and 4.38 times, respectively. Compared with the single-pass cladding layer, the corrosion potential of multi-pass cladding layers is increased by 437.6mV and corrosion current density decreased by 2 orders of magnitude. After heat treatment, the primary dendrite and block (or needle) eutectic in clad microstructure become more uniform, and the maximum self-corrosion potential increased by 45.5mV and corrosion current density was also decreased obviously.

7843-36, Session 5

The behavior of powder particles in coaxial laser cladding

N. Yang, Tianjin Univ. of Technology (China) and Tianjin Polytechnic Univ. (China); H. Dong, Dalian Jiao Tong Univ. (China)

The metal powder flow is sprayed by a coaxial nozzle with carrying gas in laser cladding, and the powder particles are radiated to be melt metal by high power laser. The melt metal enters the melton pool on the substrate which is radiated by the same laser beam. The cladding layer forms, when the melton metal cool down. It is crucial to study the influences of different process parameters on the movement and thermal behavior of moving powder particles, and the results could guide laser cladding process. In this paper, a 2D model about a moving particle's movement and thermal behavior was established. The influences of nozzle geometry, laser beam focused point, divergence angle, particle size and initial velocity of particle and shield gas were discussed systematically. And a new method to estimate the laser efficiency based on movement model was proposed. The calculated value agreed with the measured value well. So, the results are very helpful to design the nozzle and to select process parameters in coaxial laser cladding.

7843-37, Session 5

Investigating material removal mechanisms during laser ablation of InSb

A. Garg, S. K. Bansal, K. N. Tripathi, A. Kapoor, Univ. of Delhi (India)

We have investigated laser ablation in InSb in the fluence regime of 8.5 J/cm2 to 21 J/cm2 by studying the crater morphology. Crater morphology shows a non linear change in depth, volume and roughness at fluence of 14.5 J/cm2 (Fcr) and above. These non linear variations with presence of several micro-cavities at the crater bottom (potential bubble nucleation sites) suggest a different material removal mechanism at Fcr and above. The results have been explained in light of various ablation theories which support explosive boiling as a mass removal mechanism at Fcr and above. Thermal melting model for laser ablated InSb is in good agreement with the experimental results.

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7844-01, Session 1

Novel semiconductor lasers and integrated photonic devices

J. He, Zhejiang Univ. (China)

Novel design concepts, simulations and experimental results on semiconductor lasers and integrated photonic devices are presented, including a digitally wavelength switchable semiconductor laser, arrayed waveguide grating (AWG) devices, and high-sensitivity passive and active waveguide sensors.

7844-02, Session 1

Phase control in photonic crystal VCSEL

W. Zheng, A. Liu, W. Zhou, W. Chen, H. Wang, H. Qu, L. Chen, Institute of Semiconductors (China)

No abstract available

7844-03, Session 1

High brightness InAs/GaAs quantum dot tapered laser at 1.3 μm with high temperature stability

Y. Cao, P. Xu, H. Ji, L. Chen, T. Yang, Institute of Semiconductors (China)

High brightness InAs/GaAs quantum dot tapered lasers at 1.3 μm were developed with high temperature stability. The devices consisted of a straight index-guided section formed by a ridge waveguide (RW) and a gain-guided tapered section. The optimization of the beam parameters was carried out mainly by optimizing the lateral device geometry. The laser length L =1.5mm with a constant full taper angle =4 °, the length of the straight section L_{RW} was varied. For the 1.5 mm long devices, L_{RW} was 0.5, 0.7 and 1 mm, respectively. For above-mentioned geometries the power-voltage-current characteristics and the beam quality factor (M^2) are presented. The lasers with a smaller L_{RW} have higher threshold current and lower slope efficiency due to the larger area of the tapered section at fixed lasers length. In the case of L=1.5mm with L_{RW} = 1 mm, the M^2 are 1.95 and 2.46 for the lasers when operation current I =0.4 and 0.8A, respectively. The M^2increases with the current increasing, it means the beam quality becomes poor because of the heat produced increases under the higher current. We also measure the threshold current dependence on the temperature for the kind of laser above. The threshold current is almost constant over a temperature range from 30 to 70°. It is of important significance for the practical application because that the temperature range overlapped with the operating temperature range.

7844-04, Session 1

Beam-shaping of laser diode stack for uniform illumination by cylindrical micro-lenses

W. ShangGuan, H. Yan, Y. Jiang, X. Zhang, C. Yang, Zhejiang Univ. (China)

A novel beam-shaping method for a high-power laser diode (LD) stack is introduced which obtains nearly uniform illumination. The LD stack is widely used because of its high efficiency, but the output beams of the LD stack must be shaped owning to its large divergence-angle. Based on the invariability of the angular distribution when the Gaussian beams propagate, a flat-top intensity profile can be achieved by the superposition of multi-tilted Gaussian beams. Due to the theory above, the individual lensing techniques are introduced to control the divergence-angle of each output beam. This technique also changes the emitting-angle of each output beam so that they overlap to create a uniform intensity distribution. The experimental results agree well with the theoretical simulation, and uniform illumination can be obtained. Cylindrical micro-lenses are used to reconfigure the beams of the LD stack. Through adjusting the precision position of each cylindrical micro-lens, each output beam has different emitting-angle and superposes in the angular domain to form a multi-tilted Gaussian beams shape for a 12o×10o field-angle illumination. With the proper uniformity and high efficiency, the beam-shaping system we have proposed for high-power LD stacks can be well suitable for laser illuminator in laser active imaging and detecting system.

7844-05, Session 1

Single-mode laser diode modified by one-dimensional photonic crystal

W. Chen, A. Liu, W. Zhou, W. Zheng, Institute of Semiconductors (China)

Ridge waveguide semiconductor laser diodes (LDs) have been developed as an economical light source for their simple fabrication process. LDs of this type have been study for many years and wildly applied. In various applications, beam quality and the output power are the mainly considered two factors. Due to the epitaxial structure of the semiconductor wafer, the divergence angle in the vertical direction is large, and the beam quality is low. Moreover, to maintain single lobe far field, the width of the waveguide in the lateral direction was restricted to several microns, which limited the out put power of the laser. Field extension is the most efficient way to reduce the divergence angle and meanwhile increase the output power. In this paper, one dimensional photonic crystal (PhC) was introduced into the laser diode to modify the optical field. In the vertical direction, the optical field can be modified by PhC periodically, and extent to the PhC area, greatly increasing the size of the lasing area. In the lateral direction, one dimensional PC can also be introduced to extend the higher order mode. By pumping at selected area, the difference in optical confinement can distinguish the fundamental mode, and inhibit all the higher order mode, and the width of the waveguide can be increased.

7844-06, Session 1

Research on amplified feedback DFB lasers and their application in all optical clock recovery

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Self-pulsating DFB laser is a promising device which has application in the all optical clock recovery and millimeter-wave wireless communication system. Amplified Feedback DFB Laser(AFL) as one of self-pulsating DFB laser has wide frequency tunable range and tunable wavelength which can be tuned to match the optical signal. 20GHz AFL and 40GHz AFL have been designed and fabricated. For 20GHz AFL, the continuously tunable range of self-pulsation frequency was 20 GHz to 26GHz with 3dB linewidth only 3 MHz. The extinction ratio is larger than 8dB in the whole frequency range. All optical clock recovery was realized by using the AFL with the time jitter of 123.8fs. For the 40GHz AFL, the tunable range of self-pulsation frequency was 31 GHz to 52GHz with 3dB linewidth only 3 MHz. The extinction ratio is larger than 8dB in the whole frequency range. All optical 40GHz clock recovery was realized with time jitter of 356fs. The clock recovery of different degraded signal was also studied. All optical 3R regeneration is experimentally investigated with the AFLs for clock recovery and SOA-DI for the optical decision gate.

7844-07, Session 1

MEMS-tunable wavelength vertical-cavity surface-emitting lasers

X. Guo, B. L. Guan, X. J. Ren, S. Li, C. C. Li, S. Guo, C. X. Hao, G. Shen, Beijing Univ. of Technology (China)

Tunable wavelength vertical-cavity surface-emitting lasers (VCSELs) are considered as key components for advanced optical communication systems. We will present the behaviors and characteristics of the MEMS tunable VCSELs subject to DBR cantilever control from a coupled cavity, including the fabrication, characterization of tunable wavelength and mode dispersion during the tuning range. Experiment measurements revealed that the continuous tuning ranges over 18.8 nm near 968.8 nm to 950nm for 0-7 V tuning bias. In addition, the multilayer DBR cantilever structure was optimized by the Comsol Multiphysics analysis, which was followed by the fabrication using via hole etching.

7844-08, Session 1

Experimental demonstration of a widely tunable two-section DFB laser

Y. Wang, M. Li, J. He, Zhejiang Univ. (China)

Distributed feedback (DFB) laser has been widely used in optical communications for its high single-mode selectivity. However, its wavelength tuning range is usually limited to 2~3 nm by varying the injected current and/or temperature. The wavelength tunability can be enhanced by using two-section DFB. The reported largest tuning range of a two-section DFB tuned by injection current is about 7nm. In this paper, we report our experimental results on a two-section DFB laser with a wide tuning range of over 10nm. The device consists of two individually injected gain-coupled DFB sections with a uniform grating pitch. The total device length is only 350um, with 150um for one section and 200um for the other. The threshold current is only 16mA total for the two electrodes. The lasing mode lies on the longer wavelength side of the stop band. In the tuning process, we adjust only one injected current monotonically until the other DFB mode at the shorter wavelength side of the stop band is about to be excited. Then we alter to the other electrode and repeat the process. We found that the shorter wavelength DFB mode can be suppressed efficiently through this method and a mode-hop-free tuning range as large as 10 nm can be obtained. The side mode suppression ratio (SMSR) is over 45dB in optimal conditions and is maintained above 40 dB when the wavelength is tuned from 1541nm to 1549nm, while the output power variation is less than 3 dB. To our knowledge, this is the largest tuning range achieved for a two-section DFB laser with a simple uniform grating tuned only by injection current. The device is suitable for applications in DWDM systems as well as laser spectroscopy and lidar sensing.

7844-09, Session 1

Complex coupled green VCSELs based on organic and inorganic optical thin films

Y. Wang, T. Kusserow, F. Messow, H. H. Hillmer, Univ. Kassel (Germany)

Semiconductor lasers that directly emit green light with high efficiency and long lifetime are still missing in the laser family. The frequency doubled Nd:YAG lasers are successful alternatives, but their applications are greatly confined by their limited efficiency and the difficulties in miniaturization. In contrast to the conventional solid state lasers, a novel conception of complex coupled hybrid laser is pursued in the scope of this work, which is expected to enable miniaturized vertical cavity surface emitting lasers (VCSELs) in the green spectral range with low lasing threshold.

The conception of complex coupled VCSEL is introduced by this work for the first time. In such hybrid VCSEL structures, alternating organic and inorganic thin films provide periodic variations of refractive index and optical gain, which enable the single mode operation and low threshold of the VCSELs. Based on the transfer matrix method and the real measurement of material properties, model calculations are carried out and the results are compared with traditional design of micro-cavity organic lasers. Free standing dielectric and semiconductor membranes are successfully implemented to enable the technological fabrication of the alternating organic and inorganic multi-layered structures.

Model calculations revealed great reduction of the lasing threshold with factors above 30 compared to the existing micro-cavity lasers. Combining the advantage of broad photoluminescence spectra of the organic active materials and the high coupling efficiency of the laser structure, complex coupled hybrid VCSEL is a very promising approach to fill the gaps in the lasing spectrum of the semiconductor lasers.

7844-10, Session 1

High-power optically pumped semiconductor lasers for THz generation and sodium guidestar laser

L. Fan, Lasertel, Inc. (United States)

Optically pumped semiconductor laser (OPSL, also called VECSEL or semiconductor thin disk laser) can convert fairly low-cost, low-beam-quality optical pump power from high-power diode laser bars into a near-diffraction-limited output beam with good efficiency. Compared to well-established diode-pumped solid-state lasers based on ion-doped dielectric materials, the advantage of OPSLs is their lasing wavelength can be well-designed since they employ semiconductor quantum wells as gain medium. They can operate in wavelength regions which are not covered by solid-state laser gain materials. The external free space cavity of OPSL and high circulating power within the cavity makes it possible to generate other lasing wavelength by using intracavity nonlinear frequency conversion, potentially providing wider lasing wavelength range from deep UV to THz. Such OPSL performance

should be well-suited for many applications such as laser displays, LIDAR, optical clocking, and frequency metrology. This paper focuses high power dual-wavelength OPSL for THz generation and 1178-nm OPSL for sodium guidestar laser.

7844-11, Session 2

Optical signal processing using highly nonlinear optical fiber

L. Yan, A. Yi, W. Pan, B. Luo, J. Ye, Southwest Jiaotong Univ. (China)

Optical signal processing functionalities using highly nonlinear optical fiber are reviewed, especially all-optical regeneration, wavelength and format conversion, with some recent experimental demonstration results updated. Progresses in SBS-based slow light are also discussed.

7844-12, Session 2

Optical fiber sensors for landslide monitoring

Y. Liu, Z. Dai, J. Li, L. Zhang, Z. Ou, C. Zhou, Y. Liu, Univ. of Electronic Science and Technology of China (China)

We present optical fiber sensors technology for landslide monitoring application. The optical fiber sensors are used to monitor the intra-stress distribution and variations in landslide bodies, and can realize the early warning of the occurrence of the landslides. Several optical fiber sensor technologies that are suitable for the landslide monitoring are introduced. In particular, we describe a distributed fiber stress sensor based on polarization coupling coherence to monitor the intra-stress distribution and variations. The sensoring system is formed by a superluminescent diode, a section polarization-maintaining fiber, a Michelson interferometer and a signal processor. According to the requirements for the application in landslides monitoring, a distributed fiber stress sensor with stress measuring range 0-15Mpa, spatial resolution 10cm and measuring range 0.5km, was designed. The warning system is also investigated experimentally.

7844-13, Session 2

Suppression of time delay signatures of chaotic output in mutually delay-coupled semiconductor lasers

J. Wu, Z. Wu, J. Shen, L. Ding, N. Li, G. Xia, Southwest Univ. (China)

In the last two decades, chaotic output of semiconductor laser (SL) has attracted much attention for its potential applications in secure communications, fast physical random bit generation and chaotic radar etc. Since high dimension broadband chaos can be relatively easily obtained by introducing time delay (TD) feedback, external cavity feedback semiconductor laser (ECF-SL) system has been regarded as a good candidate in high-speed cryptosystem and a perfect physical entropy source for ultra-fast random bit sequences. Very recently, Kanter et al. reported a 300Gbits-1 random bit generator by using ECF-SL system. Usually, the chaotic output of ECF-SL system usually retains obvious TD signatures. For ultra-fast random bit generation, the TD signature induces recurrence features and affects seriously the statistical performance. As for chaotic cryptosystem, the TD signature also provides a possible clue to the encryption attackers. Hence, the TD signature elimination becomes crucial for improving the statistical performance of random bit sequences and ensuring the cryptosystem security.

In this paper, we experimentally and numerically investigated the TD signature suppression in a mutually delay-coupled semiconductor lasers (MDC-SL) system. By comparing with ECF-SL system, the MDC-SL system owns unique advantages such as the ability of concurrently exporting two chaotic sequences and purely physical TD signature suppression. Moreover, such MDC-SL device is all fiber construction and then is more compactable and controllable. The results show that excellent TD signature suppression can be achieved and all TD signatures are suppressed into background noise level. Meantime, two chaotic sequences are obtained concurrently and the corresponding self-correlation curves exhibit almost perfect function profile. This work offers a highly effective, compactable and purely physical TD signature suppression scheme for high speed random bit generation and high rate cryptosystems.

7844-14, Session 2

Modulation-free frequency stabilization system of external cavity diode laser based on Sagnac interferometer

F. Wei, Shanghai Institute of Optics and Fine Mechanics (China)

We have constructed frequency stabilization system of Littman-Matcalf configuration external cavity diode laser (ECDL) using a novel modulation-free technique based on Sagnac interferometer without optical path misalignment. To avoid the offset of phase variation between the counter-propagation beams a phase shifter is introduced in the loop by total internal reflection (TIR). From difference signal between the sagnac output TEM00 port and the “pump” port, a dispersive signal from saturated-absorption spectroscopy of 5S1/2(F=2) 5P3/2(F´=3,2,1) transitions of 87Rb is acquired, so that the frequency of our home built ECDL is stabilized to F=2 CO 2-3 for 87Rb. The frequency drifts less than 0.5MHz peak-peak. This simple, robust and low-cost scheme can be extended to other atomic experiments and metrology. Other advanced schemes and theory for frequency stabilization will be also proposed in this paper.

7844-15, Session 2

The equivalent modulation inside the periodic structures: from devices to systems

Y. Dai, Tsinghua Univ. (China); K. Xu, J. Wu, J. Lin, Beijing Univ. of Posts and Telecommunications (China)

The paper will introduce the replacement of phase modulation by amplitude modulation inside the periodic structures, especially in the Bragg gratings, the corresponding principle, applications, and advantages. Applications in advanced signal processings based on fiber Bragg gratings, and in multi-wavelength-arrayed /monolithic-integrated-tunable semiconductor lasers will be reviewed. Other applications, including the arbitrary waveform generation as well as the photonic microwave filter, will also be discussed. Advantages of greatly-simplified fabrication and implementation over the traditional technology will demonstrate the importance of the new technology.

7844-16, Session 2

Power equalization using nonlinear polarization rotation in a single semiconductor optical amplifier

S. Zhang, Y. L. Zhang, K. Zhang, S. Liu, Y. Liu, Y. Liu, Univ. of Electronic Science and Technology of China (China)

An all-optical power equalization based on nonlinear polarization

rotation in a single semiconductor optical amplifier (SOA) is proposed for waveform fluctuation reduction. The theoretical model is built up to illustrate the proposed scheme. With the model, we develop an analytical expression for the output polarization angle of a SOA-based power equalizer in terms of the input polarization angle and further investigate the relationship between the magnitudes of output power, input power, and input polarization angle. Simulations have been done for the degraded RZ and NRZ signals to demonstrate the feasibility of the proposed scheme. The primarily simulated results indicated that the switching power is not more than 10 mW. The all-optical power equalization mentioned in this paper has promoting potential to improve the signal quality and needs low optical power. Our approach has a simple configuration and allows for photonic integration, which can be constructed by commercially available components.

7844-17, Session 2

A novel optical heterodyne approach for measuring frequency responses of photodetectors

Q. Yan, Beijing Univ. of Posts and Telecommunications (China)

A novel approach, using a PNA(network analyzer) instead of Spectrum Analyzer in optical heterodyne measurement system, to characterize the frequency response performance of photodetectors is proposed. This scheme synthesize the advantages of both the optical heterodyne technique and accurate calibration technique of PNA. In this paper, two tunable narrow linewidth lasers are used to reduce the errors caused by the variations in the linewidth of the beat signal, and the optical power is accurately monitored and controlled to minimize the noise due to laser output power fluctuates. We analyze the influence of variations linewidth, and associative simulation on this influence is been done. And an error eliminate model is presented to remove the influence of variations linewidth. SOLT calibration technique is used to accurately calibrate the power receiver of PNA. Experiments result show that the frequency responses obtained using this novel method agree well with the data provided by the manufacturer. In addition, when configured with a 80 GHz frequency mixer in this measurement system, we can achieve the frequency response measurement of a 80 GHz photodetector since we are using a 40 GHz PNA.

7844-18, Session 2

Adaptive nano- and nonlinear- photonics engineering

J. Zhou, X. Xie, Y. Guan, P. Zhang, Sun Yat-Sen Univ. (China)

Recent development in the field of nano-photonics has witnessed a rapid progress both in scientific researches and practical applications. Here we present the study of adaptive optical control for nano-photonic engineering and applications.

A photosensitive medium under the excitation of a variable laser pattern with sub-micro-sized periods will act as a dynamically configurable photonic structure, giving rise to complicated light refraction, deflection and even frequency conversion. A target function of a photonic structure can be defined, and the recorded output is then compared to the target function. The following self-adaptive control will result in a self-optimization of the photonic output, helping design and obtain the nano-photonic structures.

Along this direction, an alternative approach for combining laser beams was developed. Multiple laser beams propagating non-collinearly were combined to form powerful second-harmonic laser beams. Notably, the power of second-harmonic beam was over 2 order of magnitude greater than that from a single laser beam.

Furthermore, a similar adaptive system was used to improve the transmission of a light field through a sub-wavelength aperture in a near-field scanning optical microscopy (NSOM). A spatial light modulator was implemented in a NSOM system to control the wavefront of the input fields, and a self-adaptive control algorithm was applied to automatically maximize the transmission. Significant enhancement of the transmitted power was measured, and the way to further improving the transmission efficiency was discussed.

7844-19, Session 3

Phase estimation in coherent communication systems with semiconductor laser noises

C. Yu, National Univ. of Singapore (Singapore)

We review our proposed decision-aided (DA) maximum likelihood (ML) phase estimation in coherent optical communication systems with semiconductor laser noises. Our method eliminates the phase unwrapping and argument nonlinear operations. In addition, the proposed adaptive DA receiver has a strong self-adaptation capability to recover the carrier phase effectively without knowledge of the statistics of the phase and additive noises.

7844-20, Session 3

Theoretical analysis of emission characteristics of second-order distributed feedback semiconductor lasers

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Distributed feedback (DFB) semiconductor lasers with single-frequency and single spatial mode have wide applications in areas such as optical communication, optical sensing and interconnection. Compared to traditional first-order DFB lasers, second-order DFB lasers are quite superior for their simpler structure, looser manufacture requirement, non-degeneracy mode and stability.

Based on the modified coupled-wave theory, the emission characteristics, including threshold gain, photon density distribution in the cavity, external differential quantum efficiency, emission spectrum, output power et al, for second-order DFB lasers are investigated. Numerical simulation results show that for given device structure with wavelength of 1.55 μm, the feedback coupling coefficient and surface radiation coupling coefficient of the second-order grating have great influence on the emission characteristics of the device. On the other hand, by choosing different grating duty cycles, we can change the two coupling coefficients, thus control the emission characteristics. For instance, the threshold gain difference of ±1 order mode becomes larger with the grating duty cycle increasing from 0.05 to 0.45; the photon density distribution in the cavity in quite uniform for grating duty cycles around 0.05 and 0.43, which could avoid spatial burning hole; the external differential quantum efficiency reaches as high as 50% for grating duty cycles around 0.45.

For an overall consideration, an optimal grating duty cycle of 0.43 is chosen. The optimized results show that the device works without degeneracy mode and spatial burning hole. The side-mode suppress ratio (SMSR) and external differential quantum efficiency reach as high as 42 dB and 47%, respectively. The analytical method and optimized results have great reference value for experiment research.

7844-21, Session 3

Reaserch of the intracavity second harmonic generation characteristics of optically pumped semiconductor disk laser

Z. Li, Y. Song, P. Zhang, Beijing Univ. of Technology (China)

In this paper, we discussed the intracavity second harmonic generation characteristics of optically pumped semiconductor disk laser. The InGaAs/GaAs quantum structures semiconductor chips were used as gain medium, and the gain structrues were optically pumped at 808 nm by the laser diode. then,we got an output of 60mW at 1030 nm. After that, we put the nonlinear frequency doubling crystal LBO in the cavity, we got the second harmonic generation output, and it's center wavelength is 515 nm. At the same time, we also use the frequency doubling crystals just as KTP, KNbO3 respectively to get the frequency doubling output at 515 nm in this experiment. In addition, we also adopted the different cavity structures in this experiment, optimized the parameters of laser, and discussed the output characteristics of the three kinds of frequency doubling crystals and the methods which could improve the output efficiency in experiment and theory. Finally, because the thermal effect of the semiconductor gain chip affects the output power critically, we also calculated the thermal distribution of the semiconductor gain chip in theory, and proposed the methods of cooling.

7844-22, Session 3

Optical bistability in InP/InAlGaAs multi-quantum-well semiconductor ring lasers

Y. Chen, L. Mao, W. Guo, S. Zhang, S. Xie, J. Yu, X. Yu, Tianjin Univ. (China); X. Gu, Tianjin Polytechnic Univ. (China); X. Li, L. Qi, China Electronics Technology Group Corp. (China)

We demonstrate optical bistability in InP/InAlGaAs multi-quantum well(MQW) semiconductor ring lasers(SRL) which can be used in a multi-ring to achieve all-optical storage. The optical cavity of SRL is made of closed ring-like ridge waveguide and its input and output are made of straight ridge waveguides coupled to the ring. All the ridge waveguides are fabricated by the use of inductively coupled plasma reactive ion etching (ICP-RIE).As the etching depth affects the performance of SRL, through analysis and experiments, we successfully achieved optical bistability in SRL by etched away the cladding, with etching depth 1.90μm. When a threshold current is injected into the top electrode, there will be light propagating along the ring cavity and it will be divided into two directions called clockwise(CW) mode or counter-clockwise(CCW) mode. Optical bistability reveals that just above threshold, the laser operate in a state where the two counter propagating modes changed regularly as the injected current increasing. Conventionally there are three distinct operating regimes can be identified from the bistability, they are bidirectional continuous wave (bi-CW),bidirectional with alternate oscillations (bi-AO) and unidirectional bistability(UNI).But currently only the unidirectional bistability can be used in optical logic. The device described in this article has the third regime UNI started directly from the threshold, skip bi-CW and bi-AO and achieves threshold current 60mA which is quite low compared to other reported devices, greatly reduce the injection current required in applications.

7844-23, Session 3

Electromagnetic optimization of high-speed TO laser modules

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In this paper, the high-speed TO packaged laser module is investigated using 3D electromagnetic simulations. The effects of the resistance discontinuity on high-speed performances of TO-can and its interface circuit are studied by setting up a distributed structure based 3D model. Results show that the main resistance discontinuities are occurred in the glass metal based feedthrough parts and the leads of the TO-can. The influence of the dimension of the TO-can on the high-speed transmission is analyzed. To improve the microwave performance, different types of submount for laser chips are designed. By decreasing the length of the bonding wire and inserting a thin film resistor, improved S parameters are obtained. The interface circuits of the TO-can are under careful consideration as well. Different transmission line types, such as straight microstrip line, tapered microstrip line, and tapered coplanar waveguide, are compared, and results show the coplanar waveguide with a tapered structure has the best performance. Using the tapered structure for signal feeding can decrease the reflection in the interface between the TO-can and the circuit. Results also show the air gap between them will also affect the high-speed transmission, which may cause the great reflection and excite resonances. Based on the optimized results, a high-speed laser module is packaged using a TO56 header. The 3dB bandwidth more than 10GHz is achieved.

7844-24, Session 3

High-speed analog DFB laser module operated in direct modulation for Ku-band

Y. Liu, J. Man, W. Han, X. Wang, H. Yuan, H. Zhu, L. Xie, N. Zhu, Institute of Semiconductors (China)

A high-speed DFB laser module in butterfly packaging has been fabricated in our laboratory, which is operated in direct modulation for Ku-band. The bandwidth of the laser module is measured up to be more than 18 GHz with highly linear characteristics and low noise figure. The input points for 1 dB compression and third order interception of the laser have also been obtained as 23 dBm and 30 dBm respectively, and it can be utilized in analog optical link systems with great performance.

7844-25, Session 3

Experimental observations of bistable characteristics of an optically injected semiconductor laser biased nearby the threshold current

X. Lin, Z. Wu, L. Wang, X. Ping, G. Xia, Southwest Univ. (China)

An optically injected semiconductor laser produces an enormous variety of nonlinear dynamics such as period one, four-wave mixing, period-doubling route to chaos, non-locking beating, optical bistabilities (OB) and so on. In particular, optical bistability, which is the coexistence of two output of a semiconductor laser for the same parameter values, have been a focus of attention due to its practical potential for optical switching, signal processing, and memory elements. As one of the OB, power-bistability in an injected semiconductor laser has been widely investigated since it has been observed firstly by Kobayashi in 1981. When the parameters such as the injection optical frequency, the injection optical power of the master laser (ML) and the bias current of the slave laser (SL), are varied along different direction routes to the same value, the output power of the semiconductor laser may be different, thus the power-bistability can be obtained. Recently, another type OB named state-bistability in a DFB semiconductor laser under optical injection has been reported, and the state-bistability between locking and bimodal region has been observed. Such state-bistability is driven by sweeping the power of ML along different routes with a fixed frequency detuning or by sweeping the frequency of ML along different

routes with a fixed injection power.

In this paper, a new style state-bistability has been observed by back and forth sweeping the current of SL nearby its threshold, and the influence of the injection power on the width of state-bistability loop has been discussed.

7844-26, Session 3

Influence of asymmetrical bias currents on chaos synchronization performance of mutually coupled semiconductor lasers

T. Deng, G. Xia, Y. He, Y. Liu, Z. Wu, Southwest Univ. (China)

In recent years, chaos and chaos synchronization of mutually coupled semiconductor lasers (SLs) have been extensively studied for its potential application in optical chaos secret communications. Previous relevant studies have proven that the mutually coupled system based on two symmetrical SLs can not obtain stable and permanent chaos synchronization for the existence of the random noise. Recently, Klein et al. obtained stable chaos synchronization without delay by adding feedback to two symmetrical mutually coupled lasers, but this system requires such harsh terms as the feedback delay time equaling to coupling delay time, identical laser parameters and precise controlling of feedback level. This greatly compromises the system practicability. More recently, Zhang et al. proposed an extremely asymmetrically mutually coupled system by adjusting two directional coupling coefficients and then bidirectional chaos secrete communication can be realized in theory. However, some extra elements is necessary for realizing different coupling coefficients and the system becomes complex.

In this paper, we experimentally and numerically investigate the chaos synchronization characteristics of mutually coupled system consisted of two semiconductor lasers (SLs) with asymmetrical bias currents. The results show that, for the case of the two SLs with identical free running oscillation frequencies, the mutually coupled system can achieve excellent chaos synchronization under relatively large asymmetrical bias currents. Furthermore, the frequency detuning Δf ($\Delta f=f1-f2$, where f1, f2 are the free running frequencies of SL1 and SL2, respectively), controlled by adjusting the temperature of one of the two SLs, has obvious influence on the synchronization performance. For the case of the SL1 biased at a relatively much larger current compared with that of SL2, the synchronization performance will be degraded with the increase of the positive frequency detuning ($f1>f2$), while the synchronization performance can be further improved with suitable negative frequency detuning. The simulated results are basically consistent with experimental results.

7844-27, Session 3

Analysis of strain energy in nanowire heterostructures with component gradient buffer section

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One-dimensional nanowire can relieve strain energy via lateral relaxation, offers the promise of creating highly mismatched, yet dislocation free heterojunctions. Theoretical and experimental results shows there is a critical diameter limit in heteroepitaxial nanowires, beyond the critical value, the large stress and strain at the interface results in poor-quality interfaces with high mismatch dislocation density, disorders of growth orientation and structure fluctuation. Critical diameter of heteroepitaxial nanowires depends on the lattice mismatch. When the lattice mismatch is large, the critical diameter is small. In this study, analytical method is employed to analyze the system strain energy and critical diameter of one kind of longitudinally heterostructure nanowires which contains component gradient buffer sections. Based on the critical diameter model of F. Glas in heterostructure nanowires, calculation has been made to research on how does single-layer thickness and total thickness of gradient buffer effect the critical radius of the system. The results illustrate that component gradient buffer layer can effectively reduce the system strain energy, and the thinner the single-layer buffer section thickness, the more obvious the improvement of its critical radius; if the lattice mismatch of the heterostructure nanowire is smaller, the strain energy can be reduced more significantly, also the greater rate of increase of its critical radius. The freedom cut of the nanowire diameter can be realized by controlling the component and thickness of buffer sections. By using the buffer layers, epitaxial growth of well-aligned InAs/GaAs NWs was not limited by the misfit strain induced critical diameter, which confirmed the above conclusion.

7844-28, Session 3

Experimental study of laser dicing sapphire substrate by green DPSS laser

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Sapphire is an important material for fabricating photonic devices such as LED. Laser dicing technology has been employed for semiconductor wafer dicing at different wavelength and technologies, which shows advantages of no chipping, small kerf width, and high throughput over mechanical blade dicing. Currently most of studies on dicing sapphire are conducted by UV laser, few by green laser. Thus, a green DPSS laser with wavelength of 532nm is employed to dice sapphire substrate. Effects of parameters as laser power, repetition rates, scanning velocity and number of scanning on kerf width, kerf depth and aspect ratio are analyzed. Kerf width and depth are measured by optical microscope and micro-morphology of sapphire is observed by optical microscope and scanning electron microscopy. Results indicate that high aspect ratio and better surface quality can be obtained under the conditions of medium laser power, medium scanning velocity, lower repetition frequency and multiple scanning.

7844-30, Poster Session

Growth of Au-assisted GaAs/InGaAs core-shell nanowires by metalorganic chemical vapor deposition

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In recent years, semiconductor nanowires (NWs) have attracted considerable interest due to their potential applications in electronic and optoelectronic devices. Nanowier-based lasers, photo detectors, field effect transistors, and single-electron memory devices have already been demonstrated. GaAs/InGaAs core-shell radial heterostructure NWs are one of the most popular heterostructure NWs, because they can be used to fabricate semiconductor lasers and photo detectors. We have investigated the growth and photoluminescence (PL) characteristics of GaAs/InGaAs core-shell nanowires (NWs). GaAs NWs were first grown at 470 on GaAs (111) B substrate by means of vapor-liquid-solid (VLS) mechanism; then, InGaAs shells were grown on GaAs NWs sidewalls at 560 by metalorganic chemical vapor deposition (MOCVD). From scanning electron microscope (SEM) images, it is can be found that there are two types NWs, thin NWs and thick NWs. It is shown that all NWs are vertical the substrate. Sidewalls of NWs are hexagon and the facets belong to {112} families of planes. From transmission electron microscope (TEM) and high resolution TEM (HRTEM) images, it is shown that there are many defects, such as stacking faults and twins in thin

NWs. However, for thick NWs, TEM data clearly show pure zinc-blende structures are stable from bottom to top, and they are defect-free.The PL measurement reveals that there is a peak at 1100nm. This study on GaAs/InGaAs core-shell NWs have many potential applications for nano-electronic and nano-optoelectronic devices.

7844-31, Poster Session

Design and experiments of common aperture active imaging system

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Comparing with the passive imaging systems, using active imaging technology to illuminate far, tiny and dim objects can reduce the background illuminating impacts, and can improve the tracking accuracy and the imaging measurement capability. There are two kinds of active imaging systems: separate aperture systems and common aperture systems. Comparing with the separate aperture active imaging systems, those common aperture systems have larger effective illuminating range, and the images detected by them have higher signal-to-noise ratio, which means that the noises caused by the back scattering of atmosphere turbulence can be reduced.

Common aperture active imaging system always use beam splitter to make the illuminating laser and the imaging sensor share one optical axis. As it is known that, there are several kinds of beam splitters. In this paper, the researches and experiments on the feasibility of an active imaging system using polarization beam splitter have been presented. The system includes a CCD imaging unit, a semiconductor laser unit, a polarization beam splitter and a telescope objective. According to the analysis with Jones matrix, the system gains remarkably high utilization ratio of luminous energy, 99.9998945% theoretically, by adding a linear polarizer and a quarter-wave plate in at designed location. Based on the above works, an experimental system, which includes the above 6 components, a designed laser collimating lens and mechanical assembling structures, has been constructed. Theoretically, the system can reach an illuminating distance of 3km, a laser divergence angle of 0.504° and a degree of uniformity of 83%. Then, experiments have been conducted to test the system by using it to obtain images of objects at the distance of 300m and 3km. From the experimental results, clear illuminated objects can be identified, so the feasibility of the system has been demonstrated. However, to make this kind of systems more effective, higher demands on extinction ratio, reflectivity and transmissivity of the polarized components and uniformity of the illuminating spot should be met.

7844-32, Poster Session

The effect of injection-locked FP-LD source on WDM-PON system

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Wavelength-division-multiplexed passive optical network (WDM-PON) technology is one of the best solution for the next generation access network, but the high cost is still a major obstacle to its commercialization. In recent years, the spectrum-sliced amplified spontaneous emission (ASE) injection-locked FP-LDs used as colorless ONU is considered to be a viable low-cost component option, it is a hot point in WDM-PON research and development work[1]. While for a high-speed rate WDM-PON system, the injection-locked FP-LD ONU performance was found affected by the injection of the spectrum-sliced ASE [2][3].

In this work, experimental comparison among different bandwidth of the seed light to injection-locked FP-LDs were studied. It was found that the wider the injected light bandwidth the better performance of the OUN, in the context that the injected light bandwidth match that of the remote node AWG's channel. An analysis of the reasons for this phenomenon is given in the text that the filter effect of the remote node AWG and the noise characteristics of spectrum-sliced ASE affect the performance of FP-LD ONU, a 32×1.25Gbit/s WDM-PON system based on injection-locked FP-LD ONU is demonstrated.

[1]Chang-Hee Lee, Sil-Gu Mun, "WDM-PON based on wavelength bocked Fabry-Perot LDs," Journal of the Optical Society of Korea, 12(4), 326-336(2008).

[2]Kun-Youl Park, Chang-Hee Lee, "Noise characteristics of a wavelength-locked Fabry-Perot laser diode," IEEE Journal of Quantum Electronics, 44(11), 995-1002(2008).

[3]Sil-Gu Mun, Jung-Hyung, et al, "A WDM-PON with a 40 Gb/s(32×1.25Gb/s) capacity based on wavelength-locked Fabry-Perot laser diodes," Optical Express, 16(15), 11361-11368(2008)

7844-33, Poster Session

Self-mixing interference effect of VCSEL and the application on micro-displacement measurement

H. Hao, M. Wang, G. D. Mei, W. Xia, Nanjing Normal Univ. (China)

Self-Mixing Interference (SMI) effect in a laser diode (LD) occurs when a portion of light emitted from the LD is reflected by an object and coupled into the LD cavity. The reflected light carries some information of the external target. The reentered light mixes with the original light in the LD cavity and changes the output power and spectra of the laser. The Vertical-Cavity Surface-Emitting Laser (VCSEL) has a high coupling efficiency, high slope efficiency, low operating current and low tracking error and provides high optical performance. The SMI effect of a VCSEL is studied in this paper. The analysis and experiment are presented to verify the dynamics of the VCSEL. The phenomenon is observed and contrasted with traditional interference phenomenon. The output property of VCSEL is modulated by the change of cavity length and feedback intensity. An interferometer using VCSEL self-mixing based on temporal carrier phase shifting technique is studied. Phase modulation of the beam is obtained by an electro-optic modulator (EOM) in the external cavity. The phase of SMI signal coming from the photo detector is extracted by the phase shift demodulation algorithm based on sampling technique. Theoretical analysis and simulation calculations are presented and some errors of this method are discussed.

7844-34, Poster Session

Distributed Bragg reflector mirror with a double-wavelength reflection: design and calculation

C. Yan, Changchun Univ. of Science and Technology (China)

Optically pumped vertical-external-cavity surface-emitting lasers (VECSEL's) have a simple cavity, which makes the pumping convenient and efficient, and can be made compact. VECSELs essentially consist of vertical-cavity surface-emitting lasers with the top distributed Bragg reflector (DBR) and an external mirror. VECSEL can make use of external cavities and optical pumping techniques to achieve a combination of high optical output power and near-diffraction-limited beam quality that is not matched by any other type of semiconductor laser source. Unlike a VCSEL, in which two high-reflecting semiconductor DBR mirrors are incorporated into the laser structure to form the optical cavity, a VECSEL just has one of the two mirrors. As a result, this kind of resonant cavity can easily include a free-space region to be used.

Therefore, VECSEL with the external cavity mode can be exploited for applications such as intra-cavity frequency doubling and passive mode-locking technology, which is potentially of interest as compact laser sources of ultra-short pulses at high average power. However it is clear that some of the pumping laser power absorbed by the bottom DBR is an important reason for the device temperature rise. In order to solve this problem we design a distributed Bragg reflector mirror with a double-wavelength reflection band. This kind of mirror can reflect the lasing wavelength light to make resonance and reflect the pumping light back into absorbing area for increasing the absorption efficiency.

By using multilayer GaAs/AlAs heterostructures we design a distributed Bragg reflector structure to realize this function. The two reflection wavelength peaks are selected at 808nm and 980nm respectively. This kind of mirror can reflect both the lasing light wavelength as a resonance mirror and the pumping lasing wavelength to reflect the pumping light back into absorbing area for increasing the absorption efficiency to improve the thermal characteristics. Furthermore, this kind of two-band semiconductor reflector can also be used on to other optoelectronic devices to increase the absorption wavelength range and efficiency.

7844-35, Poster Session

A novel wavelength-locking system of tunable three-electrode distributed Bragg reflector (DBR) laser for multiple ITU channels

N. Ye, Institute of Semiconductors (China)

A novel wavelength-locking system for tunable c is presented. A 1*2 fiber coupler is used as a beam splitter to form two optical paths, one for wavelength monitoring and the other for power reference. For wavelength monitoring, two single mode fiber collimators- one as a transmitter and another as a receiver-form a collimated optical path for laser beam and a highly stable air-paced Etalon inserted between two fiber collimators is used as a reference to lock the laser wavelength to five or more ITU channels (the channel spacing maintains 100GHz). Also, a photo detector connected with receiving fiber collimator by FC/PC connector turns the optical signal into electronic signal. Then wavelength shifting signal feed backed to the phase region of DBR laser for stabilizing the laser wavelength. And for power reference, one of the coupler output pots is directly connected with a photo detectors mentioned above. The whole control loop is controlled by a computer and the frequency accuracy is better than during a linear laser temperature change for all locking points.

7844-36, Poster Session

Optical influence of different standard illuminant on Nephrite's green color From Manasi

H. Du, G. Ying, China Univ. of Geosciences (China)

To evaluate the optical influence of illuminant on green color with low chroma (C*≈1 12) of nephrite from Manasi, three different standard illuminant-daylight D65, incandescent light A and fluorescent light F2 (CWF) were applied during the experiment. Two-way ANOVA was used to analyze the illuminants tested considering the coordinates of lightness L* and chromaticity a*, b*. The results indicate significant differences for L*, a* and b* ($p<0.05$). Only L* between D65 and F2 didn't vary significantly ($p=0.691$) with the multiple comparisons (LSD- test). The green color with higher C*and L* were found be influent easily by illuminant, and the color-difference was larger and the color appearance varied more obviously while the illuminant changed. The changes in color parameters and visual effects showed that the D65 light illuminant is more suitable for the evaluation of green nephrite's color grading while light source A can be used during trading.

7844-37, Poster Session

Application of CIELAB-based color difference formulae in quantitative frading of jadeite-jade

G. Ying, China Univ. of Geosciences (China)

Fe2+, Cu2+ and Fe3+ of 146 piece turquoise from HuBei are studied to assess their contribution to the bluish green color. Disregarding the impact of its mineral water on color saturation, the content of these three cations is measured with chemical composition analysis, and then their impact on lightness, chroma and hue angle are quantified respectively with three-dimensional uniform color space CIE LAB. In a nutshell, it indicates that Cu2+ determines turquoise's vivid blue color; Fe2+ turns the color to green, improves the saturation and slightly enhances the visual appearance as a result; Fe3+ leads to the red and yellow tone and makes saturation descend, furthermore, the color turns to brown with lower saturation as its content increases, and ultimately the quality of color is reduced.

7844-38, Poster Session

Lifetime estimation of high power lasers

G. Lu, Changchun Institute of Optics, Fine Mechanics and Physics (China)

For industrial applications, the reliability is rated as the key parameter deciding about the more or less extensive use of high power laser diode arrays in future. Its importance is even higher than the achievement of new records in the optical output power of laser bars. Evaluation of the reliability of a laser diode arrays has a cost associated with it.In this paper, we present the results of long-time aging tests, acceleration factors, and thermal activation energies for high power 808nm laser bar. Extensive studies have been done to understand some main failure mechanisms such as mechanical stress damage, facet degradation and solder migration.

7844-39, Poster Session

Numerical simulation of echo power for semi-active laser detection

H. Chen, Beijing Institute of Technology (China)

Semi-active laser detection is used extensively on many kinds of weapon systems in the military field. Laser designator is carried by infantries, vehicles or helicopters to indicate the target. And the target should be constantly irradiated in the process. Seeker on the mortar munition receives laser scattered by the target, senses the deviation between movement of mortar munition and angle to the target, outputs the deviation signal.

Considering the changing of divergence angle of beam from laser designator, distance to the target and size of the target, different expressions are needed to calculate scattered laser power. One is that beam size on the target is smaller than target size. The other is that beam size on the target is larger than target size.The paper analyzes the expression of scattered laser power from the target related with the beam area and size of the target, numerical simulations were done for different situations.

7844-40, Poster Session

Modeling of BRDF based on genetic algorithm

H. Chen, Beijing Institute of Technology (China)

In order to represent the optical scattering properties of the complex surfaces, a semi-empirical model for bidirectional In order to represent the optical scattering properties of the complex surfaces, a semi-empirical model for bidirectional reflectance distribution function(BRDF) based on micro-facet theory was proposed, with which optical scattering properties of a certain kind of material are decided by parameters.

In order to prove the model, the experiment system to measure the bidirectional reflectance distribution function has been designed, where a 905nm pulsed laser diode is used as the light resources, a PIN photodetector is used to measure the echo signal, and the reflection from an aluminum sample is measured. For the complex nonlinear relationship between the experiment data and modeling parameters, genetic algorithm was used to retrieve the model parameters. The results prove that calculation of the model complies with experiment data. It can be used as a reference for target feature extraction and recognition in the future.

7844-41, Poster Session

An InP based wide gain spectrum asymmetrical quantum wells for large scale optoelectronic monolithic integration

H. Xie, Z. Lu, P. Shen, Beijing Univ. of Technology (China)

Large scale optoelectronic monolithic integration for optical fiber communication makes more and more optoelectronic active devices and passive components integrate into a single chip. It is necessary to provide enough wide gain spectrum to satisfy the requirement from each device. In this paper, based the analysis on the gain spectrum of InGaAsP/InP quantum well, the dependence of its gain spectrum bandwidth on the well width and doping concentration was derived. An asymmetric quantum well with the same doping concentration and different well width was design to realize the destination. The well width of 5.8nm, 6.3nm and 7.7nm were used with the number of 3, 3 and 2 respectively. The simulation results prove that the asymmetric quantum well indeed make the gain spectrum wider. Then the asymmetric quantum wells were grown successfully by low pressure MOCVD at 665 C. The full width at half maximum (FWHM) of 115nm was observed in its amplified spontaneous emission (ASE) spectrum, which was flatter and wider than that of the symmetric quantum wells.

7844-42, Poster Session

A special sampling technology for sampled grating laser

Y. Zhou, Nanjing Univ. (China) and Changzhou Institute of Technology (China); Y. Shi, S. Li, X. Chen, Nanjing Univ. (China)

In this paper, we propose a special structure. Firstly, compared with a conventional equivalent π phase-shift sampled Bragg grating (SBG), theoretical analysis shows that the proposed structure also obtains an equivalent π phase-shift both in its ±1st order channel. Secondly, based on transfer matrix method (TMM), numerical simulation indicates that for the special structure, whether a fiber Bragg grating or a SBG semiconductor laser, there is a transmission peak appearing both in the ±1st order stop band of their transmission spectrum. That is to say, in the proposed structure, there is an equivalent π phase-shift is introduced in the ±1st order channel. Finally, using a hydro-photosensitive EDF, we experimentally prove that the special structure, like as the conventional equivalent π phase-shift SBG, has same impact on the ±1st order channel.

Up to now, to our best knowledge, there is no paper to report such a special equivalent π phase-shift structure and its properties. If the sampling period of a semiconductor or fiber SBG laser is selected properly, the lasing wavelength of the SBG laser can be controlled aptly. Therefore, combined with the two kinds of equivalent π phase-shift structure, SBG lasers with different lasing wavelengths can be designed and fabricated conveniently. The proposed structure, we believe, will benefit the design and fabrication of multiwavelength semiconductor or fiber lasers.

7844-43, Poster Session

Multiple phase shifts DFB semiconductor laser based on reconstruction equivalent chirp technology

Y. Shi, S. Li, L. Lu, X. Chen, Nanjing Univ. (China)

A distributed feedback (DFB) semiconductor laser with multiple phase shifts based on reconstruction equivalent chirp (REC) technology is proposed and studied numerically. The simulation results show that the performances of the multiple phase shifts DFB semiconductor laser based on REC technology are nearly the same as the actual multiple phase shifts DFB laser. They have the same P-I curves, the internal power distributions and the output ASE spectra. However, it only changes the sampling structures of the REC based laser with the uniform seeding waveguide grating. So the fabrication of such laser is very easy. Finally, some original experimental results are also given in this paper.

7844-44, Poster Session

Hydrogen and argon plasma passivating technology in GaAs/AlGaAs LD cavity surfaces

C. Liu, C. Wang, Y. Yao, Jilin Normal Univ. (China)

Hydrogen(H2) and Argon(Ar) plasma passivation technology was investigated to improve the optical properties of the III-V laser diodes. The main experiment was carried out in the vacuum chamber of the magnetron sputtering system.At first,H2 and Ar plasma passivation treatment is performed on the GaAs(110) surfaces. The obtained optimum passivation conditions are 65-W radio frequency (RF) of power and 15-min duration, the flow of hydrogen and argon are also 20 sccm. The effect of passivation was characterized by photoluminescence (PL) measurements,the PL intensity of GaAs(110) after passivating is about 10 times of that the unpassivated samples. And then the laser cavity surfaces are treated under the optimum passivation conditions. Consequently,compared with unpassivated lasers with only AR/HR-coatings, the catastrophic optical damage (COD) threshold value of the passivated lasers by H2 and Ar plasma treatment is increased by 30 per cent.In the 20 ~ 80 temperature range, characteristic temperature value of 128K is incresed by 11.3 per cent.The processing is simple and high efficient, can be widely applied to the III-V laser diode devices.

7844-45, Poster Session

Collimated the laser diode beam by the focus lens

Q. Xu, J. Li, W. Zhang, Xidian Univ. (China)

Laser diode array (LDA) are of importance for the delivery of high-power beams, providing highly efficient miniaturized light sources. However, their potential applications are limited by the poor output-beam quality.

In almost all applications, the output beam of the LDA must be shaped by use of an appropriate optical system. Because of simpleness and sufficiently accurate, shorter focal length, high numerical aperture objectives would most often be used as beam collimators.

A mathematical model of the laser diode beam through the collimating lens is presented. The wave propagation beyond the paraxial approximation is studied here. The phase delay of the laser diode wave in passing through the lens is analyzed in detail. the ray from the LD entering the lens at coordinates on one face emerges at approximately the same coordinate on the opposite face, if there is negligible translation of the ray within the lens. The lens delays an incident wavefront by an amount proportional to the thickness of the lens at each point, Further propagation of this field can be adequately represented by the calculation of the Rayleigh-Sommerfeld (RS) diffraction integral, and the stationary-phase method is employed in order to find the asymptotic expansion of the diffraction integral. The propagation optical field after the lens is obtained from the diffraction integral by the method of stationary phase. The model employed to predict the light intensity at various beam cross sections.

7844-46, Poster Session

Control of DBR microcavity disturbed thickness errors and determination of the effective cavity length

X. Zhao, Z. Wu, G. Xu, S. Liang, X. Hou, Xi'an Jiaotong Univ. (China)

In the fabrication process of DBR microcavity, the disturbed thickness errors of DBR multilayer films impact the reflection spectra and the center wavelength of stop-band greatly. Control of film thickness by quartz crystal vibration, will produce cumulative errors, and with the number of layers increases, the errors will be increased. The effect of accidental errors of the thickness on the transmission performance was calculated by transfer matrix method. The results show that: when the thickness error of the film thickness less than 5% of the ideal case, no significant change in its stop-band, starting from 5%, stop band split, and the strength and position changed. Optical thickness monitoring method (extreme value method) can be a good additive to eliminate these errors, and can guarantee that the reflection spectrum of DBR meet the basic design requirements. The organic layer's thickness deviation of microcavity laser will also affect the performance of microcavity. In this paper, a method of getting effective micro-cavity length by measuring micro-cavity emitting modes, which can direct the controlling of thickness of organic layers, is put forward.

7844-47, Poster Session

Demonstrations of beam quality of semiconductor lasers

C. Cao, Xidian Univ. (China)

M2 factor, used for characterizing the laser beam quality within the paraxial approximation, fails when the beam width is comparable with or less than the wavelength or when the far-field divergence angle becomes large. In general, beam profiles for semiconductor lasers are not Gaussian and they take various M2 values greater than unity, depending on their waveguide structures. The M2 factors have been analyzed by computer simulation for semiconductor lasers with various structures. It was shown that waveguide structures have a significant effect on M2 factors in both horizontal and vertical directions. Astigmatism and anti-guide-like behavior was shown to have a large correlation with the M2 factor.

To illustrate the analytical results, numerical calculations were performed. The waist-width to wavelength ratio, far-field divergence angle and beam quality factor of non-paraxial beams versus waveguide structure and collimator parameter for different values are plotted. In this study the analytical expressions for the beam width, far-field divergence angle and beam quality factor of non-paraxial beams have been derived and illustrated numerically. It has been shown that the beam quality factor of non-paraxial beams depends not only on the initial waist-width to wavelength ratio, but also on the waveguide structure and collimator parameter.

7844-48, Poster Session

Design and research of a tunnel shape measuring system based on MCU

P. Xi, Liaoning Technical Univ. (China)

In order to acquire the information of the underground tunnel better, research and develop a new measurement system of tunnel shape. Using AT89S52 MCU and wireless transmitter module, and by means of coordinating with the mechanical transmission device to achieve data measurement. This article mainly introduce the measurement system's operational principle and system construction which based on AT89S52 MCU and wireless transmitter module, and gives the flow chart of the system software, its practicality showed by experiment.

7844-49, Poster Session

Optimization of low threshold currents in proton implanted vertical cavity surface emitting lasers

H. Zhao, M. Sun, Q. Liu, W. Wang, H. Liu, W. Li, Hebei Univ. of Technology (China)

VCSELs are efficient laser sources for a number of applications including optical communication and interconnection. Although numerable theories have been realized to analyze the characteristics of VCSEL, the optimization current aperture size of proton implanted VCSEL is not given. Experimental results have been reported the influence of oxide aperture and oxygen implanted on the VCSELs' performance, including threshold and resonance frequency.

This paper presents a simulation analysis for the threshold characteristics of proton implanted VCSELs with the aid of optical-electrical-thermal-gain model. The equations for potential, the carrier density, optical transverse mode and thermal field are given. The distributions of injected current, the fundamental transverse mode, carrier and temperature for VCSELs at various aperture radii of 1,2,4 and 6 micron are studied self-consistently. The threshold injected currents versus the current aperture radii are obtained. The calculated results show that decreasing aperture sizes is an effective method to drop the threshold currents only when the current radii are larger than 2 micron. On the other hand, the threshold currents and threshold voltages increase with the decrease of aperture radii for too small sizes of current aperture. The current aperture radius for low threshold proton implanted VCSEL is found. The threshold currents may drop with improving the confinement of current, while too much small current apertures also damage the threshold. The reason that few VCSEL with smaller aperture radii realize to operate is explained.

7844-50, Poster Session

Frequency stability system of the reference laser diode for space-borne Fourier transform spectrometer

X. Jin, Shanghai Institute of Technical Physics (China)

A laser reference interferometer is mounted in a space-borne Fourier transform spectrometer t o assure the spectral accuracy. The interferogram is sampled by equal optical path difference (OPD) Δx which equals the reference laser wavelength 0(0=Δx), so the accuracy of sampling interval depends on the reference laser frequency 0 or wavelength 0(0=c/ 0, c is the light speed). The excursion of spectrum position is the same as that of the reference laser diode frequency, which means d / = d 0/ 0 (is the spectrum wavenumber). The frequency stability of the reference laser is affected by the driving current and the ambient temperature of the laser diodes. A DFB laser diode is adopted in our experiments.

A frequency stabilizing system is designed to improve the frequency stability of the laser diode. Principle, simulation and realization of the system are presented in this paper. It consists of two parts: the driving current modulating module and the temperature controlling module. A constant current source is used to drive the laser diode in the driving current module, and the value of the current can be modulated by changing the driving voltage. A time delay circuit is designed to protect the laser diode from being damaged by the surge voltage. The temperature controlling module composes of the temperature measuring circiut, the PID controller and the TEC (thermal electronic cooler) driving circuit. Experiments are carried out to measure the current stability and the temperature stability with a 16-bit data acquisition card. The frequency stability of the laser diode is measured by a wavelength meter. Experiments indicate the frequency stability of the laser diode can achieve a level of 10-5 with such a precision frequency control system.

7844-51, Poster Session

The theoretical research of carrier distribution in semiconductor quantum dot

Z. Chang, M. Zhao, Beijing Institute of Petrochemical Technology (China)

A theoretical study of the carrier distribution in semiconductor quantum dot is reported. In order to get the non-equilibrium carrier distribution over the QD ensemble rather than the Fermi-Dirac distribution, we use random population method to investigate the real distribution in QD which have multi energy levels. The inhomogeneous broadening of QDs' size is considered with a Gaussian distribution. Carrier distribution between different QD sizes are coupled via the carrier density in the wetting layer, carriers can be captures into the QD energy levels from the wetting layer as well as thermal escaping in reverse, so a detailed balance between capture and re-emission is established in the different size QDs.

From the carriers distribution at 77 K and 300 K, we can find easily that the carriers in low temperature has a apparent difference with Fermi-Dirac distribution, i.e. the quasi equalibrium distribution, however at high temperature, the distribution is nearly the same with Fermi distribution, it implies that at high temperature, the carriers in different QD and energy level approach the equlibrium because of the couple between different QD and energy levels. The results of our study is very useful to illustrate the physical effects in the photo-electronics devices made by quantum dots.

7844-52, Poster Session

High-power mode-locking external-cavity feedback diode-pumped laser based on SHG in PPKTP

W. Li, Hebei Univ. of Technology (China); Z. Liu, Yanshan Univ. (China); H. Zhao, Hebei Univ. of Technology (China); Z. Li, Yanshan Univ. (China)

The generation of high-power green laser is important for the numerous applications in industry, medicine, research and even entertainment. In addition, mode-locked lasers operating at ~100 MHz repetition rate, are particularly attractive for nonlinear optics and spectroscopy. Characteristics of high-power, mode-locking green radiation obtained by Nd:YVO4 at 1064nm in the nonlinear crystals of PPKTP are studied. Two identical highly efficient diode-pumped laser heads placed in a plane-plane resonator are used for the input laser based on theoretically investigation of the thermally stable region of Nd:YVO4 rod. The PPKTP crystal of Brewster-cut is used in the external cavity configuration, the cavity losses is significantly smaller than for an antireflection(AR) coated crystal cut for normal incident, however, the effective nonlinearity is reduction. Frequency doubling nonlinear mirror(FDNLM) based on intensity dependent reflection in the laser cavity is used for the laser mode-locking. A stable green output power of 510W with pulse repetition rate of 100MHz and net conversion efficiency of =50% at an input mode-matched power of 2KW are obtained. Meanwhile, thermal effects in the nonlinear crystal severely limit the efficiency of the laser configuration when using high pump power.

7844-53, Poster Session

Study of damage induced by trigger pulse at high repetition frequency in GaAs PCSS's material

X. Shan, Air Force Engineering Univ. (China)

Based on the analysis of temperature field generated when semi-insulating GaAs photoconductive switch was irradiated by trigger light pulse, the paper focuses on the light damage induced by nanosecond laser pulse with 1.06μm wavelength at high repetition frequency in switch material. On the basis of the thermal conduction theory, the transient temperature field in the material is simulated in a computer by using the finite difference method, the main reasons of damage induced by laser in chip material are analyzed by comparing simulation results and experimental datas of the damage test, and the damage mechanism is discussed.

7844-54, Poster Session

Multi-modulation frequencies high accuracy semiconductor laser range finder

J. Chen, Chung-Hua Univ. (Taiwan)

Semiconductor lasers with tens of Mega-Hertz repetition rates have been developed for the high accuracy laser ranging applications. We have completed a semiconductor laser range finder that measures with accuracy less than 1mm. And the measure distance can extend to over 100m. The multi-modulation frequencies algorithm is the major technology that achieved this result. We will present detail theoretical derivation together with the circuit hardware design that can measure with high accuracy. The APD receiver circuit as well as transmitter and receiver optical design to complete the system will also be present in detail.

Conference 7845: Optics in Health Care and Biomedical Optics IV

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7845-01, Session 1

Optical monitoring of tissue vitality in health care and biomedical research

A. Mayevsky, Bar-Ilan Univ. (Israel)

Monitoring of patients using new medical devices is a fast growing field in biotechnology. Optical monitoring of tissue physiological and biochemical parameters in real-time, is a new approach and a powerful tool for better clinical diagnosis and treatment. Most of the devices available for monitoring patients in critical conditions are providing information on body respiratory and hemodynamic functions. As of today, monitoring of patients at the cellular and tissue level, in real time, is a missing significant and critical tool in modern medicine. Mitochondrial dysfunction was recognized as a key element in the pathogenesis of various illnesses. We developed a new patient monitoring system (cleared by the FDA) providing real time data on mitochondrial function (fluorescence of NADH) as well as microcirculatory blood flow (laser Doppler flowmetry), hemoglobin oxygenation (two wavelength reflectometry) as well as tissue reflectance. The combination of these parameters provides a new insight into tissue level vitality.

This approach for tissue monitoring in real time could be applied to basic research as well as to patient monitoring. We have adopted the technology for monitoring of the brain In Vivo exposed to various pathophysiological conditions such as models of Stroke. In patients we used the 4 channel physiological monitor in Neurosurgical patients, Kidney transplantation surgery and in patients undergo severe operation or hospitalized in the intensive care units.

In this paper I am reviewing the theoretical, technological, experimental and preliminary clinical results accumulated. Preliminary clinical studies suggest that our monitoring approach is practical in collecting data from the various tested patients.

7845-02, Session 1

Optical molecular imaging

Q. Luo, Huazhong Univ. of Science and Technology (China)

Molecular imaging is a powerful tool to study the temporal and spatial dynamics of specific biomolecules and the biochemical and molecular pathways within intact living subjects. The combination of optical probes and optical imaging techniques shows many attractive properties, such as high spatio-temporal resolution, more sensitivity, parallel monitoring of multiple molecules and parameters, non- or minimal invasion, and low cost. Optical molecular imaging is evolving as an essential research tool for in vivo characterization and measurement of biologic processes, disease progression and therapeutic responses. Britton Chance Center for Biomedical Photonics has established optical molecular imaging research platform which consists of optical molecular probes, multi-functional nanocarriers, optical imaging devices, and visualization software, providing novel techniques and approaches for cancer research and drug development.

7845-03, Session 1

A simultaneous FMT-PET imaging system for small animals

X. Wang, B. Zhang, Tsinghua Univ. (China); S. Liu, Institute of High Energy Physics (China); X. Liu, Tsinghua Univ. (China); B. Shan, Institute of High Energy Physics (China); J. Bai, Tsinghua Univ. (China)

We have developed a hybrid imaging system for simultaneous fluorescence molecular tomography (FMT) and positron emission tomography (PET) of small animals. The system consists of a noncontact 360°-projection FMT module and a flat panel detector pair based PET module, which are mounted orthogonally to avoid mutual interference. Step-and-shot mode is used for data acquisition. For each acquisition, 512 projections of PET and 32 projections of fluorescent data are acquired. FMT data are reconstructed using Galerkin FEM with Born normalization. PET data are rebined to 2D forms using FORE method and then reconstructed to 3D radionuclide distribution with FBP and OSEM methods. Reconstructed images are fused with weighted average method on pixel level after rigid registration. With this system, preliminary tests were performed on phantom and tumor bearing mouse. Indocyanine green (ICG) dye and fluorine 18 fluorodeoxyglucose ([18F]-FDG) were used as probes for FMT and PET separately. A 25mm diameter glass cylinder (1% intralipid solution) containing a 3mm diameter glass tube (mixture of 0.1 mCi FDG and 150ug/ml×0.05ml ICG) was employed as the phantom. In the results, the localization and range of radioactive and fluorescence probes are exactly indicated, verifying the feasibility of the system. As in vivo experiments, a BALB/c mouse (female, 5-6 weeks) bearing a S180 caruncle sarcoma at the right axilla was utilized. In the fused tomography images, both PET and FMT signals indicate the location of tumor area, demonstrating the in vivo performance of the dual-modality system.

7845-04, Session 1

Quantitative phase imaging of red blood cells based on the slightly off-axis interference tomographic microscopy

L. Xue, J. Lai, Z. Li, Nanjing Univ. of Science and Technology (China)

Interference tomographic microscopy is a noncontact technique for quantitative phase imaging of live cells. The method combines the principles of polarized optics and confocal microscopy and is characterized by real-time acquisition capabilities and optimized spatial resolution. Most importantly the technique adopts slightly-off-axis interferometry which requires less detector bandwidth than traditional off-axis interferometry and fewer phase-shifted interferograms than on-axis interferometry. In addition, the angle between the object and sample path is calculated by the autocorrelation and crosscorrelation function. According to this special angle, the optimized fringe spacing is estimated. To validate the utility of this technique, experimental and theoretical comparisons between the proposed method and these traditional interferometric approaches are given. The potential of the technique for phase microcopy is demonstrated by experiments on red blood cells. This study will set the basis for interferometric phase measurements of dynamic processes with fine spatial details, especially for observing live biological cell dynamics.

7845-05, Session 1

Elimination of the twist distortion in IVUS and CAG image fusion based on the Frenet-Serret formulas

H. Li, X. Chen, D. Yu, Tianjin Univ. (China)

Cardiovascular disease can be diagnosed at higher accuracy by the fusion of IVUS (Intravascular Ultrasound) and CAG (Coronary Angiography) data. In the IVUS images acquisition process, pull-back path of the ultrasonic probe will twist due to intravascular blood flow and friction with vascular wall, which causes image distortion in the fusion of such IVUS images. In this paper, a new method used for reducing the twist between adjacent frames of IVUS is presented. First, we establish a rough perspective projection imaging model from the crossing information of two almost perpendicular projective angiography images. Then we use a discrete approximation of the Frenet-Serret formulas to calculate IVUS frames' relative twist by sequential triangulation method and correct the twist. Finally, coronary lumen data extracted from the corrected IVUS images are added to 3-D transducer paths which are reconstructed by the model mentioned above. Reconstruction of the coronary artery which contains the lumen information of IVUS removes blind spots in CAG and provides a full view of artery which is absent in IVUS images.

7845-06, Session 2

Depletion kinetics of circulating prostate cancer cells studied by in vivo flow cytometer

X. Wei, G. Liu, Fudan Univ. (China)

Prostate cancer is the most common malignancy in American men and the second leading cause of deaths from cancer, after lung cancer. The tumor usually grows slowly and remains confined to the gland for many years. During this time, the tumor produces little or no symptoms or outward signs. As the cancer advances, however, it can metastasize throughout other areas of the body, such as the bones, lungs, and liver. Surgical resection, hormonal therapy, chemotherapy and radiation therapy are the foundation of current prostate cancer therapies. Treatments for prostate cause both short- and long-term side effects that may be difficult to accept. Molecular mechanisms of prostate cancer metastasis need to be understood better and new therapies must be developed to selectively target to unique characteristics of cancer cell growth and metastasis. We have developed the "in vivo microscopy" to study the mechanisms that govern prostate cancer cell spread through the microenvironment in vivo in real-time confocal near-infrared fluorescence imaging. A recently developed "in vivo flow cytometer" and optical imaging are used to assess prostate cancer cell spreading and the circulation kinetics of prostate cancer cells. A real-time quantitative monitoring of circulating prostate cancer cells by the in vivo flow cytometer will be useful to assess the effectiveness of the potential therapeutic interventions.

7845-07, Session 2

Evaluation of whole blood coagulation process by optical coherence tomography

J. Lin, X. Xu, Zhejiang Sci-Tech Univ. (China)

This study was designed to investigate the feasibility of using optical coherence tomography (OCT) to evaluate whole blood coagulation process. Attenuation coefficients and 1/e light penetration depth (D1/e) against time of human whole blood during in vitro clot formation under static were measured from the OCT profiles of reflectance vs depth. After 1 h clotting, the attenuation coefficient decreased by 13.7% for the blood with hematocrit (HCT) of 45%. The results clearly showed that D1/e is able to identify three stages during the in vitro blood clotting process. During phase 1 (0-13s), before stable fibrous fibrin was formed, the blood sample was in a liquid state. D1/e was relatively low. During phase 2 (13-423s), the medium was turning into a gel state. In this phase, D1/e increased rapidly. In phase 3 (423-2866s), the medium was in a stable gel state. D1/e kept almost constant. The blood coagulation time linked to fibrin formation was estimated to be 423s for the blood at HCT of 45%. It is concluded that 1/e light penetration depth measured by OCT is a potential parameter to quantify and follow the liquid-gel transition of blood during clotting.

7845-08, Session 2

Dynamic temperature monitoring and control with fully distributed fiber Bragg grating sensor

Y. Ding, N. Chen, Z. Chen, F. Pang, X. Zeng, T. Wang, Shanghai Univ. (China)

Temperature control is a key point in laser-induced interstitial thermotherapy (LITT). However, the real-time tissue temperature distribution detection during the treatment is still unsolved completely. In this paper, fiber Bragg grating (FBG) is used as a fully distributed sensor to monitor tissue dynamic temperature changes during LITT. Because different temperature profiles applied on a FBG correspond to different reflected spectra, this work is mainly realized by the correlative single particle (CSP) algorithm, which is a rapid algorithm for spectrum reconstruction. Experimental LITT treatment was set up by using 532nm laser applicator on a piece of fresh liver tissue. A 10mm uniform FBG sensor at 1547nm was fixed at the end of the laser applicator. The point of 8mm of the grating was set as the boundary of the thermal treatment. To ensure the treatment safe enough, the temperature at this point should be kept below 40° all along. In the experiments, the dynamic temperature profile was successfully demodulated with a refreshing speed of 11 seconds. With the aid of dynamic feedback, the thermotherapy boundary temperature was well controlled around 35° during the treatment by adjusting the laser output power in real-time. Therefore, with this method, it is promising to precisely control the tissue temperature in vivo and improve the safety of the LITT remarkably.

7845-09, Session 2

Effects of the optical transfer function on velocity estimation with optical coherence tomography

X. Zhang, W. Gao, P. Li, Nanjing Univ. of Science and Technology (China)

Optical coherence tomography (OCT) is one of techniques which measures the local reflectivity of thin tissue layer or scattering property of tissue elements through the combination of low-coherence interferometry and scanning techniques. In addition to microstructure, blood flow in microvasculature is another important biological process in living tissue. It is then desirable to yield an image of a spatially resolved blood flow or other types of motions of living tissue constituents simultaneously with the microstructure images. Doppler optical coherence tomography (DOCT) is an extension of optical coherence tomography (OCT) for measuring blood flow dynamics simultaneously with the microscopic structures at high spatial and velocity resolution. In this paper, we analyze the effects of parameters of the DOCT system on velocity estimation, including the nonlinear scanning of the reference mirror, the random statistical properties of the medium, and the finite spectrum width of the light source. One result of these influences is

to make the source spectrum to depart from an ideal Gaussian shape and introduce a velocity estimation error. Experimental data are given to show the effects. The methods of overcoming the effects are also pointed out.

7845-10, Session 3

Latest progress of adaptive optics for human eye in IOE

Y. Zhang, Institute of Optics and Electronics (China)

Latest progress of adaptive optics (AO) for human eye in IOE is presented, including continuous high frame rates AO flood-illumination imaging of retina, AO scanning laser ophthalmoscope, AO optical coherence tomography imaging of retina, high resolution anterior segment imaging with optical tomography, AO vision simulator and combining AO and perceptual learning for visual performance improvement.

7845-11, Session 3

Wavelength probing optical coherence tomography

S. Chang, Y. Mao, C. Flueraru, National Research Council Canada (Canada)

In swept-source optical coherence tomography (SS-OCT), the swept-source stimulates system by a series of wavelengths in time sequence; a photo detector then collects all the reflected/back scattered signals from testing sample as Fourier series components. After Inverse Fourier transform of the collected signal sequence, the internal structure of the testing sample can be extracted. The bandwidth of the swept source determinates the depth resolution of the reconstructed OCT image, the broader the band, the finer the reconstructed image will be. It is difficult to fabricate an extra-broadband swept source. However, due to the nature of the SS-OCT, the processing in spectral domain can effectively integrate multiple swept-sources with different central wavelengths and k intervals, and therefore greatly increase the resolution of the integrated OCT imaging.

In biomedical applications, the central wavelength of the swept-source is critical to probe the spectral features for different bio-samples. However, the commercial swept-sources are normally limited to 1300nm and 1500nm, as they were developed originally for optical fibre communication. A standard broadband SS-OCT system can be used to extract the internal structure of the sample, then, a narrow band light is used to probe the spectral feature of the sample at this specific wavelength. This new Fourier component is properly merged in to the broadband spectrum with a weighting factor. After inverse Fourier transform, the resulting OCT image of the sample can shows both the internal structure and the spectral feature at the probing wavelength. Computer simulations and experimental results are given in this paper.

7845-12, Session 3

Quantitative microflow mapping with wide-field optical heterodyne detection

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We demonstrate that quantitative flow velocity in the 100 microns/s to 10mm/s range can be derived from the analysis of radiofrequency Doppler spectral images recorded with parallel optical heterodyne detection of multiply scattered light.

Parallel heterodyne detection with a digital camera enables wide-field imaging of the Doppler spectrum of light fluctuations. It is achieved by mixing the backscattered radiation with a separate local oscillator field. The local oscillator beam is frequency-shifted sequentially with respect to the illumination beam to enable tunable detection of spectral broadenings in the 0-100 kHz range. An efficient noise rejection scheme involving a spatial and temporal modulation of the light beating signal enables high sensitivity measures, which are crucial for accurate determination of first-order fluctuation spectra. The resulting wide-field heterodyne Doppler images and spectra are used to assess momentum transfer between scattered light and moving diffusers in biological tissues.

We report images of microvascular blood flow in the cerebral cortex and in the retina of rodents. Tissues are illuminated over the whole field of view with near infrared laser light. Recordings made in reflection configuration, yield local motion contrasts from blood flow down to the smallest capillaries. Our approach enables parallel measures and imaging of the optical Doppler spectrum in vivo in low-light conditions. It is potentially suited to the design of robust, non-invasive and non-ionizing microrheological imaging tools for in vivo hemodynamics diagnosis without any contrast agent.

7845-13, Session 3

Single-detector polarization-sensitive OCT for biological tissue imaging

Y. Wang, X. Chen, H. Li, Y. Lei, D. Yu, Tianjin Univ. (China)

Polarization-sensitive optical coherence tomography (PS-OCT) is an emerging biomedical imaging technology using polarized light. It allows non-invasive and high-resolution imaging of biological tissue in vivo, and reveals birefringence distribution, reflectivity and retardation of biological tissue at the same time.

Conventional PS-OCT is based on low-coherence interferometer and two detectors, each for a polarization composition. By detecting the optical phase delay between two orthogonal polarization compositions, conventional PS-OCT calculates Stokes vector or Muller matrix to describe the birefringence of biological tissue. The calculation costs a lot of time while the Stokes vector and Muller matrix are obscure for phsician to understand.

To solve the discussion above, we built up a single-detector PS-OCT system in this paper. Our system is nearly the same with conventional PS-OCT but using only one detector. When light travels in the birefringent tissue, the optical phase delay between its two orthogonal polarization compositions changes periodically, causing the interference light intensity oscillating. The oscillation of interference light is then detected by the only detector in our system and displayed as 256-scale grey image. The grey scale indicates the light intensity and its periodicity indicates the birefringence of tissue.

In this paper, we described the theory and setup of our single-detector PS-OCT firstly, and then experimented with a bovine cartilage sample. The results proved the ability of our system detecting tissue birefringence.

7845-14, Session 3

Monitoring collagen remodeling on opto-thermal response of photoaged skin irradiated by Er:YAG laser with optical coherence tomography

X. Zhang, S. Wu, H. Li, Fujian Normal Univ. (China)

The Optical Coherence Tomography technology was used to perform noninvasive cross-sectional imaging of internal structures in photoaged rat skin, which was irradiated by Er:YAG laser, to produce

a two-dimesional image of optical scattering . Rats were irradiated chronically with a steady doses of ultraviolet irradiation. Various laser light doses are irradiated on the back skins of the photoaged rat. An OCT was used to observe the process of the collagen remodeling in dermis. The relationship between optical characteristic parameter such as attenuation coefficient and light dose is discovered. The total attenuation coefficient changes when the light dose increases. Our finding showed that Er:YAG could be used for the symptoms of photoaged skin with some degree of thermal damage in the dermis, and the OCT can image the progress of collagen remodeling in photoaged rat dermis and may be a useful tool for determination of optimal parameters for laser skin treatment.

7845-15, Session 4

Performance of hybrid system for fluorescence and micro-computed tomography in synchronous mode

X. Liu, F. Liu, X. Guo, Y. Zhang, X. Wang, J. Bai, Tsinghua Univ. (China)

Fluorescence diffuse optical tomography (FDOT) plays an important role in studying physiological and pathological processes of small animals in vivo. The low spatial resolution, however, limits the ability of FDOT in resolving the bio-distributions of fluorescent markers in living small animals. The anatomical information provided by a secondary imaging modality such as X-ray computed tomography (CT) can be used to improve the image quality of FDOT. However, in most hybrid FDOT/CT systems, the projection data sets of FDOT and CT are acquired sequentially, which increases the acquisition time and bring in the unwanted soft tissue displacement. In this paper, we propose a synchronous hybrid FDOT/CT system which allows for faster and concurrent imaging. Compared with previous FDOT/CT systems, the two subsystems (FDOT and CT) acquire projection images synchronously, so the body position can keep consistent in the same projection data acquired by both subsystems. To validate the performance of the hybrid system in synchronous mode, phantom and in vivo experiments were performed. The experimental results suggest we are able to obtain the accuracy reconstruction results while decrease imaging time significantly compared to previous hybrid FDOT/CT systems.

7845-16, Session 4

Effect of electrode structure on the focal spot of x-ray tube

J. Guo, X. Ren, B. Zhou, H. Niu, Shenzhen Univ. (China)

The grating-based x-ray phase-contrast imaging have more advantages over the conventional x-ray imaging techniques based on the attenuation of x-rays in soft tissues in the medical diagnosis. However, until now the phase contrast imaging technique have not been put into practical uses, one of the reasons is that there is no compact x-ray source suitable for phase signal detection. The x-ray tube that can be used as the source of phase contrast imaging system is becoming the focus of research, the key issues of which could be the shape and the uniformity of focal spot. This paper provided and studied one kind of x-ray tube based on the electron impinging target. According to the system design of the phase contrast imaging, an x-ray tube with square focal spot of 0.8 mm side length was needed. An electrode structure which could form a planar- symmetric electric field distribution was so designed that the emitted electrons from filament could move to target along straight courses. For comparison, axis-symmetric field x-ray tube was designed too. The electron trajectories were simulated following the computation of the electric potential distributions in the two cases of electrode structure, respectively. The simulation results show that the x-ray tube of planar-symmetric field structure may lend more regular square shape to focus spot than the axis-symmetric field structures.

7845-17, Session 4

Characterization of photoacoustic signal using wavelet analysis

Z. Li, H. Li, W. Xie, Fujian Normal Univ. (China)

Photoacoustic tomography (PAT) has been an increasingly promising technique for biomedical diagnosis. PAT can be implemented with focused or unfocused transducer. Considerable attention has been devoted to the latter form, which image contrast and resolution depend on reconstruction algorithms. However, the signal detected by an unfocused transducer suffers from poor signal-to-noise, and the algorithm combined with the wavelet analysis is applied to suppress the noise. In this paper, we present the method for characterization of photoacoustic signal detected by a focused transducer using wavelet analysis. The original photoacoutic signal is decomposed into different frequency in wavelet domain. The results demonstrate that the full width at half maximum value of the peak at various frequencies, which is defined as the size of absorption, decrease as the frequency increase. The analysis is consistent with the fact that the spatial resolution increase with the frequency increasing. The results also show that the position of peak at various frequencies approaches the detector as the frequency decrease, which means that the information of different position could be reconstructed using various frequencies of photoacousitc signal. Thus the method for characterization of photoacoustic signal based on the wavelet transformation provides multi-resolution analysis ability for absorption at different position.

7845-18, Session 4

Multispectral colour analysis for quantitative evaluation of pseudoisochromatic color deficiency tests

M. Ozolinsh, S. Fomins, Univ. of Latvia (Latvia)

Multispectral color analysis was used for spectral scanning of Ishihara and Rabkin color deficiency testbook images. Scanning was done using tuneable liquid-crystal LC filters built in the Nuance II analyzer (CRI company).. Previously reflectance spectroscopy was applied to Ishihara and HRR pseudoisochromatic plate elements that ensured an excellent spectral resolution (Lee, Honson; 2003, Color Research and Application, V28, p.267-276). However multispectral analysis keeps information regarding spatial content of the tests. Images were taken in the range of 420 -720 nm with a 10 nm step under halogen incandescent lamp illumination. Such 10 nm steps make it possible to obtain at least ten independent spectral data inputs within the spectrum range of human retina L-, M-, and S-cone color sensitivity range. Taking into account the human eye photoreceptors' spectral sensitivity curves, the corresponding neural activity charts were calculated at the cone input level and for further neural activity at color-opponency neural pathway level. We processed the activity charts in order to find the visibility of latent symbols in color deficiency plates using crosscorrelation technique - finding the correlation between charts containing the latent stimuli with high contrast reference stimulus (same as hided latent stimuli in the diagnostics plates). In such way the quantitative measure is found for each of diagnostics plate for three different color deficiency carrier type - protanopes, deutanopes and tritanopes. Multispectral approach allows to determine the CIE xyz color coordinates of pseudoisochromatic plate design elements and to perform statistical analysis of these data to compare the color quality of available color deficiency testbooks.

7845-19, Session 5

Time-domain diffuse optical tomography: principle and practice

F. Gao, Tianjin Univ. (China)

This report describes the time-domain diffuse fluorescent tomography methodology developed in Tianjin University, including both the multi-channel TCSPC-based experimental setup and the inversion scheme for image reconstruction. The feasibility and potential of the proposed techniques are demonstrated by simulative, phantom and in vivo experiments. Finally, the prospect of the techniques is reviewed in brief.

7845-20, Session 5

Quantitative analysis of dehydration in porcine skin caused by optical clearing agents

T. Yu, X. Wen, D. Shu, D. Zhu, Huazhong Univ. of Science and Technology (China)

Optical clearing agents-induced dehydration of tissue is supposed to be one of mechanisms during optical clearing process, but it is difficult to quantitatively analyze the dehydration of tissue. Here the analysis of partial least squares regression (PLS) were applied to establish a method to evaluate the water content of tissue based on the measurements of near infrared reflectance spectroscopy and weight of porcine skin. A commercial integrating sphere with spectrometer was used to measure the reflectance and transmittance of porcine skin during the treatment of skin with different optical clearing agents, i.e., 1,2-propanediol, 1,4-butanediol, PEG200, PEG400, d-sorbitol and glycerol. And then the established method was used to evaluate the water content of skin samples, while the Inverse Adding-Double algorithm was used to calculate the reduced scattering coefficients. The results show that both water contents and reduced scattering coefficients decrease during the optical clearing process. And the dehydration of skin caused by OCAs is directly correlated to optical clearing efficacy of skins with high correlation coefficients in the range of 0.979-0.998. The reduced scattering coefficient of skin caused by glycerol or d-sorbitol decreased more quickly than water content in the course of 60 min, while the change degree caused by other OCAs is almost coincident with water content. It can be indicated that the dehydration is the main mechanism when 1,2-propanediol, 1,4-butanediol, PEG200 or PEG400 induce optical clearing of skin, whereas there are some other mechanisms besides dehydration when glycerol or d-sorbitol treats the skin samples.

7845-21, Session 5

Study on the backscattering Mueller matrix of the sphere-cylinder scattering model of anisotropic tissues

N. Zeng, H. He, T. Yun, H. Ma, Tsinghua Univ. (China)

Most biological tissues are anisotropic turbid media containing fibrous structures, such as collagen fibers, axons, or myofibrils. Tests using both unpolarized and polarized lights indicate that the anisotropic tissues can be approximated to a scattering medium containing cylindrical and spherical scatterers. Mueller matrix, as a representative measurement to examine polarization properties, can be used to analyze some important information of turbid media. In this paper, we measure the two dimensional backscattering Mueller matrix of a microsphere-silk phantom composed of a slab of well aligned silk fibers submerged in microsphere solution. We also use a polarization sensitive Monte Carlo simulation program to analyze the Mueller matrix of sphere-cylinder scattering media, such as the microsphere-silk sample. The systematic analysis show the relationship between the characteristic features in all the Mueller matrix elements and the important parameters of the sphere-cylinder scattering medium approximating biological tissues, such as the sphere-cylinder ratio, direction of the cylinders, diameters of both types of scatterers, etc. These experimental and simulation results confirm the practicability of backscattered Mueller matrix characterizing such anisotropic scattering media like biological tissues.

7845-22, Session 5

Surface enhanced Raman scattering of molecules adsorbed on gold nanostructures

X. Zhang, Y. Zhang, Q. Mao, Anhui Institute of Optics and Fine Mechanics (China)

Surface Enhanced Raman Scattering Spectra (SERS) is a potential tool in environmental pollution, medical diagnoses, et al., The gold nanostructures were fabricated by self-assembly monolayer technique, The structures were studied by field emission scanning electron microscope. And the localized surface plasmon resonance were monitored by transmission spectra. We use Raman instrument measure the strength of SERS. Through optical properties and SERS spectra, the relationship of SERS intensity and the number molecules adsorbed on nanostructures can obtained.

7845-23, Session 6

Raman micro-spectroscopy of nasopharyngeal carcinoma in vitro

Y. Li, Fujian Normal Univ. (China); Y. Su, Fujian Medical Univ. (China); W. Huang, Fujian Normal Univ. (China); J. Pan, Fujian Medical Univ. (China); S. Feng, S. Xie, R. Chen, Fujian Normal Univ. (China)

Nasopharyngeal carcinoma is one of the most serious disease threatening people's health and life which is mostly found in Asia, especially in South China. Early detection and diagnosis is crucial to effective treatment and can greatly improve survival rate. Recent developments in tissue spectroscopy may significantly expand our ability to diagnose this tumor rapidly and accurately. Among the several optical approaches currently under investigation for in vivo endoscopic applications, Raman spectroscopy is adopted widely and seems to be a very promising technique. In this work, Raman spectra of nasopharyngeal carcinoma in vitro was acquired and analyzed with principal component analysis. A confocal microscope was used in this experiment with a 785nm diode laser and a X50 lens. Consistent spectral differences appear to exist between normal and cancerous tissues, mainly in three bands 1290-1320 cm-1, 1420-1470 cm-1, 1530-1580cm-1 which is consistent with other groups results. Factors affecting Raman spectra quality were discussed and spectra statistical analysis was also performed using PCA which can easily divide the samples to two groups with a high sensitivity and specificity. The results presented here demonstrate Raman spectroscopy has the potential ability to detect and diagnose cancerous tissues non-destructively and rapidly which may be a very helpful diagnosis tool in the future.

7845-24, Session 6

Rapid measurement of alanine aminotransferase with near-infrared transmission spectroscopy

F. Huang, Jinan Univ. (China)

Near infrared transmission spectroscopy of Whole blood are investigated with different thickness (0.5mm, 1mm, 2mm, 4mm) in order to explore the feasibility of detecting alanine aminotransferase rapidly by near-infrared spectra. The results show that the whole blood sample with 0.5mm thickness is more suitable for spectral analysis. And then Near infrared spectroscopy of 176 samples were collected. Multiplicative scatter correction and second-order differential method have been used to spectral pretreatment. Stepwise multiple linear regression method and partial least squares regression method have been employed to establish quantitative detection model to predict content of alanine aminotransferase in whole blood. The alanine aminotransferase measured presents best result in calibration and prediction by Near-Infrared Spectroscopy with partial least squares regression calibration model, and the calibration correlation coefficient, the standard error of calibration and the standard error of prediction are 0.98, 2.42 and 7.22 respectively.

7845-25, Session 6

Discriminant analysis for the classification of colonic tissue autofluorescence spectra

L. Liu, B. Liu, Fujian Normal Univ. (China); W. Li, Fujian Provincial Hospital (China); L. Lin, B. Li, S. Xie, Fujian Normal Univ. (China)

The colonic cancer occurs with high incidence rate all around the world. Early detection of colonic cancer significantly improves the likelihood of successful treatment. Autofluorescence spectroscopy is a promising optical technique for the early diagnosis of neoplasia in human colon. This study evaluates the potential of a multivariate statistical algorithm to classify colonic mucosa from autofluorescence spectral features. With 337 nm excitation, the autofluorescence spectra of colonic tissues were measured from 350 to 600 nm using a FLS920 spectrofluorimeter. The autofluorescence spectral differences were observed between normal and adenocarcinoma tissues. The two emission peaks located at 380 and 485 nm can be attributed to the presence of collagen and reduced form of nicotinamide-adenine dinucleotide (NADH), respectively. Principal component analysis (PCA) combined with discriminant analysis was performed for tissue classification after smoothing and normalizing the measured spectra. As a result, the sensitivity and specificity of the discriminant analysis was 93.8% and 91.2%, respectively. The obtained results suggest the relative concentrations of collagen and NADH are the potential diagnostic biomarkers for colonic tissue classification by using light-induced autofluorescence spectroscopy, and the multivariate statistical algorithm based on principle component analysis is suitable to differentiate adenocarcinoma from normal mucosa.

7845-26, Session 6

Improvement of measurement accuracy for quantitative analysis of blood contents with near-infrared spectroscopy

Y. Luo, Jinan Univ. (China)

In this presentation, an estimation of measurement limitation for component concentration will be given, by starting from the equation of light transportation in turbid media, and then analyzing the path length of photon received at different source-detector separation (SDS). Monte Carlo simulations have been performed on a skin-like model, to investigate the effect of thickness of epidermis layer on the measurement limitation.

As a conclusion, an equation involving absorption section, path-length, and signal-to-noise ratio (SNR) is derived. It's evident to find, from the equation we derived, that measurement limitation depends on not only optical properties and thickness of media interested, but also the source-detector separation or sample thickness. For an instance, measurement accuracy of measuring glucose concentration with diffuse reflectance spectroscopy has been calculated in the end.

7845-27, Session 7A

The analysis of aging skin based on multiphoton microscopy

S. Wu, Z. Li, X. Zhang, H. Li, Fujian Normal Univ. (China)

Aging is an important issue not only in dermatology, but also in cosmetic science. Cutaneous aging involves both chronological and photoaging aging process. The chronological aging is induced with the passage of time. And the photoaging skin is the extrinsic aging caused by sun exposure. The effects of the aging process are often overlapping and include changes in both the stratified epithelium and the dermis collagen. The aim of this study is to use multiphoton microscopy (MPM) in vivo to assess the chronological-age-related and the photo-age-related difference in three-dimensional dermal. We measured the changes of dermal collagen in quantitively in difference type aging skin, and then compared with histological method. The algorithm that we used automatically produced the transversal dermal map from MPM. On the other hand, the texture of dermis and epidermis are analyzed by Gray Level Co-occurrence Matrix and Fourier transform. And the object extraction in textured images is proposed based on the method in object edge extraction, and the aim of it is to detect the object hidden in the skin texture in difference aging skin. The result demonstrates that the approach is effective in detecting the object in epidermis and dermis textured image in different aging skin, it could help to further understand the aging mechanism.

7845-29, Session 7A

Cell flow analysis with a two-photon fluorescence fiber probe

Y. Chang, National Changhua Univ. of Education (Taiwan); J. Y. Ye, The Univ. of Texas at San Antonio (United States); T. P. Thomas, J. R. Baker, Jr., T. B. Norris, Univ. of Michigan (United States)

We report the use of a sensitive double-clad fiber (DCF) probe for in situ cell flow velocity measurements and cell analysis by means of two-photon excited fluorescence correlation spectroscopy (FCS). The fiber probe can be intravenously inserted into the fluid channels deep inside the body without sedation treatments, which enables long-term in vivo monitoring of cell circulation. We have demonstrated the feasibility to use this fiber probe for in vivo two-photon flow cytometry previously. However, because of the viscosity of blood and the non-uniform flow nature in vivo, it is problematic to use the detected cell numbers to estimate the sampled blood volume. To precisely calibrate the sampled blood volume, it is necessary to conduct real time flow velocity measurement. We propose to use FCS technique to measure the flow velocity. The ability to measure the flow velocities of labeled cells in whole blood has been demonstrated. A flow velocity of as high as 20 cm/s has been measured. Our two-photon fluorescence fiber probe has the ability to monitor multiple fluorescent biomarkers simultaneously. Therefore, using high brightness nanoparticles to generate a reference signal at a distinct wavelength, we can calibrate the real time flow

velocity or calculate the average size of the cells under measure. The ability to conduct in situ cell flow analysis using the fiber probe may be useful in disease diagnosis or further comprehension of the circulation system.

7845-30, Session 7A

Fast localization microscopy for super-resolution imaging of living cells

Z. Huang, Huazhong Univ. of Science and Technology (China) and Institute of Applied Physics and Ctr. for Functional Nanostructures (Germany)

Localization-based super resolution microscopy has been widely suggested to hold superior performances in revealing dynamic processes in living cells by providing the ability to visualize biological structures with unprecedented spatial resolution a large sample area, but its widespread use in biology is thus far mainly hindered by the slow image speed. Since very fast image acquisition is now rapidly advancing with a combined used of highly efficient detectors and brighter fluorescent probes, the image speed of the localization-based techniques is increasingly limited by how fast a large number of fluorophores could be localized with high accuracy. However, all of the methods developed so far restrict real-time image analysis for either small field of view or decreasing localization precision. This severely limits the versatility and power of the technique. Here we introduced a new method, termed MaLiang (after a traditional Chinese folktale “Ma Liang and his Magic Brush”) for “maximum likelihood algorithm encoded on a Graphics Processing Unit (GPU)”. This GPU-based maximum likelihood method exploits the fact that a GPU can compute locations of molecules in parallel, while the maximum likelihood algorithm guarantees a high localization precision. The MaLiang method is fast enough for real-time processing of experimental images even from fast EMCCD cameras working at full frame rate without compromising localization precision or field of view. Finally we will present our recent progress in exploring the potential of the MaLiang method for constructing a fast localization microscopy for super resolution imaging of living cells.

7845-31, Session 7A

Quantitatively linking collagen alteration and epithelial tumor progression by second harmonic generation microscopy

S. Zhuo, J. Chen, S. Xie, Fujian Normal Univ. (China)

Collagen alteration is critical for epithelial tumor initiation and progression. Quantitatively linking collagen alteration and epithelial tumor progression is essential for developing an optical endoscopy to evaluate epithelial tumor progression. In this work, we established a quantitative link between collagen alteration and epithelial tumor progression using second harmonic generation (SHG) microscopy. It was found that SHG microscopy can provide quantitative features to effectively evaluate epithelial tumor progression, and to locate tumor and determine the margin of tumor regions. These results suggest that SHG microscopy has the potential in offering a noninvasive in vivo imaging tool to quantify epithelial tumor progression.

7845-45, Session 7B

A role for Nrf2 in UVA-mediated heme oxygenase induction and protection in human skin fibroblasts

L. Zhong, L. Deng, L. Yang, H. Li, G. Singh, Chongqing Univ. (China); R. M. Tyrrell, Univ. of Bath (United Kingdom)

Ultraviolet-A (UVA, 320-380 nm) radiation induces oxidative stress to human skin. It is the main cause of deleterious effects of sunlight which include erythema, immune suppression, photoaging, and skin cancer. Heme oxygenase (HO, includes consititutive HO-2 and inducible HO-1) is the first and the rate limiting enzyme in heme degradation, catalysing the degradation of pro-oxidant heme to carbon monoxide, biliverdin and ferrous iron. HO-1gene expression is positively regulated by the transcriptional activator NF-E2-related factor 2 (Nrf2) to form heterodimers with small Maf proteins via its upstream antioxidant response element (ARE). Nrf2-driven HO-1 expression has been reported to protect leukaemia cells against cell death. We have found previously that physiological dose of UVA irradiation increases HO-1 gene expression and significantly change the morphology of human primary skin fibroblasts FEK4.

Using Western blotting, RNA interference and immunochemistry, we found: Nrf2 activation and nuclear accumulation coordinates with HO-1 induction following UVA irradiation in human primary skin fibroblasts; Silencing of Nrf2 reduces HO-1 induction by either UVA irradiation or hemin-treatment; Heme depletion reduces UVA-induced HO-1 protein levels in FEK4 cells; Lose of Nrf2 increases UVA-irradiation induced membrane damage.

We conclude: Nrf2 protein activation is involved in up-regulation of HO-1 expression by both UVA radiation and heme treatments in FEK4 cells; Activation of Nrf2, at least partially involved UVA-released heme, protects skin fibroblasts against UVA-mediated membrane damage. Thus Nrf2-driven modulation of HO-1 expression is clinically relevant since this up- regulation provides protection against oxidative damage. Currently, we are investigating the UVA-irradiation mediated cytoskeleton alteration.

7845-46, Session 7B

Photonic homeostatics

T. C. Liu, F. Li, South China Normal Univ. (China)

Photonic homeostatics is a discipline to study function-specific homoestasis (FSH) establishment, maintenance, decay, upgrading and representation by using photonics. FSH is a negative feedback response to optimize a function. Sirtuins (SIRTs) are nicotinamide adenine dinucleotide (NAD+) dependent histone deacetylases which can maintain a FSH, respectively. There are FSH-specific SIRT activities (FSSAs). If a function is far from its FSH, the SIRT activities of the biosystem are higher than FSSAs so that SIRT activities can form a SIRT activity potential wells (SAPs), respectively. A stress may increase SIRT activities above FSSAs to induce a function far from its FSH. Low level laser irradiation or monochromatic light (LLL) can not modulate a function in its FSH or a stress in its stress-specific homeostasis (StSH), but increase SIRT activities to promote StSH establishment of a stress far from its StSH and then promote the FSH upgradation such as wound healing or degradation such as aging, respectively. This can explain the latitude effects and the season effects of sunlight, the bright light effects and the photobiomodulation of LLL, and can be applied in health care, health promotion and disease treatments. The non-resonant interaction of LLL and a kind of membrane protein can be amplified by all the membrane proteins if the function is far from its FSH. This amplification might hold for photonic emission of the membrane protein so that the photonic spectroscopy can be used to represent the function far from its FSH, which is called photonomics.

7845-47, Session 7B

Light-induced negative regulation of heme oxygenase 1 in human skin cells

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The Ultraviolet A (UVA), a component of sunlight, is an oxidizing agent that strongly induces the heme oxygenase 1 (HO1) gene and protein expression in cultured human skin fibroblasts, however, it weakly induces same in skin keratinocytes. Lower basal levels of HO-1 and much higher basal levels of HO-2 protein are observed in keratinocytes as compared with fibroblasts. The regulation of HO-1 has shown to be at the transcriptional level and involves the dynamic exchange between transcriptional Nrf2/MafK activator complexes and Bach1/MafK suppressor complexes at the antioxidant response element (ARE), located in HO-1 promoter upstream region.

Using over-expression, knock-down approaches, Western blotting and immunochemistry, we demonstrate that HO-2 modulates basal and UVA-induced HO-1 protein levels while HO-1 levels do not affect HO-2 levels in skin fibroblasts and keratinocytes; Silencing of Bach1 strongly increases HO-1 levels in HaCaT transformed keratinocytes and these HO-1 levels are not further increased by either UVA irradiation or silencing of HO-2; Bach1 inhibition leading to HO-1 induction reduced high dose of UVA-irradiation induced damage as monitored both by the extent of LDH release and by nuclear condensation.

We conclude that high constitutive levels of HO-2 expression in keratinocytes are responsible for the resistance of these cells to HO-1 induction by UVA radiation and that Bach1 plays a predominant role in influencing the lack of HO-1 expression in keratinocytes. Further, Bach1 inhibition appears to protect against UVA irradiation induced damage in keratinocytes.

7845-48, Session 7B

The effect of 630-nm light stimulation on the sEMG signal of forearm muscle

W. Hou, Chongqing Univ. (China)

Skeletal muscle fatigue is a common phenomenon we will encounter in daily life or sport, and a variety of chemical or physical methods have been established to improve the muscle fatigue. Here, 630nm light has been employed to stimulate the forearm muscle under force production or rest conditions, and the surface electromyographic (sEMG) signals were recorded from flex digitorum superficials (FDS) and extensor digitorum (ED). The features in time domain, integrate electromyography (IEMG) have been extracted from the sEMG signals. The preliminary experiment results revealed that, 630nm light stimulation would reduce the value of IEMG of fatigued muscle. The present work suggested that appropriate dose of red light could modulate the activity patterns of forearm muscle, and could be potentially used to ease muscle fatigue.

7845-49, Session 7B

Brain lesion induced by 1319-nm laser radiation

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The laser-tissue interaction has not been well defined at the 1319nm wavelength for brain exposure. The goal of this research effort was to identify the time-course of brain sub-lethal lesion induced by a 1319nm laser. The experiment was performed on China Kunming mice. Unilateral brain lesions were created with a continuous-wave Nd:YAG laser(1319nm). The radiant exposure was 580J/cm2. Subjects were sacrificed 0 day, 1 week, 2 weeks, 3 months and 7 months after laser irradiation. The brain lesions were identified through behavioral observation and Histological haematoxylin eosin (HE) staining method. After laser exposure, the mice were seen to be lordotic, tail and/or toe entasia, or paralysis at the beginning. These symptoms gradually disappeared within several days and never recurred again. The histopathological examinations showed that the brain tissue underwent a thermal damage process. Severe edema and discrete tissue was seen 0 day after irradiation. The number of nucleus decreased greatly 1 and 2 weeks after. Great number of macrophages accumulated within the necrotic region 3 months after irradiation. The necrotic brain tissue was completely absorbed 7 months after irradiation.

7845-32, Session 8A

Near-infrared fluorescent dyes with native cancer targeting and imaging properties

C. Shi, Third Military Medical Univ. (China)

Near-infrared (NIR) excitable fluorescent contrast agents offer unique possibilities for in vivo cancer imaging. Current common strategies for cancer targeted imaging requires the chemical conjugation of fluorescent probes with tumor-specific guide ligands (including small molecules, aptamers, peptides, proteins, and antibodies). For these approaches, the imaging fluorophor has limited efficacy. Our group has developed a group of unique NIR heptamethine indocyanine dyes, which possess natively effective in vivo cancer active targeting and NIR imaging properties. With a small molecular weight (<1K) and a emission profile at 800 nm, the fluorescence of these dyes can be easily detected from deep tissues. This dye can be selectively and preferentially taken up by a broad spectrum of human cancer cells including that of leukemia, prostate, breast, skin, lung, kidney, cervical, bladder, and liver cancer cells without the need of chemical conjugation with tumor-specific targeting ligands. When administrated in vivo, the dyes can be quickly cleared from the circulation and continues to accumulate in tumor cells and result in excellent signal to background ratio to detect small tumors. The finding may advance current concept of cancer targeting and these unique NIR dyes provides us with excellent bioprobes to image a broad spectrum of human cancer cells and holds great promise for the development of novel therapeutics for future cancer therapy and imaging.

7845-33, Session 8A

Study the effects of divalent (Mg2+, Ca2+, Mn2+) ions on the interaction of DNA and histones with fluorescence anisotropy assays

Y. Liu, X. Wang, W. Zhang, S. Zhu, H. Sang, China Agricultural Univ. (China)

The effects of divalent (Mg2+, Ca2+, Mn2+) ions on the interaction between DNA and histone are studied using the fluorescence intensity and fluorescence anisotropy assays. Fluorescence intensity and fluorescence anisotropy of DNA, DNA-histone in the presence of divalent ions are measured. The results indicate that when these cations are added into the DNA solution, the fluorescence intensities of the stained DNA reduced differently. Comparing to the case of DNA incubated with divalent cations or histone, there are more histones and divalent cations binding to DNA when divalent cation, histone and DNA incubated together. That is, when divalent cations and histone occur at the same time they can cooperate with each other. Divalent ions can also make the change of structure of DNA molecules, or make DNA assemble together.

7845-34, Session 8A

Photosensitizer-conjugated magnetic nanoparticles for targeting photodynamic therapy

P. Huang, Z. Li, J. Lin, D. Cui, Shanghai Jiao Tong Univ. (China)

Photodynamic therapy (PDT) is an effective, noninvasive, nontoxic therapeutics for cancer, senile macular degeneration, etc., which has become an increasingly recognized alternative of traditional therapeutics in clinic. However, PDT therapy agents, namely photosensitizer (PS), are limited in application as a result of prolonged cutaneous photosensitivity, low solubility and insufficient selectivity, which are encountered by numerous chemical therapies. Therefore, developing an effective PS carrier have became critical and remained a challenge to PDT.

In this study, novel multifunctional Chlorin e6-Conjugated Magnetic Nanoparticles (Ce6-MNPs) were strategically designed and prepared as targeting drug delivery system to achieve higher specificity and better solubility. Chlorin e6 (Ce6) is a promising photosensitizer characterized by a high sensitizing efficacy and rapid elimination from the body. Based on magnetite nanoparticles (Fe3O4) drug delivery system already attracted extensive attention, which can be steered to the target tissue simply by an external magnetic field. Nevertheless, Ce6-MNPs have not been reported at all. The prepared nanoparticles were characterized by transmission electron microscopy, X-ray diffraction, Fourier transform infrared spectroscopy and fluorescence spectroscopy. The nanoparticles were approximately spherical with 10-20 nm diameter. Intense fluorescence of Ce6 was monitored in the cytoplasm of MGC-803 cells. The nanoparticles possessed good biocompatibility and could generate singlet oxygen to cause remarkable photodynamic anti-tumor effects. These suggested that Ce6-MNPs had great potential as effective drug delivery system in targeting PDT, diagnostic magnetic resonance imaging and magnetic hyperthermia therapy.

7845-35, Session 8A

The effects of Ce3+ and Ce4+ on the stability of fibroblast frowth factor-2

L. Sun, H. Feng, R. Jiang, Beihua Univ. (China); L. Niu, Huazhong Normal Univ. (China); Y. Song, K. Feng, Beihua Univ. (China); C. Qi, Huazhong Normal Univ. (China)

The interaction between tri or tetravalent cerium ions and basic fibroblast growth factor (FGF-2) at 0.1-6 : 1 molar ratios under physiological condition was studied by fluorescence and CD spectrum. The different spectra alterations of FGF-2 induced by Ce3+ and Ce4+ showed that Ce3+ and Ce4+ caused different conformational changes of FGF-2 respectively, though both of them destabilized the protein. The instability of FGF-2 in the presence of Ce3+ is involved in the oxidation of its free cystein of protein, but that this treatment nearly does not affect the biological activity. As to Ce4+, it not only induced the conformational changes of protein but also inhibits its activity in a dose-dependent manner, which could be relative to the electrostatic repulsion between Ce4+ and its basic amino acid residues (pI=9.6) or the specific binding of Ce4+ to deprotonated amino acid residues. The interesting results would be helpful to investigate the problem of the stability of proteins.

7845-51, Session 8B

A numerical investigation of photo-thermal interactions during laser sebaceous gland treatment

J. Z. Zhang, Tsinghua Univ. (China); J. B. Ma, Shanghai Jiao Tong Univ. (China)

There are a variety of skin disorders associated with aberrations of sebaceous follicles, which predominantly affect the areas of face, chest and upper back of the human body, causing great mental suffering and unconfidence to the patients. Recently, a variety of laser-based methodologies for treating sebaceous gland have been developed, where combination of laser radiation on either an exogenous or endogenous chromophore present in the target tissue is generally involved. While it may be difficult to get sufficient chromophore in the target region to induce selective tissue damage, and the outer layers of the skin may be still damaged resulting in scarring.

The study is to explore a light-based sub-surface treatment method, in which the regions of skin dermis containing sebaceous follicles are treated and the overlying regions of the epidermis/ dermis and the underlying portions of the dermis are spared from thermal damage. A new time-dependent mathematical model was built up, which is a combination of four parts: Monte Carlo (MC) simulation, which provides photon distribution; MATLAB data processing, which calculates heat generation rate from MC output; COMSOL modeling, which computes real-time temperature change; and Arrhenius equation, which predicts the thermal damage. With this model, spatial and temporal evolutions of the temperature distribution and thermally damaged zone were simulated. Effects of some treatment-affecting parameters, such as diameter and depth of the sebaceous gland, energy density, pulse width and repetition of laser, etc., were numerically investigated. The results and conclusions are useful for optimizing laser sebaceous gland treatments and for designing new treatment procedures.

7845-52, Session 8B

Monte Carlo simulation of noninvasive glucose measurement based on FMCW lidar

X. Bing, W. Wei, J. He, Zhejiang Univ. (China)

Abstract: Continuous non-invasive glucose monitoring is a powerful tool for the treatment and management of diabetes. A glucose measurement method, with the potential advantage of miniaturizability with no moving parts, based on the frequency modulated continuous wave (FMCW) lidar technology is proposed and investigated. The system mainly consists of a near-infrared tunable semiconductor laser and a detector. The frequency modulated light scattered by the tissue beats with a reference beam at the detector, with the beat frequency corresponding to the optical path length difference. By analyzing the relationship between the interference signal intensity and the beat frequency, glucose concentration can be deduced from the slope of the FMCW signal spectrum. Mathematical theory has been established supposing that the wavelength of light source is modulated by a periodic sawtooth-wave. To investigate the feasibility of the method, Monte Carlo simulations have been performed on polystyrene foam with optical parameters similar to those of human interstitial fluid. The analysis of polystyrene foam with different glucose concentrations shows that the slope of the FMCW signal spectrum decreases with increasing glucose concentration, and a good correlation between changes in the slope of the FMCW signal spectrum and the scattering coefficient calculated by Mie theory is observed. Our study suggests that the FMCW lidar technique may potentially be used for noninvasive blood glucose monitoring.

7845-53, Session 8B

Effects of spatial and temporal parameters of MTZs on temperature and thermal damage distributions during non-ablative fractional photothermolysis treatments: a numerical study

J. B. Ma, Shanghai Jiao Tong Univ. (China); J. Z. Zhang, Tsinghua Univ. (China)

Introduced in 2003, the novel method of non-ablative fractional photothermolysis (FP) has been successfully used in treating various skin disorders including wrinkles, melasma, lentigenes and acne scars, by offering significant clinical improvement while minimal risk of complications. A distinctive thermal damage pattern by creating discrete columns of thermal damage referred to as microthermal treatment zones (MTZs) is produced during FP treatments. Fast repair of laser-induced thermal injury is subsequently simulated in less than 24 hours as the MTZs are surrounded by untreated, viable tissue. Theoretically, spatiotemporal interactions of MTZs would affect the temperature and thermal damage distributions and then therapeutic outcomes significantly, and optimized spatial and temporal parameters of MTZs might improve non-ablative FP treatments.

A 3D photo-thermal model was built up with a 3D Monte Carlo method to simulate the laser transport in the skin tissue, 3D Pennes bioheat transfer equation with variable thermal properties to calculate the temperature distribution, and Arrhenius equation to predict the thermal damage. Simulations with various diameters of laser beams, distances between laser irradiation spots, and multi-pulse durations and repetitions were performed to research the synergy effects of photo-thermal interactions and effects on tissue temperature and thermal damage distributions. The results are useful for optimizing non-ablative FP treatments and for designing new treatment procedures.

7845-36, Session 9A

New probes for two-photon fluorescence folate receptor bioimaging

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Two-photon fluorescence microscopy (2PFM) is a technique with increasing practical value in biological imaging. Although biomedical applications of 2PFM are steadily increasing, the technique still suffers from the lack of efficient, photostable two-photon absorbing fluorescent probes that possess high target specificity. In order to be truly useful for such applications, it is necessary to have not only an imaging component that undergoes two-photon absorption (2PA) at wavelengths longer than 700 nm and exhibit high photostability but also a vector that targets the fluorescent probe selectively to a partciular tissue, cell, organelle, recptor, or protein. Among the different strategies of receptor-mediated delivery of fluorescent probes, the folic acid receptor constitutes a useful target for tumor-specific delivery; because (i) folate receptors have been found to be frequently overexpressed in a wide range of human cancers, including malignancies of ovaries, brain, kidney, breast, renal cell carcinomas, brain metastases derived from epithelial cancers, and neuroendocrine carcinomas, (ii) nonproliferating normal cells are severely restricted in possessing folate receptors which provide highly selective sites that differentiate tumor cells from normal cells, and (iii) folate has a high affinity for cell surface receptors. In addition to these, folic acid is highly stable, inexpensive, and has small molecular size, facilitating facile internalization of organic fluorescent probes to which it is conjugated. To address the demand for better performing probes, we report two different approaches for folate receptor-mediated delivery of 2PA fluorescent probes for multiphoton imaging; small molecule conjugates and silica nanoparticle conjugates.

7845-37, Session 9A

Quantitative FRET measurement by high-speed fluorescence excitation and emission spectrometer

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Förster resonance energy transfer (FRET) is an important method in studying biochemistry reactions. But quantifying FRET rapidly is difficult to do because of crosstalk between free donor, free acceptor and FRET fluorescent signals when only excitation or emission property of a FRET sample is measured. If FRET is studied with excitation-emission matrix (EEM) measurements, because the fluorescence intensity maxima of donor, acceptor, and FRET emissions occupy different regions within the EEM, FRET fluorescence can be easily separated out by linear unmixing. We report a novel high-speed Fourier Fluorescence Excitation Emission spectrometer, which simultaneously measures three projections of EEM from a FRET sample, which are excitation, emission and excitation-emission cross-correlation spectra. We demonstrate that these three EEM projections can be measured and unmixed in approximately 1 ms to provide rapid quantitative FRET in the presence of free donors and acceptors. The system can be utilized to enable real-time biochemistry reaction studies.

7845-38, Session 9A

A simple method to fulfill particle trapping by optical tweezers array

Q. Li, Y. Zhou, J. Li, Beijing Institute of Technology (China)

With the discovery of manipulating micro-particles by laser power and further research, the technique called optical tweezers has developed prominently. From single optical tweezers to optical tweezers array, the technique has become one of the promising methods in the field of biology sample separation and analysis, because it can achieve non-contact physical manipulation successfully and efficiently.

In this article, we adopt double-plate sheering interferometers to perform an optical tweezers array system. The particles can be trapped and separated by moving three dimensional latticed spots. Therefore, the specific parameters should be satisfied with the trapping condition to separate the particle from original sample and fulfill the sorting process.

In optical tweezers array system, the reflecting mirror is replaced by an optical scanner to be a beam translator. The optical scanner is driven by an input signal to control the interference strips movement. However, if the interference strips move periodically, the trapped particles would move along with the strips with the same regulation. So, the particles could not be separated from the other particles. We use an external modulating device to be a shutter to control the laser beam. Then the trapped particles would continue moving because of inertia during the laser beam is blocked, and be trapped again after the shutter opens. If the moving speed of liquid is limited properly, the particles can be separated continuingly and collected. At the end of this article, we illustrate the result of conducting the simple method and characteristics of the system.

7845-39, Session 9A

Fast confocal endomicroscopy based on multi-fiber parallel scanning

S. Yan, China Jiliang Univ. (China); L. Wang, Zhejiang Univ. (China)

Confocal endomicroscopy has been developed very quickly for its high resolution and high sensitivity. It could be used for early diagnoses of disease, such as cancer. In existing confocal endomicroscopy, fiber bundle or single fiber was used for transferring exciting laser and excited fluorescence signal. Neither of these technologies had high resolution nor high imaging speed. In this paper, a fast confocal endomicroscopy(FCM) is presented. In the FCM, a multi-fiber array with 9 fibers is used for light signal transferring, including exciting laser and excited fluorescence. In the distal end of the endomicroscopy, the fibers are arranged in two dimension and form a 3X3 area array. The fibers are not arrayed closely, but with space. Under driving of a MEMS scanner, the fibers move and scan tissue in parallel. Each fiber takes charge of 1/9 of the whole diagnoses field. Then the whole field is scanned and image is acquired. In the other end, the fibers are arranged in linear array. Exciting laser is coupled into the linear fiber array and transferred to the distal end of the area fiber array. Fluorophore molecules in tissue are excited and emit fluorescence. The fluorescence is collected into the 3X3 area fiber array and transferred to the linear array end. An imaging objective lens couples the fluorescence from the fiber end to a CCD, which converts the light intensity into electrical signal. Image of tissue is reconstructed from the electrical signal. By parallel scanning, the imaging speed of confocal endomicroscope is improved by several times, which is associated with the number of fibers in the array.

7845-40, Session 9A

Noninvasive evaluation system of fractured bone based on speckle interferometry

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In general, patients expected to be diagnosed by an expert doctor who has considerable experience. In order to compensate for the shortage of doctors, automatic diagnosis systems are required that provide diagnosis equivalent to that of an experienced doctor. One example of a task that could potentially be performed by such a system is the evaluation of the state of healing of a fractured bone. When doctors perform open-heart surgery, they cut the sternum, which is the bone that protects the heart. It is difficult to evaluate the state of healing of an artificial fracture at the sternum from surgery using the conventional noninvasive method. Even if the internal organs recover completely, there is a possibility that a patient must rest quietly in bed longer than required. Hence simple and noninvasive system which can evaluate the healing state of the fractured bone is important to both of hospitals and patients. The authors have introduced new evaluation index that is contributed for monitoring the state of the fractured bone using time-series analysis based on speckle interferometry in the previously paper. In order to know the state of fractured bone, the out-of-plane displacement of the skin around fractured part is measured using speckle interferometry and its distribution is obtained as speckle fringes. In order to check performance of proposed method, the performance test using test phantom that is imitated human chest body is performed. The detailed results are indicated in full-length manuscript.

7845-54, Session 9B

Anti-HIV-1 activities of photodynamic therapy using hematoporphyrin monomethyl ether

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Photodynamic therapy (PDT) with a new photosensitizer, hematoporphyrin monomethyl ether (HMME) was investigated as a potential inactivator of human immunodeficiency virus (HIV) and virus infection, in vitro. A series of concentrations of HMME were mixed with MT4, C8166 or H9/HIV-1IIIB cells or HIV-1IIIB cell-free virus for 2 h. Cells or virus were irradiated with a 630 nm semiconductor laser with an energy density of 0.3 J/cm2. The antiviral effects against HIV-1IIIB were assayed by counting the syncytial formation or detecting the viability of cells by MTT assay or measuring the p24 antigen expression level in supernatant by ELISA. All effects observed with HMME-PDT were compared with treatments with methylene blue (MB-PDT). PDT inhibited the cell-cell membrane fusion up to 64.68% for HMME-PDT and 61.56% for MB-PDT. Likewise, virus-cell fusion was inhibited by up to 85% for HMME-PDT and 73.64% for MB-PDT. Cell-free virus inhibition of up to 100% was achieved by each treatment. However, PDT had little effect on the acute infection or chronic infection of HIV-1IIIB. Therefore, PDT can effectively inhibit cell-free HIV particle infectivity and can also inhibit membrane fusion induced by HIV-1IIIB. These results suggest that PDT may be a promising new treatment for HIV infected individuals, especially those with high viral load.

7845-55, Session 9B

Kinetic analysis of singlet oxygen generation within a living cell using singlet oxygen sensor green

B. Li, Y. Shen, H. Lin, L. Xiao, Z. Huang, S. Xie, Fujian Normal Univ. (China)

Singlet oxygen can be generated in a living cell upon focused laser irradiation of an intracellular photosensitizer.In this study, singlet oxygen generation from the photoirradiation of the photosensitizers protoporphyrin IX (PPIX) and 5,10,15,20-tetrakis(N-methyl-4-pyridyl)-21H,23H-porphine (TMPyP) in neoplastic human nasopharyngeal CNE2 cells was monitored indirectly by using a newly developed fluorescence probe Singlet Oxygen Sensor Green agent (SOSG) during the irradiation. PpIX showed a diffuse fluorescence in or around the plasma membrane following 1 h incubation, whereas TMPyP localized primarily in the nuclei for 6 h incubation. The confocal images indicated that the green fluorescence of SOSG around the cells incubated with PpIX was dramatically enhanced with the increased irradiation time, while it showed no significantly enhancement for the cells incubated with TMPyP. These findings indicated that the enhancement of the green fluorescence of SOSG depends on the subcellular localizations of the photosensitizers. For the first time, our observations directly demonstrate that the singlet oxygen inside living cells does not diffuse a great distance from its site of generation.

7845-56, Session 9B

Photodynamic therapy for port wine stains assisted by a novel robotic system

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Port wine stains (PWS) is a vascular malformation consisting of

superficial and deep dilated capillaries in the skin, which produce reddish to purplish discoloration of the skin. Photodynamic therapy (PDT) is an effective approach in the treatment of PWS. However, the procedure of treatment is a low efficient and hard work, as the doctor need to hold laser fiber to irradiate for 30 min to 50 min per lesion. So an assisted novel robotic system was developed to instead part of doctor's work. The robotic system consisted of 7 degrees of freedom, in which there were 5 passive joints and 2 active joints. Binocular vision was used as guidance for the robot which consisted of two cameras and software for three dimensional reconstructions. The work process of the robotic system was that: doctor controlled the passive joints to make the active joints which hold the laser fiber above the lesion, then the cameras located the site of lesion and give the message to robotic system, the systems automated followed the lesion. Clinical trial compared 50 lesions treated by the robotic system with another 50 lesions treated by doctor. The patients in both groups were injected intravenously with photosensitizer (PSD-007, 4-5mg/kg) and irradiated with 532 nm laser (100mW/cm2) immediately, and both groups had same good therapeutical results. The robotic system is helpful in the PWS-PDT and hopefully would become a part of PWS therapy machine in the future.

7845-57, Session 9B

Influence of photodynamic therapy on dental plaque of oral biofilm of artificial dental caries

Z. Zou, Dental Hospital of Tianjin (China); H. Yin, Y. Li, Chinese Academy of Medical Sciences (China)

To discuss the effects of PDT on the mainly oral cariogenic biofilm bacteria. An artificial caries model was built consistent with the physiological environment with Streptococcus mutans. Hematoporyrin monomethyl Ether was selected for photosensitizer. 635nm diode laser was used for irradiation, with delivered power 10mW and energy density 12.47 J/cm2. Fifty enamel blocks were formed artificial caries models. Separated them into five groups random, ten blocks each group: 1. Group of HMME; 2. Group of laser; 3. Group of PDT; 4. Positive control group of 0.05% chlorhexidine; 5.Negative control group of 0.9% saline. The influence of on dental plaque oral biofilm of artificial dental caries was observed according to plate counting of bacteria method. Compared to Negative control group, the number of Streptococcus mutans (CFU/ml) of oral biofilm in artificial caries model of HMME group was not significant difference ($P>0.05$), with the bactericidal rate only 0.05%; laser irradiation and 0.05% chlorhexidine made the number of Streptococcus mutans (CFU/ml) of oral biofilm in artificial caries model significantly reduced ($P<0.05$), with the bactericidal rate 59.94% and 58.52% separately; after PDT treatment against dental caries, the number of Streptococcus mutans (CFU/ml) of oral biofilm in artificial caries model significantly reduced ($P<0.05$), the bactericidal rate up to 99.36%. HMME-PDT was an effective method in eliminate Streptococcus mutans of oral biofilm for artificial caries model. It provided an new effective approach for dental caries prevention.

7845-58, Session 9B

Effect of concentration on photobleaching of hematoporphrin monomethyl ether (HMME) in solutions

Y. Wang, Y. Gu, Chinese PLA General Hospital (China)

To analyze the effect of concentration on HMME photobleaching in different solutions. Decreation of HMME absorption in two type solutions (PBS, Albumin buffer) was monitored using steady-state absorption spectra during 532nm laser irradiation. Three HMME concentration (4, 10, 80μmol/L) were set for each kind solution. Then the photobleaching were compared using the photobleaching rate coefficient (k) calculated according to the photobleaching data or the slope of photobleaching curve. At the same time the existence state of HMME in different solvents at each concentration point was analyzed. Experiment results demonstrate that in both PBS and Albumin buffer, the rate coefficient of HMME was the greatest at 4μmol/L, the second at 10μmol/L, and the smallest at 80μmol/L. In conclusion, there is a concentration-dependent relationship in photobleaching of HMME, it will be inhibited when concentration of photosensitizer increased above certain level at which HMME aggregates formed.

7845-59, Session 9B

Determination of singlet oxygen quantum yield of HiPorfin using singlet oxygen sensor green

H. Lin, D. Chen, Y. Shen, L. Lin, B. Li, S. Xie, Fujian Normal Univ. (China)

Singlet oxygen is a highly reactive oxygen species that is considered to be the predominant cytotoxic agent with most current photosensitizers used in photodynamic therapy. The quantum yield of singlet oxygen is a key property for the newly developed photosensitizers. HiPorfin, a hematoporphyrin derivative received the first regulatory approval in China. In this study, Rose Bengal with high singlet oxygen quantum yield was used as a comparative reference, and the determination of singlet oxygen quantum yield of HiPorfin in aqueous solution has been successfully achieved by using a specific fluorescence probe Singlet Oxygen Sensor Green (SOSG) with an appropriate measurement protocol. In the presence of singlet oxygen, SOSG can be reacts with singlet oxygen to produce SOSG endoperoxides that are emit strongly green fluorescence with a maximum at 525 nm. The singlet oxygen quantum yield of HiPorfin was determined to be 0.15±0.03. The results of this study indicate that SOSG can be used to quantitatively determinate the singlet oxygen quantum yields of the photosensitizers, and this method has distinct advantages in high sensitivity and easy detection.

7845-41, Session 10A

Novel optogenetic experiment apparatus based on spatial light modulator and solid state light source

C. Ou, Hsiuping Institute of Technology (Taiwan); H. L. Su, C. Shen, National Chung Hsing Univ. (Taiwan)

For the past few years, optogenetic tehcnique getting much attention in neuron science. Similar to other photostimulating technologies (Optical neural guiding, photodynamic therapy and photosynthesis of the cell ect.), optogenetic technology required specific spatial energy and spectrum weighting distributions to the neuron for activating the neuron response. In this report we prosed a novel apparatus for optogenetic applcations that based on our previous design for cell illumination experiment. This system can produce small light spot to the desired neuron position and trigger the activation of the neuron therough the photo-chemical effects callused by the illumination condition to the Channelrhodopsin-2 (ChR2), which is one of the light-gated ion channel. Influences factors such as the wavelength, durations, polarization, spatial intensity distribution can be all complete throught this system. During the culturing, appropriate multipoints illumination condition for the neurons inside the incubator are required to completet complicated tissues regeneration and photostimulating applications. Several examples will be demostrated.

7845-42, Session 10A

Optical requirement and the mechanism revelence between optogenetic and optical neural guiding

C. Ou, Hsiuping Institute of Technology (Taiwan)

Optical neural guiding and optogenetic are both photostimulating techniques for neuro science. It is been report by the author that the apparatus can be share through a common plateform. However, difference between the activation procedure leads to particular optical design requirement. We exam and compare the two phenomena and conjecture that these two techniques shares the common basis, such that the system design can be unified.

7845-43, Session 10A

Confocal fluorescence microendoscopy using a digital micro-mirror device

Z. Feng, L. Wang, H. Duan, Zhejiang Univ. (China)

A design of confocal fluorescence microendoscopy utilizing a digital micro-mirror device (DMD) is described. Laser beams of the microendoscope are coupled into the body through a telescopic optics system, rather than through fibers or fiber bundles which are widely used in existing microendoscopes. Each micro-mirror of the DMD is used as a confocal pinhole. The DMD not only couples the laser beams into the body by a random time-varying speckle pattern and performs the scanning mechanism of the body tissue with different positions, but also couples the fluorescent signal emitted from the markers out to the CCD camera. Because of the CCD's integration feature and DMD's rapid parallel scanning feature, a complete predetermined depth tomography image accumulated by different scanning patterns of DMD can be acquired through only one CCD exposure procedure. The objective lens to realize high resolution and high sensitivity fluorescence imaging is the other function of the telescopic optics, with a numerical aperture of 0.35. The resolution of confocal microendoscope is superior to 228 lp/mm determined by 1951USAF resolution test target. Images of a thin biological sample are also shown to demonstrate practical application of the design. The confocal microendoscope using a DMD permits the acquisition of high-resolution real-time confocal images of epithelial tissue in vivo organ and realizes the aim of non-invasive diagnosis and treatment.

7845-44, Session 10A

Evaluation of bovine bone ablation by assisted with a liquid film on the target tissue

X. Zhang, Fujian Normal Univ. (China)

The influence of an applied water film on bone hard tissue ablation by pulse CO2 laser was evaluated. Fresh bovine shank bone in vitro used in the experiment were put on a PC-controlled motorized linear drive stage and moved repeatedly through focused beam of laser without and with a water film on target tissue. The wavelength of pulse CO2 laser was 10.64 um, pulse repetition rate was 60 Hz, the energy density was 18 84 J/cm2 and the beam diameter of about 400 um. The moving speed of stage was 12 mm/s, scanning times was 5. The surface morphology and microstructure of ablation grooves were examined by steroscopic microscope and scanning electron microscope (SEM) respectively. The crater depth was measured with optical coherence tomography (OCT). the ablation rate and ablation efficiency with and without water film was compared. It shows that water film not only can clean, cool the target tissue and reduce the thermal damage, but also can augment ablation rate by optimal selection of laser irradiation parameters and water film thickness

7845-60, Session 10B

Ureteroscopy in detecting upper urinary tract neoplasms in patients with asymptomatic hematuria and abnormal computerized tomography urography or cytology

S. Xia, Affiliated First People's Hospital of Shanghai Jiaotong Univ. (China)

In order to evaluate the efficacy of ureteroscopy in detecting upper urinary tract neoplasms in patients with asymptomatic hematuria, a total of 267 patients with asymptomatic hematuria underwent multidetector computerized tomography urography, cystoscopy and cytology. 52 patients with abnormal computerized tomography urography or cytology and 8 patients with macrohematuria from upper urinary tract underwent ureteroscopy for detecting upper urinary tract neoplasms . 50 patients underwent semirigid and 10 patients underwent flexible ureteroscopic evaluation. The results show that 46 upper urinary tract carcinomas and 4 polyps were found by ureteroscopy. 6 patients had clots in calyces and 4 patients had nothing abnormal found by ureteroscopy. 10 patients with negative results for upper urinary tract neoplasm were followed for a mean period of 27 (range 6~45) months. 2 patients were found with transitional cell carcinoma in upper urinary tract 7 months and 1 year after the ureteroscopic evaluation. For detection of upper urinary neoplasm with hematuria and abnormal computerized tomography urography or cytology, ureteroscopy had a sensitivity of 95.8% and specificity of 100%. Therefore, ureteroscopic detection of upper urinary neoplasm is highly sensitive and specific.

7845-50, Poster Session

1.32μm laser stimulus causing pain in human skin of lateral margin of forearm

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The aim of the present study was to characterize pain threshold induced by 1.32μm laser in human skin. The skin of human lateral margin of forearm was irradiated by a 1.32μm Nd: YAP laser in various pulse width. The energy of each pulse and whether the subjects felt a painful sensation immediately after each stimulus were recorded. The pain threshold was defined as the laser dose at which the subjects reported a painful sensation to 50% of stimulus deliveries. The pain thresholds were determined to be 5.86J/cm2, 5.40J/cm2 and 5.03J/cm2 respectively under the stimulating condition of 4.0mm beam diameter and 8ms, 0.1s and 1s pulse duration. The threshold of 1.32μm laser stimulus causing pain does not change significantly with increasing pulse duration when the exposure time in the range of 8ms~1s.

7845-61, Poster Session

Variation of absorption coefficient of glucose water in consideration of water displacement

Z. He, Northeastern Univ. (China)

Diabetes mellitus is a medical condition in which the body does not adequately produce the quantity or quality of insulin needed to maintain a normal circulating blood glucose. Invasive measurement of blood glucose make great pain on patient. Noninvasive measurement of blood glucose by infrared spectrum has significant meaning. In

noninvasive measurement the wavelength selection is a main task to increase accuracy. Adding glucose in water will cause two influences on the aqueous solution: one is absorption coefficient addition of glucose; the other is absorption coefficient decrease of water because of water displacement. So the total absorption effect is the result of the absorption coefficient increase of glucose and absorption coefficient decrease of water. In this paper the absorption coefficient of glucose water is analyzed in consideration of water displacement. By data of handbook, we deduce a relationship between the glucose absorption coefficient addition and water absorption coefficient decrease. When one molar glucose is added into water, 6.15 molars water molecular is displaced. The wavelength selection in glucose detection should be at the place where the combined absorption is maximum. The wavelength of widely used in blood glucose concentration detection, e.g. 1.6μm, is selected as an example for analysis. When glucose is added into water, the linear relationship between glucose concentration and absorption coefficient is hold on. On the other hand, when the water molecular is decreased, the water absorption coefficient will decreased, too, which will decrease the total absorption coefficient compared to the situation without water displacement. From the calculated data it can be concluded that a large part of absorption coefficient caused by glucose addition are counteract by water displacement because water absorption coefficient is sufficiently large compared with glucose absorption coefficient. In the wave selection the position where water absorption coefficient are large should be avoided. In general, water displacement will decrease the sensitivity of absorption coefficient to glucose concentration.

7845-62, Poster Session

Uniform mesoporous dye-doped silica nanoparticles as a multifunctional drug carrier for in vivo early tumor diagnosis

J. Cao, D. Deng, Y. Gu, China Pharmaceutical Univ. (China)

In this report, we synthesize multifunctional dye-doped mesoporous silica nanoparticles by encapsulating near-infrared dyes into the nanoparticles. In order to enhance the targeting property, folate-polyethylene glycol (PEG) was used to decorate the dye-doped silica nanoparticles for targeted and sustained imaging to folated-receptor overexpressed tumors, owing to the high abundance of folate receptors in many cancer cells. The optical properties, morphology and structure of the as-prepared dye-doped silica nanoparticles were characterized. The cytotoxicity and affinity to tumor cells were measured. And the tumor targeting capability was investigated in nude mice bearing different tumor xenograft. Results indicate the dye-doped silica nanoparticles is a good probe for early tumor diagnosis and have the potential to serve as a targeted carrier for antitumor drugs .

7845-63, Poster Session

A novel detector for chromatography and estradiol immune sensor based on surface plasma resonance

H. Chen, X. Wang, H. Wu, S. Zhan, Zhejiang Univ. (China)

Biosensors based on surface plasma resonance (SPR) are attracting more and more attention from academic and industry communities. Its principle was interpreted. A novel detector based on SPR was presented for Chromatography. Associated with ion chromatography system, it was employed to detect separation behavior of mixture including glucose, fructose and galacitiol. Experimental results demonstrated that relative standard deviation (RSD) of each separated glucide was below 2.5%. The detection limits of glucose, galacitiol, fructose were 6μg, 10μg, 15μg, respectively. The linear correlation coefficient of each separated glucide was greater than 0.995 in range from detection limit to upper concentration. Combined with the immune detection technology, the SPR flow injection analysis system was designed to determine standard curve of environmental pollutant estradiol. Detection limit of estradiol was able to reach 9.4ng.

7845-64, Poster Session

The influences of turbid media on the optical property of different ultra short Gauss laser pulse

M. Zhao, Z. Chang, Beijing Institute of Petrochemical Technology (China)

With the rapid development of the laser's application on the fields of biological medicine, the tissue photics research which focus on the interaction between luminous radiation and biological tissue has become the investigation core and theoretical basis of modern medical diagnose and treatment. Most of the biological tissues are a kind of turbid media.The interaction between ultra shot laser pulse and these tissues has drawn great attention recently because of the potential application in the medicine.

Based on the diffusion approximation theory, the laser pulse energy will be attenuated and the pulse shape will be changed by scattering and absorption after transmitting through the turbid media.In this paper, Mathematics equations of the ultra short Gauss laser pulse in different are given, the reflective pulses are discussed with the boundary condition of semi-infinite homogeneous media. We get the simulation results of reflective intensity and the reflective pulse shape of different based on the diffusion equation. From the results, the ultra short Gauss laser pulse will be widened by the diffusive scattering. Besides, we find that the various medium parameters will influence the reflection of the Gauss laser pulse very differently. With the boundary condition of semi-infinite homogeneous media, the influence of the absorption, the scattering, and the anisotropy coefficient g will be also changed by the different of ultra short Gauss laser pulse. All the conditions mentioned above has been researched in the present paper. This study will be very useful for the high resolution measurement of optical properties of tissue.

7845-65, Poster Session

Optical trapping gold nanoparticles by a pulse laser

X. Liu, F. Wang, Harbin Engineering Univ. (China)

Gold nanoparticles are widely employed in nanomaterials, nanobiotechnology and health care. In optical trapping studies, gold nanoparticles are also welcome as superior handles or probes relative to polystyrene beads because they are more prone to detect for their own physical characteristics. Unfortunately, they are also found to be difficult to trap stably by usual optical tweezers.

Compared with the continuous laser which is popular to the optical trapping, pulse laser has a relatively larger power in its work pulse, which is useful for trap particles.

It is known that particles in optical tweezers are pressed by many forces, such as the radiation forces caused by the laser, the gravitation, and the forces among the molecule, etc. A stable trap for particles is depended on the exact equilibrium among all these forces.

Although the tests to trap gold nanoparticles are never paused, a particular report about trapping gold nanoparticles by a pulse laser is hard to find. So it is necessary to carry out the detailed force analysis for gold nanoparticles in the laser beam waist formed by a pulse laser.

Considering the above statements, this paper comprehensively analyzes the forces (the radiation forces, the gravitation, and the Brownian motion) on the gold nanoparticles in the optical tweezers formed by a

pulse laser, through building up a mathematical model. Finally gets the dependence relation between the characteristics of the pulse laser and that of the gold nanoparticles.

7845-66, Poster Session

Fluorescence lifetime imaging using multi-dimension time-correlated single photon counting method

C. Sheng, H. Tang, Shandong Univ. of Technology (China)

Fluorescence lifetime measurement is the key of fluorescence lifetime imaging. Time-correlated single photon counting(TCSPC) method is adopted to record fluorescence lifetime considering its virtue of near-ideal counting efficiency and ultra-high time resolution. The detection time of the first fluorescence excited by the laser pulse referred to the next laser pulse, the current location of the laser spot in the scanning area, the detector channel number for the current photon are measured as the address of the histogram memory. Thus, in the memory the distribution of the photons over time, wavelength, and the image coordinates builds up. The result is a four-dimensional data array . It is proved that the counting efficiency and the amount of information in the data can be increased by Multi-dimension imaging. Different chromophores can also be separated by this way in steady-state images.

7845-67, Poster Session

An analytic two-dimensional circular scheme for time-domain diffuse fluorescence tomography: methodology and phantom validation

J. Li, F. Gao, X. Wang, L. Zhang, H. Zhao, Tianjin Univ. (China)

Near-infrared fluorescence diffuse optical tomography has proven to be an efficient tool for visualizing the bio-distributions of fluorescent markers in tissue. We present a two-dimensional image reconstruction method for time-domain fluorescence diffuse optical tomography on a turbid medium of circular domain. The methodology is based on a linear generalized pulse spectrum technique that employs the analytical solution to the Laplace-transformed time-domain photon-diffusion equation to construct a Born normalized inverse model, which can overcome the impact of the instrumental response function and therefore eliminate the requirement for calibrating the time-origins and the coupling factors of the time-resolved measurement. A pair of real domain transform-factors is introduced to simultaneously reconstruct the fluorescent yield and lifetime images and the resultant linear inversions are solved using an algebraic reconstruction technique. The experimental validation is performed using a multi-channel time-correlated single-photon-counting system and a cylinder phantom that embeds a fluorescent target made from 1%-Intralipid solution and Cy5.5 agent. The results show that the approach retrieves the position and shape of the target with a reasonable accuracy.

7845-68, Poster Session

Development of a novel spectrometer for tongue coating analyzer based on volume holography transmissive grating

R. Zhong, G. Liu, Jiangxi Science and Technology Normal Univ. (China); L. Dai, China Eastern Airlines Co. Ltd. (China); H. Zhen, L. Zeng, Jiangxi Science and Technology Normal Univ. (China)

Tongue diagnosis (TD) is an important part in the traditional Chinese medicine (TCM). According to the viewpoint of the TCM, the changes of the tongue coating can reflect the pathological state of the patient. By observing the tongue coating, a Chinese physician can determine the nature or severity of disease. Over the years, the method of TD is mostly depended on the subjective awareness and experience of the physician. And, some factors can generate the error and impact the diagnostic results, e.g. the light source or the environmental brightness, etc. Recently years, the method of digital image processing was used into the TD. But, its application is limited by the complicated algorithm, time-consuming, big error, etc. Therefore, a novel tongue coating analyzer(TCA) is introduced in this paper. And, as the key part of the TCA, a novel spectrometer for TCA based on the volume holography transmissive (VHT) grating is developed. In this spectrometer, the VHT grating is adopted to as the diffraction grating instead of the classical surface-relief plane or concave grating. These classical gratings exist some minute cracks on the surface of the gratings' grooves, these cracks will generate the stray-light and decrease the efficiency. However, the VHT grating doesn't produce the stray-light due to the absence of groove of classical surface-relief gratings. So, its spectral range can be greatly increased and its theoretical diffraction efficiency can approach 100 percent. Experimental results show that the performance of the spectrometer for TCA has been improved by using the novel VHT grating, optimizing the light-path structure and the software algorithm, etc. Compared with others, this spectrometer for TCA has many advantages, e.g. less diffraction, less stray-light, better image quality and higher efficiency, higher resolution, etc. The spectrum range of this spectrosmeter for TCA can reach 300-1000nm, its resolution can reach 1nm and the optical density is larger than 3.

7845-69, Poster Session

Improvement of the frequency-domain inverse Monte Carlo simulation

X. Zhou, H. Zhao, S. Zhang, Z. Qin, F. Gao, Tianjin Univ. (China)

This article aims at the optical property (absorption coefficient and scatter coefficient) reconstruction from the frequency-domain (FD) near-infrared diffuse measurement on small tissues, such as a cervix, for which inverse Monte-Carlos (MC) simulation is the suitable choice. To achieve the fast and accurate reconstruction based on the inverse Monte Carlo simulation, following techniques were adopted. First, in the forward calculation, a database, which include the frequency-domain information calculated from MC simulation for a series of optical parameters of tissue, were established with fast methods. Then, in the reconstruction procedure, Levenberg-Marquardt (L-M) optimization was adopted and Multiple Polynomial Regression (MPR) method was used to rapidly get the FD information at any optical properties by best fitting the curved surface formed by the above database. At Last, in the reconstruction, to eliminate the influence of the initial guess of optical properties on the reconstruction accuracy, cluster analysis method was introduced into L-M reconstruction algorithm to determine the region of the initial guess. The reconstruction algorithm was demonstrated with simulation data. The results showed that it takes less than 0.5s to reconstruction one set of optical properties. The average relative error from the reconstruction algorithm joined with cluster analysis is 10% lower than that without cluster analysis.

7845-70, Poster Session

Comparison between radiation forces on gold nanoparticles and on polystyrene nanobeads

X. Liu, F. Wang, Harbin Engineering Univ. (China)

Gold nanoparticles have found broad applications in nanomaterials and nanobiotechnology and health care. They are considered to be superior

handles or probes relative to polystyrene beads for their own specific physical characteristics. But unfortunately they are considered difficult to trap stably by optical tweezers still owing to their specific physical characteristics.

It is known that there are two types of radiation forces in the optical tweezers: gradient force and scattering/absorption force. The gradient force always pulls the particles towards the center of the beam waist, while the scattering/absorption force tends to push the particles out of the focus. For dielectric particles, the gradient force is easy to be controlled to larger than the scattering force. Thus, the dielectric particles are relatively easy to trap. However, for metallic particles, the cases are more complicated.

This paper analyzes the radiation forces on the gold nanoparticles with different particle size (20nm and 50nm) in different particle's position within the focus, in the case of different laser wavelength (633nm and 1064nm), and different laser power (10mW and 100mW). For comparisons, the radiation forces on the polystyrene nanobeads with above conditions are also shown. Through building up a mathematical model, this paper gets the dependence relation between the gradient force and the particle size, the particle's position, the laser wavelength and the laser power, and relation between the scattering/absorption force and those parameters mentioned above, respectively. Finally, compares the radiation forces on the gold nanoparticles and on the polystyrene nanobeads.

7845-71, Poster Session

Signal and noise analysis of optical coherence tomography inscattering media with discontinuity structure at 1550 nm

L. Lin, Y. Gao, Guangdong Medical College (China) and Jinan Univ. (China); M. Zhang, Dongguan Univ. of Technology (China)

The signal and noise properties of standard time domain optical coherence tomography (OCT) system is analyzed in near-infrared region based on extended Huygens-Fresnel principle. The signal-to-noise ratio and maximum probing depth are estimated for scattering media with discontinuity plane inside. In numerical simulation, the relationship between coherent signal and scattering coefficients, and depth dependence SNR are calculated. The difference between specular and diffuse reflection is given out and analyzed. Numerical result is verified by well established experiment with different concentration mixture solution of IntralipidTM, from 1% to 15%. The OCT system consist of fiber Michelson interferometer and 1550 nm ASE optical source with coherent length of 14μm. Both numerical and experimental results show that multiple scattering events are the main reason for decreasing of signal-to-noise ratio. According to the research, wavelength at 1550 nm is also suitable for imaging of biomedical tissue because of lower scattering coefficients. More than 2 mm penetration depth is obtained in experiment for 10% IntralipidTM which has scattering coefficient similar to skin tissue.

7845-72, Poster Session

Imaging model of optical sectioning of thick specimen

C. Hua, Guangxi Univ. (China)

Based on the cartesian coordinate system, a coaxial couple cartesian coordinate system is designed. In the coaxial couple cartesian coordinate system, according to the principle of optical imaging, a form of the optical microscope's imaging model of optical sectioning biological thick specimen is derived. The model form show that if a biological thick specimen is expressed as a pile of slices with tiny interval, and a slice among the slices is put in microscope's focal plane, then the thick specimen's image in image plane is the superposition of the focal plane image and all of the defocus images. In the model form, thick specimen's image is simply sorted into focal plane image and defocus image to make it easy to look insight, so the model clearly reflects the imaging relationship between the slice of thick specimen, and it is conducive to the analysis of the microscope's imaging characteristics for thick specimen.

7845-73, Poster Session

Experimental study on measurements of optically characteristic parameters of tissue based on diffused theory

P. Sun, Beijing Normal Univ. (China)

It is important to measure optically characteristic parameters noninvasively and in vivo in applications of disease diagnoses and medical therapeutics. In this paper, some techniques of diffused theory applied to measure optical parameters of tissue are experimentally studied. The investigations refer to quantization of approximation of diffused theory, precision of optical parameters, effectively reverse algorithm and disposal method of raw data. The experimental results show that the error will be equal to or less than 8% with diffused theory on the condition that scattering coefficient is ten times larger than absorption coefficient. The stability and precision of optical parameters are markedly improved by use of step iteration to solve optical parameters and ring area to determine the center of diffused reflectance. The efficiency of reverse algorithm is significantly enhanced through select one-dimensional raw data from two-dimensional matrix of image. The measurement error of optical parameters is less than 5%. These results will provide technical supports for application of diffused theory.

7845-74, Poster Session

Comparative study of 980-nm diode laser and 810-nm diode laser to skin and mucosa vascular lesions and benign growths

H. Qiu, Y. Gu, Y. Wang, J. Zeng, N. Huang, H. Chen, Chinese PLA General Hospital (China)

Objectives: To compare the efficiency of 980nm diode laser and 810nm diode laser on skin and mucosa vascular lesions and benign growths.

Methods: 25 patients with 45 vascular lesions and 21 patients with 65 benign growths were treated with 980nm diode laser. The other 19 patients with 40 vascular lesions and 23 patients with 54 benign growths were treated by 810nm diode laser.Both of the two diode lasers output power were tuned to 3-25W according to the lesions, the continuous wave mode was used. To benign growths, the vaporization and ablation effect was used, while for vascular lesions, the coagulation effect was used. All patients were evaluated clinically at 1-2 months to assess treatment efficiency.

Results: The 980nm diode laser had better efficiency to vascular lesions than 810nm diode laser, the effective rate of the two lasers was 93.33% (42/45) and 77.50% (31/40), respectively ($p<0.05$). The effective rate of 980nm diode laser and 810nm diode laser for the skin and mucosa benign growths was 100% (65/65) and 96.30% (52/54), respectively ($p>0.05$).

Conclusions: 980nm diode laser has better coagulation effect than 810nm diode laser to skin and mucosa vascular lesions. While the vaporization and ablation effect of the 980nm diode laser is equal to that of the 810nm diode laser to skin and mucosa benign growths.

7845-75, Poster Session

Surfaced-enhanced Raman spectroscopy of nasopharyngeal carcinoma cell using gold nanoparticles

R. Chen, Fujian Normal Univ. (China); H. Huang, Fujian Univ. of Traditional Chinese Medicine (China); L. Sun, Fuzhou First Hospital (China); J. Pan, Fujian Medical Univ. (China); W. Chen, Fujian Normal Univ. (China) and Fujian Univ. of Traditional Chinese Medicine (China); Y. Su, Fujian Medical Univ. (China); S. Feng, Y. Li, Fujian Normal Univ. (China)

Nasopharyngeal carcinoma (NPC) is a malignant disease spreading with a conspicuous difference in races and religions. Figures show that the Southern China is the area with the highest incidence of this disease. A sensitive and structurally selective detecting method should be found, because there still exist difficulties in the early diagnosis of nasopharyngeal carcinoma. The near-infrared surface-enhanced Raman spectroscopy (NIR-SERS) has shown great promise in the detection of a single molecule. This paper reported the feasibility of NIR-SERS technique in the NPC cell biochemical analysis.

In our experiments, the surface-enhanced Raman scattering (SERS) spectroscopy and the normal Raman spectroscopy of single living human nasopharyngeal carcinoma cells (CNE-1) were tested and analyzed. Meanwhile, the characteristic Raman bands in the SERS spectra of living cells were tentatively assigned. Only six obvious Raman bands (718, 1001, 1123, 1336, 1446, 1660 cm-1) were observable in the normal Raman spectroscopy of living CNE-1 cells. Colloidal gold particles that were introduced inside cells intensively enhanced the Raman signals of the native chemical constituents of the cells, and over twenty SERS Raman bands appeared in the SERS spectroscopy of living CNE-1 cells.

The Raman lines of 1026, 1097, 1336 and 1585 cm-1 were assigned to the vibrations of the DNA backbone, which confirmed that some gold nanoparticles were able to enter the nucleus. Experiments showed that, based on the colloidal gold, the SERS spectroscopy might provide a sensitive and structurally selective method for detecting the native chemicals inside a cell, such as DNA and phenylalanine.

7845-76, Poster Session

New optical method for noninvasive blood glucose measurement by optical ultrasonic modulation

L. Zhu, J. Lin, W. Xie, H. Li, Fujian Normal Univ. (China)

A new optical technique for continuous, noninvasive monitoring of blood glucose levels base on ultrasonic modulation of scattering light is proposed. The ultrasound-modulated scattered light has an accurate separation of scattering and absorption changes in tissue. And the optical scattering and absorbing coefficient of tissue depends on the concentration of glucose in the extracellular fluid. As the glucose induced scattering and absorption changes, the ultrasound-modulated light also changes. In this paper, a correlation is observed between ultrasound-modulated light intensity and its modulation depth and blood glucose concentration in phantom experiments. In addition, some researches about ultrasound-modulated signal affected by the temperature of aqueous glucose are done. Preliminary experiments find that this method is a promising noninvasive blood glucose measurement.

7845-77, Poster Session

Determination of the anisotropy complex refractive indices of chicken tissues in vitro at 650 nm

P. Sun, Beijing Normal Univ. (China)

The anisotropy complex refractive index of tissue is an important parameter in understanding the behavior of light, including its transportation in and interaction with tissues. We used the specular reflection method to investigate the anisotropy complex refractive index of chicken tissue with fibrous structures in vitro at a wavelength of 650 nm. The measurement data were highly consistent with the Fesnell equations. The results showed that the real refractive index was higher along the orientation of the fibers than along the cross section, but the imaginary refractive index was nearly identical. Furthermore, the fiber orientation was in the direction of the optic axis of the chicken tissue and the chicken tissue section was similar to a negative uniaxial crystal wafer.

7845-78, Poster Session

Hematoporphyrin effect on tissue optical properties of gastric cancer in nude mice in near-infrared spectra

M. Kong, South China Normal Univ. (China)

Hematoporphyrin as a new type of contrast agent can enhance the optical image contrast of normal tissues and tumor tissues. In this study, we observed the spectral feature in near-infrared range after hematoporphyrin piled up in tumor tissues of gastric. The MCG-803 human gastric cancer cell line (from CTCC) was subcutaneous inoculated in BALB/C nude mice and the animals were divided into two groups: model group and model with hematoporphyrin group received an orthotopic graft operation. The optical attenuation coefficients of tumor tissue were detected by useing a near-infrared spectroscopy. The results show that the shape of the transmittance spectra of tumor tissues with hematoporphyrin and tumor tissues without hematoporphyrin is similar in near-infrared range from 700nm to 1500nm. But the spectral transmittance was slightly lower than the corresponding tumor tissue about 6% to 8%. The present study has suggested that hematoporphyrin accumulated in nude mice gastric cancer can effect on tumor tissue optical properties, which could provide a theoretical guidance for the optical imaging detection of tumor tissue.

7845-79, Poster Session

Marginal characteristics of skin scarred dermis quantitatively extracted from multiphoton microscopic imaging

X. Zhu, S. Zhuo, L. Zheng, J. Chen, Fujian Normal Univ. (China)

Multiphoton microscopy based on two-photon excited fluorescence (TPEF) and second harmonic generation (SHG) was applied to examine the morphological differences at the marginal regions of normal scars, hypertrophic scars, and keloids. Due to the heterogenous distribution of extracelluar matrix including collagen and elastin in dermis within one type of scars from different individuals and even within a scar, it is difficult to standardize the comparison of scars. Considering the important characteristic of keloids different from hypertrophic or normal scars that they do not regress or contract but grow and extend continuously beyond the confine of the original injury and often recur after surgical removal, high-contrast, high-resolution images of the marginal regions of the three types of scars were focused on to

find quantitative methods for discrimination. An obvious boundary were observed at the marginal region of a scar, beside which the morphological patterns of collagen or elastin are quite various from one side to the other. Since the degrees of the morphological alterations between the two sides of the boundaries are varied from different types of scars, relative SHG-to-TPEF index concerning with the alteration degree was extracted as a quantitative indicator to successfully distinguish the three different types of scars. With the advancement on multiphoton microscopy miniaturization, it will become a valuable tool for analyzing the pathological change of keloids and hypertrophic scars, and help to determine the most appropriate clinical treatment strategy for the two different types of scars and potentially monitor therapy in vivo.

7845-80, Poster Session

A processing technology of two-photon microscopic image of nasopharyngeal cancer cells

H. Lin, R. Chen, G. Chen, Fujian Normal Univ. (China)

Nasopharyngeal carcinoma (NPC) is one of the most common malignancies in china, with a deep and hidden localization. Recently, methods for early diagnosis of NPC has become one of the most important research topics in medical field. Early monitoring of shape change of NPC cells during the carcinogenesis is of great importance, and early information extracted from the NPC cells during the initial stage of NPC is critical for diagnosis and treatment. In this paper, image processing methods for two-photon microscopic image of NPC cells was investigated with the purpose of providing useful information for early diagnosis and treatment of NPC.

There is abundant information in a two-photon microscopic image of NPC cells, which can be analysed and processed by means of computers and image pattern processing algorithm. Image segmentation is one important technique in image processing, So far, there is no universal method or unified standard in defining the image segmentation. In this paper, firstly, a mathematical method of transform of Bottom-hat based on Matlab platform was employed to enhance the image of NPC cells, making the image easier to distinguish; Then, several classical edge detection algorithms were compared and discussed, for example, Roberts operator, Prewitt operator, and Canny operator etc. According to the inherent characteristics of two-photon microscopic image of NPC cells, corrosion algorithm was used to define the edge of NPC cells. Furthermore, the article gets the iterative threshold segmentation after noise denoising, on the other hand, improved discriminant analysis was adopted for threshold segmentation of NPC cells, better results were obtained.

7845-81, Poster Session

The theoretical and experimental study on light scattering property of dental enamel

Q. Chen, B. Lin, D. Liu, H. Wang, H. Shen, Zhejiang Univ. (China)

Recently, optical methods have attracted great attention in the field of early dental carious detection because of the nondestructiveness, quantitativeness, visualization and so on. Light-tissue interaction is the basic principal for optical application in biomedical field. Dental tissue can be considered to be turbid media as the scattering effect outweighs the absorbing. Photons propagation inside the dental tissue is the essential problem for the further development of optical intensity distribution-based detection method. In this paper, we aim to build a theoretical model of photons diffusion in simplified dental enamel tissue according to the convolution tool. Based on the definition of optical scattering coefficient, we suppose the spatial distribution of scattering center. And the scattering phase function determines the photon diffusion distribution possibility after photon-scatter center interaction. Then photons distribution through tissue with some depth could be considered to be multi-convolution results. Meanwhile the theoretical results are verified by Monte Carlo numerically simulation. Finally, the experiment is set and performed to detect the light intensity distribution, and the result is compared with the theoretical computation, which proves its correctness of theoretical model.

7845-82, Poster Session

Radiation force on a chiral sphere by a Gaussian beam

Q. Shang, Z. Wu, Z. Li, H. Li, Xidian Univ. (China)

This paper calculates the radiation force on a chiral sphere by a Gaussian beam. Based on the generalized Lorenz-Mie theory (GLMT), the incident Gaussian beam and scattered fields of the chiral sphere are expressed in terms of the vector spherical harmonics. Using the boundary conditions, we obtain the scattering coefficients of the chiral sphere by a Gaussian beam. The radiation force on the sphere is derived from its relation with the expanding coefficients of the incident beam and the scattering coefficients which is based on the theory of electromagnetic momentum. As a special case of the chiral sphere, the results of the isotropic sphere are examined by the results of the Rayleigh models in the literatures. The influence of the chiral parameter, the beam waist radius and the radius of the chiral sphere on radiation force is discussed numerically.

Optical tweezers can operate active cells without contacting and damaging it, it has become an important tool for research in the fields of biology, physical chemistry and medicine. The conclusions of this paper are useful for choosing parameters in optical tweezers experiments to realize a chiral particle trapping.

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7845-83, Poster Session

A novel cancer detection based on human plasma surface-enhanced Raman scattering combined with PCA-LDA statistical analysis

S. Feng, R. Chen, J. Chen, Fujian Normal Univ. (China); J. Pan, Fujian Medical Univ. (China); H. Zeng, The BC Cancer Agency Research Ctr. (Canada)

A novel surface-enhanced Raman spectroscopy (SERS) method was firstly developed for plasma biochemical analysis with the aim to develop a simple blood test for non-invasive cancer detection including nasopharyngeal cancer and gastric cancer. Silver nanoparticles (Ag NP) as the SERS-active nanostructures were directly mixed with blood plasma to enhance the Raman scattering signals of various biomolecular constituents such as proteins, lipids, and nucleic acids. High quality SERS spectrum from blood plasma-Ag NP mixture can be obtained within 10 seconds using a Renishaw micro-Raman system. SERS measurements were performed on three groups of blood plasma samples: nasopharyngeal carcinomas patients (n=43), gastric cancer patients (n=32) and healthy volunteers (control subjects, n=33). The measured SERS spectra revealed cancer specific biomolecular differences, including an increase in the relative amounts of nucleic acid, collagen, phospholipids and phenylalanine and a decrease in the percentage of amino acids and saccharides contents in the blood plasma of cancer patients as compared to that of healthy subjects. Principal component analysis (PCA) of the measured SERS spectra separated the spectral features of the cancerous groups and the healthy group into two distinct clusters with little overlaps. Linear discriminate analysis (LDA) based on the PCA generated features differentiated the nasopharyngeal cancer SERS spectra from normal SERS spectra with

high sensitivity (90.7%) and specificity (100%). Classification results obtained from cross-validation of the LDA model based on the relative SERS data sets also showed high diagnostic sensitivities (75%) and specificities (87.9%) for gastric cancer identification. These results from this exploratory study demonstrated great potentials for developing SERS blood plasma analysis into a novel clinical tool for non-invasive detection of cancers.

7845-84, Poster Session

The targeted behavior of folate-decorated N-succinyl-N'-octyl chitosan evaluated by NIR system in mouse model

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The development of more selective delivery systems for cancer diagnosis and chemotherapy is one of the most important goals of current anticancer research. The purpose of this study is to evaluate folate-decorated, self-assembled nanoparticles as candidates to deliver near infrared fluorescent dyes into tumors and to investigate the mechanisms underlying the tumor targeting with folate-decorated, self-assembled nanoparticles. Folate-decorated N-succinyl-N -octyl chitosan (folate-SOC) were synthesized. The chemical modification chitosan could self-assemble into stable micelles in aqueous medium. Micelle size determined by size analysis was around 190nm in a phosphate - buffered saline (PBS, PH 7.4). folate-SOC maintained their structure for up to 30 days in PBS. Near infrared dye ICG-Der-01 as a mode drug was loaded in the micelles, and the entrapment efficiency (EE) and drug loading (DL) were investigated. The targeted behavior of folate-SOC was evaluated by near-infrared fluorescence imaging in vivo on different groups of denuded mice, with A549 or Bel-7402 tumors. The optical imaging results indicated that folated-decorated SOC showed an excellent tumor specificity in Bel-7402 tumor-bearing mice, and weak tumor specificity in A549 tumor bearing mice. We believe that this work can provide insight for the engineering of nanoparticles and be extended to cancer therapy and diagnosis so as to deliver multiple therapeutic agents and imaging probes at high local concentrations.

7845-85, Poster Session

Monitoring the process of tissue healing of rat skin in vivo after laser irradiation based on optical coherence tomography

Y. He, S. Cai, S. Wu, Z. Li, H. Li, Fujian Normal Univ. (China)

Background: Every year there are many patients be wounded by laser irradiation with inapposite parameters, It is imperative to evaluate the tissue wound healing response after laser irradiation so that to develop effective devices for this clinical indication, and evaluate the thermal damage degree to take appropriate treatment.

Materials and methods: In our research, we prepare 6 white rat (approximately 2 months old, weight :), each rat was injected intraperitoneally a single dose of 2% pentobarbital sodium. After the rat was anesthetized, the two side of the rats' back were denuded and antisepsised a standardized. Er:YAG laser (2940nm, 2.5J/cm2, single spot, 4 times) was irradiated on rat skin in vivo, and the skin which before irradiated and the process of renovating scathe that irradiated after Er:YAG laser were observed by an Optical coherence tomography (OCT), the tissue recovery over about a twelve -day period.

Conclusions: The results indicate that the scattering coefficient of post-laser irradiation tissue has changed distinctly. The collagen and flexibility fiber is the chief component of rat dermis and collagen is the main scattering material. The normal tissue has a large scattering coefficient, after laser irradiated, the collagen became concreting and putrescence and caused the structure change. It became more uniform density distribution, which results in a reduced scattering coefficient. Our results indicate that OCT can noninvasively monitor changes in collagen structure and the recover process in thermal damage through monitor the tissue scattering coefficient.

7845-86, Poster Session

Monitoring change of optical attenuation coefficient of acupoint and nonacupoint tissues during laser acupuncture by optical coherence tomography

Y. Huang, H. Yang, Y. Wang, L. Zheng, S. Xie, Fujian Normal Univ. (China)

Laser acupuncture performs the management of diseases by laser beam irradiation on acupoint tissues with advantages of being noninvasive and painless comparing with the traditional acupuncture. Although the clinical results of laser acupuncture have been proved to be positive by literatures, the mechanism of it is still unclear. In this paper, we use an optical technique, optical coherence tomography (OCT) with high resolution and deep penetration, to study in vivo the change of the optical attenuation coefficient of the acupoint and nonacupoint tissues during laser acupuncture. The OCT images of the acupoint and nonacupoint tissues were obtained before and during the process of laser irradiation. After the suppression of noise by spatial and temporal average, the optical attenuation coefficient could be deduced from the treated image raw data with high ratio of signal to noise. The experiment results showed there were significant differences between the change of the optical attenuation coefficient of acupoint and nonacupoint during laser irradiation. It is interesting and significant for the interpreting of laser acupuncture effect.

7845-87, Poster Session

Autofluorescence characteristics of normal and leukemia cell lines

L. Xiao, Fujian Normal Univ. (China); X. Liao, Fujian Medical Univ. (China); L. Lin, Fujian Normal Univ. (China); Y. Chen, Fujian Medical Univ. (China); B. Li, S. Xie, Fujian Normal Univ. (China)

Autofluorescence spectroscopy is a powerful method to identify the endogenous fluorophores in biological cells and tissues. The purpose of this study is to characterize the autofluorescence spectra of normal and leukemia cells. Fluorescence measurements of each cell line were performed over a wide range of cell concentrations, and the fluorescence per cell was determined from the slope in the linear range of the fluorescence intensity vs cell concentration plot. In addition, the measured fluorescence levels of tryptophan, NAD(P)H and FAD were normalized to the average diameter of each cell line. All of the malignant cells indicated a statistically significant decrease in the tryptophan fluorescence per cell relative to that of the normal cells. No statistically significant differences were found in the NAD(P)H or FAD fluorescence per cell between the normal and any of the malignant cell lines. These results show that autofluorescence spectroscopy can be used to differentiate between normal cells and leukemia cells.

7845-88, Poster Session

Shear bond strength of a self-etch adhesive to Er:YAG laser-prepared dentin

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Lab. for Photonics Technology (China); W. Wu, Fujian Medical Univ. (China); X. Zhang, H. Zhao, Fujian Normal Univ. (China); S. Lin, Fujian Medical Univ. (China); S. Xie, Fujian Normal Univ. (China)

Recently various lasers had been advocated for dental tissue ablation specifically as an alternative to traditional mechanical instruments. It was suggested that open dentinal tubules and the absence of a smear layer on the irregular surface after laser preparation may be favorable for bonding procedure. However, consensus had not been reached about whether laser irradiation increases the bond strength of adhesives. The purpose of this study was to determine the shear bond strength of a self-etch adhesive to Er:YAG laser-prepared dentin. The conventional bur was used as a control group. The bonding interface was examined by scanning electron microscope (SEM) and confocal laser scanning microscope (CLSM). The observation showed hybrid layer formed on the dentine bonding interface where resin tag penetrated into the residual dentine. The experiment obtained the shear bond strength of resin composite to the laser-prepared dentin and the thickness of hybrid layer.

7845-89, Poster Session

Studying multiple scattering effects on low-coherence optical signal for tissue phantom

M. Zhang, Dongguan Univ. of Technology (China); L. Lin, Guangdong Medical College (China)

The Monte Carlo numerical model of low-coherence optical signal of tissue phantom has been established. Angle biasing is introduced to Monte Carlo simulation. In tissue sample, signal decay primarily attribute to scattering and absorbing. Multiple scattering effects on coherent signal are analyzed in the case of focused and Gaussian optical beams. The influence of refractive index, anisotropy coefficients are included in calculation. The relationship of scattering coefficients and coherent intensity is given out. The simulated results show that photons could contribute to the coherent signal depending on time delay and position on mixing plane. Scattering events increase linearly with probing depth and decrease signal-to-noise-ratio in a different way from absorption effects. Photons backscattered beyond target layer become dominated in coherent signal of deep position in sample. Different concentration IntralipidTM, from 1% to 20%, has been measured as tissue phantom by a low coherence interferometer operating at 1550nm wavelength. India ink is added into sample for changing absorption coefficient. For comparison, the depth dependence intensity data of experiments is fitted by Monte Carlo model with adjusting input parameters. Good agreement is found between numerical results and experiments. It is expected that the model can be used to extract optical properties of biological tissues or other scattering materials.

7845-90, Poster Session

Photothermal optical coherence tomography using gold nanoshells

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Molecular contrast optical coherence tomography (OCT) is an attractive method for molecular imaging with relatively good penetration depth (1-2 mm) and high resolution (1-10μm). However, molecular contrast OCT has been limited to relatively low signal-noise-ratio (SNR) and low contrast-noise-ratio (CNR). We have developed and characterized photothermal OCT as a molecular contrast mechanism that allows for high SNR and CNR molecular contrast OCT. Our photothermal system consists of an amplitude-modulated heating beam that spatially overlaps with the focused spot of the sample arm of a spectral-domain OCT microscope. A focused beam from a laser diode at 808 nm is modulated at frequencies of 500 Hz - 10 kHz while irradiating a solution containing nanoshells. Because the nanoshells are designed to have a high absorption coefficient at 808 nm, the laser beam induces small-scale localized temperature oscillations at the modulation frequency. These temperature oscillations result in optical path length changes that are detected by a phase-sensitive spectral-domain OCT system. Validation experiments in tissuelike phantoms containing gold nanoshells achieved high SNR and high CNR by optimal modulation of the thermal excitation beam. This technique could potentially augment molecular contrast OCT as a method for deep-tissue, depth-resolved molecular imaging with relatively high SNR and target sensitivity, without photobleaching or cytotoxicity.

7845-91, Poster Session

Wavelength-swept laser around 1060 nm based on polygon filter in Littrow telescope-less configuration

M. Chen, Z. Ding, L. Wang, T. Wu, B. Wang, Zhejiang Univ. (China)

A high-speed linear wavelength-swept laser source working at center wavelength of 1060 nm is demonstrated. Wavelength tuning is performed using a compact polygon filter in Littrow telescope-less configuration. The repetition frequency of the wavelength-swept laser source is up to 50 kHz over a turning range of 130 nm with the polygon scanned at a speed of 694 rotations per second. The average output power can reach to 20 mW. The developed swept laser source can be implemented in optical frequency domain imaging, optical reflectometry, and other test and measurement applications.

7845-92, Poster Session

Comparison of two linear differential polarization imaging methods in tissue characterization

D. Li, R. Liao, N. Zeng, Y. He, H. Ma, Tsinghua Univ. (China)

Linear differential polarization imaging can improve image quality and characterize the polarization properties of biological tissues. Degree of polarization imaging yields images based on photons backscattered from the superficial layers of the sample, but shows different measurement results for different incident polarization or sample orientations. The rotating linear polarization imaging method can characterize the anisotropic properties of tissues, by recording the linear differential polarization as a function of multi-incident and multi-detection polarization angles and gives a set of new parameters insensitive to incident polarization angles. Experiments with typical tissues indicate that G and phi_3/2 are correlated to the order of alignment and the orientation angle of fibrous structure in the tissue samples. The physical meanings, dependence on the incident polarization angles and the imaging depth of the parameters of the rotating linear polarization imaging will be compared with those of degree of polarization imaging, which indicate the application potential of the two linear differential polarization imaging methods in tissue imaging and medical diagnosis.

7845-93, Poster Session

A large format x-ray image detector of high resolution and sensitivity

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X-ray phase contrast imaging technique that can be used as a practical diagnostic tool for medical purposes requires the image detector of higher resolution and sensitivity, and of larger format as well. The above mentioned parameters cannot be come to their best on one detector at present, so there is some kind of compromise among these parameters, for example, improving one parameter may be at the cost of impairing another one. This paper designed an x-ray image detector composed of a structured scintillation screen, optic taper and CCD camera etc. Photo-assisted electrochemical etching method was used to make an array of deep holes in the crystal silicon. The scintillator (CsI:Tl) was molten into the deep holes after the silicon wafer had been heat-oxidized. When the screen was coupled with CCD camera by optic taper, the detector fabricating was finished. We use the detector and an x-ray tube of 1mm focal spot to image a test pattern, the spatial resolution better than 20lp/mm was obtained under the x-ray tube voltage of 45kVp and current of 2mA. The total image pixel of this detector is 2048 x 2048, with the 13.5 micrometer pixel size of the camera. The ratio of the input face size of optic taper to output size was 2:1. High sensitivity was implemented by the course of x-rays in the scintillator, the longer the course, the more the x-ray was absorbed, and the higher the sensitivity. In the scintillation screen of this detector, the depth of the holes was great than 150 micrometers, with the 1.5 micrometers side length of the square section of a hole.

7845-94, Poster Session

A sphere-cylinder scattering model for skeletal muscle

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We acquired polarized reflectance images and Mueller matrix of fresh bovine skeletal muscle. Using polarization-dependent Monte Carlo simulations based on a sphere-cylinder scattering model, we are able to reproduce the characteristic features in the experiment results. We also simulate the changes of reflectance profile during stretching and rigor process, which are regarded as the changes of cylinders' diameter and the cylinder-sphere ratio in our model. The good agreement between simulations and experiments indicates that the unique pattern of polarized reflectance of skeletal muscles can also be due to scattering of well aligned fibrous myofibrils rather than coherent diffraction on the sarcomeres. It provides another angle to understand the interaction between photons and skeletal muscle and a proper model which characterizes the microstructure of the skeletal muscle. In addition, we give a parameter K calculated from the M12 element of Mueller matrix. The K-value is sensitive to different parameters in sphere-cylinder scattering model, therefore it is expected to use for monitoring the states of the skeletal muscle.

7845-95, Poster Session

Study on structural change of early artificial caries using linear polarization PS-OCT and polarized sensitive Monte Carlo simulation

L. Li, N. Zeng, Tsinghua Univ. (China)

Dental caries, otherwise known as tooth decay, is one of the most prevalent chronic diseases of people worldwide; Individuals are susceptible to this disease throughout their lifetime. The primary caries detection and the structure transformation of the enamel and dentin between sound and broken teeth are given serious attention by dentists. They can use these information to guide their treatment for caries and help the patient effectively. In this paper, using our Fourier-domain polarization-sensitive optical coherence tomography (FD-PS-OCT) setup by three incident linear polarization states and two detection states, we can get the 9 Mueller matrix elements from M11to M33 of the decay areas of the artificial caries measured. We also applied our polarized sensitive Monte Carlo program in the simulation of the PS-OCT detection process. We used a sphere-cylinder scattering model as an approximation of anisotropic tissues to describe the optical properties of tooth. By comparing the Mueller matrix elements of both experimental and simulation results, especially the diagonal elements (M11, M22 and M33), we reach the point that the main structural change of the caries that affects its scattering features is the expanded diameter of the enamel rods and dentinal tubules caused by the acid corrosion due to caries lesion.

7845-96, Poster Session

Pulse compression in two-photon excitation fluorescence microscopy

X. Liang, W. Hu, S. Zeng, Q. Luo, L. Fu, Huazhong Univ. of Science and Technology (China)

The 2P absorption probability is inversely proportional to pulse width. Pulse compression using photonic crystal fibers (PCFs) has great advantages: the high nonlinearity of PCFs supports wider spectral bandwidth and pulse can be compressed much shorter; the liberty of fiber dispersion control can promote the quality of compressed pulse. By using the experiment and simulation results, we have demonstrated that compressed pulse width varies with the parameters of pulse compressor. The 94 fs pulses from a Ti:Sapphire laser can be compressed to 21.5 fs. While integrating the compressor with a two-photon excitation fluorescence microscope, a pulse width of approximately 44 fs is achievable on the sample. By using the compressed pulses, the two-photon fluorescence imaging depth of cerebellum slices from GFP transgenic mouse can be enhanced up to 170 um and the signal of fluorescence increases approximately 3.2 times compared with the uncompressed pulse. 5.6 times increase in autofluorescence intensity of NAD(P)H in Nasopharyngeal carcinoma cells is also demonstrated, showing its potential in enhanced imaging and sensing for disease diagnosis.

7845-97, Poster Session

Measurement of retina temperature increase during photodynamic therapy for choroidal neovascularization

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To study the risk of retinal thermal injury from 532nm laser in photodynamic therapy (PDT) for choroidal neovascularization (CNV) by measuring the retinal temperature increase of rabbit eyes.

An ultrafine thermocouple technique was developed to measure retinal temperature increase during PDT in pigmented and non-pigmented rabbit eyes. 532nm laser exposures was performed with 100-sec, 2-mm spot size, with irradiance ranging from 300 to 1200 mW/cm2. A homemade mini K-thermocouples was inserted through the sclerotomy and advanced until the tip reached the retina at the posterior pole. The thermocouple was connected a computer that recorded temperature measurement was taken each second for 100-sec laser exposure.

The measured temperature increased firstly, then reached maximum in a few seconds and kept constant during laser irradiation. Once laser exposure ended, the temperature soon decreased to normal. With the increase of laser power density and spot size, the retinal temperature raise too. The maximum temperature increase of non-pigmented rabbits was lower than that of pigmented rabbits. For parameters used to treat choroidal neovascularization (600mW, 2mm, 83sec), the maximum

retinal temperature from 532nm laser irradiation was less than 45 oC. The results confirm prior theoretical prediction of retinal temperature during PDT. And it also suggested that more attention should be given to the selection of power settings when performing PDT for CNV to avoid unwanted thermal damage.

7845-98, Poster Session

Sensitivities of the spatial-resolved diffuse reflectance to scattering parameter

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The sensitivity expressions of spatial-resolved diffuse reflectance to first-order, second-order and third-order scattering parameter are derived in the approximation of transport theory. The influence of first-order scattering parameter on the approximation and diffusion approximation reflectance are compared. The numerical analysis of second-order and third-order scattering parameter sensitivity expressions are also done. It is found that the sensitivities change with source-detector separations and reach a maximum in the region of between one transport mean free path and two transport mean free paths, and are positive in the region of beyond one transport mean free path. The influence of third-order optical parameter on the diffusing reflectance can be ignored by compared with the influence of second-order optical parameter.

7845-99, Poster Session

Sampling brain volume using photon migration in visible Chinese human head for functional near-infrared spectroscopy

T. Li, H. Gong, Q. Luo, Huazhong Univ. of Science and Technology (China)

Near-infrared spectroscopy has been developing as a useful tool for neuroimaging studies (fNIRS). However, the accuracy and reliability of fNIRS have not been accepted, which is mainly due to incomplete knowledge of the region in the brain interrogated by near-infrared light. Layered head model and the realistic head model based on MRI slice have been used to address this issue. Here the Visible Chinese Human (VCH) head model was researched, which most realistically represents the anatomical structure of adult head. By using the Monte Carlo simulation method for light propagation in there-dimensional voxelized media, the interrogated brain volume and the penetration depth at varied separation between light source and detector for fNIRS were studied. The visualized interrogated brain volume was shown to be distributed along and inward the sulci and broadened with the increase of source-detector separation, which significantly did not form the well-known “banana” shape. The penetration depth almost kept constant (~ 3 cm) at the common source-detector separations (2 ~ 4 cm), which is beyond the expectation of previous researched (1 ~ 2 cm). These results indicate that the anatomical structure of human head causes a strong but positive effect for fNIRS detection of brain activation. The three-dimensional visualization of sampled volume within the anatomical structure of the VCH head is useful for signal localization of fNIRS.

7845-100, Poster Session

Dual-modality imaging system combined fluorescence molecular tomography and micro-CT for small animal imaging

X. Yang, G. Quan, H. Gong, Q. Luo, Huazhong Univ. of Science and Technology (China)

Given the ability of imaging the fluorochrome quantitatively in small animals in vivo, fluorescence molecular tomography (FMT) has shown the potential applications in disease research and discovery and development of drugs. However, the absence of the anatomical information in FMT makes the result hard to explain. Here, we present a dual-modality dedicated system that combines FMT and micro-CT to simultaneously reveal molecular and structural information in small animals. The FMT system is mounted orthogonally to the micro-CT. The image of micro-CT is reconstructed with FDK while algebraic reconstruction technique are used to reconstruct images from the FMT. A non-image-based method is employed for merging images from the two imaging modalities. A pilot study using the combined system on nude mice with optical marker shows the feasibility of applying the system in small animal research.

7845-101, Poster Session

Statistical analysis of CCD noise in laser speckle contrast imaging

J. Qiu, P. Li, Q. Luo, Huazhong Univ. of Science and Technology (China)

Statistical accuracy, which is significantly important for laser speckle contrast imaging, is affected by various noises. Though the impact of DC noise and dark noise in CCD noise on laser speckle contrast imaging has been investigated previously, the impact of shot noise on laser speckle contrast imaging has yet not been investigated thoroughly. In this study, we investigate the impact of CCD noise on laser speckle contrast imaging through both numerical simulation and phantom experiment. It is shown that shot noise leads to higher statistical error in speckle contrast through reducing signal to noise ratio of speckle images, and that the comprehensive impact of DC noise, dark noise and shot noise causes the statistical error reducing firstly and increasing afterward with the increase of mean intensity. The numerical simulated results coincide with the experimental results very well.

7845-102, Poster Session

Minimal invasive treatment using 6.02 micrometer DFG laser for carious dentin.

K. Awazu, Osaka Univ. (Japan) and Fukiui Univ. (Japan); K. Ishii, M. Saiki, Osaka Univ. (Japan)

Recently, ErYAG laser has been applied to remove hard dental tissues, such as dentin or enamel. The carious part of dentine are also ablated by the ErYAG laser, but it is not the minimal invasive (MI) treatment from the view point of laser tissue interaction. We have tried to use mid infrared wavelength laser made by difference frequency generation (DFG) method for the purpose of MI treatment for carious dentin model. As carious dentin model, decalcified bovine dentin disks were exposed to a high-energy mid infrared tunable laser at power density of 5 to 25 [W/xcm2] to estimate the removal threshold. The wavelength at 6.02 μm could remove a decarcified dentin selectively without a serious side effect to sound dentin (15 W/cm2 X 20 s). Therefore, low power 6.02μm irradiation is the novel removal method for realizing MI treatment of sound dentin.

7845-103, Poster Session

Optical imaging of Caspase-3 activity based on the genetically encoded FqRET probe

S. Liu, J. Yang, Z. Zhang, Huazhong Univ. of Science and Technology (China)

The technique of Fluorescence quenching Resonance Energy Transfer (FqRET) has been widely used to synthesis the chemical probes, which fluorescent dye linked with quench molecule. Recently, a non-fluorescent EYFP mutant, called REACh (Resonance Energy-Accepting Chromoprotein), was reported. Caspase-3 is one of most important signal molecular involved in apoptosis and be used as a protease target to evaluate the novel FRET probe. Here, we construct a probe that encoded caspase-3 recognition site (CRS) DEVD fused with REACh on the terminal of GFP. The fluorescence of GFP will be absorbed by REACh because of the energy transfer. When caspase-3 activated, the FqRET probe was cleaved at caspase-3 recognized site, which separating REACh and GFP. It results in a 5-fold increase of the fluorescence signal of GFP in vitro and 3-fold increase in the nasopharyngeal carcinoma cells treated with 5-FU. In addition, the acceptor REACh is non-fluorescent, GFP emission will be observed in the spectral window and have less crosstalk with the acceptor emission. It proves a sensitive sensor to monitor caspase-3 activity during anti-cancer drug induced tumor apoptosis in vivo.

7845-104, Poster Session

Finger temperature controller for non-invasive blood glucose measurement

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Blood glucose level is an important parameter for doctors to diagnose and treat diabetes. The Near-Infra-Red (NIR) spectroscopy method is the most promising approach. It is noted that the skin temperature does fluctuate with the environmental and physiological conditions and we found that temperature has important influence on the glucose measurement. Since 90% of blood components are water, skin temperature of measurement site has significant influence on blood glucose measurement. Also the skin temperature is related to the blood volume, blood volume inside capillary vessels changes with skin temperature. In this paper the relationship of skin temperature and signal from the skin and inside tissue was studied at different skin temperatures. Based on the relationship of skin temperature and collected signal, a finger heater device was designed to heat and maintain the skin temperature of measurement site. In vivo trials were carried out and the in vivo results show that when the heater is implemented the prediction accuracy of blood glucose is improved.

7845-105, Poster Session

Imaging of cysteine cathepsins activity during apoptosis

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Apoptosis is a crucial process in the regulation of homeostasis in almost all organs and tissues. Dysregulation in the process of apoptosis definitely leads to the development of disease. Apoptosis is mediated by different mechanisms and there is growing evidence that various cysteine cathepsins are involved in the regulation of apoptosis. However, there is a lack of tools that can be used to monitor the dynamic nature of the active cathepsins in living cell directly. Herein, we developed a novel activity-based probe (ABPs) that can direct imaging lysosomal cysteine proteases in living cells. By using the probe, we monitor the activities and intracellular localization of lysosomal cysteine proteases real time successfully during the process of apototic cell death induced by tumor necrosis factor in living cells. We anticipate that this activity-based probe is potentially valuable for understanding the roles of cathepsins in the lysosomal cell death pathway.

7845-106, Poster Session

The fMRI study of Electro- acupuncture at different acupoints modulating the relative specific brain network

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Objective: The specific brain effect of acupoint is an important scientific concern in acupuncture. However, most fMRI acupuncture studies focused on acupoints on the limb, employed simple design and data analyzing method. Researches on acupoints of different properties, using new and designs and data analyzing methods are warranted.

Material and Methods: In this study, brain effects of acupuncture on abdomen at acupoints Guanyuan (CV4) and Zhongwan (CV12) were tested. fMRI scan was conducted on 21 healthy volunteers at resting state, during needle retention, electroacupuncture (EA), and post-EA resting state. The brain functional activity and connectivity between CV4 and CV12 were compared using SPM2 and the local and remote connectivity maps analysis.

Results: EA at CV4 and CV12 induced apparent deactivation effects in the limbic-paralimbic-neocortical network (LPNN). The default mode of the brain at rest was modified by needle retention and EA, respectively. The functional brain network was significantly changed after EA. Interestingly, the instant post-acupuncture effects were mainly found in the ventral medial prefrontal cortex and the anterior cingulate cortex in the LPNN. The results showed that relatively small differences of brain activity and functional connectivity were found between these two acupoints. It indicates that relative specificity of acupoint effect in the brain exists. The functional brain network mode of acupuncture effects are similar as the functional circuits of emotional and cognitive regulation. The therapeutic effects of acupuncture analgesia, acupuncture on anxiety and depression may be mediated by the limbic-paralimbic- neocortical network (LPNN).

7845-107, Poster Session

Microscopic mechanism analysis on rheology and harmful effects by low level laser irradiation of blood

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The microscopic mechanism on rheology and harmful effects of low level laser irradiation of blood were analyzed by Quantum theory. The analyzed results showed that laser may resolve fibrin clot, then the property of rheology of blood is improved; and some bonds of the cholesterol in blood were fractured by low level laser (abbreviate LLL), hence the ratio of membrane cholesterol/membrane phosp-hatide of red cell were reduced, then blood circulation can be improved. So low level laser irradiated blood possess the action of mending rheology of blood. But our analyses point out that LLL may cut off some bonds of living biomolecule (e.g. Protein molecule) yet, then some normal protein may emerged denaturation, so normal cells in blood may be destroyed, namely low level laser irradiation can produce the harmful effects on blood. This paper criticized the viewpoint intravascular low level laser irradiation (abbreviate ILLLI) have not action.

7845-108, Poster Session

Study on pathological area of knee by infrared imaging

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The application of infrared imaging in biomedical fields has been very broad, but the research results of the lesion of knee by using of infrared imaging have seldom been reported at present. On the basis of infrared images research, we present the exploring image analysis and relate the programming optimum entropy algorithm about infrared imaging analysis. Optimum entropy algorithm can get the maximum information quantity about the distribution of the target and background in the infrared images. It is adept in distinguishing between target and background, and the algorithm is easy to be implemented. The image threshold is determinated through Shannon entropy's basic theory that the equivalent probability distributing has maximum entropy. By this way, we can divide an image into several equivalent probability sub-parts. The theoretical derivation and the realization step are analysed. The paper demonstrates the comparative study on the infrared images contrast between the pathological knee and the reference normal group through the optimum entropy algorithm. The rule of variation between the normal image and pathological changes of level about knee lesion in patients is gained. The research results provide a kind of methods for the clinical diagnosis of the pathological knee and also discuss the value of application about the optimum entropy algorithm in infrared imaging analysis. Contrasting the MRI or CT, the infrared imaging is cheap and harmless. So the method can be used in health care and prophylactic detection.

7845-109, Poster Session

Optimization of fibre optic probes for biomedical spectroscopy

B. Wang, Y. Tang, Shandong Univ. (China)

Optical spectroscopy including reflectance, fluorescence and Raman spectroscopy has been used for biomedical applications, such as for cervical cancer, lung cancer and skin cancer diagnosis. Fibre-based probes provide an effective and flexible optical interface between the spectroscopic device and the samples to be measured. The fibres have double roles in these systems: delivery of illumination to the target and collection and delivery of signal to the spectrometer or detector. These fibre-based probes are flexible and thus can be miniaturized and put into cavities for endoscopic measurement, or inserted into microstructures such as needles. So far, fibre probes can be made with an outer diameter less than 0.5 mm. The optical probe is not only limited by size, but also the illumination and collection efficiency. However, most of the probes reported in literature are lack of optimization in illumination and collection efficiency, although this is critical for low signal detection such as fluorescence and Raman spectroscopy measurement. In this paper, we present a theoretical model in designing fibre optic probes for biomedical applications to maximize the illumination and collection efficiency. This model is applicable to probes with single or multiple fibres with or without special processing of the fibre tip. We investigated a number of probe configurations (e.g. fluorescence probe, which consists of seven 100 m multimode fibres with one for illumination and the other six for fluorescence collection) and find that contact measurement for such kind of probes is very inefficient. By carefully choosing the probe and sample distance itself, we can enhance the fluorescence signal by 5-10 fold. Experimental results with the above fluorescence probe will also be present, which are in good agreement with the theoretical analysis.

7845-110, Poster Session

A study about change of chlorophyll content in seedling after He-Ne laser mutation on seeds of Erigeron breviscapus

Z. Canbang, B. Gao, J. Tian, H. Li, L. Lin, J. Zhang, Honghe Univ. (China)

Erigeron Breviscapus is known as a natural plant medicinal material with special clinical effect on cardiovascular and cerebrovascular diseases. Studies were mainly focus on the Chemical Components or pharmacological application. However, the laser mutation on seeds of Erigeron Breviscapus is not found reported. In this work, the seeds of Erigeron Breviscapus were irradiated by He-Ne laser (632.8nm, 6mw) with different doses. Chlorophyll content was determined one month after germination as the treated groups to study the He-Ne laser effect to the Erigeron Breviscapus seeds. While the seeds without laser irradiation was the control group. The results show that the Chlorophyll Content in Seedling changes after He-Ne Laser Mutation on Seeds of Erigeron Breviscapus. This suggests that the Photosynthesis is improved after He-Ne Laser Mutation, which is benefit for growth of seedling. The results are also further analyzed preliminarily by quantum mechanics.

7845-111, Poster Session

Diagnosis gynecological tumors based on urine first derivative spectra

S. Gao, J. Lu, G. Chen, Jiangnan Univ. (China)

The gynecologic cancer is the most common malignant tumor in the world, and its incidence rate increases obviously recently.There is no valid auxiliary examination to screen and diagnosis early stage gynecologic cancer (especially ovarian cancer) at present, so it is necessary to search for a new method. A large number of clinical studies have been demonstrated that fluorescence spectroscopy can be used to detecting the malignancies in many organ sites. In recent years, the main interest in using fluorescence spectroscopy in biochemical research has been devoted to derivative spectra investigations, since static or "average" information on the complex structure of proteins and molecular assemblies may result in misleading interpretation, their functions being often dependent on conformational changes and structural fluctuations. The first order derivative spectra method and clinic diagnosis standard to cluster analysis the information are combine in this paper. The intrinsic fluorescence spectra from limosis morning urine of gynecologic cancerous patient and the healthy group are measured. Using the Xenon arc lamp to irradiate the urine from 21 gynecologic cancerous patients and 16 healthy women Gynecological Tumors, we obtained fluorescence emission spectra. And then the urine first derivative spectra are Obtained and analyzed based on cluster analysis. These patients are diagnosed by Medical diagnostic gold standard. Resulting the diagnostic sensitivity and specificity are respectively 81% and 75% while setting r=300 as a basis for judgment. This study describes initial investigation of the potential of intrinsic urine fluorescence spectra for detecting early ovarian cancer.

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7846-02, Session 1

Dynamical complex optical lattices for soliton manipulation

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We produce dynamical complex optical lattices induced by counterpropagating nondiffracting beams. We show that, rotating optical lattices featuring complex transverse shapes are possible. The rotation rate of these complex optical lattices can be controlled by varying the contribution of the counterpropagation nondiffracting beams. We demonstrate the direct application of these dynamical lattices to drag different soliton structures.

7846-03, Session 1

Rabi splitting in a subwavelength cavity constructed by metamaterials

T. Feng, Tongji Univ. (China); Y. Zhang, Xuchang Univ. (China); Y. Li, Tongji Univ. (China); F. Yang, Xuchang Univ. (China)

Metamaterials, including double negative materials and single-negative (SNG) materials, have attracted intensive studies in the past few years, due to their unique electromagnetic properties and potential applications. For double negative materials, the electromagnetic parameters, permittivity and permeability, are simultaneously negative. There are two kinds of SNG materials: one is the epsilon-negative (ENG) materials, in which the permittivity is negative but the permeability is positive; the other is the mu-negative (MNG) materials, in which the permeability is negative but the permittivity is positive. Through our theoretical investigations, it was found that a pair structure consisting of ENG and MNG materials can be used to construct a cavity with strongly enhanced electromagnetic field and with dimensions beyond the half-wavelength limit and this kind of cavity may be important for potential application in cavity quantum electrodynamics (QED) and in quantum communication, such as enhancement of coupling between tunneling mode and atoms, realization of Rabi splitting in a subwavelength cavity, and so on[Tuanhui Feng et al., J. Appl. Phys. 104, 013107 (2008)]. In this paper, we experimentally studied the Rabi splitting in a subwavelength cavity constructed by SNG materials. First, the SNG materials were fabricated by using coplanar waveguide with lumped-element series capacitors and shunt inductors loading. Then, the subwavelength cavity was constructed based on the SNG materials. Finally, Rabi splitting in the subwavelength cavity was experimentally realized.

7846-04, Session 1

Chirped-dual-periodic structure for quasi-phase-matching

X. Hu, J. Yang, G. Zhao, Nanjing Univ. (China)

We propose here a chirped-dual-periodic structure. This type of new structure combines the advantages of chirped and dual-periodic structures, and can be used for both multiple quasi-phase-matching and multiple bandwidths control. Numerical simulation of second-harmonic generation performance is in good agreement with the Fourier spectrum of the structure.

7846-05, Session 1

Generation of 1178 nm based on cascaded stimulated Raman scattering in KTA crystal

K. Zhong, Tianjin Univ. (China)

Stimulated Raman scattering (SRS) is an efficient and flexible method to generate new frequencies. Using suitable Raman medium such as Ba(NO3)2, PbWO4, BaWO4, KGW and YVO4 et al, a wide band from the visible to near-infrared including frequencies that are impossible for direct laser transition in gain medium can be covered from frequency shifting of the Nd3+ doped lasers at 1.06μm or ~1.3μm. Moreover, efficient yellow-orange lasers are feasible through frequency doubling of Raman lasers.

The KTiOAsO4 (KTA) crystal has paramount applications in optical parametric conversion from the visible to mid-infrared range. Besides the second-order nonlinear frequency conversion, KTA is also predicted to be a kind of attractive Raman material with its two prominent Raman shifting peaks at 234cm-1 and 671cm-1 since the 1990s. Efficient generation of 1091nm and 1120nm KTA Raman lasers have been realized pumped by acousto-optically (A-O) Q-switched Nd:YAG lasers, and watt-level yellow laser at 573nm have been obtained through the self-frequency-doubling of Stokes wave at 1146nm.

In this letter, we report the generation of 1178nm based on cascaded Raman scattering in KTA crystal, intracavity pumped by a A-O Q-switched Nd:YAG laser. The output power at 1178nm is around 80mW when the diode pump power was 7.6W at 808nm. At the same time, the low-order Stokes waves at 1091nm, 1120nm, 1146nm and visible yellow laser at 573nm (the second harmonic wave of 1146nm) are also detected. The total Stokes output power was 240mW and the yellow laser was 115mW. The power at 1178nm can be increased with output mirrors that are more suitable. The spectra of the generated wavelengths were experimentally analyzed and they accords well with theoretical results.

7846-06, Session 2

Periodically erasing the second-order optical nonlinearity in thermally poled optical fibers with UV light

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In the paper, we report experimental results of the effect of UV-light exposure on the induced second-order optical nonlinearity in thermally poled optical fibers. Focused light beam from a frequency-doubled Ar+ laser operating at 244 nm was used to locally erase the induced nonlinearity in optical fibers to create a periodic structure for quasi-phase matching application. The UV-exposed fibers were then observed under a two-photon microscope which can measure the distribution profile of the residual nonlinearity. Effects of scanning speeds of the laser beam on the length of nonlinearity-erased area and amplitude of the residual nonlinearity were investigated. It was found that the required UV-light scanning time is much lower than that typically required for fabricating fiber Bragg gratings.

7846-07, Session 2

Observation of the fast and slow light in an optical fiber based on sbs gain region

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(China)

The stimulated Brillouin scattering (SBS) is one of most prominent nonlinear effects in optical fibers because of its low threshold with a narrowband pump. It can produce a gain in Stokes area and a loss in the anti-Stokes area. Due to the K-K relation, a pulse which lies in the gain region can experience great changes in its group refraction index which leads to slow light, whereas fast light can be obtained when gain saturation is reached. Moreover, fast light can be generated for the pulse in the loss region.

Experimentally fast and slow light based on the SBS gain can be obtained by adjusting the pump power. This method offers attractive advantage for its continuous control of the light speed from slow to fast.

The relations of the signal time delay with the pump power, the input signal Stokes power and the delay fiber lengths are investigated. The results show that for the same signal power and fiber length, the signal time delay increases linearly with the increasing pump power, and reaches the maximum when the pulse gain is the maximum. When the pump power is further increased continuously, the time delay will become small, and then negative which reveals fast light is observed. For the same pump power and fiber length, the time delay becomes small for higher signal power in small gain region, with negative time delay becoming larger in gain saturation region. For the same signal power and pump power, the time delay increases with the fiber length.

7846-08, Session 2

A novel type of low-dispersion high-birefringence photonic crystal fiber with high-nonlinear for four-wave mixing

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A novel type of photonic crystal fiber (PCF) is proposed and optimal designed by using the full vectorial finite element method with anisotropic perfectly matched layers. This fiber is composed of a solid silica core and a cladding with squeezed-hexagonal-lattice elliptical air-holes along the fiber length. Dispersion and birefringence are investigated simultaneously by using the full vectorial finite element method. Numerical results show the proposed fiber possesses the property of low-dispersion and high-birefringence. Moreover, by adjusting the structure parameter of the proposed PCF, such as the squeezing hexagonal ratio , the relative air hole size and the air hole ellipticity , we find the optimized design parameters of the PCF with the result of the total dispersion being within 5ps/nm.km over ultra broad wavelength range from 1360 to 1670 nm and the corresponding high birefringence being about 1.5×10-2 at 1550 nm. Furthermore, when the parameters of the proposed PCF are optimized as =0.35, =0.55, =0.48, and, the nonlinear coefficient and the confinement loss of the optimized PCF are also numerically analyzed, and present and high nonlinear effects and low confinement loss. Therefore, high birefringence, low flattened dispersion, high nonlinear and low confinement loss effects are combined in the proposed PCF perfectly, which has the great significance to the four-wave mixing.

7846-09, Session 2

Donor strengthening strategy for FTC-based organic nonlinear chromophore

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Organic nonlinear optical (NLO) chromophores having large molecular hyperpolarizability values, as well as the polymer materials containing them, have attracted a great deal of attention due to their electro-optic (EO) applications in emerging optoelectronic and photonic technologies. The molecular chromphores with high first hyperpolarizability values have been reported with the development of conjugated polyene-bridge or thiophene-bridge system and strong tricyano-containing heterocyclic electron acceptors. In this work, we investigated the enhancement of the electro-optic response by introducing various groups, such as OCH3, Ophenel, OTBDMS, etc, as an additional donor part on conventional FTC type donor-pi-acceptor molecules. These new type donor exhibited a strong solvatochromic effect, indicating an extra donation to the pi-conjugated bridge, which shifted the charge-transfer absorption of the chromophores to the lower energy region. Furthermore, the simple modification on the donor moiety resulted in a great improvement in the first hyperpolarizability and macroscopic electro-optic coefficient (r33) over the benchmark dialkylamino FTC counterparts.

7846-10, Session 2

Microwave signal generation with the optical frequency-selectively injection-locking of semiconductor laser diodes

H. Xue, Y. Feng, Z. Zhou, X. Ye, Tsinghua Univ. (China); X. Wang, North Univ. of China (China); X. Chen, Univ. of Science and Technology Beijing (China)

We have generated a microwave signal at 6.8GHz by optically injection-locking two slave diode lasers to the blue and red first-order sidebands of a phase modulated source respectively, which involved a 3.4GHz electro-optical modulator (EOM) following a narrow-linewidth External Cavity Diode Laser. We used the optical heterodyne beat method to test the different behavior of the optical frequency-selectively injection-locking of the slave laser diode between the blue and red first-order sidebands. The result showed that 78% of the power could be locked to the blue first-order sideband with the measured locking bandwidth of ~1.2GHz, or 91% of the power be locked to the red first-order sideband with the measured locking bandwidth of ~1.8GHz, due to the different modulation efficiencies of both sidebands and the intrinsic characteristics of the slave Fabry-Perot laser diode. The microwave signal at 6.8GHz could be measured by the optical beatnote with a linewidth of ~600Hz, without considering the noise contributed by the acousto-optical modulator (AOM) signal source, which has been used to shift 80MHz of one slave laser beam for measuring the power spectral density without the disturbance of the Four-Wave Mixing effect, and shown as a dominant noise source for the linewidth broadening of the microwave signal. The proposed method is used for driving stimulated Raman transitions between the Rubidium ground-state hyperfine levels in an atom gyroscope.

7846-11, Session 3

Performance comparison of nonlinear crystals for frequency doubling of an 894nm Cs vapor laser

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An examination of the efficiencies of three commonly used nonlinear crystals (PPKTP, LBO, and BiBO) when creating second harmonic frequencies of a Cesium laser is presented. The experiment investigates the intracavity second harmonic generation of several watts of 447nm light when operating in both quasi-CW and CW modes and pumped by several tens of watts. Here, degradation of the conversion efficiencies for each crystal was observed when high fundamental powers or a high duty cycle of the pump were used. For a Cs laser, operating at 894nm, PPKTP is found to be the optimal crystal for intracavity SHG in both

pulsed and CW modes when operating at modest SHG powers. At higher powers, however, the increased absorption coefficient of PPKTP at 447nm, compared to that of BiBO or LBO, may become significant to where other crystal will be more appropriate for this application.

7846-12, Session 3

Dynamic responses of cold atoms to the magnetic field in an unbalanced 3D MOT

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The high-speed imaging technology has been used to characterize the dynamic behavior of a cold atom ensemble in an unbalanced 3D magneto-optical-trap(MOT). Multiple reflections of a released atomic cloud inside the MOT were observed for the first time as we known and explained with a theoretical model. An 87Rb cold atomic cloud is trapped and pushed out to form a continuous cold atomic beam via the radiation pressure difference, which is generated inside the 3D MOT by a specially designed leak tunnel along one trapping laser beam. The Loading or release processes of an atomic cloud when turning on or off the magnetic field respectively was recorded at the sampling rate of 500 frames/s with a high-speed camera. Experimental results showed that about 30ms should be taken for an atomic cloud from generation to stabilization in the center of the 3D MOT, and the position at which the atomic cloud is initially generated is not centered the MOT. The results also showed that the inhomogenity of the MOT magnetic field and the concentricity of the magnetic field and optical field play important roles in determining the initial velocity, velocity distribution and stability of the atomic beam.

7846-13, Session 3

Phase modulation of electromagnetically induced grating in a four-level system

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Electromagnetically induced phase grating is investigated in a microwave-coupled four-level atomic system, where the two closely spaced lower fold levels are driven by a microwave field. The existence of the weak microwave field leads to the striking increasing of the diffraction efficiency of phase grating. Under the weak microwave and weak standing wave field condition, by tuning the interaction length of atomic sample, modulating the detuning of the microwave and probe field, the diffraction efficiency is improved greatly and can reach 33%.

7846-14, Session 3

Characterizing double-resonance optical-pumping spectra of cesium 6P_3/2 - 8S_1/2 excited-states transitions and its application

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Natural Doppler-free spectra of the transitions between atomic excited states are widely used in measurement of hyperfine splitting, determination of hyperfine structure constant, laser frequency stabilization and so on. The transitions between atomic excited states can be approached traditionally by the optical-optical double-resonance (OODR) technique. However, the signal-to-noise ratio (SNR) of OODR spectrum is poor especially in atomic system with large spontaneous emission rates. Recently double-resonance optical-pumping (DROP) technique can be adopted to improve the SNR of the spectrum between atomic excited states. DROP technique detects the population variation of ground state instead of intermediate state.

Compared with the co-propagating (CP) pump and probe beams configuration, two-photon atomic coherence effect in cesium 6S_1/2 - 6P_3/2 - 8S_1/2 ladder-type system can be clearly displayed in the counter-propagating (CTP) pump and probe beams configuration. This issue has been theoretically analyzed. The two-photon atomic coherence effect can make DROP spectrum narrower remarkably (the cesium DROP spectrum's line-width of ~ 9.3 MHz for the CTP configuration and ~ 15.4 MHz for the CP configuration are measured in experiments). The narrow line-width and high-SNR DROP spectrum is very suitable for the laser frequency stabilization. The DROP spectrum of cesium 6P_3/2 F'=5 - 8S_1/2 F"=4 excited-states transition is employed to frequency stabilization of a 795nm external-cavity diode laser system.

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7846-15, Session 3

Ghost imaging with XY phase series space light modulator

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Ghost imaging has emerged a decade ago as an imaging technique. Its feature is the image will appear on the optical path, but this optical path never goes through the object actually. In this paper, we give an overview of quantum imaging, include the experiments with entangled two photon states generated by spontaneous parametric down conversion, and with pseudo thermal light. Then we design a ghost imaging experiment scheme with the pseudo thermal light source, which we obtain it with the use of the XY Phase Series Spatial Light Modulator to modulate the laser light. This spatial light modulator changes the phase of the output light field by controlling the loading element on every pixels.

7846-16, Session 3

Dynamics of ultrashort dissipative fiber solitons

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Various forms of the complex Ginzburg-Landau equation (CGLE) and solitary-pulse (SP) solutions to it is a topic that has been attracting a great deal of attention [1]. Many authors have studied this equation in several contexts, and nowadays a diversity of solutions are well-know [1]. In optics, this equation describes a diversity of systems, namely, laser systems, soliton transmission lines, nonlinear cavities with external pump, and parametric oscillators [1]. Some special solutions of this model, like the pulsating, the erupting, and the creeping solitons, were found recently in numerical simulations [2,3]. These simulations show that the above solitons have complicated pulsating behaviour. The erupting soliton was also observed experimentally in a passively mode-locked solid state laser [4].

In this paper we investigate numerically the dynamics of plain, composite, pulsating, erupting and creeping soliton solutions of a generalized complex Ginzburg-Landau equation under the influence of some higher-order effects, namely the third-order dispersion, intrapulse Raman scattering and self-steepening. Taking these higher-order effects

into account, the CGLE can be written in the form:

where Z is the normalized propagation distance, T is the retarded time, u is the normalized envelope of the electric field, stands for spectral filtering ( ), is the linear gain or loss coefficient, accounts for nonlinear gain-absorption processes, represents, if negative, the saturation of the nonlinear gain, corresponds, if negative, to the saturation of the nonlinear refractive index. 3 accounts to the third order dispersion effects (TOD), s accounts for self-steepening (SST), and is a coefficient related to the intrapulse Raman scattering (IRS). A split-step Fourier method [5] was used for solving the above CGLE numerically.

Among other results, we observed that the IRS effect causes an asymmetry of the composite pulse. We found also that, if the pulsating and creeping pulses propagate in the presence of IRS and TOD, for small values of the parameters, they can achieve a fixed shape. On the other hand, the explosions of the erupting pulse in the presence of the same effects are drastically reduced. Moreover, numerical results suggest that all these kind of pulses can achieve a fixed shape, if their propagation occurs in the presence of IRS, TOD and SST, with a proper choice of the parameter values.

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7846-17, Session 4

Comparison of dispersion compensation in a 40Gbps WDM optical communication system

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Dispersion management in single mode fiber (SMF) can be accomplished in many ways, though the most widely used approach employs lengths of transport fiber of opposite dispersion characteristics to the principal fiber in the link, usually standard single mode fiber (SSMF). Typically, a 10 to 20km length of dispersion compensating fiber (DCF) is placed before the regenerators inducing negative dispersion to compensate for the positive dispersion accumulated over the 60 to 80km length of the SMF. Depending upon the placement of DCF in each span, the dispersion compensation is categorized into two implementations: pre-compensation (DCF prior SMF) and post-compensation (DCF after SMF). This optical system has a total link-length of 600km. Each 100km span consists of G.652 SMF (80km) and DCF (20km). From the eye diagrams gotten in this experiment, we can conclude that the performance of pre-compensation scheme is slightly more improved than the one of post-compensation. Due to the interplay between dispersion, nonlinearity, and signal power, the dispersion affects the pulse evolution.

7846-18, Session 4

Unconditional security of relativistic quantum key distribution protocol

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Relativistic quantum key distribution (QKD) protocol, or QKD protocol with synchronously delayed classical signals, is a kind of modified BB84 QKD protocol based on the principles of not only quantum mechanics but also special relativity[1]. Its advantage compared with BB84 protocol is that all of the qubits could be used for key generation, and Alice and Bob are able to select any measuring bases, and any coding as well. Besides, based on the security of relativistic QKD protocol, the idea of synchronously delayed classical signals can be applied to other protocols, include EPR based one.

We prove here its unconditional security against coherent attack via the method based on CSS codes [2] for it does not introduce any unitary operations other than those in BB84 scheme. We begin the proof with a modified EPR based protocol which can be proved unconditionally secure, then reduce the protocol to a CSS codes based protocol. Finally, the CSS codes based protocol is demonstrated equivalent to the relativistic QKD protocol, and we arrived at the conclusion of the unconditional security of the final key. We also obtained the relationship between key rate and error rate, and proved the relativistic QKD protocol had a larger tolerable error rate than that of BB84 protocol.

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7846-19, Session 4

Analysis of the coefficient of QBER and its influence on QKD

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The quantum bit error rate (QBER) based on the weak coherent pulse’s quantum key distribution is analyzed. It is indicates that the coefficient of QBER is not a constant but is increased exponentially with the transmission distances. Based on the three experiments data, the function fitting has been done. We discover that these fitting functions have the same function form. Subsequently we use these functions to optimize the mean photon number for the BB84 quantum key distribution with decoy states. It is shown that the optimized mean photon number depends on the transmission distances. Based on these results and the GYS’s experimental parameters we compared the key generation rates proposed by Lo et al with the modified one. We find that the latter is superior to the former within a certain distance.

7846-20, Session 4

Principles and improvements of quadrature-based quantum key distribution

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In this article, we give an overview of quadrature-based quantum key distribution. Firstly, the comparison between single-photon schemas and continuous variable schemas are presented and an explanation on why continuous variable is also provided. Then, we introduced principle concepts including detect technique and attack classifications in continuous variable which facilitate understanding in this article. This article focuses on the classical and state-of-art protocols. Especially, Gaussian-modulated(GM) schemas and its two-way variations will be investigated intensively. Discrete-modulated(DM) schemas, entanglement-based schemas are covered.

Security proof is also analyzed intensively. Firstly, a comparison between prepare-measurement model and virtual entanglement model as well as concrete explanation will be made. Based on these

models, Classical protocol's Security proof under collective attack and individual attack will be exhibited as well. Then, recent developments of unconditional security proof are introduced. On this issue, we will give an overall explanation about critical improvements. The optimality of Gaussian Attack, de Finetti theorem and its application together with symmetry of quantum system in proof go first. Accordingly, we will give the method to calculate key rate bound on GM and DM schemas. Then, a slight modification, which makes the model more physical, on the classical model which ascribes the excess noises totally to receiver is mentioned.

At last, the article discusses experimental realization of various protocols and the main trends in this field based on the problems we discussed previously.

7846-21, Poster Session

Efficient preparation of multipartite entanglement of atomic ensembles

F. Zhao, Shaanxi Univ. of Science & Technology (China)

We propose an efficient scheme to prepare multipartite entanglement of atomic ensembles trapped in separate cavities. Our scheme has high fidelity even with realistic noise based on the repeat-until-success strategy. By employing the quantum memory of the atomic internal state, the scaling efficiency decreases only with the number of atomic ensembles by a slow polynomial law. Moreover, the atomic ensembles also can function as quantum repeaters, which enable our system to compatible with the current experimental technique for quantum communication using atomic ensembles.

7846-23, Poster Session

Achieving efficient and stable coherent population transfer by ultrashort double pulses

Z. Wang, X. Fan, Shandong Normal Univ. (China)

It is shown that, when two femtosecond chirped Gaussian pulses with equal pulse area and same size but opposite sign of the chirp coefficient, which will be simply called as double pulses, overlap and propagate in the three-level -type atomic medium, both coherence between the double pulses and interaction between the double pulses and the atomic medium arise. Adjusting size of the chirped coefficient can change shape, i.e. field distribution, of the composite pulse of the double pulses, at the same time affect the interaction between the composite pulse field and atoms, and thereby control oscillation process and value of the atomic population. By selecting suitable size of the chirp coefficient, we can make the atoms at the lowest level exciting completely to the higher level; moreover the new population distribution is stationary. It is also shown that, for the double pulses with any area, efficient and stable population transfer always can be realized by adjusting size of the chirp coefficient. And this conclusion doesn't vary with the pulse width or the medium density varying.

7846-24, Poster Session

An analytic expression of spontaneous emission FWHM in GaAs planar micro-cavity

H. Zhao, M. Sun, Z. Kang, Z. Gao, Hebei Univ. of Technology (China)

The spontaneous emission in the semiconductor is a nonlinear process that difference with the atom for many carries are filled in the conductor band and valence band in room temperature. The spontaneous emission spectra of semiconductor micro-cavity cannot be showed in which many carrier effect is neglected the in some Refs.

The full-width half maximum (FWHM) is one of important parameters that can exhibit the micro-cavity effect. An approximate analytic expression of spontaneous emission for GaAs micro-cavity in our previous work can be instead of the numerical integral, but it is so complex that it cannot give the analytic expression of FWHM. This paper will set up another approximation to give a new analytic expression of spontaneous emission, that can give the same results with the numerical integral in the vertical direction, in which Fermi-Dirac distribution functions of electrons and holes are considered. Although the new approximate analytic expression is simpler than that in our previous work, it can be used to study the spontaneous emission spectra FWHM with a small angle in the vertical direction of planar micro-cavity. The two approximate expressions of FWHM for enhancement spontaneous emission spectrum into the small angle are obtained by the new analytic expression of spontaneous emission, in which the triangular function relation and the first order series of sine and cosine are used respectively. The curves for the FHWM versus the reflectivity by the two expressions of FWHM in the GaAs micro-cavity are also compared.

7846-25, Poster Session

Spatial characteristics of radiation from an electron driven by an intense few-cycle laser pulse

Y. Tian, Nanjing Univ. of Posts and Telecommunications (China)

With ultrashort pulse high-power lasers it has become possible via strong focusing to extend the irradiance to levels to and with petawatt level lasers intensities much higher than this may be achieved. Now, ultrashort intense laser pulses with durations less than 5 fs are available as research tools. In this case, the laser pulse contains about two optical cycles, the laser intensity varies almost as rapidly as the laser oscillations and the time variation of the electric field depends sensitively on the initial phase of the few-cycle laser pulse. Due to these properties of few-cycle pulses, many novel and attractive phenomena in laser-atom interactions, such as photoionization and high harmonics generation, have been demonstrated theoretically and observed experimentally in the few-cycle regime. The full spatial characteristics of the radiation in the cases of few-cycle laser pulse did not receive enough attention in previous studies. Such is one of the aims of the present paper. Relativistic motion and full spatial characteristics of radiation from an electron driven by an intense few-cycle laser pulse have been investigated theoretically and numerically with a single electron model. It is discovered that the influence of the initial phase on the process of relativistic motion and spatial characteristics of the radiation is apparent for intense few-cycle laser pulse. The characteristics can be used to measure the initial phase of intense few-cycle laser pulse in experiment.

7846-26, Poster Session

Investigation of parabolic pulse generation in a normal dispersion-decreasing-linearly fiber

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Parabolic pulses are of great interest for various applications and it is known that they can be generated by use of a normal dispersion-decreasing fiber in a "passive" manner. However, it is more practicable and significant for the dispersion-decreasing-linearly profile to be considered than for any other profiles once actual fiber manufacture was taken into account. In this work, we investigate the process of parabolic pulse generation (PPG) in a normal dispersion-decreasing-

linearly fiber (NDDLF) by introducing two dimensionless structural functionals to characterize the pulse temporal and spectral shape respectively. The different evolution curve of the two functionals signifies the different pulse temporal and spectral evolution process. Furthermore, based on the principle of virtual “equivalent” gain, we transform the nonlinear Schrodinger equation (NLSE) with linearly decreasing dispersion into one of the form with “hyperbolic” gain and uniform dispersion. By numerically solving the two forms of NLSE, we show that wave breaking (WB) can still take place during the evolution and the distance where it happens can be determined by the chirp oscillations appeared in the pulse edges. Thereafter four-wave mixing (FWM) together with self-phase modulation (SPM) undertake the pulse spectrum broadening for the WB point is the threshold that FWM begins to take effect. Further pulse evolution illustrates that SPM dominates in the initial phase while gradually being taken over by the FWM. For comparison, these results are in consistent with that obtained from the dispersion-decreasing-hyperbolically profile except that WB occurs much ahead and both functional values are less close to the standard “parabolic shape” value 0.0720.

7846-27, Poster Session

Phase-dependent gain without inversion in an inhomogeneous broadened quasi -type four-level system with VIC

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The effect of the relative phase ( ) between the probe and driving fields on the gain without inversion (GWI) is studied in a Doppler broadened quasi -type four-level atomic system with vacuum induced coherence (VIC). It is shown that: The probe detuning region in which GWI exists and size of GWI are very sensitive to variation of the relative phase, the Doppler width ( ) also has dramatically modulation role on the phase-dependent GWI. The GWI maximum value ( ) varies periodically with the relative phase varying, the period is 2π; but the concrete varying rule is closely related to the value of the Doppler width. In the case of = 0 (i.e. without Doppler broadening), when 0 < < π, increases monotonously with increasing; when π < < 2π, decreases monotonously with increasing; when =π, has the largest value. Under the condition of $\neq$ 0 (i.e. Doppler broadening presents), in both regions 0 < < π and π < < 2π, does not monotonically increase or decrease with increasing; the value of , which corresponds to the largest value of , decreases gradually from π with increasing, when value of is large enough, the value of , which corresponds to the largest value of , is about π/2. In general speaking, decreases with increasing; but larger than that in the corresponding static atomic system (= 0) can be gotten by choosing suitable values of and .

7846-28, Poster Session

Spectral properties of femtosecond chirped Gaussian pulse propagating in a dense three-level -type atomic medium

Z. Wang, X. Fan, Shandong Normal Univ. (China)

It is shown that, variation of the sign and size of the chirp coefficient (C) of the pulse has considerable effect on spectral properties of the pulse and the effect is closely relative to size of the pulse area. When the pulse with smaller area, 2π pulse, propagates in the medium, pulse splitting doesn’t occur and the pulse evolves gradually to an approximate normal Gaussian pulse (C=0); new high frequency component doesn’t basically appear; with increasing value of C, oscillation amplitude of blue shift and red shift components increases and blue shift component oscillates more severely; moreover, the strength of the spectral component near the central frequency decreases considerably but the strength of blue shift component increases obviously. When the 4π pulse propagates in the medium, the pulse will split into sub-pulses with different numbers and shapes, new high frequency component can be produced, but the strength of the high frequency component is smaller; similar to the case of 2π pulse, blue shift component oscillates more severely; in addition, the strength of the spectral component with higher frequency decreases evidently with increasing value of C. When the pulse with larger area, 8π pulse, propagates in the medium, the pulse splitting is similar to that in the 4π pulse case, but super-continuum spectrum with larger strength, higher frequency and wider frequency range than that in the 4π pulse case can be obtained; varying the sign and size of C can not produce new high frequency component, but can change strength of different frequency components in the spectrum, thus can get high frequency components with higher strength.

7846-29, Poster Session

Generation of tunable coherent nanosecond 8-12μm mid-infrared pulses based on difference frequency generation in GaSe and ZnGeP2

K. Zhong, Tianjin Univ. (China)

The 8-12μm mid-infrared region is an important atmospheric transmission window for a range of applications including spectroscopy, remote sensing and military affairs[1]. Compared with the bulky and discontinuously tunable CO2 lasers, nonlinear optical frequency conversion based on all-solid-state lasers provide us versatile methods for radiation sources in this band, in which difference frequency generation (DFG)[2,3] is the most simple one with no cavity and no threshold. In this letter, we realize the generation of tunable and coherent nanosecond mid-infrared radiation covering the 8-12μm range by use of DFG in a GaSe and a ZnGeP2 (ZGP) crystal, based on the theoretical analysis on the phase-matching relations, effective nonlinear coefficients, walk-off and acceptance angles. The two pump waves are generated by a type intracavity pumped dual-wavelength KTP OPO around 2μm.

Using an 8-mm-long GaSe crystal, we achieve the mid-infrared generation that is continuously tunable from 8.28μm to 8.365μm. the maximum pulse energy is 31μJ at 8.76μm, corresponding to the conversion efficiency of 0.9%. The pulse width is 4.5ns referring to that of the pump pulse, therefore the maximum mid-infrared peak power is about 7kW. In the case of using an 8-mm-long ZGP crystal, the tuning range is from 7.2μm to 12.2μm. The maximum pulse energy is about 10μJ at 9.22μm, corresponding to the conversion efficiency of 0.45% and the peak power of 2.2kW. The long-wavelength end is limited by the transparent range of the crystals, while the short-wavelength end is due to the tuning range of the KTP OPO, restricted by the coating parameters of the cavity mirrors.

7846-30, Poster Session

Dispersion and nonlinearity in subwavelength-diameter optical fiber with high-index-contrast dielectric thin films

W. Shu, C. Zhao, S. Wen, Hunan Univ. (China)

We have made a careful and overall analysis of subwavelength-diameter optical fiber (S.O.F.) with high-index-contrast dielectric thin films for guiding waveguide dimension design for potential applications. The proper dielectric film material has been carefully chosen to obtain high nonlinearity. We have numerically approximated and analyzed the dispersion properties and the nonlinearity of S.O.F. with high-index-contrast dielectric thin films. Supposing the wavelength of laser

is at 632.8 nm, the curves of waveguide dispersion and nonlinear coefficient have been illustrated separately. Considering a typical pulse width T0=100 fs and the peak power P0=1 kW, the dispersion length and the nonlinearity length have been calculated. The ratio of the nonlinearity length to dispersion length has been analyzed to discuss the propagation properties of pulse in S.O.F. with high-index-contrast dielectric thin films. The ratio of Lnl to Ld is zero when fiber diameter is around 450nm, and it does not vary when the pulse width or the peak power changes, which is only determined by fiber structure. The change in effective index of HE11 mode has also been calculated as the index of core and film changed. The sensitivities differ with different radius of S.O.F. with high-index-contrast dielectric thin films. The research shows that the S.O.F. with high-index-contrast dielectric thin films could perform well in many application fields especially as sensors and nonlinearity devices.

7846-31, Poster Session

Incoherent Dark Solitons Splitting in LiNbO3: Fe Crystal

Y. H. Zhang, Xi'an Institute of Optics and Precision Mechanics (China) and Xi'an Technological University (China)

We observed experimentally one-dimensional even-number sequence of dark photovoltaic solitons in LiNbO3: Fe crystal without additional background illumination with spatially incoherent beam that contains a dark stripe generated from an amplitude jump in the center of the incoherent beam. In experiment, we found that the initial stripe width at the input face of the crystal is a key parameter for generating an even-number sequence of dark incoherent photovoltaic solitons. If the initial width of the dark stripe was small, only a Y-junction soliton pair was generated. As the initial width of the dark stripe was creased to 20.1μm, the stripe can split into an even-number sequence of soliton structure. The soliton pairs far away from the center had smaller width and less visibility. In addition, the separations between adjacent dark stripes became slightly smaller than that of the Y-junction dark solitons. In particular, when the input width in the entrance face of the crystal is 30.8μm, the diffractive beam in the output face of the crystal was no longer expanding its outer bonder, but shrank its width and split.

7846-32, Poster Session

Pulse compression of negatively chirped pulses in silicon photonic nanowire

W. Meng, C. Zhao, S. Wen, Hunan Univ. (China)

The effects of the initial negative frequency chirp and core diameter variation on pulse compression have been numerically analyzed. Wave guiding properties of silicon subwavelength-diameter wire has been studied with exact solutions of Maxwell's equations. It is shown that in a certain range of core diameters of the silicon nanowire, it has large negative waveguide dispersion comparing with those of weakly guiding fibers and material dispersions, and has large nonlinear refractive index which gives a higher nonlinear coefficient and relatively lower energies required for nonlinear applications. The negatively chirped pulse with the wavelength of 1550 nm propagates in the silicon nanowire which has large positive group-velocity dispersion when the core diameters vary from 250 nm to 320 nm. We find that the effects of the different initial negative frequency chirp on the pulse compression factor cannot be neglected. The compression factor increases with the increasing value of the initial negative chirp, and a compression factor of 9 can be achieved by a pulse with initial negative frequency chirp of -20 and initial FWHM duration of 1.665 ps in the silicon nanowire that is 4.85 mm long. Due to the interaction of SPM and positive group-velocity dispersion with the initial negative frequency chirp, the compression factor decreases with the increasing core diameters vary from 250 nm to 320 nm.

7846-33, Poster Session

The exact dark soliton solutions to the higher-order nonlinear Schrödinger equation with variable coefficients

Y. Guo, Wuhan Institute of Technology (China)

The nonlinear Schrödinger equation with variable coefficients have very important position in many physical fields, in actual fiber communication the soliton pulses of propagating information always can be described by an higher-order nonlinear Schrödinger equation with variable coefficients. The higher-order nonlinear Schrödinger equation with variable coefficients is analyzed by means of the projection matrix method. The exact analytical dark soliton solutions are obtained, which clearly shows how the variable fiber dispersion, higher-order nonlinear, and loss coefficients affect the propagation of ultrashort pulses. The obtained solution is used to analyze the propagation properties of ultrashort pulses in dispersion-decreasing fibers. It is found that the ultrashort pulse can realize stable dark soliton transmission if the fiber dispersions have some certain profiles related to the fiber loss and nonlinear properties. the obtained results. The fiber higher-order nonlinear parameter arouse that the soliton center position will appear nonlinear excursion. A small variation in the dispersion has a similar perturbative effect to an amplification or loss. The exponentially decreasing dispersion fiber is studied exemplificatively to demonstrate numerical simulations confirm the analytical solution.

7846-34, Poster Session

Phase control of linewidth of electromagnetically induced transparency coupled by double fields

X. Feng, L. Zhang, L. Yang, X. Li, Hebei Univ. (China)

The electromagnetically induced transparency (EIT) is associated with a three-level system where two hyperfine levels within an electronic ground state are coupled to a common excited state level by a coupling field and a probe field. Due to its fascinating physics and potential applications, there have been numerous works about EIT or extending study in more complicated systems. In the other hand, recently, some studies based on the phase-control, such as phase effects in spontaneous emission spectra/ population trapping and phase control of electromagnetically induced transparency, have attracted great interest. They show that in the atom level system, both dynamics and the steady state of the atoms depend on the relative phase of the transitions. In this paper, the common -type configuration is extended by introducing a second laser coupling field which also drives the lower ground level to the upper excited level. The effect of the relative phase of the two coupling fields on the spectral linewidth of EIT is studied theoretically. It is shown that the introducing of the second coupling field would influence the width of the normal EIT which is mainly governed by the coherence relaxation rate between the two lower hyperfine levels. In this case, the relative phase between the double coupling fields shows a great degree of influence on the spectral width of EIT window. The linewidth can be modulated by changing the relative phase. Particularly, as the double coupling fields have opposite phases, the linewidth of EIT window can be extremely narrow distinctly. Our result may provide an alternative way in the control of the linewidth of EIT window.

7846-35, Poster Session

Observation of bistable upconversion emission in Tm,Yb codoped yttria nanocrystal

L. Li, X. Zhang, Y. Peng, B. Jiang, M. Nie, Harbin Engineering Univ. (China)

Intrinsic bistable emission in rare-earth-doped materials has attracted intensive attention for its potential applications related to optical data switching and manipulation. Such nonlinear dynamic systems with bistable light emissions allow the coexistence of two different stable emission intensity (or spectrum) for a single given pump excitation. The unusual bistable photoluminescence from Yb3+, Cr3+, and Er3+ ions was observed previously, but there have been rare reports of bistable light emission from Tm3+ ion. In this work, we have experimentally studied nonlinear upconversion emission properties in Tm and Yb codoped yttria nanocrystals under 973 nm laser excitation. The samples used for our experiment were prepared by a simple sol-gel method. The dependences of upconversion luminescence intensities and emission spectra from Tm3+ ions in the range of visible to near-infrared on 973 nm excitation intensity have been analyzed. Intrinsic optical bistability and hysteresis have been distinctly observed for the bright blue upconversion luminescence of Tm3+ ions at room temperature. The origin of intrinsic luminescence instabilities in Tm,Yb codoped yittria nanocrystal has been discussed theoretically by taking into account the internal pump-induced heat accumulation. The bistable light emission phenomenon from Tm3+ ions is related ultimately to local thermal effects which cause the changes of phonon-assisted energy transfers and nonrediative relaxations.

7846-36, Poster Session

Phase control of electromagnetically induced transparency in a four-level system

L. Yang, Hebei Univ. (China)

We present a theoretical study on the frequency position and the the linetype of electromagnetically induced transparency (EIT) in a four-level atomic system with a coupling field, two microwave fields and a probe field, as shown in fig.1. The absorption spectrum which is characterized by two EIT windows is obtained by a weak probe field scanning corresponding transition. It can be found that the frequency position of EIT and the linetype of EIT change with the relative phase of the two microwave fields. The frequnecy interval reaches the minimum when the relative phase is reverse. If two microwave fields have the same strength and reverse phase, the absorption spectrum will exhibit an EIT. This proposes a way to controlling frequency position of EIT by modulating the relative phase between two fields.

7846-37, Poster Session

Synthesis and 3PA induced optical limiting effect of a carbazole derivative

Y. Chen, J. Liu, M. J. Huang, Henan Univ. (China)

N-Butyl-3,6-diformylcarbazole was synthesized by the reaction of N-alkylation and the product yield was 45%. The structure was characterized by Nuclear Magnetic-Resonance (NMR)(400 MHz in CDCl3,): 9.88 (s, 2H, O=C-Ph), 7.51-8.79 (m, 6H, ArH), 4.16-1.31 (m, 6H, CH2), 0.90 (m, 3H, CH3). Its optical properties were studied. The absorption and emission spectra were measured using a UV-vis-NIR Cary5000 spectrophotometer and a fluorolog3-Tau fluorescence spectrometer, respectively. The absorption spectra had two peaks and showed strong UV absorption in range of 285-400 nm. Molar absorption coefficients were more than 10000 l/cm.mol due to the transition absorption from π to π^*. The compound has strong fluorescence emission, and the fluorescence quantum yield was 0.40. Utilized experiment, we surveyed the effect of temperature on steady state fluorescence intensity, at 278K, 288K, 298K, 308K and 313K in DMF respectively. We found that the lower the temperature was, the stronger the fluorescence intensity would be. The measurement of the three-photon absorption (3PA) induced optical limiting effect was done in a 10-mm-long transparent quartz cell, using a Q-switched Nd: YAG laser with pulse duration of 38 ps, repetition rate of 10 Hz at 1064nm. In the case of low incident intensity, the transmittance varied linearly with incident intensity. However, the transmittance increased slowly under the condition of high incident intensity. The calculated results based on 3PA theory agreed well with the experimental results and it was inferred that the optical limiting of the compound resulted from its 3PA. The 3PA coefficient value was 6.1×10-23cm6/w2 and its corresponding absorption section was 8.7×10-79cm6s2.

7846-38, Poster Session

The entanglement properties of photon subtracted two-mode Gaussian states

L. Wu, China Jiliang Univ. (China); X. Chen, Zhejiang Gongshang Univ. (China)

We analyze the entanglement condition of a new kind of non-Gaussian quantum state, which is prepared by photon number subtraction from a two mode Gaussian state.

Fock space criterion and Shchukin-Vogel criterion are applied and the results are compared. Two kinds of the original Gaussian states are utilized. Their photon subtracted states have different entanglement properties.

7846-39, Poster Session

The cumulants of bosonic quantum states

L. Jiang, Zhejiang Gongshang Univ. (China)

We address the issue of quantifying the non-Gaussian character of a bosonic quantum state and introduce cumulants of quantum states as the measure of non-Gaussianity. The cumulants are calculated for Fock state, cat state, non-Gaussian state prepared by photon subtraction and phase damped state. The time evolution of non-Gaussianity is also studied. The third-order cumulant is a vector of length 4 and the fourth-order cumulant is a vector of length 5 for single mode quantum state.

7846-40, Poster Session

Evaluating the quantum capacity of bosonic dephasing channel

L. Jiang, X. Chen, Zhejiang Gongshang Univ. (China)

Phase damping is the main decoherence in the evolution of quantum states. In most of the known quantum computing and quantum information processing devices have amplitude damping times that are around 1-2 orders of magnitude larger than the corresponding dephasing times. For lossy optical fibre as a quantum channel, the quantum capacity is well known. The channel is degradable. We know that dephasing channel is also degradable, thus it can be anticipate that the channel capcity is available.

We calculate the capacity with verious methods in this paper.

7846-41, Poster Session

Studying the VCSEL to VCSEL injection locking for enhanced chromatic dispersion compensation

L. Li, Guizhou Univ. (China)

Recently, Chaos secure communication has attracted significant attention and got an extensive application, Optical chaos becomes a hot topic of secure communication for its large bandwidth and low loss, high complexity and the highly sensitive to the parameters. As one of the microchip lasers, vertical-cavity surface-emitting lasers (VCSELs) exhibit many advantages, such as single longitudinal-mode operation, low threshold current, circular output beam with narrow divergence, low cost and etc. Optically-injection-locked (OIL) VCSELs, which are locked, to a master laser by photon injection at similar wavelength, have been experiment demonstrated to be effective for enhancing the small-signal modulation bandwidth, as well as reducing the frequency chirp of directly modulated diode lasers. It may be a promising candidate for future all optical networks.

In order to supply a theoretical guide for digital chaotic telecommunication, the technique of Optical injection locking (OIL) of semiconductor lasers on the chaotic communication have been investigated based on the theoretical models used to describe the dynamics of solitary vertical-cavity surface-emitting laser (VCSEL) subjected to the external optical injection and signal transmission in fiber. The numerical simulation results show that, the frequency chirp and time-resolved chirp are reduced in magnitude, using a VCSEL laser as master and another VCSEL as slave, which are closely correlate to the chromatic dispersion, it leads to a no-penalty transmission over 50 km of uncompensated in standard single mode fiber (SSMF) at 10Gb/s, and it could be higher rate and more remote if there were appropriate compensation.

7846-42, Poster Session

Supercontinuum source with tapared photonic crystal fiber

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Supercontinuum (SC) generation with photonic crystal fiber (PCF) has attracted research interests in recent years, and some estimable outcomes have achieved. More than normal PCF, SC generation can be also obtained by propagation short impulse form through tapered PCF. Compared with normal PCF, tapered PCF for SC generation has at least two advantages: decreasing zero-dispersion wavelength (ZDW) and increasing the power intensity. For SC generation processing, short ZDW is available for extending the spectra to visible. And the high power intensity can enhance the conversion efficiency, and shorten the length of PCF used.

In this paper, about 2W all-fiber supercontinuum is demonstrated by pumping a section of tapered PCF with a picosecond fiber laser. The taper PCF is fabricated by a conventional taping rig, using the melting and stretching method experimentally. Initial length of the whole PCF is about 100cm, one end of the PCF (about 6cm) is tapered, with 25um PCF waist diameter and the waist length up to 29 mm. The other end of the PCF is spliced and the pigtail fiber of picosecond laser to form all-fiber structure. The picosecond fiber laser is a self-made passive mode-locked ytterbium-doped fiber laser, with center wavelength of 1064nm, pulse width of 13ps, repetition rate of 59.8MHz. Compared with our previous work, the tapered PCF obviously enhanced the visible of the SC source.

7846-43, Poster Session

Backward propagation of light pulse in phthalocyaine gallium polymethyl methacrylate

H. Wang, C. Zhang, Fujian Normal Univ. (China)

The authors experimentally observed the backward propagation of light pulse in Phthalocyaine Gallium polymethyl methacrylate (PMMA) firstly. The largest time advancement of 10.43 ms was got when the sample length was 2 mm long, the corresponding group velocity was -0.19m/s. We can control the time advancement (group velocity) by adjusting the modulation frequency and other parameters such as: input intensity and sample concentration.

7846-44, Poster Session

The switch between electromagnetically induced transparency and absorption due to the power broadening of probing field

X. Li, C. He, Hebei Univ. (China)

In this paper we present a theoretical study of the nonlinear effect in the quasi-lambda type four-level system. The system consists of an excited state level and three ground state hyperfine levels. Probing and coupling field are coupled to between the excited state and two higher ground states, and the microwave field drives the two lower ground states which are associated with probing field. By solving the precision solutions of the equations of motion of density matrix, the absorption properties as a function of Rabi frequencies of the probing field and microwave field are given. As a result, the switch from double EIT to single EIA is found due to the power boarding of probing field. However, the splitting frequency of double EIT has relation to the Rabi frequency of microwave field.

7846-45, Poster Session

Double-resonance optical-pumping spectra of rubidium 5S_1/2 - 5P_3/2 - 4D_3/2, 5/2 transitions and frequency stabilization of 1.5 micro-meter laser

J. Gao, J. Wang, B. Yang, T. Zhang, J. Wang, Shanxi Univ. (China)

Doppler-free laser spectroscopy for the transitions between atomic excited states plays an important role in a variety of fields, including high-resolution spectroscopy, frequency standards, multi-photon laser cooling and trapping of atoms and so on. Among these applications, the rubidium 5P_3/2 - 4D_3/2, _5/2 transitions with a wavelength of 1529nm has attracted considerable attentions as a frequency reference in WDM and DWDM systems of optical communication for correction of the dense communication channels. The optical-optical double-resonance (OODR) spectrum as a sophisticated technique has been widely utilized to approach the transitions between atomic excited states. However, the signal-to-noise ratio (SNR) of OODR spectrum is poor especially in atomic system with large spontaneous emission rates. Recently, a kind of novel optical pumping spectroscopy, double-resonance optical-pumping (DROP) spectrum, can remarkably improve the SNR of the spectrum between atomic excited states. The main idea of DROP is to monitor the population variation of the atomic ground state instead of the excited state. We investigated the Rb87 5S_1/2 - 5P_3/2 - 4D_3/2, _5/2 transitions via OODR and DROP spectra experimentally, compared these two kinds of spectra, discussed the influence of pump and probe laser beams' intensity, polarizations combination, and the alignment

(co-propagating and counter-propagating) on the properties of DROP spectra. Thanks DROP and the atomic coherence in ladder-type atomic system, high-SNR and narrow-linewidth DROP spectrum of Rb87 5S_1/2 - 5P_3/2 - 4D_3/2 transitions is achieved with a room-temperature atomic vapor cell. We preliminarily stabilized a butterfly-sealed 1529nm distributed-feedback (DFB) diode laser, which is widely used in WDM and DWDM systems of optical communication, by employing the high-SNR and narrow-linewidth 87Rb DROP spectrum as frequency reference.

7846-46, Poster Session

Frequency doubling of 1560nm diode laser via PPLN and PPKTP crystals and laser frequency stabilization to rubidium absorption line

S. Guo, J. Yang, B. Yang, T. Zhang, J. Wang, Shanxi Univ. (China)

Frequency stabilized 780nm CW and pulse lasers are very important in cooling/trapping and manipulation of rubidium atoms. Although 780nm laser diode and Ti:sapphire laser are commercial, but achieving nano-second laser pulses with good frequency stability and higher peak power, which are required for manipulation of rubidium atoms, is still a big challenge. Employing well-developed fiber-pigtailed semiconductor laser, high-speed waveguide-type modulator, and mediate-power Er-doped fiber amplifier (EDFA) on S-band range of optical fiber communication as well as quasi-phase-matching (QPM) periodically-polarized nonlinear crystal with relatively-higher second-harmonic-generation (SHG) efficiency, 780nm CW laser and pulse lasers can be approached via frequency doubling of 1560nm laser. In our experiment, a PM fiber-pigtailed butterfly-sealed 1560nm distributed-feedback (DFB) laser diode is firstly amplified by a 2-Watt EDFA, then a multiple-period PPLN crystal (1mm 10mm 20mm) and a single-period PPKTP crystal (1mm 2mm 30mm) are utilized to perform single-pass SHG. The 780nm laser power of ~ 41mW for PPLN and ~24mW for PPKTP are obtained with ~2W 1560nm laser input, corresponding to SHG efficiency of ~2.1% for PPLN and ~1.2% for PPKTP respectively. Further PPLN and PPKTP crystals for higher-CW-power SHG in single-pass configuration are investigated and compared using 5-Watt EDFA, including the temperature compensating, the optimal focusing conditions, and 780nm laser intensity noise. Finally the 1560nm laser diode's frequency is locked to rubidium absorption line via SHG and rubidium absorption spectroscopy. Limitation of improvement of frequency stability is discussed. In this system, we can further employ a fiber-pigtailed waveguide-type high-speed intensity modulator between DFB laser and EDFA to slice frequency-stabilized CW laser to achieve nano-second 780nm laser pulses. This approach has advantages of higher peak power, good frequency stability, adjustable pulse repetition rate, and tunable pulse width, and it is suitable for internal state manipulation of rubidium atoms.

7846-47, Poster Session

Theoretical study of optically controlled group velocity of light in an optical fiber

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Three-wave coupled equations of optically-controlled group velocity of light base on stimulated Brillouin scattering (SBS), together with their boundary and initial conditions, are solved using finite difference method, relations of system time delay, pulse boardening factor and changes of pulse shape with gain parameter are obtained. Further more, circumstances with different stokes power, signal pulse width, fiber length are discussed then.

The result shows that system time delay decreases when stokes signal power increases, and pump power decreases when gain saturation is reached; stokes signal width makes no difference of system time delay when gain saturation is not reached, but stokes signal with narrower width experences larger pulse broadening; delay lines with different fiber length share the same relation of time delay with gain parameter, which goes a step further and shows that gain parameters of different fiber length is just the same when gain saturation is reached, with the gain saturation pump power of fiber length L=1 km system approximately 50 mW. Moreover, optimal parameters to maximum the system time delay are obtained under our calculations and analysis when the input stokes power is 0.1 μW, pulse width is 120 ns, fiber length is 150 m, gain parameter is 12, with the broadening factor of the output pulse 1.2, fractional time delay 0.74, which gives considerable directives to our experimental work.

7846-48, Poster Session

Experimental studies of the coherence properties of supercontinuum generated in photonic crystal fiber

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Photonic crystal fiber (PCF) based Supercontinuum has been extensively studied in recent years due to the fact that such ultra-broadband light sources possess enormous potential applications in a variety of civil and military areas such as optical communication, optical sensing, optical coherence tomography (OCT), laser weapon. At present, most of the research papers have focused on the Supercontinuum generation in highly nonlinear PCFs by various pumping sources and its applications, however, few have investigated on the coherence properties of the Supercontinuum. In this paper, the temporal coherence properties of Supercontinuum generated by nanosecond pulses in highly nonlinear photonic crystal fibers are experimentally studied using a Mach-Zehnder Interferometry approach. The results show that the coherent length of the Supercontinuum generated in the paper is near 70μm at 870nm.

7846-49, Poster Session

All-optical control of polarization and intensity of light in periodically poled lithium niobate

Y. Kong, Jiangnan Univ. (China); X. Chen, Shanghai Jiao Tong Univ. (China)

Periodically poled LiNbO3(PPLN) was extensively studied in the past decade for quasi-phase-matched nonlinear interaction. However, the reversal of ferroelectric domains in this material reverses not only the nonlinear coefficient but the electro-optic coefficient. In the applications, a combined nonlinear and electro-optic(EO) effect in PPLN has received much research interest. This combined function provides us with great convenience in realizing simultaneous generation and processing of the optical signal, which makes the device both compact and efficient.

The domain period of PPLN is a function of wavelength as well as temperature, in special case, periodic structure of PPLN may simultaneously compensate for the phase mismatches of polarization coupling and SHG. Under the QPM conditions for both polarization coupling and SHG, the polarization coupling and SHG would compete with each other, and lead to a continuous energy transfer among the interaction waves. The coupling process depends on not only the ratio of coupling coefficients(can be modulated by external DC electric field), but also the initial power, which can be provided by the control-light.

The coupling behavior with the different control-light power at different

ratio of coupling coefficients is investigated. Numerical results show that the original energy transfer among the three waves is entirely disturbed due to the additional input power. Besides the ratio of coupling coefficients, the additional control-light power has obvious influence on the coupling behavior. In other word, we can tune the control-light intensity freely to control the three waves in the PPLN. Due to this property, a new and convenient method for achieving light tuning can be achieved.

7846-50, Poster Session

Mode behavior of second harmonic wave in a ridge-type periodically poled lithium niobate waveguide

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The mode behavior of Second harmonic (SH) generated by nonlinear interaction was investigated in this paper. We fabricated a z-cut 12-mm-long ridge-type Mg doped periodically poled LiNbO3 (MgO:PPLN) waveguide with a QPM period of 4.3 μm, which satisfies the quasi-phase-matching condition for blue light generation about 460 nm region. The physical area of the ridge waveguide was measured by microscope to be 7.5 μm X 5.0 μm, which is large enough to guide multi-mode waves. A fundamental wave from the -wave diode pumped solid state Ti: Sapphire Tunable Ring Laser was coupled into the MgO:PPLN waveguide with the polarization of transverse-to-magnetic field(TM).

We could observe not only fundamental mode but also the higher-order modes distribution without any disturbance from the others owing to their unique phase matching condition. The conversion efficiency for SH mode was measured by changing the wavelength of first harmonic (FH) and temperature. The maximum conversion efficiency of 260 %/W for fundamental mode was obtained at the wavelength of 921.5 nm where both fundamental modes of FH and SH satisfied the quasi-phase-matching condition. On the other hand, high odd mode was generated with maximum efficiency at 923 nm where they were phase-matched to the odd-even mixed mode of FH. We also investigated the effect of overlap factor between FH and SH modes on conversion efficiency, and the experiment showed a good agreement with simulation results.

7846-51, Poster Session

Shaping complex optical lattices for soliton manipulation

S. Lopez-Aguayo, A. Ruelas, J. C. Gutiérrez-Vega, Instituto Tecnológico y de Estudios Superiores de Monterrey (Mexico)

We produce complex optical lattices that can be either a pure quasinondiffracting beam or an accelerating nondiffracting beam. In particular, these complex lattices are used to show novel soliton dynamics. These results open the possibility to create a wealthy variety of opportunities for soliton routing and steering.

7846-52, Poster Session

An advanced design of receiver for free space quantum key distribution system

S. Gao, J. Wu, F. Tang, X. Wang, B. Zhu, Univ. of Science and Technology of China (China)

We presented an advanced design of receiver in free space quantum key distribution (QKD) system based on BB84 protocol. In this system, a novel four polarization beam splitter is used in the receiver. It simplifies the receiver fabrication process, and the reflection loss is reduced too. Then we built the transmitter and the receiver for QKD system. The outdoor 200m free space QKD experiment was carried out, the bit error rate is 0.91% when the average photon number in each optical pulse was about 0.1. This result indicates that our design for the QKD system is feasible.

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7847-01, Session 1

Prospects and challenges of InN based nanoscale heterostructures and devices integrated on Si

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InN has emerged as a highly promising candidate for future integrated nanophotonic devices and systems on a Si platform, due to the small direct energy bandgap, the bandgap tunability with the incorporation of Ga, and the excellent electrical transport properties. However, the progress in InN based materials and devices has been severely limited by the lack of native substrates, the difficulty in achieving intrinsic and p-doped InN, as well as the uncontrolled surface charge properties. In this context, we have performed a detailed investigation of the molecular beam epitaxial growth and characterization of In(Ga)N based nanowire heterostructures and devices on Si substrates. We have developed a self-catalytic growth process and achieved nontapered, nearly defect-free In(Ga)N nanowire heterostructures on Si. The resulting InN exhibit an estimated residual doping concentration of ~ 2E15 cm-3, or less, which confirms, for the first time, the achievement of nearly intrinsic InN. From detailed photoluminescence and micro-Raman studies of both nearly intrinsic and Si-doped InN nanowires, we have further identified the definite role of the bulk electron density in transforming the electronic properties of nonpolar InN surfaces. In addition, we have demonstrated InGaN-based dot-in-a-wire nanoscale heterostructures on Si, which exhibit an internal quantum efficiency of >45% in the green, yellow, and red wavelength range, compared to the commonly measured values of <10% in this spectral range. The achievement of low cost, high efficiency deep green and red-emitting InGaN/GaN dot-in-a-wire LEDs as well as InGaN-based nanowire solar cells on Si are currently in progress and will be presented.

7847-02, Session 1

Advanced nanocomposite lens materials for wafer level optics

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Highly integrated optoelectronic imaging and sensing systems have been under extensive development for wafer level mass production. Solventless, photocurable, transparent, colorless and haze-free materials are primary choices for lens fabrication in wafer level optics. In order for improved imaging performance, advanced lens materials are being explored for quality properties compatible with wafer level processes. Thermally such materials are expected to pass thermal reliability tests, survive stack-reflow processes and have low coefficient of thermal expansion. Optically such materials are desired to have high refractive index and extreme dispersion. Mechanically such materials are needed to possess low stress and shrinkage. Proposed here is a novel nanocomposite system based on 1) finely constructed core-shell nanoparticles with photopolymerizable surfactant crosslinkers and 2) compatible polymer matrices. The design, preparation and application of such nanocomposite lens materials are discussed in detail. Such nanocomposite lens materials are promising candidates for imaging and sensing systems with breaking-through performance.

7847-03, Session 1

Optical properties of CdSe1-xSx nanoparticles

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The effect of quantum confinement on the optical properties of semiconductor quantum dots has recently attracted considerable interest [1-5], because the quantum confined energy levels can be tuned by changing the quantum dot radius and variable stoichiometry during growth can lead to high quantum efficiencies. This has led to a wide range of potential applications that include designer lasers and optical amplifiers where the required wavelength can be achieved by material selection and controlling the quantum dot size.

We have synthesised CdSe1-xSx nanoparticles with different radii, different sulphur concentrations, and a sulphur concentration that varies near the nanoparticle surface. We have focussed on these nanoparticles because it is known that the peak photoluminescence emission wavelength can be varied by changing the Se/S ratio [6]. In this paper we report the results from structural, optical, photoluminescence, temperature dependent excited state lifetime, and transient absorption measurements on CdSe1-xSx nanoparticles in solution or in solid form. We present a model to explain how the excited state lifetimes and energy levels are affected by a graduation of the sulphur concentration near the nanoparticle surface and by the different nanoparticle radii.

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7847-04, Session 1

Design and fabrication of high performance InGaAs/InP photodiodes

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Ultrafast and high responsivity photodetectors that operate at long wavelengths are key components of modern high bit rate optical and wireless communication systems as well as ultrafast measurement systems. The InP-InGaAs based uni-traveling carrier (UTC) photodiode is a promising solution because of its unique mode of operation compared with the conventional PIN photodiode. The novelty of UTC structure is the separation of the absorption layer and depletion layer in which only electrons generated and accelerated in the two layers are active carriers. As a result the UTC photodiode is not limited by the slower transportation of heavy photogenerated holes, enabling high speed and high out-put simultaneously . In this paper, an optimized

structural design of TW-UTC PD is exploited to realize high speed, high efficiency and high output performance, and at the same time, a new device structure was developed to simplify the process and increase the yield.A traveling wave InGaAs/InP UTC waveguide photodiode was designed and fabricated, a device with large bandwidths and low dark current is presented.

7847-05, Session 1

Correlation between dislocations and internal electric field of CdZnTe radiation detectors

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The compound semiconductor CdZnTe (CZT) has attracted extensive scientific and commercial interests due to its great potential as a room-temperature radiation detector material for measuring X-rays and gamma rays. At Brookhaven National Laboratory (BNL), we employed a high-resolution synchrotron X-ray mapping technique together with a Pockels-effect measurement system to investigate the performance-limiting factors for CZT detectors. With the above characterization methods, we are able to reveal the non-uniform distribution of the internal electric field of CZT detectors. Such non-uniformity of E field was compared with the distribution of extended defects in CZT, which were shown using a synchrotron white beam x-ray topography measurement system. As a result, we found that crystal defects (e.g., dislocations) substantially distort the electric field in CZT detectors and therefore, deteriorate the detection performance. We discuss a possible mechanism based on the localized distribution of impurity-related energy levels near the dislocation regions. Data gathered with a low-temperature ultra-high-resolution photoluminescence mapping system will also be provided to support the impurity-related model. Our investigation allows a better understanding of the insufficient charge carrier collection in CZT detectors.

7847-06, Session 1

Low-cost light-emitting-diode based leaf color meter for nitrogen estimation in the rice field

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The amount of the nitrogen level in the rice is an important parameter for evaluating the growth of the rice in the field or the need of the nitrogen fertilizer per rice field. It can be done easily and cheaply by using a 6-level leaf color chart. However, the accuracy of the resulting color level depends on the ability of the farmer to compare the color with the reference chart as well as on the direction of Sun light. With this issue in mind, this paper proposes a low-cost light-emitting-diode (LED) based leaf color meter that can be used to estimate the nitrogen level in the rice field. In particular, we show how we integrate a commercially available green LED, a silicon photodiode, and an 8-bit microcontroller in a compact packaging style for the implementation of this needed leaf color analyzer. Other key features are ease of use and upgradability for different color levels. Our field test study will also be highlighted.

7847-07, Session 1

The study of the high time resolution PMTs in T0 system for beam test

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In order to study the performance of MRPC, which will be used for the upgrade of EndCap TOF in BES , a T0 system was composed of high speed response PMTs H6533 coupling with BC420 plastic scintillators.

A suitable working high voltage V0 was confirmed by researching the dependence relationship between the PMT gain and energy resolution of SPE (single-photoelectron spectrum). Because the T0 system should offer a toughly strict timing start, the TTS (transit time spread) of H6533 under V0 has been measured by two different ways, using the Cherenkov light generated by the radiation source or the short pulse light generated by the laser.

The basic quantities such as rising time, dark current and linearity have also been tested in cosmic ray experiments. The results not only confirm that this type of PMT meets the fast timing requirements of T0 system, but also offer the specific reference for the T0 system in the beam test of MRPC in the future.

7847-08, Session 1

Effects of solvents on the performance of P3HT:PCBM solar cells

W. Li, J. Guo, X. Sun, B. Zhou, Shenzhen Univ. (China)

In this work, we used different kinds of solvents, chlorobenzene(CB), 1,2-dichlorobenezene(DCB), a mixture of DCB and chloroform, to investigate the effects of solvents on the performance of poly(3-hexylthiophene-2,5-diy1) (P3HT):C61-butyric acid methyl ester (PCBM) bulk heterojunction solar cells. It was shown that different solvents resulted in different solubilities of donor or acceptor materials and caused the different interfacial area between the donor and acceptor, and the larger interfacial area increased the current density of the cell. On the other hand, We found that the short current density (Jsc), fill factor(FF), and power conversion efficiency ( ) of a cell with a photo-active layer made using materials dissolved in a higher boiling point solvent to be higher than those of a cell made using the same materials dissolved in a low boiling point solvent, and the device performance was improved by using the solvent mixture. Evaluating the surface morphology, charge mobility, and current-voltage curve of cells made using different solvents, we concluded that photo-active lavers fabricated from different solvents would have different morphological structures in spite of having the same constituents. The polymer films using a higher boiling point solvent had longtime to self-organize, got a higher degree of crystalline, had high ability in light absorption, led to lower device series resistance, thereby increased the short current density (Jsc), fill factor(FF),and power conversion efficiency ( ) of the photovoltaic devices.

7847-09, Session 1

Image restoration for indirect far-field image using microlenses array integrated with LCD

F. Yang, A. Wang, H. Chang, D. Lei, H. Ming, Univ. of Science and Technology of China (China)

Image restoration for constructing high-spatial-resolution images in an imaging system which realizes indirect far-filed image by integrating the microlenses array with LCD is reported. We investigate the indirect far-field imaging condition where adjacent sampling points contribute the detected signal. Experimental setup with microlens of 200um diameter and 9mm focal length is built to prove this condition by studying the

decrease of the resolution and contrast with the increase of the work distance. Since any one iterative method is not optimal for all image deblurring problems, some deblurring iterative algorithms are applied to our imaging system and we compared the effectiveness of these iterative procedures to choose right one for our use.

7847-10, Session 1

Asymmetrical design for non-relaxed near-UV AlGaN/GaN Distributed Bragg Reflectors

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Towards the development of high efficient GaN-based Vertical Cavity devices, the fabrication of cracks-free high reflective semiconductor mirrors is still an issue. For near-UV operating devices, one of the best solution is the use of Al1-xGaxN/GaN materials family. With a relatively high amount of Aluminium in the ternary alloy, it is possible to obtain a large enough index contrast to fabricate high reflectivity mirrors. However, the lattice mismatch between AlGaN and GaN increases with the Al amount and induces a lot of cracks in the structure which affect its optical and electrical properties. Moreover, for a regrowth of an active layer on the top of the mirror, it is necessary to suppress crack generations to achieve a smooth surface. Recent works have shown the efficiency of insertion layers, such as superlattices or AlN layers, to limit the cracks but such structures can be relaxed. In this work, we have investigated asymmetrical designs in order to realize AlGaN/GaN mirrors without relaxation, and thus without cracks. First, the experimental critical thickness of MOVPE-grown AlGaN on GaN templates was determined and modelled with a Griffith law. Several AlGaN/GaN mirror structures were then simulated with various Al compositions in AlGaN and various degrees of asymmetry. Such calculations showed that it is possible to design fully-strained Al0.2Ga0.8N/GaN mirrors with a theoretical reflectivity higher than 90% at 450 nm using a degree of asymmetry of 0.12. Finally, it has been also shown that the best adapted Al composition in AlGaN alloy changes with the operating wavelength.

7847-11, Session 1

Magnetically modulated refractive index of a magnetic fluid film based on cigar shaped ferrite submicron particles

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Light beam propagation at a prism-magnetic fluid film interface is experimentally studied. The magnetic fluid is made through dispersion of synthesized cigar-shaped sub-micron particles of Fe2O3 in an oil solution. This was injected into a glass cell with an active area of 10mm2 and a depth ranging from 10 microns to 50 microns whose base is a glass microscope slide and on the top it was covered with a glass triangle prism with a high refractive index. The set up was developed by one of the authors to measure light switching at a prism-liquid crystal interface in a previous publication. Polarized Light (TE or TM) from a He-Ne laser impinges at the prism-magnetic film interface (PM) at the critical angle of the total reflection. The Total Internal Reflected (TIR) light is detected by a photodiode connected to a data acquisition system. Since the properties of the magnetic fluid can be modulated by external magnetic fields, we investigated the effects of the magnetic field on the refractive index of the magnetic fluid.

For our magnetic fluid, the transmission of light in a TIR regime has been investigated as a function of particles concentration and thickness of the films with a wavelength of 633nm and both TE and TM polarization, and applied magnetic fields up to 25 Oe. It was found that the intensity of Total Internal Reflected Light increases with increasing magnetic field up to 45% more and saturates at 20 Oe for TE light, while decreases with increasing magnetic field up to 30% less for TM light with the same saturation value. Moreover, under a given magnetic field, the output light increases with the increasing film thickness in TE polarization, and decreases with the increasing film thickness in TM case. The refractive index of the magnetic fluid depends on the concentration of the dilute oil-based magnetic fluid under zero field.

These behaviors are explained in terms of the organization of the submicron particles when the magnetic field is applied. The cigar-shaped sub-micron particles are oriented along their long axis to form an organized mesostructure. The different aggregation ability of the magnetic fluid particle is responsible for the variation of the optical properties under different magnetic fields and for different polarization of the incident light.

It is noteworthy that the magnetically modulated refractive index of the magnetic fluid film could have great potential in electro-optical applications.

7847-12, Session 2

Research on SOI-based micro-resonator devices

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SOI (silicon-on-insulator)-based micro-resonator is the key building block of Silicon photonics, which is considered as a promising solution to alleviate the bandwidth bottleneck of on-chip interconnects. Silicon-based sub-micron waveguide, microring/disk devices and grating couplers are investigated in Institute of Semiconductors, Chinese Academy of Sciences. The main progress in recent years is presented in this talk, such as high Q factor single mode microdisk filters, compact third-order microring filters with the through/drop port extinctions to be ~ 30/40 dB, fast microring electro-optical switches with the switch time of < 400 ps and cross-talk < -23 dB, > 10 Gbps high speed microring modulators integrated with compact grating couplers, which enables the wafer-scale on-line measurements.

7847-13, Session 2

Study of silicon photonics based on standard CMOS foundry

J. Yang, Zhejiang Univ. (China)

Silicon photonics can found applications in optical interconnects and optical signal processing. Recent years, silicon photonics was developed rapidly. In this paper, we report our research work on silicon photonics. Based on the standard CMOS foundry, we studied the free carrier dispersion effect based silicon modulators and switches. We also investigated the silicon components based on the slot waveguides and the photonic crystal defect waveguides, exploring the approaches to lower the power consumption and component size of the silicon components.

7847-14, Session 2

Performance improvement to silicon-on-insulator waveguide directional coupler based devices

D. Sun, Univ. of Ottawa (Canada)

For the SOI-waveguide directional coupler (WDC), optical access loss (OAL) and relative polarization dependence (RPD) are two serious passive phenomena and have restricted the adoptability and deployment of the WDC in the development of photonic integrated components and systems. The OAL is defined by the extra optical loss the WDC-structure causes apart from the normal traveling loss of lightwave in waveguides and the RPD is the ratio of coupling length difference between TE-wave and TM-wave to that of TE-wave. Our simulation shows the SOI-WDC with conventional bending waveguides has an approximate OAL of 0.6dB and an approximate RPD of 38% for an SOI-WDC with a 2.0 m rib width and a 1.0 m coupling separation. Even, both the OAL and RPD are radically dependent on waveguide size. These two main drawbacks of SOI-WDC further cause the negative impacts to the performance of SOI-WDC based electro-optic (EO) switch with free-carrier dispersion (FCD) effect, including optical on-chip loss (OCL), polarization dependent loss (PDL) and isolation. A corner-mirror structure is introduced into a 3dB SOI-WDC, both our numerical calculation and FIMMWAVE/FIMMPROP simulations show not only is the footprint reduced, the OAL can be reduced to 0.1dB and the RPD can be improved to 10%. For instance, we designed and manufactured 3dB-coupler based Mach-Zehnder interference (MZI) structures according to our numerical calculation and simulation, experiments show the OCL can be reduced by more than 0.8dB, the PDL can be reduced by more than 1.5dB, and the isolation can be improved by more than 5dB.

7847-15, Session 2

Pump to signal RIN transfer in silicon Raman lasers

X. Liu, X. Sang, Beijing Univ. of Posts and Telecommunications (China)

Silicon-on-insulator (SOI) based photonic devices have attracted much attention due to photonic integrated circuits and nonlinear silicon photonic devices demonstrated in the recent years.Stimulated Raman scatting is much stronger in silicon than that in conventional optical glass fibers. Silicon amplification and lasing were reported. Pump-to-stokes RIN transfer was experimentally and numerically investigated in Raman fiber lasers and the results agreed well. Here, pump-to-Signal RIN Transfer and its impact on propagation of characteristic in silicon Raman lasers are investigated. The Mathematical model for RIN transfer in silicon Raman lasers is derived. RIN Transfer in the silicon Raman laser under different conditions is discussed. RIN transfer's impact on propagation of characteristic in silicon Raman lasers is presented. The result shows that RIN transfer will strongly influence on the output RIN of the chip scale silicon Raman laser. High-frequency RIN transfer show intense oscillation at about, which is several orders higher than that in Raman fiber laser (about). We find that RIN transfer reaches a peak value at resonance frequencies and decreases with the increasing the free carrier lifetime.

7847-16, Session 2

Compact resonant Bragg grating filters using submicron silicon-on-insulator(SOI) waveguide for optical communication network

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The development of silicon based wavelength filters has a high importance in modern optical communication systems as this will increase the efficiency and reduce the cost of Dense Wavelength Division Multiplexed (DWDM) networks. Among the various planar waveguide structures for wavelength filtering application, a Bragg grating has the advantages of flexibility in wavelength selection and prospects for easy optimization in grating parameters to get a desired spectral feature. This paper in this context illustrates submicron Silicon-On-Insulator (SOI) waveguide Bragg grating that is designed and fabricated for realizing compact Fabry-Perot resonant filters with a spectral feature desirable for DWDM communication channel. The targeted spectral features include high Free Spectral Range (FSR), high quality factor (Q-factor), high transmission, high selectivity and a flat top spectrum. The waveguide vertical side wall Bragg gratings will be considered as this has the advantages of fabrication in a single lithography step, easy apodization, tapering possibilities and constant effective index modulation along the grating.

7847-17, Session 2

Thermal dissipation in a laser and semiconductor optical amplifier

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In this paper, we calculate the thermal dissipation in semiconductor Optical Amplifier and laser. We investigate the effect of the material composition, the number of wells, the type of structure (Buried or Ridge), on the thermal resistance of the component and try to extract some rules towards minimization of temperature elevation. An increase in the number of quantum wells within the same type of structure increased the thermal resistance but not significantly. The type of source, a concentrated single source or a distributed in the different wells, does not play a significant role in the thermal resistance of a structure. The difference between Pside up or down mounted device is clear and well known. The variation of Separate Confinement Heterostructure has, in both the Pup and Pdown structures, almost no effect on the Rth. We studied the influence of an additional waveguide layer beneath the active stack. This layer composition is close to InP and can be important to make a cylindrical optical beam that can be coupled to a fiber in a more efficient way. Adding Ga in the material leads to increase the refractive index and decrease the thermal conductivity. Increase of the thermal resistance is therefore expected. Finally the overall heat dissipation in the optical module is calculated ; the objective is to the decrease the overall electrical consumption keeping the performances required by the appication.

7847-18, Session 2

Single-mode low-divergence-angle holey VCSEL based on separated confinement principle

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Single-mode high-power low-divergence-angle VCSELs are usually demanded for a number of applications, including high-speed laser printing, optical storage, free-space optical interconnects, and long-wavelength telecommunications. Because the lateral dimension is usually much larger than the effective cavity length in the longitudinal direction, the conventional oxide-confined VCSEL usually operates in multiple transverse modes. For example, for the 850-nm oxide-confined VCSEL, the single-mode operation is realized by reducing the oxide aperture to about 3 μm in diameter. However, the output power is limited to about 3 mW, and the divergence angle exceeds 20°. This drawback originates from the dual roles of the oxide aperture, which is used to confine the optical field and injected current simultaneously, and the large index step introduced by the oxidized layer. In this paper, we qualitatively study the bottleneck to achieve single-mode high-power low-divergence-angle VCSELs using the waveguide model. The way to overcome the bottleneck is concluded, and holey VCSELs based on separated confinement principle are presented. They operate based on the concept that the optical confinement is decoupled from the current confinement. The oxide aperture is only used to confine the injected current, whereas the optical field is confined by the holey structure on the top distributed Bragg reflector (DBR). By etching holes on the top DBR, the refractive index distribution is tailored, and single-mode operation and low divergence angle beam are achieved. The measured results show that the side mode suppression ratio exceeds 30 dB, and the lowest divergence angle is 3.2°.

7847-19, Session 2

Ytterbium-doped double-cladding fiber laser

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An Ytterbium-doped double-cladding fiber laser is demonstrated. The threshold of the pump power is about 1.1W. The maximum output power is 9.9W at the wavelength of 1045nm when the pump power is 15.25W. The slope efficiency is around 70%. We discuss an exact numerical model, with a shooting method to solve the power steady-state equations. Numerical results about the output power as a function of the pump power are in good agreement with measurements. At last, we calculate the output power as a function of the fiber length in different pump power and dopant concentration. A good agreement between our results and published data is obtained.

7847-20, Session 2

Glass-based integrated optical splitters: engineering-oriented research

Y. Hao, W. Zheng, J. Yang, X. Jiang, M. Wang, Zhejiang Univ. (China)

Optical splitter is one of most typical device heavily demanded in implementation of Fiber To The Home (FTTH) system. Due to its compatibility with optical fibers, low propagation loss, flexibility, and most distinguishingly, potentially cost-effectiveness, glass-based integrated optical splitters made by ion-exchange technology promise to be very attractive in application of optical communication networks. Aiming at integrated optical splitters applied in optical communication network, glass ion-exchange waveguide process is developed, which includes two steps: thermal salts ion-exchange and field-assisted ion-diffusion. By this process, high performance optical splitters are fabricated in specially melted glass substrate. Main performance parameters of these splitters, including maximum insertion loss (IL), polarization dependence loss (PDL), and IL uniformity are all in accordance with corresponding specifications in generic requirements for optic branching components (GR-1209-CORE). In this paper, glass based integrated optical splitters manufacturing is demonstrated, after which, engineering-oriented research work results on glass-based optical splitter are presented.

7847-21, Session 2

Photoconductive ultraviolet detectors based on ZnO films

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Zinc oxide (ZnO) is a wide band-gap (3.37 eV at room temperature) II-VI semiconductor that holds a great potential for light-detecting devices in the UV range. The film quality is essential for the device performance. In this work, high-quality ZnO-based films were epitaxially grown on different substrates by pulsed laser deposition at temperatures in the range from room temperature to 500 °C.

The structural, optical, and electrical properties of films were studied. ZnO-based films exhibited a high c-axis orientation and hexagonally shaped microcrystallines. The ZnO films grown at room temperature were also of high crystallinity. The as-grown films showed a high visible transmittance ~90% and a predominant UV emission in the PL spectra. Further, the oxygen pressure played an important role in determining the film properties. The intensity of the (002) peak was evidently enhanced and the FWHM values decreased with increasing oxygen pressure. An oxygen-rich environment in the growth process could increase the oxygen density in the ZnO film and made it more stoichiometric. As the oxygen pressure increased, ZnO films showed improved optical and electrical performances and was more suitable for optoelectronic applications.

Photoconductive UV detectors with planar interdigital electrodes were fabricated by the lift off technique. Linear I-V characteristics were observed under dark, 365, and 254 nm UV light illumination, showing obvious difference. The influence of finger width and pitch on the device performance was also analyzed.

7847-22, Session 3

Fabrication of a multimode-interference-based multimode power splitter in glass

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The multimode power splitter is one of the key passive components in optical network. Multimode Interference (MMI) based devices has the advantages such as ease of fabrication, low sensitivity to fabrication parameters, compact size and wide bandwidth.

Here in this paper, we fabricated a 1×2 multimode power splitter with MMI structure in glass using the Ag+-Na+ ion-exchange technique. To solve the problem that the diffusion depth always depends on the lateral mask width, a two-step process was utilized. First, Ag+-Na+ ion exchange was run in nitrate melt at 350 .Then a electric field was applied at 300 so that the silver ions continued their migration award .When the open mask ranged from 40 to 200μm, the lateral boarding of the straight waveguides were almost equal to 21μm,and the depth showed a slight increase, from 72.48μm to 79.51μm.

We used three-dimensional beam propagation method (3D-BPM) to simulate and design the device. The width of the input and output multimode waveguides was 50μm and they were tapered to 75μm at the interface. The MMI region was also quadratically tapered .The whole length of the device was 3.6cm.After fabrication, A 1550nm LD was used as a light source .The results showed that the measured loss of multimode straight waveguide can be lower than 0.32dB/cm,and the insertion loss and uniformity of the splitter were 4.28dB and 0.21dB.

The insertion loss was a little high probably due to silver precipitation during ion-exchange process and imperfect coupling with input/

output multimode fibers. To further improve the performance of the device, more research on the parameters of the fabrication process and structure of the device are needed.

7847-23, Session 3

Hybridized low-loss plasmonic-optical waveguides for ultracompact integration

Z. Sun, Xiamen Univ. (China)

To develop ultra-compact planar lightwave circuit, in recent years, various novel waveguide structures were proposed beyond conventional dielectric waveguides based on index contrast, which include photonic crystal (PC) waveguides, plasmonic waveguides and dielectric slot waveguides. The main goal of these novel waveguides is to realize sharp bending and small waveguide pitch (no cross-talk) for high integration. As a fact, dielectric materials based PC waveguides and slot waveguides didn't show advantage in these aspects compared to the conventional dielectric waveguides with high index contrast (such as Si waveguides). Some plasmonic waveguides, such as metal-dielectric-metal (MDM) waveguide, are able to strongly confine the light both for sharp bending and zero cross-talk, but high absorption loss due to metal get in its way towards further development.

In this work, we report a novel waveguide structure that hybridizes the conventional dielectric waveguides with the MDM plasmonic waveguide by incorporating the former inside the dielectric part of the latter. As a result, the strongest field in the waveguide locates at the center of the guide instead of the metal/dielectric interfaces, which can significantly reduce the propagation loss, and meanwhile offer excellent confinement of the plasmonic lightwave. Theoretically the inside wave mode is to be shown a hybrid plasmonic-optical mode. We further analyze the mode properties of such waveguides with various structure dimensions, and demonstrate its wave propagating characteristics with numerical simulations. The theoretical study suggests that such waveguides are promising ultra-compact integration of lightwave circuit. Additionally, fabrication of such waveguides is compatible with current micro/nano-fabrication technologies.

7847-24, Session 3

An intrinsic limitation to silicon-on-insulator waveguide Mach-Zehnder interference based electro-optic devices

D. Sun, Univ. of Ottawa (Canada)

Mach-Zehnder interference (MZI) structure for developing the central integrated optical modulated devices - optical switch and modulator has played quite important role in the development and applications of the integrated optical/photonic technology in modern optical networks. Meanwhile, silicon-on-insulator (SOI) waveguide, as a new advanced integrated photonic platform, is one of currently growing interests in highly integrated photonic devices and systems. In this work, for the SOI-waveguide MZI-type electro-optic (EO) modulated devices with free-carrier dispersion (FCD) effect, the extra optical absorption (EOA) loss caused by the FCD-based modulation and its negative impact upon the FCD-based MZI-type EO modulated devices are studied, and an intrinsic limitation to this type of devices is found, which is the tension between the EOA loss and the interaction length for a half-wave modulation. The numerical calculation shows the modulation-caused EOA loss of <1.0dB requires the minimal interaction length of >5mm. The numerical calculations are validated via the simulations of software tool: MEDICI. The performance decay processes of both EO modulator and switch due to the modulation-caused EOA loss are modeled. Further the numerical calculation shows, for both modulator and switch, the on-chip optical loss is 0.8 and 2.3dB at the off- and on-state, respectively, and the extinction ratio is less than 20dB. Due to the intrinsic limitation the output imbalance of switch and the bandwidth decay of EO modulator are also discussed. A feasible solution to the intrinsic limitation is proposed. This work is very conducive to the research and development of SOI-waveguide FCD-based EO devices.

7847-25, Session 3

Based on micro-ring resonators silicon-based modulator performance improvement

Z. Yan, Xi'an Univ. of Technology (China)

Silicon-based electro-optic modulator is a key device that used to implement optical interconnections.To SMR, the value of the coupling coefficient influences the 3dB bandwidth, the extinction ratio and other characteristics directly. The coupling coefficient also has an important effect on those parameters. The performance of the modulator based-on cascade DMR can be improved with a higher modulation rate and a larger modulation depth.

7847-26, Session 3

Design and implementation of a dichroic beam combiner based on the theory of photonic crystals

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Diachronic beam combiner is the kernel technology of the dual mode guiding simulation system. Based on the photonic band gap structure of one-dimensional Photonic Crystals, a new method of designing a diachronic beam combiner is proposed in this paper, through which mid-IR region high reflection mirror coating is designed and calculated by using plane-wave expansion method. Simple construction, combination of broad wave band beams in 2D and wide-angle is realized, and polarization of off-axis incident beams is prevented. The analysis of infrared reflectivity and radio frequency transmission rate demonstrate that this new method can perfectly satisfy the demand of design.

7847-27, Session 3

Criterian of single-mode photonic liquid crystal fibers

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The endless single mode behavior is the most attractive property of the photonic crystal fibers (PCFs). The PCFs filled with liquid crystal are called as photonic liquid crystal fibers (PLCFs). Based on the finite element method, we can determine the certain structure parameters and V value which allows only the single mode transmits along the PLCFs over a wide range of wavelength. Similar to the fundamental space filling mode theory, we use the index of the fundamental mode of the liquid crystal core instead of the index of the liquid crystal. After calculation we find that when the V=12.4, it indicates that the second order mode has been cut off. From the specific PLCFs having d/ =0.2, it can find that the second-order mode cutoff. Therefore, only support a single mode when the wavelength is ranged from 0.57 to 4 m. The radius of the second-mode fields of the PLCFs also changes sharply. The transition of the radius of mode field is also used to support our simulation.

7847-28, Session 3

New configuration of photonic logic gates based on single hexagonal-lattice photonic crystal ring resonator

J. Jiang, J. Wang, X. Xu, J. Li, Fujian Normal Univ. (China); X. Chen, Minjiang Univ. (China); Y. Qiu, Z. Qiang, Fujian Normal Univ. (China)

Photonic logic gates are fundamental building blocks in realizing all-optical signal processing system. Logic gates based on photonic crystal technology have attracted great attention due to their potential in offering compactness, ultrafast switching and low power consumption. We reported earlier compact logic gates based on 45°square-lattice photonic crystal ring resonator (PCRR) without introducing additional nonlinear material. It is very significant to further improve the defined logic '0' and '1'.

Here, we propose a new configuration of logic gates based on single hexagonal-lattice PCRR composed of cylindrical silicon rods in air. Two types of inner ring including regular hexagonal and circular are numerically discussed by using 2D finite-difference time-domain (FDTD) technique. The impact of surrounding periods and scatterers like size and relative phase at each input port was investigated. The logic '0' and '1' of circular ring type can be defined as less than 52% and greater than 85%, respectively, while for hexagonal ring, they can be defined as less than 17% and greater than 85%, respectively, much better than our early results. The simulation results also proved that photonic logic gates based on this new single PCRR can really function as NOT and NOR gates, respectively. These findings make PCRRs potential applications for all-optical logic circuits and ultra-compact high density photonic integration.

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7847-29, Session 3

Simulation on Mikaelian lens of triangular lattice photonic crystals using multiple scattering method

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Numerical studies using Multiple Scattering Method (MSM) on a graded negative index lens made by a slab of triangular lattice graded refractive index photonic crystal (PC) composed of air holes in dielectric background are reported. Firstly, we provide a simple model for the graded PC lens with linearly varying air holes along radial direction of lens which proves that this structure can lead to a graded-index distribution along the direction transverse to the propagation. Then, a PC Mikaelian Lens (ML) of which the refractive index distribution curve of along the radial direction is a hyperbolic secant. Our simulations show that the ML can be realized with a slab of PC with nanometers thickness.

7847-30, Session 3

Compensation of the influence of birefringence dispersion on a long distance distributed stress sensor using high birefringent fiber

H. Zhang, F. Shi, X. Chen, D. Jia, Y. Zhang, Tianjin Univ. (China)

Distributed stress sensor with a white-light scanning interferometer is used to detect stress distribution by analyzing polarization mode coupling caused by forces exerted on PMFs (polarization maintaining fibers). Because the propagation constant difference ( ) is wavelength dependent, and it leads to birefringence dispersion existing in PMFs. Due to birefringence dispersion, the polarization coupling strength measurement and spatial resolution of coupling point descends obviously with transmitted distance, especially in long distance PMFs. Two methods for compensating birefringence dispersion in sensing system are proposed. The first method is spectrum domain measurement. A Fourier-transform spectral interferogram and a polynomial curve fit are applied to retrieve the phase function. The birefringence dispersion of long high birefringence can be obtained by take the second derivative of the phase function. The experimental results show that the polarization coupling strength caused by the same coupling point doesn't almost descend with the transmitted distance. Another time domain numerical dispersion compensation algorithm is presented to calculate the coupling strength. The algorithm based on the interferogram envelope area is a constant thought the influence of birefringence dispersion on the PMFs, and the algorithm ignore the optical intensity loss propagate along the fiber. The interferogram envelope area can be obtained by the Hilbert envelope retrieval and nonlinear least square fitting. The experimental result show that the algorithm has a high accuracy, the absolute deviation is less than 1%.

7847-32, Session 4

Optical waveguide oscillating field sensor

Z. Cao, Shanghai Jiao Tong Univ. (China)

Evanescent wave sensor has been rapidly evolving by using schemes such as surface plasmon resonance, leaky mode waveguide, optical fiber and reverse symmetry waveguide (RSW). The common feature of the evanescent wave sensor is that the sample to be detected locates in the region where the evanescent wave of the resonant modes propagates. If N and ns represent the effective refractive index (RI) of the resonant modes and the RI of the sample respectively, the sensitivity of the sensor is usually defined by the change in N per change in ns, i.e., dN/d ns, which can expressed as

dN/d ns=(ns /N) (p/ ptotal) (1)

Where p is the mode power located in the sensing region, ptotal represents the whole power of the resonance mode. It is shown that the sensitivity of such sensors depend strongly on the power distribution of the resonance mode (p/ ptotal) and the ratio of the RI (ns /N). Apparently, there always have (p/ ptotal)<<1 and (ns /N)<1 for the evanescent wave sensors. Various platforms have been proposed to increase the mode power flows in the cover or substrate and therefore achieves optimum sensitivity to ns changes, such as reverse symmetry waveguide (RSW). However it is seriously limited since the most part of mode power locates in the guiding layer.

To address the issue of enhancing the sensor sensitivity, a new optical waveguide oscillating field sensors by using a symmetrical metal-clad waveguide (SMCW) with millimeter scale is developed in this paper. There are three substantial improvements relative to the evanescent wave sensors:

(1) Sample is not located in the cover or substrate, but in the guiding layer where oscillating wave propagates and most of the mode power concentrates;

(2) The ultrahigh-order modes (N 0) of the SMCW with millimeter scale is selected to act the sensing probe, in this case, (nsample/N)>>1 has been achieved;

(3) To prevent the disturbance caused by the power fluctuation of the light source, a large Goos-Hänchen shift is employed to replace the light intensity detection.

Expriments for RI, displacement and light wavelength detection with extremely high sensitivity have been performed. Biosensors with ultrahigh-order modes are underway.

7847-33, Session 4

1.54-μm electroluminescence from silicon-rich erbium silicate

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In recent years, erbium compounds such as erbium silicates have attracted much attention because of high Er3+ concentrations in order to achieve sufficient luminescence efficiency and net gain within very small size, which is promising to be used as the light source for integrated silicon photonics. Their efficient photoluminescence at 1.53 μm has been reported but their electroluminescence (EL) is hard to be realized directly due to their electric insulating property and the extremely low excitation cross section of Er3+. To overcome these limitations, we add excess silicon into erbium silicate to form silicon-rich erbium silicate (SRES) films on p-type silicon substrates by magnetron sputtering technique and then annealed at 850 oC in N2. Rutherford backscattering spectroscopy and Raman spectroscopy indicate that erbium silicates and excess silicon both in amorphous phases coexist in the SRES films. Efficient room temperature Er3+ 1.54 μm EL from the SRES device with a structure of indium tin oxide (ITO)/SRES/p-Si has been observed and studied. Its EL intensities are demonstrated to be markedly higher than those of the control devices without excess silicon and of the Er-doped silicon-rich silicon oxide device (ITO/Er:Si1+xO2 /p-Si) with the optimal silicon rich degree under the same forward-biased voltages.

7847-34, Session 4

Design of narrow channel spacing photonic wire AWG on SOI with three stigmatic points

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Arrayed waveguide grating (AWG) is a promising device for multi/demultiplexer in WDM system owing to its low insert loss, good uniformity, high stability and low cost. AWG consists of three different parts: phased arrays, input/output waveguides, and two free propagation regions (FPR).

In this paper, an accurate Fourier Optics method of designing AWG demultiplexer based on high-index-contract Silicon-on-Insulator (SOI) materials is presented. The typical SOI photonic wire waveguide has a cross section of 400×340nm2 satisfying single-mode condition, and operating central wavelength is equal to 1.5500um. When the channel number increases, there is a terribly bad spectral response, which is caused by the aberration of AWG. Thus, by reducing the aberration, the channel number can be improved, as well as the crosstalk of AWG. In this paper, a three stigmatic points --a method of aberration-free focal points is also applied in order to improve the accuracy, considering the aberration theory. At the same time, our AWG has another important characteristic--the flat field, which is convenient to connect with fiber-array on the straight focal line without output waveguides, and also can function as a spectrometer with well-polished end face.

In the example presented here, the design method mentioned above allows us to simulate a 1×256 channel AWG with 0.1-nm channel spacing. The simulation result shows that the insert loss is -8.5dB for the central and peripheral output ports as well, which represents a good uniformity. Free spectral region (FSR) equals to 30nm as designed. A better simulation result could be obtained by carefully choosing arrayed waveguides numbers and real input field instead of the Gaussian field here.

7847-35, Session 4

The transmission characteristics of a kind of chiral fiber Bragg gratings

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The development of high speed telecommunications networks and sensor systems has been accelerated by the using of fiber devices. The bandwidth and capacity of optical network were greatly exploited. However, there is still a great of demands on new type of fiber optic elements to fit the development.

In fact, the fiber elements with chiral configuration are not touched extensively, especially dielectrically chiral fiber devices. There are few reports on structurally chiral fiber in which the size of chiral configuration is comparable to the wavelength interested. Here, we study the so-called dielectrically chiral fiber, in which the size of chiral objective is much smaller than the wavelength, and we propose a kind of chiral fiber Bragg grating (CFBG). We study the filtering characteristics of a kind of CFBG which the permittivity is periodically distributed in a homogenous chiral background with sinusoidal modulation.

It is believed that CFBG offers promise for use in polarization filter, polarization controlled devices, polarization depended optical switches, even polarization sensors.

7847-36, Session 4

A novel high birefringence photonic crystal fiber with squeezed elliptical holes

P. Song, Univ. of Jinan (China); L. Zhang, Shandong Univ. (China)

A novel high birefringence photonic crystal fiber is proposed in this work. This PCF is composed of a solid silica core and a cladding with elliptical air holes and squeezed triangular lattice. The high birefringence is introduced on the combined effect of elliptical air holes, the squeezed lattice and the air holes of two sizes in cladding. Based on the supercell lattice method, our numerical results indicate that the birefringence can reach as high as 0.0019 at 1.55μm wavelength with a properly designed cladding structure, which is much higher than those obtained from conventional step-index fiber (10-4), circular air holes (10-3), and elliptical hollow PCFs (10-3). We also analyze the dependence of the birefringence on structure parameters, the squeezing radio of the triangular lattice and the elliptical radio of the elliptical air holes. To our knowledge, this is the first simulation studying the combined effect of elliptical air holes, the squeezed lattice and the different sizes of air holes in cladding in high birefringence PCFs.

7847-37, Session 4

The thermal analysis of polysiloxane rib waveguide

C. Wen, National Univ. of Defense Technology (China)

It is necessary to take some research into the thermal analysis of polymer waveguide, which is important to the interconnection among chips, in order to guide the improvement of the technics of conventional integration and make it more advanced. In this paper, we are successful in making a polysiloxane rib waveguide which is 21 cm long like a line, and laser can propagate along the rib area directly. In order to take some research in the compatibility between this waveguide and the integration technics, we analysis the thermal characteristics of the waveguide applying the Ansys software. We make the analysis model and the meshes of it. We also set the boundary conditions, and take some research in the thermal characteristics of the waveguide and its thermal distribution of its cross section according to the time. At last,

we get that the instantaneous high temperature can not affect the core layer. We also get that the temperature as high as 400° can not lasting more than 0.035 seconds. Those all conclusions are useful to the integration technics.

7847-38, Session 4

Principle and applications of Faraday-Fabry-Perot cavity

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Fabry-Perot (FP) cavity is a typical positive feedback device. For an inserted medium with specific effect FP cavity is able to magnify the effect by several orders of magnitude. Such property has been applied in many fields nowadays, such as Laser, ICLAS (Intra-Cavity Laser Absorption Spectroscopy), CRDS (Cavity Ring-Down Spectroscopy) and so on. However, the magnifications of the interaction length are less consistent with each other in the existing literatures. In addition, the amplification effect is mostly used in measurements of intensity parameters, such as absorption and reflection, but rarely reported in control of polarization of the beam. In this paper, we present a Faraday-Fabry-Perot (FFP) cavity made up of inserting a piece of Faraday material into FP cavity to realize polarization control, and describe its principle in detail with optical matrix analysis. The magnification expression of the Faraday rotation in resonant condition is calculated and also compared with previous conclusions. The result can be used in measuring Verdet constants of diamagnetic materials with weak Faraday effect. Based on this, two novel applications of the FFP cavity are proposed. The one is a new type of magneto-optical isolator based on passive FFP cavity. The other is a new type of difference-adjustable circular-polarization dual-frequency laser based on active FFP cavity. The principles of the isolator and the dual-frequency laser are analyzed. The quantitative relations between cavity length, Faraday rotation and isolation or frequency difference are given, respectively.

7847-39, Session 4

Optical Implementation of Tree-Type Interconnection Network Using Polarization Control Method

J. Wang, National Univ. of Defense Technology (China)

Tree-type network composed of optical splitters and optical combiners, according to the corresponding link rule, plays an important role in the all-optical communication and optical information processing. Based on the matured polarization control technology to realize routing and switching of signal beams, a novel tree-type interconnection network using phase spatial light modulator (PSLM), polarizing beam-splitter (PBS) and mirror, is proposed, including 1×2, 1×4, and 2×1, 4×1 switch elements. It is able to perform any arbitrary interconnection pattern, which has the advantages of compact in structure, efficient in performance, small size, and polarization-independent due to exploiting the building block pattern. The theoretical analysis shows the functional experimental prototype with large number of input/output ports should be helpful in the optimization and design of large-scale optical switch matrix.

7847-40, Session 4

Proposal and study on plasmonic Bragg reflector based on MIM waveguides

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A plasmonic Bragg reflector with rectangular-shaped transmission spectrum based on MIM (Metal-Insulator-Metal) waveguides is proposed and theoretically analyzed in this paper. As the MIM waveguide structure is treated as a cascade structure of multi-F-P cavities and by use of Transfer Matrix Method (TMM), the property parameters of the reflector is related to the structure parameters of grating, so that the performance index of reflector can be optimized. As an example, a wide bandgap reflector is designed by this method, the center-wavelength of it at 1550nm, the full width at half maximum (FWHM) of it at 640nm and the center-transmission of it approaching zero.

7847-41, Session 5

All-fiber laser for cylindrical vector beam

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In this paper, we proposed and demonstrated an all-fiber laser to generate CV beam. The laser system was composed of a fiber loop mirror, 977 nm pump laser, 980/1060 nm WDM, a couple of fiber based collimators, polarization controller, Yb-doped fiber, and a section of few mode fiber. A couple of fiber-based collimators were used to select the cylindrical vector beam operating. The radially and azimuthally polarized modes can be switchable just to apply pressure to a section of fiber in our fiber laser system. A 70 cm long Yb-doped fiber was used as gain medium and the lasing wavelength was around 1030 nm. By introducing misalignment of two fiber collimators, high order mode in few-mode fiber has been excited and oscillated in fiber cavity with sufficient gain. Fundamental mode was suppressed in this structure with proper transverse and angle misalignment.

According to our knowledge, it is the first time to report work of generating CV beam in all-fiber structure laser.

7847-42, Session 5

Studies on nonlinear loss and laser dynamics: from multiwavelength CW lasing to multi-pulsing transition

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Nonlinear loss plays an important role in laser dynamics. Saturable absorber is a nonlinear loss mechanism commonly used to mock-lock a laser to induce it to operate in pulse mode. Recently, we demonstrated experimentally that intensity-dependent loss can be used to alleviate the mode competition in a laser with homogeneous gain such that the laser can operate in multiwavelength cw mode. We also developed a simple iterative model which describes each component of the laser separately, rather than the whole laser together with a single master equation. Simulation results show that a laser with homogenous gain can operate in multiwavelength if the intensity-dependent loss exhibits saturable transmitter characteristics. Our results also show that for nonlinear losses that have both saturable transmitter and saturable absorber characteristics, such as in nonlinear optical loss mirrors (NOLM) or nonlinear polarization rotation (NPR), the multiwavelength output power spectrum can become very flat. The laser can also exhibit periodic and chaotic behaviors. We find that the same theoretical model can also be used to describe multi-pulsing dynamics of mode-locked lasers when the cavity energy increases. Near the multi-pulsing transitions, both periodic and chaotic behavior can be observed as operating states of the laser cavity. Our iterative model provides a simple geometrical description of the entire multi-pulsing transition behavior as a function of increasing cavity energy. The model captures all the key features observed in experiments, including the periodic and chaotic mode-locking regions, and further provides valuable insight into laser cavity engineering for maximizing performance.

7847-43, Session 5

Experimental measurements of ultrashort pulse from an all-normal-dispersion Yb-doped fiber laser with SHG-FROG using principal component generalized projections algorithm

C. Tu, Nankai Univ. (China)

The development of the means to measure ultra-short laser pulses has progressed rapidly these years. The traditional technologies, such as intensity autocorrelation, can only get partial information about the pulses. Recently two important technologies have been developed. They are called Frequency Resolved Optical Gating (FROG) and spectral phase interferometry of direct electric field reconstruction (SPIEDER). Both of them can measure the entire field of the pulses including intensity and phase. FROG is easier to construct than SPIDER, especially to SHG-FROG which is the same to the intensity autocorrelation in optical part. Meanwhile, SHG-FROG has better sensitivity than other FROG geometries. Because SHG-FROG involves only second-order nonlinearity while others use third-order optical nonlinearity, which is much weaker.

While SHG-FROG is experimentally simple, the phase retrieval algorithm can be a problem. The original FROG inversion algorithm is simple and iterates quickly, but tends to stagnate and give erroneous results to SHG-FROG for it uses a complex gate function. An improved method called generalized projection was made to overcome the stagnation in the phase retrieval algorithm. But it slows the speed to convergence. Recently, a new generalized projections algorithm has been developed called principal component generalized projects algorithm (PCGPA) .It iterates quickly, converges fast and works very well for SHG-FROG.

Recently all-normal-dispersion fiber laser has become a research focus, because it eschews the need of intra-cavity dispersion compensation, which made it easy to construct and generate higher pulse energy than self-similar lasers and prior soliton lasers. However, there has little experimental work and its temporal performance is not well characterized.

In this paper, we present the basic concept of PCGPA and use this algorithm in SHG-FROG to measure an all-normal-dispersion Yb-doped fiber laser built in our laboratory. The intensity and the phase of the pulse are derived which indicate the pulse have a large linear chirp and a duration of 40ps.

7847-44, Session 5

Research on the distortion of low duty cycle pulse amplified by erbium-doped fiber amplifier

C. Li, Y. Lu, X. Zhang, F. Wang, M. Chen, Nanjing Univ. (China)

In distributed optical fiber sensing systems such as Brillouin Optical Time Domain Reflectometer and Optical Time Domain Reflectometer, the probe pulse should be with the figure of high extinction ratio and low duty cycle in order to realize the sensing system with high signal-noise ratio and high spatial resolution. Generally, the output power of a normal commercial laser-diode is not high enough to meet the requirement of optical fiber sensing systems. Therefore, the probe pulse originated from laser-diode should be amplified before it is launched into sensing fiber. Erbium-doped Fiber Amplifier (EDFA) has significant advantages in all-optical amplification and can be used to amplify the probe pulse. However, we find that a kind of pulse distortion occurs in the amplification of the pulse of high extinction ratio and low duty cycle by use of an EDFA. Front part of the pulse obtains a much larger gain than the steady-state gain while the gain of back part is very small. The distortion apparently affects the dynamic range and the accuracy of the sensing system. However, the research on the distortion of the sensing pulse has not been reported before. In this paper, the recovery time, absorption time and concentration variation of the excited ion in a certain length of Erbium-doped fiber are theoretically analyzed with ion variation rate equation and propagation equation, and the cause of distortion is discussed as well. To verify the correctness of the theoretical analysis, pulses with different duty cycles are amplified by utilizing a bi-direction pumped EDFA with a 23m-long Erbium-doped fiber. The results observed in these amplification experiments agree well with the theoretical calculations.

7847-45, Session 5

Design and simulation of ultrashort pulsed waveguide lasers using single-walled carbon nanotube saturable absorber

H. Chen, C. Huang, Yangtze Univ. (China)

Ultrashort pulsed lasers offer a broad range of applications in various fields, such as optical communications, optical signal processing, laser-matter interaction, spectroscopy, biophotonics etc. ultrashort pulses in the picosecond regime are usually generated using mode-locked technology, two broad classes of mode-locking schemes, active mode locking and passive mode-locking, are typically used. Passively mode-locked lasers are among the best pulsed sources availabel due to their ability to generate transform-limited optical pulses in the picosecond and subpicosecong regimes. A passively mode-locked laser employs a nonlinear element, a device that possesses an intensity-dependent response to favor optical pulse formation ocer continuous-wave lasing. This ia usually a saturable absorber(SA). Compared with the conventional SAs, such as the semiconductor saturable absorber mirror(SESAM), single-wall carbon nanotubes (SWCNTs) have excellent performance, such as saturable absorption characteristics, strong thirdorder nonlinearity, ultrafast response time etc. The miniaturization and integration of photonic functional devices have stimulated the study of ultra short pulse mode-locking waveguide lasers.

In this paper, we propose an ultrashort pulsed waveguide laser using a carbon nanotubes saturable absorber integrated with gain medium, in which the carbon nanotubes saturable absorber is directly sprayed on the Er-Yb doped phosphate glass waveguide, a linear cavity is chosen. The lasing performance of the proposed waveguide laser are analyzed theoretically. The effects of the nonlinear coefficient, cavity dispersion and loss on the output characteristics of ultrashort pulsed waveguide laser are discussed.

7847-46, Session 5

Design and fabrication of InGaAsP electroabsorption modulated laser for wide temperature range operation

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We have demonstrated a novel InGaAsP-InP-based electroabsorption modulated laser by introducing tunnel injection quantum well structrue to achieve wide temperature range operation. Electrons directly injected into quantum well through tunneling a InP barrier, in order to reduce the leakage current and overcome the disadvantage of small conductive band offset in InGaAsP quantum well. The DFB lasers has obtained a characteristic temperature of 70K and a threshold current of 30mA at room temperature. The bandgap detuning of 80nm between laser and modulator was realized by low-cost quantum well intermixing method. The integrated devices operated with a slop efficiency of 0.08mW/mA and a output power from modulator end of over 5mW with laser current of 100mA. Owing to the tunnel injection quantum well structure, the modulator showed a prior static extinction ratio of over 10dB at 4V voltage swing, in which Franz-Keldysh effect was combined with

quantum confined Stark effect. With temperature raised, the red shift of exciton peak and the degeneration of extinction efficiency compensated well, making extinction ratio stable. Temperature insensitivity of the extinction characteristic exhibited wide temperature operation potential of our design.

7847-47, Session 5

The optical property of single eccentric split-ring resonator

Y. Wang, Institute of Semiconductors (China)

Surface plasmon resonance (SPR) is a prominent optical phenomenon, which involves the resonant excitation of plasmon or electromagnetic waves coupled with collective oscillations of free electrons over a metal/dielectric interface. Recently, metallic nanoparticle pairs of subwavelength patterns have been studied intensively due to their interesting optical properties and their potential applications in nanodevices. In this letter, the research focus on a single eccentric split-ring resonator (ESRR) and shows its some special optical characters.

The ESRR proposed are composed of a Au cylinder with radius of 100nm, on which a eccentric air hole is etched thoroughly. A TM light is incident from the left side. By using the two-dimensional finite-difference time-domain method, the influence of air hole size on the resonant peak is investigated firstly. Keeping the width of the split d as 10 nm, the radius of air hole r changing from 40 nm to 90 nm leads to the red shift of the peak. If r is a constant 80 nm and d varies from 10 nm to 110 nm, the peak shifts to shorter wavelength, i.e. blue shift. Fix the size d=10 nm and r=80 nm, the refractive index of air hole increasing from 1.0 to 2.0 causes the red shift of the peak.

Considering the variety of refractive index of air hole caused by injection of some bioliquid, the sensitivity of such single ESRR sensor reaches 1003 nm/RIU. In addition, if two light sources are placed near the outside surface of ESRR with the spacing of 20 nm, the same phases strengthen the interference of SP waves, while the opposite phases, one with 0 and the other with, weaken the interference. The extinction ratio reaches 220 db. These optical properties would benefit for the application of single ESRR in future integrated optoelectronic circuits.

7847-48, Session 5

The refractive index distribution of the even-numbered polygonal GRIN lens

Z. Zhou, Southwest Univ. of Science and Technology (China)

In order to solve this problem, this paper presents a regular hexagon self-focusing lens array, this array can be increased by the light area, reduce the leakage of information between the pore and thus greatly enhance the optical information transmission performance. However, an important link to solve this problem is to get regular hexagon self-focusing lens refractive index distribution. At present, generally using a numerical difference method numerical solution obtained, such results have not easily substituted into the formula and do not have a good explicability shortcoming. Therefore, this article on the hexagonal self-focusing lens refractive index distribution of the theoretical studies; proposed a solution model, using variable separation method and coordinate transformation solutions of obtaining the exact solutions. This compound eye imaging system to provide a favorable theoretical basis for further study.

7847-49, Session 5

Investigation on an off-axis fiber rotary connector

D. Jia, C. Ma, B. Hu, H. Zhang, W. Jing, Y. Zhang, Tianjin Univ. (China)

Fiber rotary connector is used to transmit a variety of optical signal through the rotary interface. Its counterpart is electrical slip ring. In some case of optical signal transmission, many objects, such as high-pressure air, water and even human being, are placed in the central axis. The optical signals are transmitted in the manner of off-axis. This type of rotary connectors is widely used in the field of ocean, medicine, transport system and military. We design a new off-axis fiber rotary connector using the annular optical component in this paper. The annular optical component has a spectral structure, which is utilized to couple the rotating optical signal into and out of the annular optical component. A model of the annular optical component is constructed in term of concept of Geometrical Optics. In order to verify the model, the model is simulated and analyzed by use of the FERD optical design software. The analysis results show that the optical signals transmitted into the annular optical component at different circumferential location can be received by a collimating optical system at a solitary location. The coupling efficiency is below 10% .

7847-50, Session 5

Theoretical model and simulation of bi-layered micro resonator on optical fiber top

Y. Liu, China Jiliang Univ. (China)

Micro resonator is widely used in micro-opto-electro-mechanical elements, such as micro-resonator sensors, micro-resonator switches, micro-modulators and etc. Normally the micro resonator is fabricated on silicon wafer by micro machined process, and then should be excited firstly by optical or electrical methods. The basic principle of this resonator sensing is that an environmental parameter (such as temperature or pressure) changes the resonant frequency, and then the environmental parameters can be detected by the change of the resonant frequency. Among all the exciting methods, optical excitation is the most interesting method owing to its special advantages of non-contact and non-destructive. For the traditional optically excited silicon resonator, there are some difficulties that baffle its practical applications, such as the accurate light coupled position between the micro resonator and the excited optical radiation. In this paper, a novel resonator structure is fabricated on the optical fiber top by carving tiny mechanical bridge resonator directly on the cleaved edge of an optical fiber. For these optical micro resonators, there are more great advantages comparing with the traditional optical excited micro silicon resonators, such as being positioned easily in such a way that the resonator covers the core of the optical fiber. By this way, the optical excited light LD coupled to the fiber core is thus put on the micro resonator accurately and then partially reflected by the Fabry-Perot interferometer formed between fiber top and resonator surface. The reflected light from F-P interferometer was back to the opto-electric detector PIN to demodulate the detected parameter indicted in Fig.1. A metal layer can be deposited atop of the resonator in order to increase the efficiency of the optical excitation. Firstly corresponding theoretical model is setup in this paper by One-dimensional Heat-flow Theory and the Thermal Theory of Elasticity, and then the typical character was simulated by computer including the resonating frequency analysis, the micro resonator dimension determination and metal coating optimization. In the end, an optimized micro cantilever structure is giver which can be applied in temperature sensing.

7847-51, Session 5

DFB fiber laser hydrophone based on a intensity demodulation

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DFB Fiber laser based sensors, including strain sensing, temperature sensing and acoustic sensing, have attached a lot interests because of high performance and small size. Their demodulation schemes are normally by using an optical spectral analyzer, or using a optical fiber interferometer and a PGC method, or observing the beat frequency of fiber laser. Here, we demonstrate an intensity modulated DFB fiber laser sensor. The theoretical analysis of the intensity modulation of the DFB fiber laser, including gain demodulation, feedback effect, and polarization demodulation, are given in detail based on rate equations. In the experiments, a DFB fiber laser is pumped with a 980nm laser diode through a WDM and its output power is monitored by a photo detector system and an optical spectral analyzer after passing an isolator. The DFB fiber laser is packaged in an aluminous frame to be used as a sensor head. We put the sensor head and a referenced B&K 8104 hydrophone in an anechoic water pool. The measurement results of the sound wave at the frequency range from 5kHz to 16kHz are demonstrated, which are limited by the anechoic water pool and the sound source, and the detected results of the proposed DFB hydrophone agree with the referenced hydrophone and the better SNR is achieved.

7847-31, Poster Session

The polarization properties analysis on photonic crystal fibers side-pulsed by CO2 laser

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We have theoretically investigated the polarization properties of an endlessly-single-mode photonic crystal fiber (ESM-PCF) provided by Yangtze Optical Fibre and Cable Company, which is pulsed one-side by CO2 laser resulting in partial air-holes collapse and deformation. An asymmetric waveguide structure caused by CO2 laser side-pulsed leading partial air-holes collapse and distortion, has a special performance on the polarization dependence loss (PDL) and the polarization mode dispersion (PMD). A full-vector finite-element method (FEM) with a perfectly matched layer (PML) is used to analyze the model structure for a deeper understanding on the polarization properties. This research provides an insight into the side-pulsed PCF as well as a guidance on the experiment of CO2 laser micro-fabrication on PCFs.

7847-52, Poster Session

Large blue shift of the absorption edge in modified potential InGaAs/InAlAs coupled quantum wells

Z. Xu, Zhejiang Univ. of Science and Technology (China)

For some optical waveguide devices, such as reflection type electro-optical switches, a negative electrorefractive index change Δn is often required.It is well known that a rectangular quantum well (RQW) has a large negative electrorefractive index change Δn caused by the quantum confined Stark effect (QCSE). However, due to absorption edge red shift, the large negative Δn is inside the absorption band where the absorption loss is too large for reflection type electro-optical switches. Coupled quantum wells can be an important candidate because a large exciton absorption change may be caused under low applied field. Five-step asymmetric coupled quantum wells and quasi-symmetric coupled quantum wells were studied, but the excitonic absorption edge in these structures was still red shift. Fortunately, other coupled quantum well structures with blue shift of the absorption edge induced by external electric field have been studied. These predict a negative electrorefractive index change can be obtained in longer wavelength region of the absorption edge.In this paper,we have studied the electric field effects in excitonic absorption edge in the modified potential InGaAs/InAlAs coupled quantum wells. The observed maximum blue shift of the absorption edge reached is 35 meV at -4 V. This indicates that a large negative refractive index change will be produced in longer wavelength region of the absorption edge. It is very useful for reflection type electro-optical switches.

7847-53, Poster Session

Effect of buffer layers on the performance of P3HT:PCBM solar cells

W. Li, J. Guo, B. Zhou, X. Sun, Shenzhen Univ. (China)

We have studied the effect of buffer layers on the performance of poly(3-hexylthiophene-2,5-diy1) (P3HT):C61-butyric acid methyl ester (PCBM) bulk heterojunction solar cells. We proved that depositing a thin pentacene layer between metal cathode and P3HT: PCBM blend, synchronously, introducing a thin P3HT layer between ITO and photoactive layer, would improve the power conversion efficiency of polymer bulk heterojunction solar cells when compared with the cells without the buffer layers. In the study, the buffer layers increased short circuit density (Jsc) from 0. 93 mA/cm2 to 1.3 mA/cm-2, open circuit voltage (Voc) from 0.53 V to 0.56 V, fill factor(FF) from 35% to 43%,and power conversion efficiency from 0.56% to 0.71%under the illumination by white light from a solar simulator with an incident intensity of 100mW/cm2. The thin pentacene layer as a cathode buffer layer provided an additional path of electron transfer from P3HT to pentacene, although that pentacene can transfer photogenerated electrons to cathode near the interface between pentacene and cathode. The thin layer of P3HT as a anode buffer layer greatly the short circuit current density of the solar cell through the creation of an extra donor/acceptor interface close to the bottom of the composite. Additionally, this layer substantially increased the electron blocking capability, leading to a large increment of the rectification ration of the cell. The thin pentacene layer and the thin P3HT layer were responsible for the improvement on the performance of photovoltaic device.

7847-54, Poster Session

The 3D buried optical splitter under non-uniform electric field

Z. Zhou, Southwest Univ. of Science and Technology (China)

We fabricate from a 1μm Inclined surface on glass under different processing temperatures with an applied voltage. The applied voltage is 40V and 3D optical waveguides by field-assisted ion exchange onto the 2 mm-thick substrate. The applied electrical field also drives the Na+ ions out of the glass substrate so the Cs+ ions can later move in to fill up the vacant sites. The lowest attenuation measured was found to be 0.1 dB/cm among the samples fabricated at 1550 nm wavelength using the edge coupling technique. We believe that further refinement on the lithographic and etching processes and adjustment on the process will reduce the attenuation. Fore waveguides of such depth, 0.1dB/cm is considered to be relatively low and is good enough in many optical propagation applications. The results on the waveguide depth and index change are very consistent among samples. Thus, this process is very reproducible.

7847-55, Poster Session

Calculation of electromechanical coupling coefficient of quartz crystal in decoupling plane

K. Yu, T. Liu, Beijing Univ. of Technology (China)

Quartz crystal is a good piezoelectric crystal and it can be used as substrate of surface acoustic wave (SAW) devices. How to cut the substrate crystal is important in design of the SAW devices. In this paper, SAW basic equation group strengthened by piezoelectric effect and boundary condition equation group including mechanical boundary conditions and electric boundary conditions are deduced. The electric boundary conditions have two kinds: free boundary condition and short- circuit boundary condition. Two kinds of SAW velocities using the two kinds of electric boundary conditions are systematically calculated for the Quartz crystal respectively in decoupling of yz plane, where the SAW is formed through coupling between electric wave and only one mechanical wave. The SAW velocities are calculated using a circle iterative method, which calculation velocity is quick and calculation precision is high. Electromechanical coupling coefficient is calculated using these two SAW velocities in yz plane of the Quartz crystal. The optimum cut direction of the substrate of the SAW devices is determined by the direction of the largest electromechanical coupling coefficient. Calculation results indicate that the maximum electro-mechanical coupling coefficient is 0.2885 at direction, which makes an angle of 73° with y axis, in yz plane of the Quartz crystal. In this case, the corresponding velocities under the electric free boundary condition and electric short-circuit boundary condition are 3989 m/s and 3823 m/s respectively. The calculation results lay a solid foundation for design and manufacture of the SAW devices. The job has theoretic guiding significance and practical value.

7847-56, Poster Session

Ultracompact channel filters based on race-track photonic crystal ring resonators

X. Xu, J. Wang, J. Jiang, J. Li, Fujian Normal Univ. (China); X. Chen, Minjiang Univ. (China); Y. Qiu, Z. Qiang, Fujian Normal Univ. (China)

Optical channel drop filters (CDFs) with high spectral selectivity and compactness are highly desirable for next-generation optical fiber communication systems and sensor systems. Owing to their potential scalable ring sizes, flexible coupling and size-independent propagation loss, recently, CDFs based on photonic crystal ring resonators (PCRRs) have attracted great attention. The reported PCRRs are mostly based on standard quasi-ring, eg, 3x3 ring.

Here, we propose a new configuration of CDF based on race-track two-dimensional (2D) PCRR composed of square-lattice cylindrical silicon rods in air. Considering the direction of race track and bus channel waveguide, two representative scenarios, i.e., parallel and perpendicular, were comparably studied. Their characteristics were numerically analyzed by using 2D finite-difference time-domain (FDTD) technique. The impact of scatterers like amount and size on mode behavior of intrinsic ring resonators was firstly analyzed to determine a good set of parameters with adequate modal spacing. The impact of surrounding periods, race-track ring size, coupling strength on the spectral property of above two CDF configurations was subsequently investigated. More than 300 spectral quality factor and 91% dropped efficiency can be achieved at 1372-nm channel for one single race-track PCRR. These findings enhance and enrich the PCRRs as an alternative to current micro-ring resonators for ultra-compact WDM components and high density photonic integration.

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7847-57, Poster Session

Influence of varied doping structure on the photoemissive property of photocathode

N. Jun, Nanyang Institute of Technology (China)

Previous investigations have shown that varied doped GaAs photocathodes can form build-in electric fields directional from the GaAs bulk to the surface within the material. Under the action of the build-in electric fields, photoelectrons may move towards the surface by the two ways of diffusion and drift, which enhance the quantum efficiency of cathode remarkably. However, the essential reason for the increase of quantum efficiency is either the increase of the amount, or the improvement of the average energy of the photoelectrons reaching the cathode surface, which has no clear understanding. In this paper, we studied the energy distribution of the photoelectrons, and analyzed the influences of the varied surface doping consistence on the width of surface band bending region, the energy distribution of the photoelectrons reaching the cathode surface, and the efficiency of the photoelectrons escaping from the surface to the vacuum. By combining with the quantum efficiency curves of the photocathodes obtained from experiments and using contrast study method to the uniform doped photocathode, we analyzed and discussed the influence of varied doping structure on the transport of the photoelectrons in the bulk. The result shows that the essential reason for the improvement of the cathode quantum efficiency is the increase of the amount of the photoelectrons reaching the cathode surface. This study result has an important reference value for advancing the understanding of the photoemission process of varied doped GaAs photocathodes.

7847-58, Poster Session

Ferromagnetism in transparent thin film of Co-doped ZnO

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Transparent thin films are made by PLD (pulsed laser deposition) at different oxygen pressure. The various property of samples is measured by X-ray diffraction (XRD), Hall effect, alternating gradient magnetometer(AGM), X-ray photoelectron spectroscopy(XPS) and optical transmission spectrum. All samples retain original structure in wurtzite lattice, and became n-type semiconductor films with the room-temperature ferromagnetism in electricity. But transparency of thin films and cobalt content have altered for the magnetism result of the thin films greatly in PLD with the oxygen pressure or not, which is shown that the oxygen pressure has impacted on the transparency of the film, doping concentration and magnetic aspects.

7847-59, Poster Session

Research of broadband waveguide amplifiers based on long-period waveguide grating and multilayer medium thin film

H. Chen, C. Huang, Yangtze Univ. (China)

Integrated broadband amplifiers based on Er-Yb co-doped phosphate glass have attracted increasing attention for their potential for reducing the cost and size of 1.55μm amplifiers and applications in fiber-to-the-home systems, and WDM system. The gain flattening bandwidth of Er-Yb co-doped waveguide amplifiers(EYCDWAs) is determined by the absorption and emission coefficient of host laser glass, and its gain spectra exhibit inhomogeneous broadening, except for the deleterious main peak at ~1532nm, there exist some other minor peaks. In order to achieve a flat gain spectrum several techniques have been developed

such as gain saturation, advanced materials, multilayer medium thin film(MMTF), long-period waveguide grating (LPWG),and so on. Among developed techniques, external filters such as MMTF and LPWG have been found most effective. The transmission spectrum of MMTF (or LPWG), however, mismatches the inverse gain spectrum of EYCDWAs, the advantage of single MMTF (or LPWG) is not very obvious. Single MMTF (or LPWG) is mainly used to suppress the main deleterious gain peak at ~1532nm, although it has some influence on the other minor peaks, the influence is limited.

In this paper, we propose an integrated broadband waveguide amplifier based on long-period waveguide grating and multilayer medium thin film filter. The light transmission characteristics of the proposed filter are analyzed theoretically. The effects of the transmission spectra of the filter on the flattening gain spectrum of Er-Yb codoped phosphate glass waveguide amplifier are discussed. It's demonstrated that the flatness of below 1dB is achieved over a bandwidth of ~ 30 nm.

7847-60, Poster Session

Amplification of evanescent waves in waveguides with an anisotropic metamaterials layer

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We have studied the amplification of evanescent waves consisting of an anisotropic metamaterials layer with double-negative of permittivity and permeability. It is found that metamaterials can enhance the amplitude of the evanescent waves for both TE and TM modes provided the surface polaritons conditions are satisfied. After the characteristic equations being derived, we examined the amplification of evanescent wave from three aspects: the electric field profile for each layer, the variation of the amplification factor and the power flux fraction with the thickness. This treatment reveals that both the amplitude of evanescent waves in the cladding layer and the amplification factor increase exponentially with the thickness of the metamaterials, but the amplification factor saturates when complete surface polaritons are established at the interfaces between the metamaterial and the cladding. In order to further explore the enhancement effect, a detailed discussion was given on the variation of the power flux fraction in cladding with the thickness, which is also a way to validate the saturation of the amplification factor. Finally, numerical results confirm our analysis.

The amplification of evanescent wave may have potential applications in integrated optical devices, such as optical direction couplers and waveguide sensors, which are based on the interaction associated with evanescent waves. With the enhancement, it may improve the efficiency of the signal translation or improve the performance of these optoelectronic devices. On the other hand, it may reduce the thickness of these optical waveguide structures, even well below the wavelength of light used.

7847-61, Poster Session

Hydrophone based on the feedback effect of composite cavity optical fiber laser

Q. Hao, Q. Chai, X. Li, J. Zhang, Q. Li, Harbin Engineering Univ. (China); P. Lu, Communications Research Ctr. Canada (Canada); G. Peng, The Univ. of New South Wales (Australia)

We proposed a novel optical fiber hydrophone based on the feedback effect of a composite cavity optical fiber laser (CCFL) and a corresponding intensity demodulation scheme. The intensity modulation of the CCFL is caused by the modulation of the CCFL feedback which is introduced by the end face reflection of the single mode optical fiber. The CCFL is composed by three FBGs with the same Bragg wavelength of 1548nm and the Er3+ doped optical fiber of 20cm in length. A 980nm laser diode is used to pump the CCFL from one side of the CCFL. The CCFL output is monitored by a photo detector system and an optical spectral analyzer after passing an isolator. We splice normal SMF28 optical fiber of 150m in length on the other side of the CCFL and a section of the cladding removed single mode fiber is twisted on a rubber cylinder of 3cm in diameter which is used as a sensor head. When there is any pressure on the rubber cylinder, the optical-elastic effect of twisted optical fiber will introduce the intensity modulation of the CCFL because of the feedback modulation. The demodulation scheme is realized based on the intensity modulated spectrum of the CCFL and a Fast Fourier transform (FFT) technology. We put the sensor head and a referenced B&K8014 hydrophone in an anechoic water pool. When an acoustic wave is produced in the pool, the acoustic signal is detected by the CCFL hydrophone and the B&K hydrophone at the same time. The signal of the CCFL hydrophone agrees with the B&K hydrophone's, and its signal and noise ratio is better.

7847-62, Poster Session

Eight-channel reconfigurable optical add-drop multiplexers based on micro-ring resonators on silicon-on-insulator substrate

Y. Tian, R. Ji, Z. Lei, L. Jia, L. Yang, Institute of Semiconductors (China)

We experimentally demonstrate an eight-channel reconfigurable optical add-drop multiplexer based on micro-ring resonators controlled through thermo-optic effect on silicon-on-insulator substrate. The device is compact with a footprint of 3000 mum x 1100 mum,which can be further decreased by optimizing the device structure. The tuning range is more than 16.8 nm, which cover the full free spectra range of the device (14.3nm). The response speed of the device is about 34 kHz and the average tuning power efficiency about 7.839 mW/nm. The minimum insertion loss is about 9.3 dB, which includes the transmission loss of the device and the coupling loss between the device and the lensed fiber.

7847-63, Poster Session

Tunable localized modes in random medium by means of external magnetic fields

W. Hong, Z. Wan, China Univ. of Geosciences (China)

Using a transfer matrix method, we demonstrated tunable localized modes in magnetic random medium by applied an external static magnetic field. The system consists of a multilayer film which alternates ferrite. The localized-modes characteristics of this random medium, such as location and width, can be tailed by altering magnetic permeability tensor. This structure can be achieved by employ magnetic medium such as ferrite. This study is an importance for well understanding of localization of light wave and lasing action in random media.

7847-64, Poster Session

Analysis of clustering in Eu(DBM)3Phen polymer optical fibe by effective-medium approximation

Z. Feng, Z. Zheng, L. Lin, Fujian Normal Univ. (China); H. Ming, Univ. of Science and Technology of China (China)

In this paper, the chromatic dispersion and absorption characteristics of fractal clusters of Eu3+ ions in Eu(DBM)3phen-doped POF slice

were explored. The dielectric components with clustering and without clusters in this kind of POFs were studied based on the effective-medium approximation (EMA) and the differential effective-medium approximation (DEMA). The transmissions of this kind of POF slices in two different situations were analyzed and compared theoretically. Using near-field scanning optical microscopy (NSOM), the near-field light intensities of this kind of POF slice were measured, and agreement was obtain between experiment and theory. The result indicates that the clustering in this kind of POF is not obvious.

7847-65, Poster Session

Research of thermal stress between long linear MCT arrays and lead board using FEM

W. Wu, W. Xia, D. Liu, Shanghai Institute of Technical Physics (China)

For the long wavelength infrared detection, HgCdTe (MCT) photoconductive detector is selected as the core of next generation sounder as it is more mature than photovoltaic one. In its assembly process, an innovative ceramic multilayer lead board providing mechanical support is designed as the electrical interconnection between MCT and drive circuits for cryogenic application. However, long linear MCT is supposed to be adhered to sapphire substrate by special glue due to its brittleness. It clearly shows that structure of assembly has a multilayer configuration which comprises various kinds of materials including lead broad, sapphire, HgCdTe and glue. Thereby, the difference of thermal expansion between the layers has the potential to introduce thermal stress at working environmental temperature (approximately 60K) which probably results in degradation of device performance and even crack.

This article analyzed the thermal stress between long linear MCT arrays and lead board using Finite Element Method (FEM). According to the result of analysis, the thickness of sapphire substrate, the Yong's modulus of epoxy and the coefficient of thermal expansion (CTE) of electrical lead board played an important role in the introducing of thermal stress. However, generally speaking, the structure of MCT detector was determined by the manufacture technology and system requirements. In order to improve the reliability of linear MCT and reduce the issued thermal stress, appropriate thickness and material of lead board as well as glue were chosen. Finally, an optimal design of assembly structure was demonstrated.

7847-66, Poster Session

Magnetooptical effects in surface plasmon waveguides

X. Wu, China Jiliang Univ. (China)

A surface plasmon-polariton (SPP) is a surface electromagnetic wave supported by a single or multiple metal-dielectric interfaces when the real parts of a dielectric and metal permittivity are of opposite signs at the operating wavelength. Recently, a variety of integrated optical devices based on surface plasmon waveguides, such as optical attenuators, modulators, switches, etc., have been demonstrated. Magneto-optic isolators used to protect the semiconductor lasers from unwanted reflected light play an important role in optical communication technique. Magnetooptical effects in surface plasmon waveguides are discussed in this paper. Two different structures of metal magneto-optic waveguide are investigated based on the analysis of surface plasmon waveguide and magneto-optic waveguide. The length to achieve a nonreciprocal phase shift difference of 90 is compared with the propagation length. Metal waveguide with magneto-optic cladding layer is the ideal structure to make isolators. Nonreciprocal phase shift and nonreciprocal loss are calculated depending on the real and imaginary part of the metal dielectric constant. Larger nonreciprocal phase shift and nonreciprocal loss can be achieved when the metal layer has larger the real part of the dielectric constant. As the imaginary part of the metal dielectric constant increases, the nonreciprocal phase shift decreases slowly, while the nonreciprocal loss increases. The real part of the metal dielectric constant has a larger impact on the nonreciprocal phase shift and less impact on nonreciprocal loss compared with the imaginary part of the dielectric constant.

7847-67, Poster Session

Analysis on the Gaussian approximation for the far-field of optical fiber

L. Li, F. Guo, Fujian Normal Univ. (China)

As the most basic parts, optical fiber has been widely used in all kinds of fiber optic communication devices. It always attracts our researching interest. Because the near-field and far-field satisfy the relationship of Fourier transform and the far-field is easy to measure, the near-field is often obtained according to the far-field. Thus, research on the diffraction far-field has important meaning in practical applications.

We begin by investigating the diffraction far-field of single-mode fiber and find that conclusions are too complicated to be used easily. Since the Gaussian beam theory is so simple and perfect that Gaussian approximation for it is researched again. First, beam propagation factor of the far-field is analyzed and then rationality of Gaussian approximation for the far-field is explained. Next, question is how to determine its divergence half-angle. There are two kinds of definitions for divergence half-angle based on the second-moment and differential operator method. Through analyzing the matching efficiency between the far-field and Gaussian field, numerical data show that they are not optimal enough.

Further research leads to a new definition of divergence half-angle in terms of the maximal matching efficiency method. Numerical calculation indicates that it is more precise than the other two. Moreover, a formula of the maximal matching efficiency divergence half-angle as function of normalized frequency is given according to a mathematical model and solving linear equations.

7847-68, Poster Session

Design of planar lightwave interleavers based on Echelle gratings structure

W. Liu, North China Univ. of Technology (China)

This paper reports the design procedure of planar lightwave interleavers based on echelle gratings structure, introduces two methods to eliminate the device aberration, two-point aberration-free design and elliptical grating facets design. Simulation results show that the device insertion loss and crosstalk can be effectively reduced by aberration compensation design. Design example is given in this paper. A design example of 50/100GHz interleavers are displayed on the SOI (Silicon-on-insulator) materials. The performance difference is compared between pre-post device using compensating design.

7847-69, Poster Session

Study of vacuum packaging technology for uncooled focal plane array

D. Liu, Q. Xu, Shanghai Institute of Technical Physics (China)

Uncooled focal plane array (UFPA) has broad application prospects in civilian and military because it's cheaper, more compact and high reliability. Many research institutes and companies have carried out the research of uncooled focal plane array. Texas and ULIS developed amorphous silicon technology, and Honywell developed vanadium oxide

technology. These two kinds of technology are the most mature ones. Both techniques require the chip working in a vacuum environment. Vacuum packaging is one of the key technologies for such detectors.

This paper shows a vacuum package design, and its architecture will be given. The assembly is an all-metal vacuum package with 42 feed-troughs, a single stage thermoelectric cooler (TEC), a getter, a cover, and an anti-reflective coated Ge window. This kind of structure has been proven rugged and reliable. The designed assembly can withstand process temperatures up to 150 . Package size can make adjustments to meet the 640×512 (pitch 35μm) and below requirements.

Out-gassing, permeation, evaporator, and air leak are factors to reduce the component vacuum lifetime. Theoretical analysis shows that material out-gassing is the main factor of pressure rise inside package. To accommodate lower out-gassing rate, appropriate vacuum bake out is need. Theoretical analysis and calculation show that designed metallic structure can meet the need of 10-year life.

7847-70, Poster Session

Numerical simulation and analysis of the sensitivity of strength-based optical fiber sensors

J. Dai, L. Lu, D. Jin, G. Wang, X. Wu, Anhui Univ. (China)

In this paper, numerical simulation and analysis of the sensitivity of strength-based optical fiber sensors have been reported .The simulated results show that suitable operating point can improve sensitivity of the system greatly even up to 2.1%. This conclusion can provide theoretical support for optimizing actual strength-based optical fiber sensors with higher sensitivity.

7847-71, Poster Session

Design and simulation of pulse control signal generator for the electro-holographic optical switch

Y. Song, J. Ji, W. Dou, National Univ. of Defense Technology (China)

The electro-holographic optical switch based on the quadratic electro-optic effect in paraelectric photorefractive crystals requires driving signal of fast pulse. The pulse rise/fall time and voltage are 10E-10-10E-8s and 10E2-10E3V, respectively, depending on the applications. A pulse control signal generator for the electro-holographic optical switch was designed and simulated. Considering the integration of pulse signal generator and the switch, the circuit employs two parallel compact fast Marx generators utilizing bipolar junction transistors operated in the avalanche mode. These transistors are mounted on microwave structure board. According to the simulated results, the output voltage ranges from 10-10E3V. The rise/fall time of this pulse is less than 10 nanoseconds. The pulse width is 30 nanoseconds, trigger jitter is ±50 picoseconds, trigger delay is about 2 nanoseconds. The repetition rate is less than 30MHz. The simulation indicates that the pulse signals from the designed generator can match the application of electro-holographic optical switch well.

7847-72, Poster Session

A novel optical approach based on subjective speckle for tracking on smooth glass

D. Lei, Univ. of Science and Technology of China (China)

This paper presents an improvement approach to realize tracking on smooth glass surface based on subjective speckle. The scattering mechanism on glass surface is analyzed and the affection on tracking precise and range for tracking with subjective speckle is researched. The speckle cached by CCD just from the upper surface of the glass is achieved by grazing incidence of the laser beam and the noise mixed with the signal is eliminated by a barrier above the surface. Based on the apparatus of subjective speckle tracking, the speckle contrast is improved from 0.25 to 1.25 by non-Gauss effect and the range of the tracking has been increased from 180 μm to 400 μm compared with the objective speckle method on the same condition.

7847-73, Poster Session

A modified squeezed radio model of squeezed photonic crystal fibers

P. Song, Univ. of Jinan (China); L. Zhang, Shandong Univ. (China)

The squeezed photonic crystal fibers (SPCF) have attracted significant attention. SPCF is a kind of photonic crystal fiber with squeezed lattice or elliptical air holes in cladding. So far there is no a universal concept to describe the squeezed degree, which is quite disadvantageous to study the influence of the squeezing on the SPCFs' characteristics. We introduce the concept of the modified squeezing ratio (MSR) to describe the squeezed degree of SPCF, and then present a corresponding model. Using this model, we investigate the influence of the structural parameters, such as lattice constants and elliptical degree of air holes, on the birefringence characteristics of photonic crystal fibers based on the supercell lattice method. Simulation results show that the squeezing of SPCFs' lattice with the elliptical air-holes in the cladding can break the multi-fold symmetry of SPCFs and make SPCFs highly birefringent. Furthermore, it is reported for the first time to our knowledge that the complex influence of the lattice constants and the elliptical air holes on the SPCFs' birefringence is discussed.

7847-74, Poster Session

Fabrication of polysiloxane optical ridge waveguides for optical interconnection

X. Feng, National Univ. of Defense Technology (China)

In this paper, large core (70×50μm2) and long multimode optical ridge waveguides are fabricated by the methods of soft molding and simple replication with the Polyvinylidene fluoride (PVDF) and the polysiloxane materials. Both transparent polysiloxane materials used for the core layer and the cladding layer are low loss and high temperature stable (> 250°C) materials. The transmissivity of polysiloxane materials bulk samples are measured by the spectrophotometer. Their propagation loss has been measured to 0.02-0.05 dB/cm in the 850nm wavelength window. The fabrication processes is based on transferring patterns of waveguides core layer to cladding layer using an elastomeric PVDF mold. PVDF is a kind of thermoplasticity fluoroplastic which provided diversity usages. The PVDF film is an excellent elastomeric material, and is easy to separating from other materials. The length of fabricated waveguides is more than 20cm, and the fabricated waveguides shows the fine performance when light pass through waveguide. The optical propagation loss of waveguides is 0.14dB/cm measured by the cutback method and 0.13dB/cm measured by CCD camera photographing method at 632.8nm. The large core and long multimode waveguide fulfils all requirements for a successful development of large size electrical optical circuit board production. This may be offer a low cost mass production solution to high-speed fully embedded board-level optical interconnects.

7847-75, Poster Session

A narrow line-width single longitudinal mode fiber laser and its frequency instability measurement

W. Ji, S. Chen, L. Fu, Beijing Institute of Technology (China)

Fiber laser has been widely used because of its properties of low threshold, narrow line-width and compact volumn. Modern technologies, especially coherent detection and dense wavelength division multiplex, have critical requirements for long term laser frequency instability. Because of that, frequency stabilized fiber laser with narrow line-width have been investigated by many researchers. This article has presented a kind of erbium-doped fiber lasers, which is operated in single longitudinal mode, and meanwhile the line-width of the laser is under the order of kilohertz by using a saturable absorber. Then a proposed self-beating heterodyne method has also been introduced to examine the instability of the laser frequency. The self-beating signal and frequency spectrum are shown in this part. Finally, the experimental data have been smoothed by FFT filter per five points, and an extraordinary result is observed. We obtain and discuss the relationship between laser frequency instability and the length of optical fiber time delay line. In conclusion, we have reported a simple and reliable method for measuring the frequency instability of a narrow line-width single longitudinal mode fiber. Researchers can measure the frequency instability of fiber laser quite easily according to our method. What's more, the results of this paper play an important role in our further work, which is the realization of frequency stabilized fiber laser with narrow line-width.

7847-76, Poster Session

Research on C+L band multiwavelength fiber laser

L. Zhang, M. Hu, Tianjin Univ. (China)

Abstract In this paper,a multi-wavelength source for dense wavelength division multiplexing transmission systems was studied. A theoretical model for the C+L band multi-wavelength fiber laser was constructed. The stable output of the laser versus injected current was numerically simulated and analyzed. A multi -wavelength fiber ring laser with One-way feedback signal was constructed by using two cascaded semiconductor optical am-plifiers as the gain medium and a high birefringence fiber loop mirror (Hi-Bi FLM) as wavelength filter. The ratio of the coupler in the laser cavity was changed separately. Different coupling ratios on the impact of mul-ti-wavelength output were analyzed. The output 27 wavelengths within 6dB bandwidth and the output 16 wave-lengths within 4dB bandwidth spacing on 100GHz were obtained. They were all basically in the C+L band.

7847-77, Poster Session

A LED-induced capillary fluorescent detection device designed for the space lab

X. Lee, Beijing Institute of Technology (China)

Many detector devices based on the LED-induced principle were developed, but there are still many problems in key parts, such as the match between the detect window and capillary and optical fiber, Excitation light intensity and Stray light noise. So how to reduce the influences of these problems and meet the requirements of the space became the key factors to make such device to be used in the space lab.

Based on the idea of modular design, this equipment is composed of four parts: the exciting light module, the light couple module, the emission light collection module and the signal procession module.In the exciting light module, the LED are carefully selected to avoid the spectrum crosstalk, the excited light are first coupled into an optical fiber. In the light couple module, the excitation light is couple on the capillary with a precision machined platform. In the emission light collection module, the fluorescence light is coupled on the detector through a objective lens and long-pass filter. In the signal processing module, the MSP430F449 is selected as the microcontroller, and a photodiode as photodetector is used as the detector,meanwhile,the result is acquires by an auto-zero and high precision 24-bits ADs chip correspondingly. The whole equipment can communicate with the host by RS232 or CAN 2.0 bus. Application of the equipment for the analysis of FITC-labeled protein separated by capillary electrophoresis was demonstrated.

7847-78, Poster Session

Multiphoton upconversion emission switching in Tm,Yb codoped nanocrystalline yttria

L. Li, X. Zhang, Y. Peng, B. Jiang, M. Nie, Harbin Engineering Univ. (China)

Frequency upconversion emission of infrared to visible/ultraviolet by trivalent rare-earth-ion doped materials has attracted intensive attention for more than 30 years, because of its potential applications for frequency conversion, upconversion lasers, multicolor display, optical cooling and detection of infrared radiation. Recently, nanosized upconversion luminescence materials have been deeply focused for enhancing upconversion luminescence efficiency and exhibiting novel photophysical phenomena due to high surface-to-volume ratio and quantum confinement effect of nanometer materials. Among the candidates of upconversion nanomaterials, dopant nanocrystalline yttrias have been widely studied because of high chemical durability and thermal stability. In this work, we have experimentally studied multiphoton upconversion luminescence (UL) properties from the Yb3+-sensitized Tm3+ ions in nanocrystalline yttria host under 973nm laser excitation. The samples used for our experiment were prepared by a simple sol-gel method. Bright pure blue luminescence in the visible spectral region is performed even at low pump excitation level. We have measured and analyzed the change of upconversion emission spectra from the Yb3+-sensitized Tm3+ ions at various 973nm excitation levels. An interesting chromatic switching behavior is observed for the near-infrared and blue spectral bands at room temperature, showing a pump intensity-controlled emission wavelength switcher. The operation mechanism, with a simplified six-level rate equation model, is discussed by taking into account the multiphoton energy transfer upconversions of Yb3+ ions to Tm3+ ions. The chromatic switching is intrinsically associated with the competition of two-photon UL and three-photon UL processes.

7847-79, Poster Session

Research on ultrawideband wavelength tunable erbium doped fiber ring laser

Q. Wang, Northeastern Univ. (China); Q. Yu, Dalian Univ. of Technology (China); Y. Zhao, Northeastern Univ. (China)

A broadly tunable erbium-doped fiber ring laser is investigated through theoretical modeling and experiment. A numerical model based on an iterative solution of propagation rate equations is used to analyze the dependence of laser output power on total cavity loss, erbium-doped fiber length and output couple ratio. The numerical results are in good agreement with the experimentally obtained data. The results indicate that minimization of the intra-cavity loss as well as optimization of the erbium-doped fiber length and the output coupling ratio is very

important. A S+C+L band tunable range which covering 135nm is achieve. This ring fiber laser has a flat, stable output spectra and better than 60 dB signal-to-ASE-noise ratio.

7847-80, Poster Session

Wavelength-switchable erbium-doped fiber ring laser employing chirped Moiré fiber grating and tunable Sagnac loop interferometer filter

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Fiber lasers exhibit many attractive features such as inherent single transversal mode and compatibility with optical fiber systems. In recent years, there is a surge of interest in multi-wavelength and wavelength-switchable fiber lasers, since they are potentially useful for dense wavelength division multiplexed (DWDM) fiber communication systems, optical fiber sensor networks and instrumentation. The most important key component of these fiber lasers is a wavelength selection filter. Among versatile techniques to realize the wavelength selection filter, a fiber Bragg grating (FBG) is an ideal intra-cavity device to select the lasing wavelength.

In this letter, the chirped Moiré fiber grating (CMFG) is used to help implement wavelength selection. The CMBG is an ideal transmissive comb filter with stable wavelength spacing, narrow filtering bandwidth and uniform channel transmittance; and it has extra advantages of easy fabrication, compactness and flexible tuning of wavelength interval within a large band depending on the chirp value.

A tunable Sagnac loop interferometer (FSI) filter is adopted to substitute the high-cost filter that contains an optical circulator.

With the help of these two main components, stable wavelength-switchable lasing oscillations with wavelength spacing of about 0.25nm have been experimentally demonstrated. Due to the usage of the FSI filter, the measured optical signal-to-noise ratio is increased from 50dB to 70dB. The power fluctuation of each wavelength is less than 0.5 dB within a one-hour period, and the output power of different channels is almost identical (difference less than 1dB) within the tunable range.

7847-81, Poster Session

Theoretical analysis of a novel polarization-insensitive arrayed waveguide grating demultiplexer based on Si nanowire and slot waveguides

L. Zhao, J. An, J. Zhang, S. Song, Y. Wu, X. Hu, Institute of Semiconductors (China)

Arrayed waveguide grating(AWG) is a crucial component for wavelength division multiplexing (WDM) systems and the studies of the ultrasmall AWG based on Si nanowire waveguide has been reported. Due to the seriously polarization-sensitive of Si nanowires, the spectral responses of the TE and TM polarization are separated in Si-nanowire-based AWG with the conventional design. The compensation methods used in the AWG based on low index contrast substrate for diminishing the polarization-sensitive can not satisfied the Si-nanowire-based AWG, because the Si nanowire waveguides have stronger dispersion than the low index contrast waveguides.

A new design for polarization-insensitive demultiplexer based on arrayed waveguide grating (AWG) by using silicon-on-insulator (SOI) substrate is proposed. In the arrayed waveguide region, Si nanowire waveguides and slot waveguides are combined to adjust the optical path differences. In the slot waveguides, the refractive indexes of the TE0 and TM0 polarizations satisfy nTM nTE while in the Si nanowire waveguides nTM nTE, so the refractive indexes of the TE and TM polarizations are complementary in these two kinds of waveguides. By calculating the relationship of Si nanowire waveguides and slot waveguides' length differences, optimizing the structure of the slot waveguides and choosing the appropriate diffraction order, the central channel wavelength and the channel spacing can both reduce the polarization sensitivity greatly. The design process is given clearly and the simulation results demonstrate that the AWG demultiplexer can achieve polarization insensitive operation. The random error analysis is discussed to acquire the fabrication tolerance.

7847-82, Poster Session

Waveform monitoring based on symmetric Mach-Zehnder interferometer optical switch and low-bandwidth PIN

Y. Yang, Donghua Univ. (China); J. Cui, BeiHang Univ. (China)

The all-optical waveform monitoring system with sub-picosecond temporal resolution is demonstrated. The optical sampling is implemented by the nonlinear gain compression (NGC) mainly caused by spectral hole burning (SHB) and carrier heating (CH) of semiconductor optical amplifiers (SOA) in a Symmetric Mach-Zehnder Interferometer (SMZ). A system model is funded based on noisy SOA dynamic function, which takes in to account carrier depletion (CD), CH and SHB, and an equivalent electric circuit model of simplified PIN photodiodes taking account of the photon absorption, transit-time, and circuit effects. Monte Carlo Method is added to analyze the sampling jitter.

Instead of flat top switch window, analysis show high-gain sub-ps pulse-shape switch window which is preferred for sampling could be obtained by using NGC effect in SMZ and sampling-delay adjusting properly. These are the major advantage of SMZ-NGC sampling than other all-optical waveform monitoring system. The shape of sampling window is mainly decided by the NGC caused by first sampling pulse and delay between sampling pulses. The small over-shot behind main switch window can be eliminated by pulse amplitude control. The difference of NGC effect can be reduced by control the saturated gain caused by CD. High bias current to SOA is preferred for improvement sensitivity of sampling system. And there is tradeoff between sensitivity and broadening scale of low-bandwidth PIN. Therefore the bandwidth of PIN should be choosing carefully to achieve good sensitivity and simple back-end circuit both. The jitter of sampling pulses causes primary system error. Sampling-recovery process had been simulated to validate the measuring capability of the SMZ-NGC sampler. 2-ps FWHW single gauss pulse and RZ ps-pulses train were used as measured signal. The results show that SMZ-NGC system can monitor waveform efficiently and the original waveform can be recovered with low error by using sampling result combing with recovery algorithm.

7847-83, Poster Session

Thermal research of infrared sight thermoelectric cooler control circuit under temperature environment

Y. Gao, Nanjing Univ. of Science and Technology (China)

Testing device TST-05B, which is suitable for adaptability test of semiconductor devices, electronic products and other military equipment under the condition of the surrounding air temperature rapidly changing, is used here for temperature shock test.Thermal stability technology of thermoelectric cooler control circuit infrared sight under temperature shock is studied in this paper. Model parameters and geometry is configured for ADI devices (ADN8830), welding material and PCB which are used in system. Thermoelectric cooler control circuit packaged by CSP32 distribution are simulated and analyzed

by thermal shock and waveform through engineering finite element analysis software ANSYYS. Because solders of the whole model have much stronger stress along X direction than that of other directions, initial stress constraints along X direction are primarily considered when the partial model of single solder is imposed by thermal load. When absolute thermal loads stresses of diagonal nodes with maximum strains are separated from the whole model, interpolation is processed according to thermal loads circulation. Plastic strains and thermal stresses of nodes in both sides of partial model are obtained. The analysis results indicates that with thermal load circulation, maximum forces of each circulation along X direction are increasingly enlarged and with the accumulation of plastic strains of danger point, at the same time structural deformation and the location of maximum equivalent plastic strain in the solder joints at the first and eighth, the composition will become invalid in the end.

7847-84, Poster Session

Modification of voltage model for electric-field-assisted ion-exchange method of glass-based waveguide

S. Jiang, W. Zheng, Y. Hao, M. Wang, X. Jiang, J. Yang, Zhejiang Univ. (China)

Traditional glass-based electric-field-assisted ion-exchange model is characterized by the product of voltage and time which is well known as the voltage model. In the voltage model, the ion exchange process is under a constant voltage (or a constant electric field) and temperature is considered to be a constant. Buried depth, which is one of the most important parameters in the modeling of ion-exchanged waveguides, is in direct proportional to a character parameter, the product of voltage and time. However, our recent studies and experimental results show that there is a thermally-induced warming effect in ion exchange, which leads to a change of local temperature in the glass substrate area and the local electrical resist decrease with the increase of the local temperature, which means traditional voltage model is not precise.

In this paper, we theoretical analyze the influence of the temperature variation in the voltage model and introduce a new temperature-independent character parameter, the integration of current density-time, to modify the traditional voltage model. After the modification, we solve the influence of ion-exchanging temperature variation. Experiment results show that the voltage model with the temperature-independent character parameter modification is more applicable than the traditional one. We record ion-exchanging buried depths, voltage and current under several different voltages and compare the linear relationship between buried depths and each character parameters, in both voltage model and modified model. The latter one's linear fit is much better than the former one's, 2.08×10-2 compare with 5.90×10-2, which means the voltage model with modification is more precise than traditional model.

7847-85, Poster Session

Flat-top steep-edge response of photodetetors by circuit control method

L. Wang, Beijing Univ. of Posts and Telecommunications (China)

WDM (Wavelength Division Multiplexing) technologies have been widely used in many fields such as backbone networks, metropolitan networks and access networks. In the WDM system, the response with flat-top lessens the requirements of accuracy and stability for lasers and the response with steep-edge reduces the crosstalk between wavelengths, so the research on the flat-top steep-edge response of photodetectors is very significant.

This paper proposes a circuit control method achieving the flat-top steep-edge response of photodetectors. The response is realized using three wavelength selective photodetectors PD1, PD2, PD3(PD2 is in the middle, two sides are PD1, PD3 and the response of PD2 must have intersections with PD1 and PD3) and the circuit which consists of amplifiers, comparators and AND gate. Two groups of experiments are carried out. In group1, 0.5dB, 3dB, 20dB bandwidths are 2.76nm, 3.29nm, 4.58nm from 1546nm to 1549.3nm. In group 2, 0.5dB, 3dB, 20dB bandwidths are 3.19nm, 2.89nm, 3.06nm from 1554.8nm to 1557.6nm. The results of experiments show that the desirable flat-top steep-edge response can be gained and the width is adjustable by selecting the wavelength parameter of photodetectors, so that the requirement of the WDM system and networks can be met. The method is easy to realize with low cost and has wide application in optical measurements and optical processing etc.

7847-86, Poster Session

Optimization of an ultracompact triplexer using planar photonic crystal waveguide

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An ultracompact triplexer based on planar photonic crystal waveguide (PCW) with a triangular lattice of air holes is presented and optimized. The principle is based on a shift of the cutoff frequency of the fundamental mode in a PCW, which is realized by modifying the radii of the border holes adjacent to the PCW core. Some defect holes are introduced to control the beam propagation. And the radii of some holes at the intersections between the sections with different radii of the border holes are changed to realize it. Due to the strong coupling between the defects and the propagation fields, the significant improvement on the output efficiency and the wavelength directionality are achieved. To optimize the proposed device, another defect hole on the crossing point between the input PCW and one of output PCWs is introduced to realize the further improvement of extinction efficiency of the proposed triplexer. The finite-difference time-domain method is employed to analyze and simulate the device. The numerical results show that the optimized triplexer can realize the demultiplexing of the three specific wavelengths, i.e. 1310, 1490 and 1550 nm with the extinction ratios higher than -18 dB. The designed device is ultracompact with a total size 12 μm × 6.5 μm, has a simpler structure. It is feasible for the practical application, can be applied in the system of fiber to the home

7847-87, Poster Session

Drop filters in a rod-type photonic crystal based on self-collimation ring resonators

G. Lin, X. Chen, Minjiang Univ. (China); J. Li, Y. Qiu, Fujian Normal Univ. (China)

We design a rod-type drop filter (RTDF) in 2D PhC employing the self-collimation effect. The perfect 2D PhC consists of a square-lattice of dielectric cylindrical rods in air. The dielectric constant and the radius of host rods are =12.25 (correspondingly the refractive index n = 3.5) and r=0.40a, respectively, where a is the lattice constant. In such a PhC, the self-collimation (SC) phenomenon occurs for the E-polarized (TM) light beam of frequencies between f =0.176c/a and f =0.192c/a. The energy flow of Block waves does not spread or focus even if there are no physical boundaries for confinement. The designed DF utilizes the SC effect and the bending and splitting mechanisms of line defects to route the propagation of light, instead of conventional indexed-guided waveguides or photonic crystal band gap waveguides.

The proposed drop filters based on SC ring resonator (SCRR) structure consists of two line defects introduced to act as the 1:1 beam splitter (BS1, BS2), and two small rectangular air blocks introduced to be have as 45° mirrors to achieve 90° light bending [M1,M2]. The transmission spectrum of the DF has been investigated with the finite-difference time-

domain (FDTD) method. The calculation results show that peaks have nearly equal frequency spacing 0.0030c/a. Increasing the geometrical length of one loop l can cause peaks shift left to lower frequencies. As a result, the peak spacing decreases linearly from 0.0034c/a to 0.0026c/a when l is increased from a to a. By changing the reflectivity of the beam splitter (BS1, BS2), the full width at half maximum (FWHM) and quality (Q) factor of peaks can also be easily tuned.

For the central operating wavelength around 1.55 m, the dimensions of the RTDF are about tens of microns. Though our study is based on a 2D PhC, it can be extended to PhC slabs. So this RTDF may be applied in future high-density photonic integrated circuits

7847-88, Poster Session

The study on high reliability InGaAs detector arrays hermetic encapsulation technology

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With the development of the aviation, aerospace technology and the research and mass production of military, civil and other complex electronic equipment, the quality and the reliability of electronic components and microelectronic devices become more important. Therefore, it is essential that detectors have excellent hermetic package, and should be protected effectively against the impact of the external environment.

In this paper, 256×1 and 512×1 element linear InGaAs detector arrays were hermetic packaged. Package structure, packaging components and packaging technology were studied, including the structure design, thermoelectric cooler(TE) heat load performance test, TE vacuum baking, the sealing of the window and the cover lid, the seam welding of the cover lid and shell, and so on. The results show that the cooling temperature difference of TE can reach 55 K or more at room temperature, cooling temperature difference decreases by about 0.51 K with additional 50 mW heat load, which meets the assemblies' requirements. Vacuum baking experiments show that, TE has managed to maintain the same performance after 500 hours of baking at 120°. After the sealing of the window and the cover plate, the Parallel to the seam welding of the cover plate and shell, the relevant measure of leakage rate was taken, and the results show that the leak rate of metallic packages can be tested to levels of better than 10-10 Pa.cm3/s, and actual data from the field indicates that the hermeticity of the package is much better.

7847-89, Poster Session

A novel optical scanning device based on electrowetting micro-prism

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A novel optical scanning device based on electrowetting micro-prism (EMPs) is proposed, to solve the problems of beam deflection controlling with laser line source . The basic beam control unit is made from EMPs, which including three kinds of immiscible liquids (water / oil / water),whith utilizing electrowetting modulation of liquid contact angle in order to mimic the refractive behavior for various classical prism geometries. Through the electro-wetting effect, the beam deflection angle of the liquid prism can be adjusted about -15 ° ~ 15 °continuously in a specific voltage range (30 ~ 110V).

And compared to other electronic control deflection, this device has great deflection angle, whith exceeding the continuous steering angles demonstrated for optical phased-array technology. At the same time, as the devices become smaller in size, its switching response speed can be much less than ms. This device will help us study robust Fresnel and phased-array optics.

7847-90, Poster Session

A novel silica-waveguide acoustooptic frequency shifter using ZnO piezoelectric films and its beam propagation analysis

C. Chen, Changchun Univ. of Science and Technology (China)

A novel silica-waveguide integrated acoustooptic frequency shifter (AOFS) with high diffraction efficiency is proposed for an optical wavelength of 1.55μm in this paper. Choose tapered silica waveguides fabricated on silicon substrates by PECVD and C-axis oriented ZnO piezoelectric films deposited using RF-sputtering as the interdigital transducer for the excitation of SAW. The interdigital Al electrodes are located at the interface between the nonpiezoelectric substrates (SiO2) and the ZnO piezoelectric films, that is, ZnO/IDT/SiO2 structure; when the ZnO films thickness h and SAW's wavelength satisfy the relation h/ =0.4 0.5, electromechanical coupling coefficient of the interdigital transducer achieves the maximum value 16%. Diffraction properties are simulated and analyzed using beam propagation method (BPM) and AO interaction area is well-designed in order to obtain optimum interaction characteristics. The results show that a diffraction efficiency of approximately 70% can be obtained.

7847-91, Poster Session

Low-loss high-strength lens-coupling connection on photonic crystal fibers

L. Zhang, Shandong Univ. (China); P. Song, Univ. of Jinan (China)

Photonic crystal fibers (PCFs), which are also called micro-structured optical fibers or holey fibers, have been investigated with great interest and have considerably altered the traditional fiber optics since they appeared in the mid 1990s. Because of their freedom in design and novel wave-guiding properties, PCFs have been used for a number of novel fiber-optic devices and fiber-sensing applications that are difficult to be realized by the use of conventional fibers.

To realize the full potential of PCFs, it is necessary to efficiently couple light from conventional single-mode fibers (SMFs) to PCFs. However, because PCFs have micro-hole structures that are totally different from conventional fibers, the connection among different PCFs and conventional fibers are difficult.

In this paper, we report a new way of using optical coupling lenses assembly to achieve low-loss high-strength connections involving different kinds PCFs. This technique is effective when connecting together two PCFs, or a PCF with a conventional fiber, and it has no special limitation to the structure of PCFs. Moreover, in comparison to the splicing method, it can connect two fibers with different glass materials, which carries different melting temperatures and coefficients of thermal expansion; And eliminate the loss brought by the mode mismatch between two connected fibers; A simple seal connecting technique avoids the hole collapse and prevents moisture or other contaminants from entering the holes. As a simple example, a 0.44 dB connection loss between an endlessly single-mode PCF and a conventional SMF (G.652 fiber), which is much lower than the splicing method, was obtained with a good repeatability.

7847-92, Poster Session

Effects of PDL and second-order PMD on the DOP-feedback PMD compensation

L. Zhang, Shandong Univ. (China); P. Song, Univ. of Jinan (China)

Polarization mode dispersion (PMD) compensation is critical to network performance in long-haul high-speed optical fiber systems, especially when the system bit rate goes up to 10 Gb/s and above. By monitoring the degree of polarization (DOP) of the signal, PMD compensation can be realized. However, DOP is not a perfect feedback signal for PMD compensation in the presence of other important effects, such as signal initial chirp (which causes the wavelength-dependence of PMD, mainly the second-order PMD), polarization dependent loss (PDL, as well as polarization dependent gain), and so on. In this paper, the combined destructive effects of PDL and second-order PMD on the DOP feedback signal in PMD compensation is theoretically analyzed and simulated in a 40 Gb/s non-return-to-zero modulated system. We find that DOP relates not only to both the first- and second-order PMD in the presence of PMD and PDL, but also to the total PDL vector of the fiber system; Moreover, PDL affects DOP only in the presence of PMD, and the deplorization effect of second-order PMD on the signal's DOP would be more distinct even if the direction of the total PDL vector changes a little. The PDL minimum endangering PMD compensation is determined by not only the step size of the PMD compensating algorithm, but also the first-order PMD in optical fiber systems. Modifications to the combined destructions of PDL and second-order PMD on DOP-feedback PMD compensation are discussed finally.

7847-93, Poster Session

A polarization splitter based on squeezed photonic crystal fiber with elliptical air holes

P. Song, Univ. of Jinan (China)

A novel polarization splitter based on photonic crystal fiber with the squeezed triangular lattice is presented. Studies show that high birefringence can be introduced by the squeezed triangular lattice and elliptical air holes, which makes the coupling lengths of two orthogonal polarization states different. We design photonic crystal fiber with elliptical air holes in the squeezed lattice and two core regions. The two orthogonal polarization states are separated in this photonic crystal fiber. The supercell method is applied to analyze the influence of the structure parameters, such as the diameter of the elliptical air holes and squeezing radio of the lattice, on the coupling length of x-polarization and y-polarization. Based on beam propagation method, the characteristics of this splitter is simulated. The properties of the polarization splitter can be improved by setting the proper structure parameters.

7847-94, Poster Session

Experimental study on temperature dependence of dispersion of G.652 fiber and its effect on high speed optical communication system and compensation

K. Zhong, N. Jia, T. Li, M. Wang, J. Chi, Beijing Jiaotong Univ. (China)

Temperature dependence of dispersion of G.652 fiber is experimental studied. The dispersion and dispersion slop variations over a temperature rang of 80 , from -20 to 60 are measured. A value of -1.45×10-3ps/nm/km/ was obtained for the chromatic dispersion thermal coefficient and a value of 3.16×10-6 ps/nm2/km/ was obtained for the dispersion slope thermal coefficient at 1550nm. The effects of temperature dependence of dispersion on 80Gbit/s 100km OTDM system is experimental studied. Eye diagrams ascribed to the temperature of -20 ,0 ,20 ,40 ,60 are demonstrated after 100km transmission link. The effect was also evaluated by BER curves. At last, dispersion thermal coefficient and dispersion slope thermal coefficient of dispersion compensating fiber were experimentally measured. A value of 28.64×10-3ps/nm/km/ was obtained for the chromatic dispersion thermal coefficient and a value of -68.87×10-6 ps/nm2/km/ was obtained for the dispersion slope thermal coefficient at 1550nm. The possibility of dynamically compensating chromatic dispersion and chromatic dispersion slope of G.652 fiber due to environmental temperature alterations by controlling the temperature of dispersion compensating fiber.

7847-95, Poster Session

Study on the characteristics of transient signal transmission based on GaAs photoconductive switches

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The GaAs photoconductive switch plays an important role in the measurement of the signal of ultra high-speed, which has unique properties comparing with traditional switches. The first realization of picoseconds time resolution with a photoconductively gated scanning tunneling microscope was reported by the group of S.Weiss in 1993. They obtained simultaneously 2-ps time resolution and 50 spatial resolution by combining ultrashort laser pulses techniques with scanning tunneling microscopy(STM). This work provides the possibilities for studying the performances of electron and molecule devices with ultra speed. In this paper, the transmission model of transient signals on GaAs photoconductive switch is given. Based on the testing result of delay-time-modulation method, the relationship between signal amplitude and the form of connection mode is analyzed and discussed. The calculating results are corresponded with the experimental ones.

7847-96, Poster Session

Light output enhancement of light-emitting diodes with photonic crystal structure

X. Wang, Beijing Institute of Machinery (China)

A new light-emitting diodes (LED) structure constituted by the photonic crystal is presented, and the effects of structure parameters are investigated. Relying on the results of investigation, the structure parameters of photonic crystal LED are optimized theoretically. By Using the FDTD algorithm, the enhancement factor of photonic crystal LED is calculated efficiently, and the optimum values of structure parameters are obtained after numerical optimization. With the optimum photonic crystal structure, the output efficiency of LED is enhanced over 50%.

7847-97, Poster Session

Characterization and fabrication of rare-earth doped amplifying fibers based on atomic layer deposition

X. Sun, Y. Dong, C. Li, X. Liu, Shanghai Univ. (China); S. Li, Aalto Univ. School of Science and Technology (Finland)

Nano-Rare Earth Doped Fibers (NREDFs) have shown great application in the development of amplifiers, fiber lasers and sensors. The rapid developing of fiber communication systems has a higher requirement on the NREDFs. Atomic layer deposition (ALD) is a chemical vapor deposition technique based on the sequential use of self-terminating gas-solid reactions. As a film deposition technique, ALD is known for its effective material utilization at low temperatures, accuracy thickness control, excellent step coverage, good uniformity and adhesion, good conformability. In this paper, ALD was used in fabricating high

concentration alumina-erbium co-doped amplifying fibers. Based on Modified Chemical Vapor Deposition (MCVD) and ALD, using nanomaterials as a dopant, for example, Al(CH3)3 (TMA) and H2O as the precursors to deposit Al2O3, Er(thd)3 and O3 as the precursors to grow Er2O3, the alumina-erbium co-doped amplifying fibers were fabricated. The main advantages of this novel method include good uniformity, high dispersibility, and high doping concentration. Scanning electron microscopy (SEM), transmission electron microscopy (TEM) images and X-ray energy dispersive spectroscopy (EDS) showed the physical and chemical feathers of the deposited film upon a porous silica soot layer. Photoluminescence (PL) and absorption spectra were used to characterize the optical properties. The fibers have high gain, low noise, high power and are independent of polarization, which make them desirable for fiber devices.

7847-98, Poster Session

A novel design of dispersion and dispersion slope compensator for LEAF fiber in WDM systems

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Chromatic dispersion and dispersion slope management is an essential feature in WDM systems. Many optical dispersion compensating devices are often used to solve this problem, including dispersion compensating fiber (DCF), superstructure fiber grating, sampled fiber Bragg gratings (SFBG)... etc. However, NZ-DSF fibers such as LEAF fiber, with a lower dispersion but a significantly higher relative dispersion slope in comparison with normal fibers, are now being deployed and raise a challenge for dispersion and dispersion slope compensators. No matter what approachs be used to compensate dispersion, the shortcomings are still exist: Perfect matching of the dispersion and dispersion slope of LEAF fiber with DCF still represents a challenge. Superstructure fiber grating technology suffers from a poor manu-facturability for the high channel counts required to cover broadband signal. SFBG has been proved as an efficient way to produce multi-channel gratings covering a wide spectral range, but this approach is confined to fibers with a weak dispersion slope.

Here, we demonstrate a design of dispersion and dispersion slope compensator for LEAF fiber in WDM systems. It can compensate dispersion and dispersion slope compensator respectively by combining broadband nonchannelized linear chirped fiber Bragg grating and a pair of nonlinear chirped fiber Bragg gratings, which be inversely cascaded in a four-port optical circulator. Comparing with other FBG technologys, nonchannelized FBG has structure, manu-facturability and price advantages. To prove the feasibility of this design, we prepare a numerical experimen to compensate a 50-km-long WDM system, which using LEAF fiber.

7847-99, Poster Session

Parallel-cascaded micro-ring resonators waveguide photodetector with flat-top and steep-edge response

Y. Qin, Beijing Univ. of Posts and Telecommunications (China)

Wavelength Division Multiplexing (WDM) communication systems require high performance and highly integrated photodetectors which have good wavelength selectivity to accommodate large channel counts. Photodetectors with flat-top and steep-side response, which lower the requirements on accuracy and stability of the laser and greatly reduce system cost and crosstalk between wavelengths, can meet this requirement.

A novel waveguide photodetector with flat-top and steep-edge response is proposed in the paper. The response is obtained by designing a racetrack resonator following several parallel-cascaded micro-ring resonators. The parallel micro-ring resonators as a filter cavity improve the response and a racetrack resonator integrated a waveguide photodetector as an absorbing cavity enhances the power absorption. Simulation results for a two parallel-cascaded and a three parallel-cascaded structure are demonstrated and an increasing rectangular spectral response is obtained. The maximum values of the quantum efficiency in bandpass are 99.8%. For the two parallel-cascaded structure, its 0.5dB, 3dB, and 20dB bandwidth is 0.22nm, 0.39nm, and 1.1nm respectively; for the three parallel-cascaded structure, its 0.5dB, 3dB, and 20dB bandwidth is 0.28nm, 0.32nm, and 0.5nm, both of which meet the requirements of WDM system. Compared with single micro-ring resonator photodetectors and RCE-PDs, this photodetector has high quantum efficiency and good flat-top and steep-edge response. The structure is compact and conducive to large-scale integration. We can see that it is very promising in WDM system.

7847-100, Poster Session

Experimental investigation on erbium-doped superfluorescent fiber source by using high performance erbium-doped fiber for the fiber optic gyroscope

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As the development of the Erbium-doped fiber (EDF), the absorption have been extremely improved, achieved 4 times and 18 times(110dB/m) enhancement at 980nm and 1530 nm respectively. This challenging less than 1-ppm objective of meanwavelength stability of superfluorescent fiber source(SFS) has still stimulated detailed studies, and effective methods for reducing them have been reported.

In this paper, using the high performance EDF, for the temperature stability of meanwavelength, particularly, from a different viewpoint, we analyzed the variation of spectral output of SFS at different wavelength range and different temperature. firstly, the spectral output of a SFS at 10 is selected as a standard data, then as the temperature is increased, spectral output from -40 to +60 (10 per change step) minus the standard data is calculated for the spectral temperature dependent instability. It is found that the variation of spectral output from short wavelength(1480nm) to long wavelength(1630nm) can be divided into three parts, and in the middle wavelength region from 1540nm to 1560nm, the dBm values of the spectral output are decreased with increasing temperature, but with wavelength-flattened characteristics. On the other hand, for wavelength small than 1540nm and larger than 1560nm, the dBm values of the spectral output change inversely with temperature, and the variations are larger than the middle region. Based on this characteristics, we design a new configuration of SFS for the first time, the meanwavelength stability can be achieved 3ppm/ and 2ppm/ in the range of pump power from 100mw to 130mw and in the range of temperature from -40 to +60 , respectively. So it can be used to meet the demand of industrial application.

7847-101, Poster Session

Investigation of the coupling efficiency for specialty solid coupled optical taper

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The rectilinear mobile wireless optical communication is a very important broad-band communication technology. It is necessary to keep alignment between optical transmitting and receiving antenna

in order to ensure the reliable communication, otherwise the focused beam reaching the optical receiving terminal can not be detected. Moreover, the coupling efficiency between the focused beam and photo-detector will decrease. If such attenuation is very serious, the communication will be interrupted. To solve this critical issue, a special solid coupled (SSC) optical taper was introduced into the receiving termination. The optical coupling efficiency between the SSC optical taper and focused beam mainly depends on tapering shape curve, incidence angle, deflection distance, incidence depth, and so on. Based on the curvature-shape matching relationship, the profile curve equation for SSC optical taper has been deduced. According to geometrical optics, the output energy of focused beam via the SSC optical taper has been analyzed. Furthermore, the optical coupling efficiency can be analyzed by the comparing the input and output light energy based on Fresnel reflex loss. The results show that the theoretical simulation is in good accordance with the experimental data. The errors were also given. The optical coupling loss was analyzed at different radial displacement. The coupling loss was less than 10dB as the radial displacements vary within 1.5 mm in x and y directions, respectively. For this experimental system, the receiving performance of SSC optical taper can satisfy the communication.

7847-102, Poster Session

Fluorescence properties of RE-doped SiO2 spheres

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Silica spheres doped with rare earth (RE) ions have significant potential for use in biology, optical devices and materials science such as biological tracers, microlasers, thin-film device structures, active photonic crystals, luminescent markers and nanosensors. Therefore, preparation and investigation of RE doped silica colloidal spheres have very important scientific and applicable value.

In this paper, RE-doped silica spheres were prepared by two different method, that's, the modified base-catalyzed method and the seed growth method. The former synthesize silica hybrid spheres by adding RE complex during the hydrolysis and condensation reactions of tetraethyl orthosilicate (TEOS), while the latter adds RE complex to hybrid spheres by using pure silica spheres as seed nuclei.

The modified base-catalyzed method can incorporate RE complex into the entire silica spheres, to obtain monodisperse silica hybrid spheres with submicron diameter, while the seed growth method, by use of pure silica spheres as the seeds, can produce silica hybrid spheres surfacely doped with monolayer or multilayer RE complex based on the different demands.

Both of the doped hybrid particles were characterized by the transmission electron microscope (TEM) and fluorescence spectrometer. The TEM images of the particles doped with Eu(TTFA)3 synthesized by two methods show that the particles have the spherical morphology and the smooth surfaces.

The fluorescence spectra of colloidal SiO2 spheres with different Eu(TTFA)3 doping concentrations showed that the typical PL spectra of Eu3+ ions were achieved and its fluorescence intensity increased with the doping concentrations. The PL spectrum of the hybrid spheres synthesized by the seed growth, shows similiar PL spectrum of Eu3+ ions.

7847-103, Poster Session

The effects of annealing temperature on structure and photoluminescence of SiC/AlN bilayer thin film

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By adding AlN buffer layer between the Si substrate and SiC thin film the properties of SiC thin films can be improved. The SiC/AlN bilayer thin films were grown by RF magnetron sputtering on the silicon(110) substrate, then were annealed from 500 °C to 1100°C through the nitrogen gas. The optimum synthetic process was obtained, that is, the gas pressure was 0.5Pa, the flux of Ar was 60sccm, the sputtering power of SiC target was 150W for 1.5hr, while the sputtering power of pure Al target was 100W for 1hr, the ratio of Ar to N2 was 2:1. Then the XRD,AFM and photoluminescence (PL) spectra of these films were measured with D/Max- B X-ray differaction and FL-4500 Fluorometric meter. Two PL emission peaks were observed respectively around 380nm and 400nm, and they came from the SiC particles and the carbon clusters respectively. The strength of PL emission rises with the increasing of annealing temperature. The PL emission intensity of SiC/AlN bilayer thin film at 380nm is superior to monolayer SiC thin film while the that of SiC/AlN bilayer at 400nm is inferior to monolayer SiC thin film, because the introduction of AlN buffer layer between SiC thin film and Si substrate can reduce the interface defects and improve the SiC thin film crystalline quality, so enhance the light emission of SiC thin film. In addition to, the grain size of SiC/AlN bilayer thin film is finer than that of monolayer SiC thin film resulting from AFM morphology.

7847-104, Poster Session

Tunable drop filters based on photonic crystal self-collimation ring resonators

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A tunable drop filter (TDF) based on a self-collimation ring resonator (SCRR) in a two-dimensional photonic crystal (PC) is proposed. The PC consists of a square lattice of air cylinders in silicon. The refractive index of silicon, lattice constant and cylinder radius are 3.5, a and 0.33a, respectively. This structure has square-shaped equal frequency contours (EFCs) in the wave-vector space at the frequencies between 0.172-0.188 c/a for TE modes. At these frequencies and in the direction perpendicular to the EFCs, a narrow light beam can propagate within the PC without broadening (i.e. self-collimation effect). The SCRR proposed consists of two mirrors and two splitters. Light propagates between them employing self-collimation effect. The air holes inside the SCRR are infiltrated with a kind of liquid crystal whose ordinary and extraordinary refractive indices are 1.522 and 1.706, respectively. The effective refractive index of liquid crystal depends on the applied electric field. Simulated with the FDTD method, the transmission spectrum at the drop port of the SCRR are comb-shaped with a uniform peak spacing between 0.172-0.188 c/a. Transmission peaks shift to the lower frequencies when is increased. When changes from 1.522 to 1.706, the peaks shift left over 0.00303 c/a. Consequently, this SCRR can work as a tunble drop filter. For the operating wavelength around 1550nm, its dimensions are only several microns. Because of its large tuning range and small dimensions, the SCRR-based TDF may have practical applications in photonic integrated circuits.

7847-105, Poster Session

Gradient-doping GaAs NEA photocathode grown by MBE

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Negative electron affinity (NEA) GaAs photocathodes activated by the coadsorption of cesium and oxygen have already found widespread application in modern night vision image intensifiers. In order to improve the performance of GaAs NEA photocathodes, such as electron diffusion length and electron escape probability, a gradient-doping structure GaAs material has been put forward, in which from the GaAs bulk-to-surface doping concentration is distributed gradiently from

high to low. This doping structure can result in many downward band bending regions which help form built-in electric fields to facilitate photoexcited electron movement towards surface.

We apply this gradient-doping GaAs structure to the transmission-mode GaAs photocathodes. This sample was grown on the high quality p-type GaAs (100) substrate by MBE with p-type Be doping. During the growth process, the epitaxial layers composed of obstruction-layer, emission-layer, buffer-layer and protection-layer were grown by MBE according to priority. Corresponding to each layer, the thickness is 1μm, 1.6μm, 1μm and 0.5μm respectively.

We have calculated the band-bending energy in gradient-doping GaAs emission-layer, and the total band-bending energy is 41.6 meV which helps improve the photoexcited electrons movement towards surface for the thin epilayer. The carrier concentration distribution in Be-doping GaAs/GaAlAs epilayers after the MBE growth is studied with electrochemical capacitance-voltage (ECV) measurement. Besides, the inherent mechanism of electron transport in gradient-doping GaAs photocathodes is also analyzed.

7847-106, Poster Session

Semiconductor quantum dots fiber amplifier excited by evanescent wave

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Semiconductor quantum dots (QDs) have received much attention due to their unique optical and electronic properties, and have found high potential applications in optical amplifiers. Based on the amplification properties of semiconductor quantum dots, a novel optical fiber amplifier was proposed and demonstrated by using a tapered single mode fiber. The semiconductor quantum dots fiber amplifier (SQDFA) was fabricated by coating PbS quantum dots doped sol-gel onto an optical tapered fiber. The PbS quantum dots were synthesized by the colloidal method. The size of the PbS particles was obtained as less than 10nm observed by a transmission electron microscopy (TEM). The optical tapered fiber was pulled by the conventional oxyhydrogen flame technique. To excite quantum dots through evanescent wave by using the tapered fiber, we doped the PbS quantum dots into sol-gel material to ensure a lower refractive index. With a wavelength division multiplexer (WDM) of 980nm and 1310nm wavelength, a signal and a pump were injected simultaneously into the fused taper region and interacted with the PbS QDs film through evanescent wave. Based on the principle of stimulated emission, the signal was amplified by the SQDFA. To investigate the gain dependence on the pump power, the gain properties were tested by tuning the pump power from 10mw to 140mw. The optical gain was observed to be more than 10dB at 1310nm with 140mw pump power. Due to the all-fiber structure and the good amplification performance of the QDs, the proposed SQDFA will find great potential in wide band and high speed fiber-optic communication.

7847-107, Poster Session

A united model of fiber coupler based on the variation technique

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Abstract: In general, coupling characteristics of a fused single-mode fiber coupler were separately studied in its different zones separately because of its special geometrical shape. It's necessary to build a united model to simulate the coupling characteristics of each zone of the coupler simultaneously. Some appropriate continuous functions were chosen to describe the tapered curve and the transverse cross section. The mode-field distribution in the coupler was obtained by the weighted superposition of triangular distribution and Gaussian distribution, in the condition of lossless propagation. Thus, a more accurate model was obtained, in terms of the variation technique and the local mode theory, and some formulas were presented. The effects of the fiber-cores in the fuse zone and the coupling effects in the taper zones were considered.

Based on the proposed united model, a complete analysis of the fused single-mode fiber coupler was made. Theoretical analysis indicated that the coupling characteristics depended on the drawing length, the degree of fusion, and the wavelength. Coupling coefficient increased exponentially with the decreasing of the dimension of the coupler. The coupling coefficient was directly proportional to the wavelength in the strong coupling zone. The relation between the coupling coefficient and the degree of fusion was revealed. The relation between the output power of the coupler and the drawing length was obtained. the larger the coupling coefficient was, the shorter the beat length was. The results show the model can be used to guide the practical design and fabrication of couplers and WDMs more accurately.

7847-109, Poster Session

Numerical study on laser and infrared compatible stealth with "Spectral Hole" of doped photonic crystal

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Compatible stealth of laser and infrared is an urgent demand of modern battlefield, but the requirements of laser and infrared stealth are mutually contradictory. As a new type of artificial structure function material, photonic crystals could realize broadband thermal infrared stealth because of its high-reflection photon forbidden band. By use of "Spectral Hole" formation of doped photonic crystal defect state level, high transmittance at 1.06μm or 10.6μm laser was realized, so compatible stealth of laser and infrared was achieved. The infrared-transparent thin-film material, CdSe and SiO2 were selected to design photonic crystals which have high-reflection forbidden band in the middle and far infrared band. Then the reflectance spectrum was calculated by characteristic matrix method. The designed two-cycle CdSe/SiO2 photonic crystal realized dual-band high-reflection in the middle and far infrared band, whose spectral reflectivity of 3~5μm and 8~14μm spectral reflectance is greater than 95%, which satisfies the compatible stealth of the middle and far infrared band preferably. The reflectance spectrum, transmitted spectrum and absorption spectrum of CdSe/SiO2 photonic crystals doped with ZnSe were calculated by the characteristic matrix method. The result showed that the doped photonic crystals could satisfy the demand of compatible stealth of thermal infrared and 1.06μm or 10.6μm laser.

7847-110, Poster Session

Calculation of reciprocal velocity curves of intrinsic surface acoustic wave in quartz crystal

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Quartz crystal has excellent piezoelectric properties, it can be used as substrates of surface acoustic wave (SAW) devices, for example delay line, filter, oscillator, convolver, acousto-optic (AO) device and so on. Intrinsic SAW can propagate along face of piezoelectric crystal, but it isn't inspired by the crystal. So the intrinsic SAW velocity is determined by the internal property of crystals. In this paper, Intrinsic SAW basic equation group and SAW mechanical boundary condition equation group are deduced from character equation of the crystal. Intrinsic SAW velocities are calculated using circle iterative method in three coordinate planes of Quartz crystal systematically. Stiffness coefficient of piezoelectric crystal can be changed by piezoelectric effect and it is named as piezoelectric modified stiffness coefficient. Reciprocal velocity curves of Quartz crystal in the three coordinate planes using the non-modified stiffness coefficients and the piezoelectric modified stiffness coefficients are drawn respectively. Calculation results indicate that intrinsic SAW velocities are quickened due to the piezoelectric effect. Besides figures of the reciprocal velocity curves in three different planes are similar to projection of crystal cell of the Quartz crystal in corresponding plane. It means that there is internal relationship between the SAW properties and point group symmetries of the crystal. Many properties of the SAW device are related to the acoustic velocities, for example in AO device AO merit is inversely proportional to cube of acoustic velocity. Research results lay a solid base for design and manufacture of the SAW device. It has theoretical significance and practical value.

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7848-01, Session 1

Resonance mechanism for the electromagnetic enhancement by an isolated subwavelength metallic groove

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Surface enhanced Raman scattering (SERS) offsets the drawback of weak cross section of Raman scattering and attracts intense interests in high-sensitivity biochemical detection [1]. Subwavelength metallic grooves are promising albeit simple structures that can achieve a giant enhancement factor (EF) of the electric field for the SERS application. Enormous electric-field enhancement of a single groove [2] and of groove gratings [3] are reported, and a physical analysis of the field enhancement by a single nano-groove is proposed [4]. In this report, we propose a detailed analysis of the resonance condition on the field distribution of an isolated metallic groove, based on a semi-analytical Fabry-Perot model. We also investigate the impact of the type of noble metals (such as gold, silver and copper) on EF. Our results show that the electric field near the groove mouth that contacts the specimen is drastically enhanced for groove depths fulfilling the resonance condition but is depressed for groove depths out of the resonance condition. Giant EF up to 1E4 can be obtained at the groove mouth for narrow grooves under resonance condition, which implies 1E8 magnification of Raman signals [5]. A weak dependence of EF on the type of noble metals is presented and explained. Our results are helpful for understanding the resonance mechanism of the electromagnetic enhancement by subwavelength grooves and may facilitate the design of SERS devices that incorporate metallic grooves as elementary field enhancement units.

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7848-02, Session 1

Beam shaping by the use of plasmonics

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In this paper, we will discuss methods to manipulate beams with surface plasmon polaritons (SPPs) and present their design guidelines. There are two representative methods to manipulate beams with SPPs; the first uses a sub-wavelength metal slit surrounded by surface gratings, and the second exploits multiple metallic waveguides.

The first method to generate beams is to make SPPs, which are excited on a corrugated metal surface from a sub-wavelength metal slit, radiate into a certain direction by using surface gratings. Because the radiation direction of SPPs depends on the profile of the surface gratings, we can render beams by adjusting the surface gratings’ profile. To be specific, we can render an on-axis directional beam with symmetric surface gratings designed to make SPPs radiate perpendicularly. If we use asymmetric surface gratings, making SPPs radiate not into a perpendicular direction but into a certain direction, it is possible to render an off-axis directional beam. In addition, we can focus light with chirped surface gratings.

The second method to manipulate beams is to control the phases of SPPs induced in metallic waveguides, which end up with radiating at the output surface of the metallic waveguides. If it is possible to control the phases of SPPs radiating at the output surface, we can manipulate beams based on Huygens’ principle. Since the phases of SPPs at the output surface of the waveguides rely on the propagation constants as well as the waveguides’ length, we can render beams by adjusting the width and the length of the waveguides.

7848-03, Session 1

The influence on the luminescence europium complex by local surface plasmon of silver and gold nanoparticles

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Many studies on luminescence enhancement by surface plasmons were reported, among which metal nanoparticles were paid much attention to, because of their special optical properties. The local surface plasmon resonance can be tuned by changing nanoparticles’ size, shape, interparticle spacing, and dielectric environment. They can be used for altering the optical properties of luminescence materials, and are being used in the rare earth (RE) ions doped materials.

For the RE doped materials, according to the Fermi golden rule, the spontaneous emission rate from excited level |i> to lower level |j> is, where Mij is the matrix element related to the two energy levels, is the optical density and is also known as the photon mode density (PMD).

In the present work, we experimentally demonstrated the influence of silver and gold metal nanoparticles on the luminescence of Eu complex. These nanoparticles had different size and shape, including the spherical, triangular shaped silver and gold nanoparticles. Based on the luminescence, lifetime and nanoparticles’ absorption measurement, the luminescence enhancement and quenching were both obtained. Their influence on the lifetime were aslo different, which refered to the different infuence on the radiative and non-radiative decay rate. We further confirmed that the different influence of these nanoparticles on the photon mode density, seperately. We found that their influence on it had a great relationship with the overlap between the nanoparticles’ local surface plasmon resonance band and the emission wavelength or the excitation wavelength, which would give us a better understanding of the mechanism of the influence on the envionment of the RE ions.

7848-04, Session 1

Single-slit and inter-slit effects of the extraordinary optical transmission in subwavelength metal double slit structure

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Tsinghua Univ. (China); F. Wang, Capital Normal Univ. (China)

The extraordinary optical transmission (EOT) in a subwavelength metal slit array, is mainly governed by the single-slit and inter-slit effects. Here the single-slit effect refers to that the EOT occurs in an isolated single slit; while the inter-slit effect refers to the influence of the surface plasmon polaritons (SPPs) coming from the nearest neighbor (nn) slits. A double-slit device is the simplest system including the two factors. In this paper, we intend to employ this device to investigate the interplay between the single-slit and inter-slit effects.

To make clear the interplay is helpful for one to achieve the greatest transmissivity. If the two effects are independent of each other, they will influence the total transmission severally. In this case, we can adjust the depth of each slit in a double-slit structure to obtain the largest transmission, and then adjust the inter-slit distance under fixed slit depths to achieve the largest transmission. As a result, both effects give the largest contributions and the total transmission of the double-slit structure must also reach the largest value. Otherwise, obtaining the largest transmission of such a structure would be not easy.

We use the finite-difference time-domain (FDTD) method to simulate the optical transmission in a double-slit setup and investigate the relationship between the single-slit and inter-slit effects. By fitting the simulation results, an experiential formula of the transmissivity is obtained which can be simplified into the product of two factors, determined by the length of a single slit and inter-slit distance, respectively. This form shows that the single-slit and inter-slit effects affect the transmissivity almost independently.

7848-05, Session 2

Doppler phase-shifting interferometry and holography

T. Yatagai, Utsunomiya Univ. (Japan)

A new technique is proposed, in which a phase-shifting algorithm utilizing the optical Doppler effect and a high-speed CMOS camera are employed. In many phase-shifting algorithms, the phase distribution of the object is calculated by using a few reference phases with equal phase difference. In our proposed method, a reference mirror is moved continuously or randomly to make phase shift based on the Doppler effect. The phase distribution of the object is calculated by Fourier transforming the time-depending interference fringe data. If the reference phase shift is equally introduced to all the data points in the interference fringe image, the phase distribution at the peak frequency component

in the Fourier spectrum gives the phase distribution of the object.

Since a few hundred or more images were required in this method, a CMOS camera with a high frame rate of 500fps was used.

7848-06, Session 2

Three-dimensional information encryption with phase extraction and phase shifting interferometry

Y. Shi, Y. Wang, Graduate Univ. of the Chinese Academy of Sciences (China); Y. Yang, Beijing Univ. of Technology (China); J. Zhang, Graduate Univ. of the Chinese Academy of Sciences (China)

Three-dimensional information encryption based on the phase extraction and the phase shifting interferometry is proposed. The three-dimensional information with the pure amplitude and pure phase are constructed as the encryption target. First the complex amplitude of the three-dimensional information is calculated under the scalar diffraction theory, and its phase distribution is extracted independently. Then it is encrypted by the double random phase encoding, the complex amplitude of which is recorded by using two-step of phase shifting interferometry. Computer simulations demonstrate the feasibility, the robustness and the security of the proposed method, including its resistance against the known plaintext attack. Furthermore, the potential of applying our method for the three-dimensional information encryption with much larger information quantity is revealed as well.

7848-07, Session 2

The study of spatial phase shifting by triple-grating interferometer

S. Yang, Z. Zhao, Nanjing Univ. of Aeronautics and Astronautics (China); Y. Chen, N. Sun, A. He, Nanjing Univ. of Science and Technology (China)

Double-grating interferometer is usually used to obtain phase information from distorted wave front by its temporal phase shifting characteristic. In our recent work, it is found that there is stable phase shift between plus-first and minus-first order interferograms by the double-grating interferometer. However, in order to obtain the detorted wave front from the spatial phase shifting method, at least three or four phase shifting images should be generated simultaneously. In this paper, based on the spatial phase shifting characteristic of the double-grating interferometer, the third grating whose direction is set perpendicular to those of the other two gratings is added. Because of the light splitting characteristic of gratings, six spatial phase shifting interferograms are generated simultaneously, as a result of which the destorted wave front can be achieved by the spatial phase shifting method. Due to the simple configration is only made up of three gratings, it is superior to the other spatial phase shifting devices with respect to the mechanical stability. In particular, six spatial phase shifting interferograms are generated simultaneously, which means it will have higher accuracy of reconstruction.

7848-08, Session 2

The research of image matching technique for spatial phase shifting interferograms

S. Yang, Nanjing Univ. of Science and Technology (China)

A triple-grating spatial phase shifting technique is used to simultaneously obtain six phase shifting interferograms and the phase of the wavefront distortion is extracted. As the phase shifting technique is the point to point operation between corresponding pixels of interferograms, ensuring the strict matching between the interferograms should be taken as an important premise of the phase extraction. But, in the actual image acquisition process, the relative position between the CCD and observation plane, distortion of the lens and etc. will affect the matching between interferograms. As a result, the accuracy of phase extraction will be affected. Aiming at this problem, the article calibrates the CCD firstly, and then correctes the image distortion, while the strict matching phase shifting interferograms are segmented finally. The corresponding algorithms and procedures have been verified by the experiment, and the satisfying matching results are obtained.

7848-09, Session 2

3D Tire Size Code Measurement by Digital Speckle Pattern Interferometry

M. Zhu, Z. Huang, H. Cai, H. Zhang, Tianjin Univ. (China)

Tire size code identification often base on image processing and laser line-by-line scanning. Image processing method dependent on

uniform illumination which is difficult for tire size code surface and laser scanning method is a time consumption work. Digital Speckle Pattern Interferometry (DSPI) is a well-established technique for measuring curvature, slops. Phase Shifting interferometry(PSI) is often used to measure the wave front phase. DSPI and PSI were integrated to capture tire surface 3D architecture. By recording the speckle pattern reflecting from tire surface, the phase pattern can be calculated by phase shifting Interferometry. The phase reconstructed from wrapping phase pattern represent the optical path difference, furthermore the Tire size code height difference was reconstructed respectively. With capturing speckle pattern interferogram by speckle-self-reference interferometry, multiple laser diodes of DSPI-PSI interferometer were arranged to enlarge the illumination area; the viewing field was also expanded by battery of lens containing field lens and imaging lens. In the experiment results, the viewing filed was more than 60 degree, the resolution of surface profile match the tire size code height difference as 1mm. DSPI-PSI is an efficiency and high precision technique for measuring the tire size code.

7848-10, Session 2

The feasibility of moiré deflectometry in rocket exhaust's temperature and electron number density diagnosis

Y. Chen, Nanjing Univ. of Science and Technology (China)

Optical computerized tomography (OCT) methods have been widely used in various flow fields' visualization, measurement and diagnosis. Among all the current OCT methods, moiré deflection tomography is famous for simple configuration, superior ability of anti-error and adaptation to tough environment characteristics. As a result, it has been used to measure 3-D density distribution for rocket exhaust, which enlightens us to further study the feasibility of it in rocket exhaust's temperature and electron number density diagnosis theoretically. Firstly, on the basis of investigating the dependence of rocket exhaust's refractive index on temperature and pressure in certain probe wavelengths, it is analyzed that moiré deflection tomography can be used to measure the temperature distribution for rocket exhaust. And then, the temperature measurement error is also discussed. In further, based on researching the dispersive characteristic of rocket exhaust, the feasibility of two-wavelength moiré deflection tomography in electron number density diagnosis is analyzed. As expected, this study may break the record that moiré deflection tomography only has been used as the visualization or density measurement tool for rocket exhaust so far, which can expand the applicable range of OCT methods.

7848-11, Session 3

Efficiency improvement for a color filter based on a submicron metal grating with energy recycling system

Y. Ye, Soochow Univ. (China)

A submicron metal grating with broadband transmission was proposed. The device consisted of such four parts as a substrate, a ZnS layer, a metal submicron grating and an MgF2 overlay was analyzed by the rigorous coupled-wave analysis (RCWA). When an incoming white light impinges on the designed device, the specific colored light will be obtained at the output for the transverse magnetic (TM) polarized light and the most light will be reflected at the input for the transverse electric (TE) polarized light. Three broadband color filters with FWHM of 100 nm and the peak transmission of more than 65% are got with TM polarized light by optimizing the structural parameters. The reflected light at the input can be recycled by rotating the TE polarization to circular polarization and re-impinging on the designed device to increase the total energy utilization. The numerical results shows that the peak transmisson efficiency can be increased about 20% when polarization conversion factor is 0.5 and the loss is 10% in backlight unit with the recycle of the reflection of the TE polarized light.

7848-12, Session 3

Evanescent excitation of a plasmonic nano-array for single molecular sensing

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There is presently an urgent need for sensors that integrate multiple (arrays) nanophotonic and nanoplasmonic structures on a single chip. High sensitivity and a strong interaction with light, coupled with the capability of integration of on-chip electronics are particularly promising for planar waveguide sensing mechanisms, including Raman scattering, fluorescence, and refractive index change. In particular, devices are currently required for distributed environmental sensing, chemical and biological hazard detection for civilian and military applications, and public health monitoring and disease diagnosis. We report on our research program to develop a highly sensitive two-dimensional sensor array platform for molecular detection and identification, working on the principles of coherent, localized surface plasmon resonance enhanced Raman emission spectroscopy.

Surface enhanced spectroscopy based on plasmon excitation is a well-known phenomenon in optical sensing. It can enhance a dipole response of an excited molecule up to 10^14 times. However, a controlled regular response of such a substrate, which is necessary for sensing applications, is hard to realize especially with a conventional way of excitation, which is usually based on the confocal microscopy. Evanescent excitation, using a multi-layer planar waveguide structure, of a periodic nano-array can potentially overcome the natural difficulty of the confocal excitation, namely, the waste of probing light by radiative scattering and inefficient transformation into informative signal. We will discuss the aspects of this transition and a gain in sensitivity it brings about. In addition, we will present theoretical results for three types of evanescently excited nano-arrays.

7848-13, Session 3

Efficiency improvement in nanorod amorphous silicon thin film with ultrathin metal electrode for photovoltaic application

C. Chin, Y. Ye, D. Huang, National Taiwan Univ. (Taiwan)

In recent years, photovoltaic cells have attracted much attention and have been extensively studied by many groups. The amorphous silicon (a-Si) thin film solar cells have the advantages of lower cost and potential for building-integrated applications although the conversion efficiency is usually below 20%. In this paper, we show an a-Si thin film solar cell with nanorod structures for light trapping enhancement and an ultrathin silver film as transparent electrode with a lower resistivity for performance improvement. In such a design, the conversion efficiency can be greatly improved. The periodicity and fill factor of the nanorods were optimized to enhance the diffraction of the light within 600-900 nm into guided modes in the a-Si thin film and thus the total optical absorption can be enhanced. Furthermore, a 5-nm ultrathin metal film was used as a transparent electrode to replace the conventional transparent conductive oxide while having a lower sheet resistance of 9.6 Ω/ and a transmittance from 90% to 70% within the spectral range from 300 nm to 900 nm. Our design was analyzed by using the full-wave finite-element method to calculate the optical absorption of the incident sunlight in the a-si thin film. According to the simulation results, the light absorption can be relatively enhanced by 69.6% and the total conversion efficiency can be relatively improved by 69.2% compared to the conventional thin film a-Si solar cell without nanorod structures.

7848-14, Session 3

Surface plasmon resonance imaging biosensor based on silicon photodiode array

S. Yin, Q. Deng, L. Xia, C. Du, Institute of Optics and Electronics (China)

The detection limit of surface plasmon resonance imaging (SPRI) biosensor is constrained in part by the SPR biochip and in part by the resolution of the optical intensity of detecting instruments. In this paper, silicon photodiode array is proposed as the optical intensity detecting element instead of the traditionally used charge coupled device (CCD), combining with the micro lens array and the analog/digital converter, this method can efficiently reduce the cost and increase the sensitivity of the SPRI system while keeping its virtue of multi-channel real time detecting. Based on this method, An SPRI system with four channels is designed and the optical intensity of each channel is detected by four photodiodes. By carrying out testing experiments using sucrose solution with different concentrations (corresponding to different refractive index), the system sensitivity of 10-6 refractive index unit (RIU) is obtained.

7848-15, Session 3

Metallic superlens designed with close-to-cutoff the long range SPP mode

Y. Sheng, G. Tremblay, Univ. Laval (Canada)

The metallic superlens proposed by Pendry can collect and amplify the evanescent object waves resulting in super-resolution imaging. We propose to combine the surface plasmon polariton (SPP) waveguide theory with the SPP resonance theory for analyzing the metallic superlens. We find that the typical two peaks in the transfer function are related to the long- and the short-range SPP modes, which are necessary to amplify the evanescent waves compensating its exponential decay, but enhance in the same time the spatial frequencies disproportionally, resulting in strong sidelobes in the image. We design the metallic superlens with close to the cutoff condition of the longrange SPP mode to balance the SPP amplification and the flatness of the transfer function, and thus eliminating the sidelobes in the image. The design experiments for the Al superlens at 193 nm with both the transfer matrix approach and the numerical finite difference in time domain method are shown.

7848-16, Session 3

Passive microrheology of polysodium styrene sulfonate

Y. Chen, National Yang-Ming Univ. (Taiwan) and Lehigh Univ. (United States) and Univ. de Rennes 1 (France); C. Chiang, Y. Huang, P. Yen, National Yang-Ming Univ. (Taiwan); M. Wei, Lehigh Univ. (United States); J. Jun-Yeh, National Yang-Ming Univ. (Taiwan); O. Lavastre, H. Guillaume, D. Guillaume, Univ. de Rennes 1 (France); A. E. T. Chiou, National Yang-Ming Univ. (Taiwan)

We report the passive microrheology of Polysodium 4-styrenesulfonate (NapSS) in water solution using Laser-Particle Tracking (LPT) technique in which the complex shear modulus of NapSS solution was deduced via a Generalized Stokes-Einstein (GSE) equation from the time-dependent mean square displacement (MSD), < r2(t)>, of thermally-driven polystyrene beads suspended in the fluid. Optical tweezers were applied to confine the polystyrene bead to extend the particle-tracking period, Of particular interest is the sol-gel transition or “gelation”, in which a viscous fluid (the sol) transforms into an elastic solid (the gel); the “gelation” can be defined as the critical point of polymerization in a polymer network-forming system. Gelation properties of NapSS with different molecular weights (70kDa, 200kDa & 1000kDa), and at different concentrations (10-6 M - 10-3M) over extended frequency range (1-1000Hz) will be presented, and the effect of optical forces will be discussed.

7848-17, Session 4

Studies of optical properties of two-dimensional square lattice photonic crystal based on holographic polymer-dispersed liquid crystal

M. Li, S. T. Wu, S. Y. Huang, H. Lin, A. Y. Fuh, National Cheng Kung Univ. (Taiwan)

Two-dimensional (2-D) square lattice (SL) photonic crystals (PCs) are fabricated and their optical, and electro-optical properties are studied. The PCs are based on polymer-dispersed liquid crystals (PDLC) that are formed using two-beam interference with double-exposures. The PC structure that is observed using a scanning electron microscope (SEM) matches with the calculated interference pattern. The results of optical/electro-optical studies demonstrate that superprism and negative refraction effects occur at certain incident angles over a range of frequencies, and are consistent with the simulated ones. Moreover, the negative refraction efficiency is electrically controllable.

7848-18, Session 4

Spontaneous-emission control by the local density of states of photonic crystal cavity

B. Jiang, Y. Zhang, A. Liu, W. Chen, W. Zhou, W. Zheng, Institute of Semiconductors (China)

Spontaneous emission is one of the most fundamental phenomena that impact the creation of light. However, the active control of spontaneous emission still remains difficult. For example, in photonic crystal point cavity laser, the active inhibition and enhancement of spontaneous emission are still under study. According to quantum theory, the rate of spontaneous radiation is determined by the photonic density of states (DOS) and the electric-field strength at the position of the emitter. In order to combine the effect of both DOS and the electric field distribution, the concept of local density of states (LDOS) is used. We take square lattice photonic crystal rod cavity for example. The radius of periodic rod is 0.2a (a is lattice constant), and the radius of point defect rod is o.3a. The epsilon of rod is 11.56. The frequency of degenerate defect dipole mode is 0.363($2\pi c/a$). We calculate the LDOS at several points to see how the spontaneous radiation changes with locations. The LDOS are quite different from DOS, and has more forbidden frequency ranges. The LDOS of defect mode at (0, 0) is small which is different from the DOS of the defect mode, while we find that the LDOS of defect mode at point (0, 0.3a) is greatly enhanced. This is because the amplitude of electric field Ez of degenerate dipole mode is very small at point (0, 0), while the amplitude of electric field Ez is large at point (0, 0.3a). From the above discussion, when designing a laser on the basis of the square lattice photonic crystal rod cavity, the active material could not be inserted in the center of the defect rod, but be inserted at position deviated from the center. So our method gives a guideline for the design of the position of active material in laser.

7848-19, Session 4

Novel families of vortex solitons in the photonic superlattice

J. Zhao, X. Gan, S. Liu, Northwestern Polytechnical Univ. (China)

We predict the existence of two novel families of vortex solitons supported by the optically induced photonic superlattice, which is constructed by superimposing two staggered square lattices with the same period and different index potentials. Due to the additional potential in superlattices, the linear spectrum is split into mini-bands by mini-gaps. The two novel vortex solitons introduced here are bifurcated from the top symmetry points at the first and second mini-bands, respectively, in the self-focusing nonlinear regime. The first one is discrete off-site vortex solions, which reside in the semi-infinite gap. Its intensity has four lobes on the nearest four lattice sites, which is similar to the discrete vortex solitons in single-potential lattices. However, the vortex soliton exhibits strongly asymmetric profiles and noncanonical phase distributions. Two of the four lobes on the high-potential sites own lower intensity, and the intensity of the other two lobes locating on the low-potential sites has larger value. The second type vortex solitons resides in the first mini-gap with the singularity locating on the high-potential site. Although occurring in the mini-gap, the vortex soliton has four symmetry lobes on the four low-potential sites. It is quite different from the second-band gap vortex soliton array in single-potential lattices, which has a local vortex structure around each site center. Furthermore, the existence domains and properties of these two novel vortex solitons are discussed carefully with respect to the ratio of the two lattice potentials.

7848-20, Session 4

Controlling light flow with optically induced anisotropic triangle photonic lattices

S. Liu, X. Gan, P. Zhang, J. Zhao, Northwestern Polytechnical Univ. (China)

Light propagating dynamics in optical periodic structures exhibits intriguing behavior that has no analog in homogeneous media. In photonic lattices, the rotational symmetry of the medium will be broken due to the periodicity, leading to abundant novel diffraction and refraction phenomena. Recently, there are increasing interests to explore discrete light behavior in lattice structures other than simple square lattices. Both linear and nonlinear light propagation in triangle and honeycomb lattices are involved. Specifically, the fundamental lattice soliton and multi-vortex solitons in triangle lattice have been reported, in addition to the resonant Zener tunneling. Here, we present a novel method to control the propagation of the multi-vortex beam in anisotropic triangle photonic lattices optically induced in a nonconventionally biased photorefractive crystal. It is revealed that the lattice cells of the optically induced photonic lattices will be deformed into ellipses under nonconventional bias condition due to the enhanced anisotropic nonlinearity, resulting in the breach of the inherent symmetry of the triangle lattice and the distortion of the photonic band-gap structure. As a result, the propagation constant as well as the propagation direction of a multi-vortex beam will be different according to different bias conditions. Remarkably, we found that the propagation direction of the input beam is determined by the orientation of the elliptical lattice cell, which can be easily controlled by adjusting the bias direction. Therefore the propagation direction of an input multi-vortex beam can be controlled at ease solely by altering the bias condition.

7848-21, Session 5

Proposal for the synthesis of kinoforms to eliminate reconstruction speckles with a noise immune method

S. Yang, Kyushu Institute of Technology (Japan)

The kinoform is a phase only computer-generated hologram that has merits of on-axis reconstruction and high diffraction efficiency. Because a kinoform only has phase modulation, there is a serious problem of speckles appearance in the reconstruction. These speckles limited the application of kinoforms such as for wave shaping. It was indicated that the speckles are the existences of isolated zeros among the sampled reconstructed points of a kinoform by Wyrowski and Bryngdahl in 1988. The existences of isolated zeros depend on the wrapped sum of phase differences of four neighbored sampled points. Methods to avoid speckles were suggested to select an initial image phase distribution without isolated zeros but speckles appear again after the kinoform is confirmed with constant amplitude and phase quantization. The authors had suggested an iterative algorithm for the speckle reduction utilizing the two pai ambiguity of image phase differences. The idea of this iterative speckle reduction algorithm uses the image phase freedom to force the wrapped sum of reconstructed image phase differences of four neighbored sampled points to be zero so that no isolated zeros exist in the reconstruction. The algorithm can achieve a kinoform distribution without speckles successfully but speckles may appear caused by the noise in optical reconstruction. In this study, we propose a noise immune method by giving a certain image phase margin to avoid the speckles in the optical reconstruction. We also use some experimental results to show the valid of the proposed method.

7848-22, Session 5

Design of an encapsulated subwavelength fused-silica grating for wideband two-port beam splitter

W. Sun, C. Zhou, Shanghai Institute of Optics and Fine Mechanics (China)

In this work, a highly efficient wideband two-port beam splitter of an encapsulated subwavelength fused-silica grating is presented, which is designed to operate at a wavelength of 1550nm for TE polarization under Littrow mounting. Explanation of the physical mechanism of such a wideband two-port beam splitter grating is mainly based on the simplified modal method with consideration of two beam interference of the modes excited by the incident wave. Meanwhile, this encapsulated grating can be considered equivalent to a effective Fabry-Perot cavity, therefore, Fabry-Perot interference of grating modes inside the grating area also plays an innegligible role in achieving high efficiency and equality in the diffracted zeroth and minus-first orders. Considering the above two factors, we can determine the grating parameters generally. The exact grating profile can be optimized by using the rigorous coupled-wave analysis(RCWA). Numerical simulations show that, with the optimum grating profile, a total diffraction efficiency of 99.78% and the equality of 0.9999 that is intensity ratio between the diffracted zeroth and minus-first orders can be obtained at the wavelength of 1550nm. Moreover, the efficiency and equality are still high, over the C+L band range. Compared with conventional fused-silica grating, this embedded design enables an efficient suppression of reflection losses, and its monolithic layout brings about long-term stability and convenience to handle and clean, therefore it should be a useful optical component for practical applications.

7848-23, Session 5

Diffraction efficiency analysis of blazed grating fabricated by direct laser writing

D. Kuang, Z. Fang, Nankai Univ. (China)

For the laser spot size, the blazed diffractive grating fabricated with direct laser writing will has a slantwise lateral facet edge. To evaluate the influence of the slope of the facet edge of blazed diffractive grating, we calculate the diffraction efficiencies in +1 order and zero order as a function of the angle for the slantwise lateral facet edge with rigorous coupled wave analysis. As the lateral facet edge is getting more slantwise, the diffraction efficiency in +1 order decrease more, which degrades the image quality in monochromatic imaging. But the diffraction efficiency in zero order always keeps very low to assure the application in optical limiting.

7848-24, Session 5

Improved Simulated Annealing Algorithm Applied in Near Field Beam Shaping

Z. Yu, National Univ. of Defense Technology (China)

Beam shaping plays a very important role in the field of inertial confinement fusion (ICF) laser processing and optical data memory. To improve the efficiency of the laser systems, interest has been concentrated on the conversion of a Gaussian intensity distribution into a flat-topped profile in the near field. Simulated annealing algorithm is a common algorithm used for beam shaping. But the general simulated annealing algorithm is complicate in constitution and lengthiness in computing time, especially when the spatial resolution of the phase corrector is large. In this paper, the near field beam shaping based on the combination of simulated annealing algorithm and Zernike polynomials is proposed and demonstrated. Considering phase distributions can be represented by the expansion of Zernike polynomials, the problem of searching appropriate phase distribution can be changed into a problem of optimizing a vector made up of Zernike coefficients. On the one hand, this improved algorithm can simplify the problem of near field beam shaping in large spatial resolution and reduce the computing amount. On the other hand, this improved algorithm can generate continuous phase plane which is valuable for experiment validation and practicality application. The feasibility of this method is validated theoretically by translating the Gaussian beam into quasi-flattop beam in the near field. Finally, the closed control loop system constituted by phase only liquid crystal spatial light modulator and simulated annealing algorithm is used to prove the validity of the technique. The experiment results show that the system can generate laser beam with desired intensity distributions.

7848-25, Session 5

Deep-etched fused silica gratings and applications

C. Zhou, Shanghai Institute of Optics and Fine Mechanics (China)

Deep-etched fused silica grating is a kind of high density phase gratings whose surface is etched into an optimized depth for achieving a series of novel functions, such as high efficient diffraction at the -1 order, polarizing beam splitting, 1X2, 1X3 beam splitting, etc.. Since deep-etched fused silica grating is made of pure dielectric material of fused silica, so it has a high laser damage threshold for high power laser applications.

We fabricated the polarizing beam splitter of the fused silica grating and realized the even and odd modes for analysis of fused silica grating. We gave the generalized equations for describing the performance of polarizing beam splitting and high efficent diffraction at the -1 order. We gave the analytic equation of 1x3 diffraction, which is impossible to obtain with the previous rigorously coupled wave method.

For fabrication of deep-etched fused silica gratings, holographic recording, lithographic technique, and inductively coupled plasma etching are used to make the deep-etched gratings.

Deep-etched gratings have a variety of practical applications. It can be used for demultiplexing optical signals in DWDM optical fiber communications. It can also be used as a pulse compressor of femtosecond or picosecond laser pulses. It can also be used as polarizing beam splitter, high efficient grating for spectrometer, etc.. Deep-etched fused silica gratings have a bright future for practical applications.

7848-123, Session 5

Properties of Fraunhofer and Fresnel diffraction by an high-order spiral phase plate made by direct laser writing lithography

C. Fan, J. Xu, H. Pang, C. Ying, H. Wang, Zhejiang Normal Univ. (China)

We describe a simple, reliable, and reproducible fabrication technique for a high-order spiral phase plate. The production error is no more than 1% and the diffraction efficiency is no less than 86%. The performance of the fabricated SPP is verified by using Vortex characteristics of Fraunhofer and fresnel diffractions of a finite-radius plane wave, which is in agreement with the theoretical calculation result. All the results suggest we have succeeded to generate a high-order optical vortex with the fabricated SPP.

7848-26, Session 6

Fabrication of optical mosaic gratings by consecutive holographic exposures employing a latent-fringe based alignment technique

L. Shi, L. Zeng, L. Li, Tsinghua Univ. (China)

Large-size diffraction gratings are essential for pulse compressors in chirped-pulse-amplified high-power laser systems, spectroscopic telescopes, grating scale, etc. Fabricating large gratings requires large-aperture laser beams with collimated and aberration-free wavefronts. As an alternative a method of making monolithic gratings by optical mosaic has been proposed. Optical mosaic makes multiple-exposures in different areas of a substrate to enlarge the grating size. Between exposures the position and attitude of substrate must be adjusted to minimize the overall wavefront errors.

For the exposure alignment in optical mosaic we fully utilize the latent fringes (exposed but undeveloped fringes in photoresist). We make consecutive exposures using the latent fringes as the core adjustment object and the exposure beams as the adjustment beams to lock the position and attitude between exposures. This approach greatly simplifies the alignment system and eliminates many possible system errors. However, the diffraction efficiency of a latent grating is extremely weak (~10^-6) and excessive double exposure should be avoided. Furthermore, the position and attitude alignment accuracy requirements are very tight (in the order of a few nanometers and a few tenths of micro-radians, respectively). We overcome these difficulties by carefully blocking stray lights and using a high-sensitivity CCD to monitor the interference fringes of –1st- and 0th-order latent-fringe diffracted wavefronts. Experimentally we have made 2 × 2 mosaics of (53+30) × (60+28) mm^2 grating area. Typical peak-valley and root-mean-square values of the measured –1st-order diffraction wavefront errors are 0.06

and 0.01 , respectively.

The mosaic conditions, detailed alignment steps, and experimental results showing attitude and position controllability will be presented. The important issues of extending the present work to fabricate large (possibly sub-meter size) mosaic gratings will also be discussed.

7848-27, Session 6

Projection photolithography method used for fabricating continuous surface structure with aperture less than 10um

L. Shi, W. Zhang, X. Dong, Institute of Optics and Electronics (China); C. Du, Institute of Optics and Electronics (China)

A method is presented for fabricating continuous surface structure with aperture of a few micrometers by using a constructed projection system where the central element is microlens array used to obtain minified images. The minification of the images can be over hundred or thousand times of the object and the number lies on the microlens array. By using diffraction theory of light, the object corresponding to the target image can be designed and the structure with continuous surface can be formed in the projection system. In this paper, theoretic research was developed to analyse the parameters of system. The relationship of the object and the image was also discussed and the design process of the object was given. Experiments were carried out and the continuous surface structure with aperture less than 10um was manufactured. The results are shown in the paper.

7848-28, Session 6

Compound eye lenses array on an spherical plane with a controllable imaging plane

Y. Zhang, Sichuan Univ. (China) and Institute of Optics and Electronics (China); J. Du, Sichuan Univ. (China); L. Shi, X. Dong, C. Du, Institute of Optics and Electronics (China)

A single-layer spherical compound eye is proposed to image a large field of vision on the detecting plane by modulating parameters of the microlens array. The microlens array is comprised of hexagonal microlens with equal caliber distributed compactly on substrate as a plano-convex lens. According to the theory of geometrical optics, focal spots of the microlens can be modulated on the same plane paralleling the substrate, which just is the detecting plane of photo-detector, by regulating the thickness and radius of microlens. In the paper, we have offered the function between the detecting plane and the thickness, radius of microlens. For verifying the function, the simulation results are presented with ray tracing by the soft ware LIGHTTOOLS. From the simulation results, we know that a large field of vision can be focused on the photo-detector and the marginal field of view (FOV) is in around 82.3°.

7848-29, Session 6

Fabrication of the convex blazed grating

Q. Liu, H. Wang, P. Sun, J. Wu, Soochow Univ. (China)

Hyperspectral imaging spectrometers are radiation sensors that provide a collection of spectral images of an inhomogeneous scene. This allows the spectral signature for each object point to be determined. They can be applied to perform many different tasks such as accurate mapping of wide areas, object identification and recognition, target detection, process monitoring and control, clinical diagnosis imaging and environment assessment and management. Application areas include forestry, geology, agriculture, medicine, security, manufacturing, colorimetry, oceanography, ecology and others.

The convex grating is one of the key elements in hyperspectral imaging spectrometers. In this paper the diffraction characteristics of the convex blazed grating is investigated by using rigorous coupled-wave theory, which indicates that within the wavelength from 0.4μm to 0.8μm, the plus first-order diffraction efficiency can be over 35% through controlling the blaze angle of blazed grating. The convex blazed grating with the period of 5μm in the center, the blaze angle about 4.3 degree, and the ruled area - a convex substrate with its radius 72mm and aperture 35mm has been fabricated by holographic- scan ion beam etching. Experimental measurements show that the plus first-order diffraction efficiency is more than 30%, within the wavelength from 0.4μm to 0.8μm.

7848-30, Session 6

Fabrication of microstructures on silicon by multiple beam holographic method using nanosecond laser pulses

H. Zhang, Z. Fang, Soochow Univ. (China)

Silicon is an important solar cell material. Here we demonstrate the fabrication of a silicon micro-grating structures (MGSs) and sub-micron sized dot array(DA), using a nanosecond diode-pumped solid-state laser (DPSSL wavelength 351nm and pulse duration 20 ns) as light sources. The laser is split into two or four interfering nanosecond laser beams with two diffractive beam splitters and then interfered on the top surface of the sample. The results measured with scanning electron microscope (SEM) and atomic force microscopy (AFM) show that the depth of grooves of MGSs and DA varies from 0 nm to 150 nm as laser energy changing from 0.9 to 1.8 mJ. The mechanism to form MGS and DA is analyzed and it was found that the obtained structures have a negative shape of the interference pattern. A second-order peak between two first-order peaks also occurred due to the hermal-affecting expansion. The optical properties of these nanostructures are also investigated. These silicon nanostructures display greatly enhanced absorption over a large range of wavelengths and angles of incidence, due to suppressed reflection. The enhancement effect is particularly strong for DA, which provide nearly perfect impedance matching between silicon and air through a gradual reduction of the effective refractive index. The silicon DAs function as both absorber and antireflection layers, which offer a promising approach to enhance the solar cell energy conversion efficiency.

7848-31, Session 7

Compensation for pixel mismatch based on a three-pixel model in volume holographic data storage

H. Gu, L. Cao, Q. He, G. Jin, Tsinghua Univ. (China)

This paper describes a post-processing method to improve the signal-to-noise ratio of the readout data in volume holographic data storage. To compensate misregistrations between a detector array and the image of a two-dimensional data page, a method based on a three-pixel model is proposed against sub-pixel misalignment, which can be used to compensate arbitrarily misaligned data pages and improve the signal-to-noise ratio. Several methods for pixel mismatch compensation are compared. It is pointed out that the quadratic two-pixel method is inapplicable when the local shift is negative or the size of the aperture is relatively small. The inter-pixel cross-talk model is revised, and an improved three-pixel model is developed. Both simulation and experimental results show that the signal-to-noise ratio can be doubled approximately by use of the compensation method based on the three-pixel model. The proposed method is appropriate for both positive and negative pixel shifts, and has similar effects of equalization, which effectively improves the signal-to-noise ratio.

7848-32, Session 7

Study of collinear VHS: point spread function, shift selectivity, and temperature tolerance

C. Sun, Y. Yu, C. Cheng, National Central Univ. (Taiwan)

In this paper, we present our theoretical study of the collinear volume holohraphic storage under paraxial condition with scalar diffraction theory and VOHIL model. The developed formulas are much helpful in figuring out the characteristics on point spread function (PSF), the shift selectivity and even the diffraction effect by the thermal expansion .

To calculating PSF, which, under the paraxial condition, is related to the auto-correlation function of the reference pattern times a specific phase function. It shows that a certain phase modulation will benefit the PSF. Accordingly, we proposed lens array plate (LAP) to modulate the reference pattern. The enhanced SNR achieves 63.2. The paraxial diffraction formula is helpful in designing high SNR reference pattern.

To calculating shift selectivity, the deveopled calculation formula shows that shift selectivity can be proportional to the square of the Fourier transform of the intensity of the reference pattern when the reference is not phase encoded. However, when the reference is phase encoded, the shift selectivity should be calculated with considering the pixel effect.

To calculating temperature tolerance of the recording medium, the deveopled calculation formula related to the temperature effect is obtained under paraxial condition and the assumption of linear expansion of the medium. The formula shows that the diffraction light on the CCD plane by the transmission gratings will suffer phase change but by the reflection grating will not. The resultant diffraction pattern is an interference one by these two parts.

7848-33, Session 7

Increase of signal-to-noise ratio of a collinear holographic storage system with reference modulated by a ring lens array

Y. Yu, C. Cheng, C. Sun, National Central Univ. (Taiwan)

Holographic Versatile Disc system using collinear algorithm has been shown large storage capacity, high transfer rate, short access time, and also compatible with existing disc storage system, such as CD and DVD. Besides, small shift selectivity in both radial and tangential directions is also proposed. However, the seriously blurring of the point-spread function (PSF) in a collinear system could not be resolved until the radial line amplitude modulation in reference was proposed. In this paper, we propose an approach of a reference modulation in a collinear holographic storage system to increase the signal-to-noise ratio (SNR). We derive a solution that shows that the point-spread function is related to the autocorrelation function of the reference pattern times a defocusing phase term. Accordingly, the lens-array phase modulation is proposed and demonstrated theoretically. The SNR of the system can be dramatically enhanced to 63.2, rather than 2.3 in the traditional approach. By improving the PSF, the storage capacity and the data-transfer rate can be enhanced at the same time.

7848-34, Session 7

Deformation originated from the thermal expansion of volume holograms

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The thermal expansion under the reading process can lead to the deviation of diffracting angle or wavelength selectivity and the decrease of diffraction light intensity, since the reconstruction of volume holograms must obey the Bragg condition. The recording media is LiNbO3 crystal of which the dimensions are 10x10x10 mm3.We record a reflection volume hologram in LiNbO3 crystal with two plane waves where the ratio of intensity is 1:1. The wavelength of plane wave is 532 nm and the polarization is perpendicular to the optics axis of LiNbO3 crystal. The formed grating vector of volume holographic grating is parallel to optics axis. When the reference beam probes the volume holography, the diffraction light is imaged on the screen. The heating source which is iron wire connected with electric power touches one corner of the crystal. The iron wire heats the crystal and causes the inhomogeneous temperature distribution in the crystal. This increasing temperature results in slight deformation of the volume hologram for thermal expansion. We use the model of volume hologram being an integrator of the lights emitted from elementary light sources (VOHIL) to calculate the diffracted field when the deformed hologram is probed by the reference light. The parameters of simulation include the refractive index=2.2 and the coefficient of thermal expansion=1x10-5(1/). The simulation result is shown to be consistent with the experiment result.

7848-35, Session 7

Experimental investigation of the two-color holographic recording in nearly stoichiometric LiNbO3:Fe:Mn crystals

M. Zhu, Y. Liu, Nanjing Univ. of Aeronautics and Astronautics (China)

Since the two-color recording scheme was proposed, nonvolatile photorefractive holographic storage has been realized, using the all-optical process. Recently, with the development of the growth methods of the crystals, the nearly stoichiometric LiNbO3 is available. And the nearly stoichiometric LiNbO3 crystals are intensely investigated these years, because of their better properties in holographic storage. In this contribution, we investigated systematically the saturated diffraction efficiency and sensitivity in the nearly stoichiometric LiNbO3:Fe:Mn crystals with different dopant (Mn:Fe=50 ppm:100 ppm, 50 ppm:250ppm, 50 ppm:500 ppm) and oxidation states (oxidized in O2 atmosphere at 900 for 6, 10, 18 hrs). In the two-color recording experiment, the volume holographic gratings was recorded by red light (633nm), simultaneously sensitized by violet light (405nm). The results show that the saturated diffraction efficiency increases with the increase of the ratio of recording light to sensitizing beam intensities, however the sensitivity decreases. The variation of Fe concentration induces the changes both in the saturated diffraction efficiency and sensitivity. Higher concentration of Fe makes higher diffraction efficiency and higher sensitivity. Also, the differences of the oxidation states affect these two parameters. With the increase in the oxidation time, both the saturated diffraction efficiency and the sensitivity decrease. The ratio of recording to sensitizing intensities, the dopant concentration and the oxidation state affect the holographic properties of the crystal, respectively. An optimization may be obtained by modifying these three conditions appropriately.

7848-36, Session 7

Rewritable Collinear Holographic Image Storage with BR-D96N Film

A. Ning, M. Wei, Inner Mongolia Univ. (China)

Rewritable collinear holographic image storage was realized in a genetically mutated bacteriorhodopsin BR-D96N film by using its photochromic property. For a BR-D96N film with 3.0 optical density, under 632.8nm, 700mW/cm2 recording light (optical reference ratio is about 1:1.2), the optimum recording time is about 3s, and optimum

reconstruction light intensity is about 50mW/cm2, and the safetime of the hologram is about 10min. The experiment shows that, in collinear holographic storage system, simple optical setup, small volume, low environmental effect and the high density storage can be realized; and it is proved that the BR-D96N film has advantages like short storage time, high light sensitivity, high reversibility, long-term stability and easy used, which can be used as a higher sensitive rewritable collinear holographic storage media.

7848-37, Session 8

Dynamic holograms with photorefractive polymers

G. Li, Univ. of Missouri-St. Louis (United States)

Our recent work on dynamic holograms with photorefractive polymers will be reviewed. Photorefractive polymers as dynamic holographic materials have unique features such as high diffraction efficiency with thin films, different working wavelengths based on the design, fast response time, low cost, and ease of fabrication. Therefore photorefractive polymers are attractive for real-time optical signal processing, imaging, and image display. Usually the decay time of the dynamic hologram is in the same order as the response time and short decay time is desirable for rapid signal processing and imaging. However, for 3D rewritable display based on holographic stereogram, an array of elementary holograms (hogels) is recorded before the 3D image can be reconstructed and the display needs to maintain for certain time. Thus for this application a long decay time of the dynamic hologram is needed. This has been a challenging task in the field of dynamic hologram. In this talk, we will present our recent work on dynamic holograms with subsecond recording time and long persistence time (in the order of hours). Two techniques will be presented. One is based on laser thermal fixing of the hologram in high-Tg photorefractive polymers, the other is based on direct writing in low-Tg photorefractive polymers. Study of the hologram recording using pulsed beams will also be discussed.

7848-39, Session 8

Experimental results of measuring picosecond laser pulses using an autocorrelator

L. Zhu, C. Zhou, J. Wei, Shanghai Institute of Optics and Fine Mechanics (China); Z. Fan, Y. Ma, Beijing GK Laser Technology Co., Ltd. (China) and The Academy of Opto-Electronics (China); G. Niu, Beijing GK Laser Technology Co., Ltd. (China)

In this paper, we report experimental results of measuring picosecond laser pulses using a second-harmonic generation (SHG) intensity autocorrelator. This home-made setup of the intensity autocorrelation is an attempt to measure the SHG pulse's intensity change with time. It is clear that an intensity autocorrelation can be used for measuring the pulse length of the ultrashort pulses laser.

This setup involves splitting the laser pulse into two, one is variably delayed with respect to the other, and the two pulses are spatially overlapped in a SHG crystal (such as a BBO crystal) after a focused lens. The SHG crystal will produce light at twice the frequency of input light with a field, and this field has an intensity that is proportional to the product of the intensities of the two input pulses. The SHG energy of the two pulses is recorded by a high sensitivity power meter. The power meter can record the intensity's change with the delay in real time. Using the data, the pulse length can be obtained.

Using this SHG intensity autocorrelation, we measured the pulse length of a diode-pumped mode-locked laser which delivers pulses of 2-3ps duration centered on 1064nm at a repetition rate of 52MHz. Compared with the commercial autocorrelator, this setup has a larger measurement range, higher accuracy, and more reliable results. In addition, using a high resolution spectrum instrument and frequency-resolved optical grating (FROG) algorithm, the phase of the pulse might be retrieved. So this setup might be very useful in practical applications.

7848-40, Session 8

Focal shift and axial dispersion of binary pure-phase filters in focusing systems

J. Yu, C. Zhou, W. Jia, A. Hu, Shanghai Institute of Optics and Fine Mechanics (China)

Reshaping of the three-dimensional focused field with various kinds of pupil filters including amplitude-only, pure-phase and hybrid ones, is attracting extensive attentions for its wide applications, such as optical data storage, confocal microscopy, lithography, and optical trapping, etc. Among them, the binary pure-phase filters (BPFs) are becoming increasingly important because of its high efficiency, satisfactory performance and easy fabrication. In the past, however, most attentions are concentrated on the BPF with phase shift, whose axial focused field is symmetric about the geometrical focus in Debye approximation. Recently, it is shown that the axial intensity distribution of the BPF, whose phase shift is not equal to multiple of pi, is not symmetric any more and its principal maximum of axial intensity will displace away from the geometrical focus. This phenomenon is referred as focal shift effect of BPFs, which is different from the traditional focal shift effect in focusing systems with low Fresnel numbers. This focal shift is independent of Fresnel number, and it is mainly dependent on the structure of BPFs (its normalized radii and phase shift) for a certain focusing system. Moreover, this focal shift usually induces axial dispersion when a certain BPF is used in a focusing system. By adopting appropriate normalized radii, this axial dispersion can be negative and it can be used in compensation of the positive dispersion induced by convergent lens in some special cases.

In this paper, the rule of focal shift and the property of axial dispersion of BPFs are studied in scalar diffraction theory based on Deybe approximation. Numerical results of focal shift values of 2-zone and 3-zone BPFs with various normalized radii and phase shift values are also given. At last, as an example, the application of BPFs with axial dispersion in compensation of chromatic aberration in an ultrafast focusing system is given. The numerical results show that the chromatic aberration is compensated well nearly for the whole spectral bandwidth of the ultrafast laser. Therefore, this focal shift effect induced by BPFs should be of great interest for its potential applications in compensation of chromatic aberration and compact tunable focal modulation in some special cases.

7848-41, Session 9A

Ultra-high channel-count fiber Bragg grating based on the utilization of the phase-only sampling

H. Li, Shizuoka Univ. (Japan)

As one of the fiber-based wide-band promising components, high channel-count fiber Bragg grating has recently attracted great interests. In this paper, we introduce our recent developments in the design techniques for the ultra-high channel-count fiber Bragg gratings (FBG), the key technique is based on the utilization of a continuous phase-only sampling, which is the same as the one to optimize a phase-only grating in the diffractive optics. We have theoretically demonstrated a novel double sampled FBG with channels up to 153, which could be used as either the dispersion compensator or the comb filter in broad-band WDM system.

7848-42, Session 9A

Linearly chirped supercontinuum for time-stretched analog-to-digital conversion

Y. Teng, Beijing Univ. of Posts and Telecommunications (China)

The research on all-optical analog-to-digital conversion (ADC) has been extensively attempted to break through inherently limited operating speed of electronic devices. With increasing bandwidth demands from the Internet backbones, researchers have been targeting 100 Gbit/s and higher data rates per wavelength division multiplexing (WDM) channel using spectrally efficient multilevel modulation formats. Demodulation of such signals requires analog-to-digital converters (ADCs) with very high performance and resolution. Such ADCs are also crucial for defense applications such as radars and for wide-bandwidth laboratory instruments such as oscilloscopes and vector spectrum analyzers. In a photonic TS-ADC, the RF signal is modulated over a linearly chirped optical pulse. It is subsequently slowed down in time when it passes through a highly dispersive medium, owing to its group velocity dispersion (GVD), before being converted back to electrical domain by a photo detector. Photonic crystal fiber has attracted lots of attentions due to unique optics characteristics such as endlessly single-mode transmission, controllable dispersion, and high nonlinearity and so on. Some studies had been reported based on the nonlinearity and dispersion characteristics of fiber to achieve high sampling rate analog-digital conversion. We propose to use the photonic crystal fiber for time-stretch analog-to-digital conversion (A/D) system through generating low-noise, linear chirp distribution, flat super-continuum generation. Based on the RF analog signal modulation-to-line of chirped pulses, large dispersion photonic crystal fiber is used for time-domain stretching.

7848-43, Session 9A

Application to the design of guide-mode resonance grating filter with using simulated annealing method

J. Ma, Shanghai Institute of Optics and Fine Mechanics (China)

Although there are several well -known methods such as RCWA, FMM, for analyzing the diffraction properties of gratings, design of these optical elements with specified spectral properties is commonly a challenging problem. It is relatively not easy for the researchers to design narrow line-with diffraction filters based on guided mode resonance phenomenon with common diffraction algorithm.

Simulated Annealing (SA) method is evolutionary, robust technique that has been widely utilized to design optical diffraction components. This method is inspired by the physical process of heating and controlled cooling of metal material to increase the size of its crystals and reduce their defects. The most distinctive features of this method lie in its powerful ability of convergence towards the global minimum in a reasonable computation time and the independence of the initial parameter values.

In this paper, first, the physical basis of SA and its mathematical realization are introduced. Then, a Guided-Mode Resonant Grating Filters (GMRGF) with single layer is designed by using SA algorithm. The central wavelength of GMRGF is locked at 532nm and its line-width is fixed at 1nm. The plane wave light radiates the grating from air cover with normal incidence. The optimized parameters are refractive indices and thicknesses of high and low material of grating, other parameters are grating period and fill factor of the grating. It is shown from our calculation that an excellent reflection spectrum with narrow line-width, high peak and low sideband can be obtained after optimizing the grating parameters. Next, a double layered GMRGF with line-width of 4nm, which is relatively easy fabrication in experiment, is designed at central wavelength of 1064nm. The grating substrate and waveguide layer are Sio2 and Hfo2 respectively, the grating structure is directly etched on the waveguide layer. The optimized parameters are grating period, groove depth, incident angle and fill factor respectively. The above grating values should be included in reasonable ranges in consideration of grating fabrication in our experiment condition. It is demonstrated from the calculations with the parameters obtained from SA optimization algorithm that the peak diffraction efficiency is more than 99% at central wavelength 1064nm and the sideband reflection is depressed at the level bellow 5% in a large wavelength range. Moreover, the parameters of a three layered GMRGF structure with antireflection property are also provided with this powerful method. Meanwhile, the results found by SA method are compared with RCWA theory.

7848-44, Session 9A

Research on the recording hologram with foveon in digital color holography

Q. Song, Kunming Univ. of Science and Technology (China)

In the digital color holography, three holograms are recorded by a monochromic CCD respectively, which is complex for manipulating system. Moreover, the system lost a character of real-time. In the usual color CCD, color aliasing artifacts in the Bayer mosaic case generally makes holograms can not be used. With optimizing of control mode, the Foveon X3 CCD generates few color aliasing artifacts associated with sampling. The influence of color aliasing is basically eliminated in the phase testing. We realize the digital color holography using a color hologram recorded by Foveon X3 CCD, and the object is illuminated by three lasers with different wavelengths (red, green, blue) at one time. According to contrast of experimental results between holograms recorded by Foveon X3 CCD and those recorded by monochromic CCD, it validates Foveon X3 CCD can be used in the digital color holography.

7848-45, Session 9A

Measurement of inner surface profile of a tube using two wavelength phase-shifting digital holography

M. Yokota, T. Adachi, Y. Sakamoto, Shimane Univ. (Japan)

A novel phase-shifting digital holographic method for measurement of inner surface profile of tubes is proposed. For a surface contouring, two wavelength method using an injection-current induced wavelength change of a laser diode is applied. To illuminate and investigate the inner surface of a tube, a cone shaped mirror is set inside the tube. The reflected and/or scattered light at the inner surface is reflected back to a CCD surface as an object beam. Therefore, the information of the inner surface profile is transferred into a sectional plane of the object beam and then a lateral size of the inner surface is compressed and only the height profile of the surface is maintained.

Two sets of phase-shifting holograms for two wavelength are recorded and the reconstructed complex amplitudes of the object are used to obtain a phase difference distribution for surface contouring. A speckle noise occurring in the phase difference image is effectively suppressed by an adaptive filtering technique consisting of an exponential averaging and masking filtering processes.

Distribution of optical path length for the object beam is calculated and the result well explains a distortion observed in the experimental one. The calculated distribution can also be used to remove the distortion of experimental profile and lead to an evaluation of height profile of inner surface. Not only the height profile but also the lateral shape of a thin film pasted on the inner surface can be detected with an image processing using an interpolation technique.

7848-52, Session 9B

Capture of the three-dimensional information based on integral imaging and its sampling analysis

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Three-dimensional (3D) imaging provides a mean to capture the 3D information of the object scene. It plays a crucial role in many research fields where additional dimensionality is beneficial in understanding and manipulating the object scene. Recent great attention on the 3D displays also demands an efficient 3D imaging technique for their contents creation.

Integral imaging provides a simple way to capture 3D information of the object scene. Numerous small elemental lenses which constitute a lens array sample the angular distribution of the light rays at their optical axes, enabling capture of the full light ray distribution on the lens array plane. 3D information of the object scene can be extracted from the captured light ray distribution for various applications.

In this presentation, we show several 3D imaging techniques based on integral imaging. 3D microscopy is one example. The 3D information of the microscopic specimen can be captured by applying the integral imaging principle to the conventional microscope. 3D holography can also be synthesized by integral imaging. 3D information embedded in the captured ray distribution is exploited to synthesize the 3D holography of the object, which provides an efficient way for incoherent holography capture. We also show an analysis of the sampling of the ray distribution. By analyzing the spatio-angular bandwidth of the ray space, the optimum sampling strategy can be found.

7848-53, Session 9B

Application of wavefront coding technology to mutilband IR optical system

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The optical system with mutil band capability or spectral ranges within one band capability are required extensively, which have advantage of decreasing reaction time and false alarm, increasing target recognition capability due to specific emissivity features. The performance of classical mutil band optical system is limited by sort of material or reduced diffraction efficiency away form design wavelength with diffraction optics. The wavefront coding technology (WFC) is an innovative technology that joints the optical design and digital image processing together. By adding a phase mask close to the pupil of the optical system and coefficient optimization of the phase mask, then the optical system with the wavefront coding technology becoming very insensitive to misfocus related aberrations, but the formed image is not sharp and clear, the final clear imagers can be obtained by signal processing of the formed image. The theoretical analyses of characteristics of the wavefront coding technology are explored for chromatic aberration. And then the application of wavefront coding technology to mutil band IR optical system are presented, including a design example of mutil band IR optical system with wavefront coding technology. The optical system with F number 2, waveband form 3um to 12um, and field of view 10°, the effective focal length 120mm. In the end, the imaging process of the WFC system and restoration were simulated with MTALAB. The results show that system with Wavefront Coding Technology could only using one material which working waveband form 3um to 12um, and achieved athermalization in a -40 +60 .It can be conclude that wavefront coding technology could play an important role in mutil band IR optical system.

7848-54, Session 9B

Compressive imaging and spectroscopy

K. F. Kelly, Rice Univ. (United States)

Compressive sensing is an emerging field based on the revelation that a small number of random linear projections of a signal or an image contain enough information for reconstruction of a high resolution one. This technique is already being applied to traditional imaging devices such as magnetic resonance imaging and neutron scattering. Inspired by the success of this technology, we have developed of a new optical imaging methodology that directly exploits compressive sensing. The camera we have designed is capable of megapixel images while utilizing a single optical detector for acquisition. We have directly implemented compressive sensing in the acquisition through the use of a digital micromirror device to randomly modulate and acquire the necessary projections of the image. Our design has additional desirable properties including scalable output bit stream and variable image resolutions. Application of this to infrared imaging and spectroscopy is one area where the compressive advantages of lower costs and higher sensitivity are particularly beneficial. The same methodology has also be applied to terahertz imaging.

7848-55, Session 9B

Phase compensation for eliminating black-matrix effect of phase-only spatial light modulator

J. Tian, H. Qi, J. Zheng, D. Li, Shenzhen Univ. (China)

A method for improving the performance of phase-only spatial light modulator (SLM) is proposed in this paper. Spatial light modulators are widely used in many cases where modulation of light is required because of their high optical efficiency, high number of degrees of freedom, programmability, and wide availability. For an electrical-addressed SLM, the electrodes surrounded the pixels form an opaque grid, just like a 2D black-matrix. It will have an intrinsic effect on the incident light whether image is loaded into SLM. This inherent effect was called black-matrix effect characterized with zero-order diffraction of high brightness and high-order diffraction terms in the Fourier plane. This is strongly influenced the quality of phase modulation.

In order to eliminate the black-matrix effect of SLM, a digital Fresnel lens is compensated to the original phase map and the observation plane is located in the focal plane of the digital Fresnel lens. Because the black-matrix effect has not formed at this position, the only disadvantage is a uniform background lightness caused by the pixelated structure of SLM with Fresnel propagation. Therefore, the black-matrix effect is eliminated only through digital phase compensation. Furthermore, the diffraction pattern will be observed without lens, because of the focus function of digital Fresnel lens. The theoretical analyze, computer simulations and experimental results are all presented to demonstrate the validity. Possible applications include almost all phase modulation applications.

7848-56, Session 9B

Phase calibration of spatial light modulators by heterodyne interferometry

R. Wang, M. Hu, Shenzhen Univ. (China)

In this paper, a method of measuring the phase-modulation properties of spatial light modulator (SLM) by heterodyne interferometry is proposed. As a kind of key elements in the advanced optical information processing systems, spatial light modulators is widely used in many important fields such as pattern recognition, digital holography, optical metrology, optical interconnection, generating programmable lenses

or diffractive optical elements, and adaptive optics. Especially, phase-only SLM devices were applied to photoelectric information systems extensively because of the performances of high light efficiency and high diffractive efficiency. So, the phase calibration plays an important role in the SLM applications. The phase response of SLM is determined most commonly by two kinds of method, diffraction-based techniques or traditional-interferometer based techniques. However, both of them get the phase response indirectly by measuring light intensity, which reduces the calibration accuracy. For this problem, a heterodyne-interferometer based method is proposed to calibrate the phase modulation of SLM. Compared with previous methods, this technique measures the phase response directly by taking advantage of the heterodyne mechanism, so it will lead to higher accuracy. A heterodyne-interferometer based calibration system making use of acousto-optic frequency-shifters has been designed and realized. A hardware-based automatic phase calculation system was also implemented to process the heterodyne signals. Theoretical analysis and experimental results demonstrate the validity of this method.

7848-46, Session 10A

High resolution digital holographic technique based on image filter

L. Deng, H. Wang, L. Ma, Zhejiang Normal Univ. (United States)

An approach that increase resolution of three-dimensional (3-D) samples by image filtering is presented in the filed of digital holography. In the off-axis image plane holography, we present uses a low-pass filter in the frequency domain by 4f system, in order to make object wave which meet to the resolution of charge coupled device (CCD) interfere with reference wave; Controlling .the area of filtering and imaging to recording the interferogram that contains all parts of the frequency about object, then we get and stitch any parts of frequency about object by numerical reconstruction. Thus, the high resolution results can be getting by this technology. Experiment results for phase grating showing the capabilities of the proposed approach are presented.

7848-47, Session 10A

Polarization imaging and angular multiplexing in digital holography for high resolution reconstruction

J. Di, J. Zhao, Northwestern Polytechnical Univ. (China)

Polarization imaging and angular multiplexing are presented aimed at improving resolution in digital holography. Two orthogonal polarized waves O1 and O2 with a small angle illuminating on the sample are employed as object waves. O1 has a horizontal polarization state and illuminates the sample vertically while O2 has a vertical polarization state and illuminates the sample with a small incident angle. The two orthogonal polarized waves hold the information of each different frequency bandpass of the object spectra and avoid the interference between each other. A linear polarized plane reference wave R which has a polarized angle of 45° with respect to the two orthogonal polarized waves is introduced to interfere with the two object beams at the surface of CCD target and form the multiplex hologram. To achieve selective filtering for different frequency information from samples in the Fourier transform domain, angular multiplexing is used, and then the two diffraction terms are chosen to propagate and reconstruct separately and the phase aberration in the two wavefront fields is corrected to produce the high resolution reconstructed image. A resolution target is used for the verification of this method. The experimental results show that the feasibility of polarization imaging and angular multiplexing for high resolution reconstruction in digital holography.

7848-48, Session 10A

Contrast between wavelet transform and the traditional frequency domain filtering method for digital hologram reconstruction

H. Xia, M. Li, M. Tang, Soochow Univ. (China)

Based on the basic principle of digital holography, reconstruction methods for digital hologram are analyzed theoretically. Charge-coupled device(CCD) is used for recording digital off-axis holograms, which are reconstructed by the Fresnel reconstruction method. Wavelet transform coefficients method and the traditional Gaussian high-pass filter method are used for the reconstruction of the digital holograms. In order to eliminate the speckle noise near the filtered zero-order diffraction spots more effectively, the high and low frequency coefficients in the wavelet transform were adjusted. A holographic experimental system based on Michelson interferometer was set up and digital off-axis holograms were recorded. By adopting the Robert gradient method in Iconology, the reconstructed results both by wavelet transform coefficients method and the traditional Gaussian high-pass filter method were compared. The larger the gradient magnitude value (G) is, the more information the image contains, and the image is clearer. The G values of the reconstructed images got by wavelet transform coefficients method and the traditional Gaussian filtering method are 1099891 and 1042562, respectively. The results validated that applying the wavelet transform for digital hologram reconstruction can more effectively eliminate zero-order diffraction image and improve the SNR and quality of reconstructed image than applying the traditional Gaussian high-pass filter.

7848-49, Session 10A

Application of phase unwrapping based on least-squares and iteration in digital holography

H. Xia, R. Guo, Z. Fan, X. Qian, B. Yang, Kunming Univ. of Science and Technology (China)

Abstract: Phase unwrapping is an important content of digital holography, which gets continual and real phase from wrapped phase. The least-squares phase unwrapping is a fast and effective method. But for wrapped phases with complicated variation and much noise, the unwrapped phase got by least-squares method will produce errors. In this paper iterative unwrapping of phase difference is combined with least-squares unwrapping to eliminate the errors. This method is used in digital holography to unwrap phases with complicated variation. The phase variation of object wave through a polymethyl methacrylate (PMMA) specimen with a hole under uniform tensile force is measured by holography. The phase is unwrapped by phase unwrapping based on least-squares and iteration. The cosine patterns of unwrapped phase and wrapped phase are consistent. Which means this method is correct and can be used to unwrap phases with complicated variation and much noise.

7848-50, Session 10A

Study of color digital holography of large size object with zero-order elimination

J. Gui, J. Li, Y. Zhang, Y. Lou, Z. Fan, Kunming Univ. of Science and Technology (China)

Color digital holography received more increasing interest with cheap high resolution CCD cameras and the increasing power of computers. Study of color digital holography is significant of accurately synthesizing digital holography testing information of multi-wavelength, although

digital reconstruction image of color object is not as good as the image recording from digital cameras. It is an important content in color digital holography that reconstructed object wave fields of different color illuminating with a same image size. In order to acquire the color holographic image, the holograms with different recording conditions must be padded zeros to keep same size, because the reconstruction image size with Fresnel diffraction equation is related to wavelength. But it is not easy to avoid pad errors. Using spherical wave as reference wave, we presents a reconstruction method with adjustable magnification in other papers. With this method, we get the frequency spectrum of transmission light fields of hologram with spherical wave illumination, then reconstruction holographic image by using angular spectrum equation. This method is meet demand of studying of color digital holography. But when the radius of spherical wave is small, zero-order image will have a serious effect on reconstruction image because of the expansion of each frequency spectrum. In order to avoid this effect, we have to select smaller filter size to get object wave spectrum, but some high frequency lost, thus reduce image quantity. Furthermore, when object size is quite larger than the recording area, long recording distance will be selected to separate object frequency from frequency spectrum, but the high frequency lost also, thus result in a low quantity reconstruction image.

In this paper, we propose an optic system with negative lens, reconstruct a holographic image of a large color object (110mm×100mm) with adjustable magnification reconstruction method. In order to improve quantity of reconstruction image, an elimination zero-order method proposed. The result will propose a reference in holography application.

7848-51, Session 10A

Optimization research for digital hologram recording system of big objects

Y. Lou, J. Li, Y. Zhang, J. Gui, C. Li, Z. Fan, Kunming Univ. of Science and Technology (China)

A optical system using concave lens, which is used to image a big object preliminarily, is presented. Object's minified virtual image is recorded by off-axis digital holographic system, and reconstructed with numerical calculation of diffraction. This is an applicable method in optical noncontact detection. Although the method to obtain minified real image with convex lens is proposed by others, theoretical study implies that using concave lens can make the recording system more compact and the application more convenient. For convenience in digital holography detection with the same system under multi-wavelength illumination, concave lens is chosen as a virtually imaging system according to SFFT of Fresnel diffraction. Setup optimization for digital hologram recording system is studied. In this way, the reconstructed image is separated from zero order diffraction with respect to certain object and CCD. Further more, in order to make the system be suitable for multi-wavelength illumination, focus of lens is modified according to certain wavelength, and the setup optimization is performed so as to record hologram successfully with multi-wavelength illumination. To valid this method, several holograms are recorded under dual-wavelength illumination with the setup and object fields are reconstructed through focus modification.

The theoretical analysis and experimental test of this work is described in detail.

7848-57, Session 10B

Analysis on the 3D crosstalk in stereoscopic display

H. Choi, Sejong Univ. (Korea, Republic of)

The 3D crosstalk in stereoscopic display is a luminance leakage between the left/right images. With a high 3D crosstalk, the luminance and contrast ratio of 3D display will be significantly reduced and the 3D crossatlk can also cause a serious 3D nausea. Therefore, it is needed to analyze and optimize it. In this paper, current methods to measure the 3D crosstalk will be reviewed and a method to analyze the measured 3D crosstalk and to acquire an acceptable level of 3D crosstalk will be proposed.

7848-58, Session 10B

Design of color separation resonant grating used in Fresnel diffraction region

Y. Fang, Q. Tan, G. Jin, Tsinghua Univ. (China)

The liquid crystal display (LCD) has been widely used in multimedia products. Conventional color filters consisted of dyed material are general used as color separator in LCD, which generate the desired visible colors by absorbing the undesired spectra. For the transmitted efficiency of a color filter is less than one third, several other methods have been proposed to achieve a higher efficiency, such as cylindrical lens array and phase gratings. Talbot grating based on the fractional Talbot effect realizes the spatial color separation in Fresnel field in the consideration of the practical thickness of the LCD. In this paper, the color separation grating with shorter period for red and blue in Fresnel field is designed and analyzed by vector theory. The grating period is 1.5wavelength, in the range of 1wavelength to 2wavelength, to ensure three diffraction orders only. The diffraction behavior is analyzed by modal method, so that the field distributions of the propagating modes and the diffraction orders can be expressed. The first two even propagating modes are taken into account and the higher modes are neglected. Using the initial solution given by modal method, the exact design parameters can be obtained by RCWA without searching all the parameters. When the depth is 0.374 micron and color separation plane is chosen at 2.06 micron, the efficiency for red is 73.3%, and 75.9% for blue. The color separation ratio is 0.9. Furthermore, the possibility of color separation for three colors is discussed.

7848-59, Session 10B

Depth-fused display using polarization distribution

S. Park, S. Min, Kyung Hee Univ. (Korea, Republic of)

Depth-fused display (DFD) method is one kind of multifocal plane display which provide autostereoscopic three-dimensional (3D) image with small visual fatigue. We propose novel DFD method using polarization distribution and demonstrate the feasibility of the system with experiment.

DFD method is based on the characteristic of human depth perception when the luminance-modulated two-dimensional (2D) images are overlapped. The perceived depth position is decided by the luminance ratio of each plane. As a result, 3D images can be generated by properly providing luminance-modulated images on each layer.

The proposed system includes polarization selective scattering films (Imajor; Teijin DuPont Films, Japan) and polarization modulating device. The polarization selective scattering film has characteristic of partial scattering according to the polarization state and transmits the rest light from the scattering. When films are stacked with the scattering axis rotated, each layer of film provides different scattering ratio according to the incident polarization. Consequently, appropriate modulation of polarization can provide DFD image through the system.

Depth map provides the depth information of each pixel as a gray scale. Thus, when a depth map is displayed on a polarization modulating device, it is converted into a polarization distributed depth map. Conventional twisted nematic liquid crystal display (TN-LCD) can be used as polarization modulating device without complicated modification.

The proposed system is simple compared to the previous systems and shows high compatibility with computer generated 3D images. We demonstrate the proposed system with simple experiment, and compare the characteristic of the system with simulated result.

7848-60, Session 10B

Laser imaging method using computational holography

T. Wang, Y. Yu, H. Zheng, L. Zheng, Shanghai Univ. (China)

To form a laser image we can see with our eyes, there usually are two kinds of image forming method. One is to direct the slender laser beams to special points, which form one image, by light directing element (LDE), the other is named as light-blocking method. For the later method, one part of light passed through a panel to form the bright area, and the other part was blocked to form the black area. The former method has high light efficiency for the reason that none light was blocked and all energy of light was used to form image, but a precision mechanical instrument used as LDE is needed. In this paper, we describe a new kind of laser imaging method based on holography. Coherent light is used as source and phase-modulated spatial light modulator (SLM) as the LDE. Phase-modulated SLM can change the phase of light illuminated on it. The light on the pixel will travel in new direction according to the phase change by the phase-modulated SLM. In order to get the image, we must know the phase relay of each pixel by SLM. In this paper, The Iterative Fourier Transform Algorithm (IFTA), also known as G-S algorithm, was used to calculate the phase distribution on SLM. The laser image formed by the phase-modulated SLM is simulated with VirtualLab software. The optical system is built to form the laser image. With the proposed method, we can form 2D or 3D image, and it enjoys the advantages of laser display, such as full color mount and sharp intensity. In our opinion it is a promising method in the near future.

7848-61, Poster Session

A new method of reconstructing polarization distribution of light wave

C. Niu, Univ. of Science and Technology Beijing (China)

Polarization is a very important parameter for optical wave. Altering the polarization, by introducing ellipticity, rotation, or other residual instrumental effects, can strongly affect system performance. For example, the radially polarized beam will maximize the efficiency of the energy exchange between the laser and the electrons, permits the electron beam to be focused by the laser field and provides other advantages. Moreover, polarization distribution can be used to record image information for optical encryption system. But, most of the existing techniques for detecting polarization state of optical wave are focused on uniform polarization distribution, for example, uniform linearly polarized beams or uniform circularly polarized beams. For a two-dimension wave plane of an incident light beam, polarization state at every point can be particular and contribute to performance of whole beam. So, it is very necessary to provide a method for detecting polarization state of every point for a plane. In this article, a novel method for reconstructing polarization distribution of incident light is proposed. Detected light beam is incident on the proposed system and is divided into two light beams with orthogonal polarization. The two light beams are then separated on the Fourier plane of a 4f system. Through putting proper filter on the Fourier plane, o-light or e-light can be chosen solely and be recorded. Using a halfwave plate can transform polarization state of e-light into polarization state as the same as that of o-light, and then o-light and e-light can intervene with each other and be recored. By using a phase correction technique, the phase difference between two beams can be determined. And then, polarization distribution of the incident light beam is entirely reconstructed. Numerical simulation proves that the proposed method can reconstruct polarization state of a light beam effectively.

7848-62, Poster Session

Numerical study on radially polarized beam focusing through dielectric interface and metallic film

X. Gao, L. Ning, Guilin Univ. of Electronic Technology (China); X. Gan, Swinburne Univ. of Technology (Australia)

The strong lateral polarization component of radially polarized beam focused by high numerical aperture objective shows totally axis-symmetrical property, which gives rise to its widely applications in many optical problems. The equations of vectorial 3D electric field of radially polarized beam focused by high numerical aperture objective are given based on the vectorial Debye theory. The finite difference time domain(FDTD) method is applied to simulate the focusing of radially polarized beam. The electric field of radially polarized focal beam in a defocus plan calculated by Debye theory is induced as input source using the total/scatter field approach. We simulated the focusing processes in single dielectric medium and through the interface of two dielectric media, respectively. The distribution of electric field of the focus obtained from the FDTD results coincides with that directly calculated by Debye theory, which proves the facility of FDTD method for simulating the focusing optical field. Additionally, we simulate the focusing of radially polarized beam through dielectric half ball shaped nano-holes with different sizes. The focus shift effect caused by the different sizes of nano-holes provides the mechanism for changing the longitudinal position and the lateral resolution of the focus in subwavelength scale. At last, the surface plasmons excited by the radially polarized focus are shown at the surface of the metallic film and form a smaller focus. The simulation results of this paper will give contribution to the super-resolution focusing in nano-lithography.

7848-63, Poster Session

Theoretical and experimental analysis of Maxwell fish-eye spherical lens diffraction intensity

H. Lv, Xiaogan Univ. (China)

The diffraction intensity of the Maxwell fish-eye spherical lens is analyzed using the matrix optic theory and the experimental setup. In addition, the diffraction intensity of the homogenous spherical lens is given basing on Kirchhoff's diffraction theory. Comparing the theoretical data and the experimental data of the Maxwell fish-eye spherical lens and the homogenous spherical lens, respectively, there are good agreed with each other. Results indicate the diffractive intensity of the Maxwell fish-eye spherical lens and the homogenous spherical lens is lager than 95% and smaller than 80%, respectively, and the Maxwell fish-eye spherical lens has smaller focusing size than the homogenous spherical lens.

7848-64, Poster Session

Diffraction calculation method suitable for both far and near field

C. Li, X. Wang, S. Yuan, Kunming Univ. of Science and Technology (China)

In digital holography, diffraction calculation plays an important role in reconstructing object wave numerically. Starting with the angular

spectrum theory of diffraction, Rayleigh-Sommerfeld integral formula is adaptable to simulate diffraction distribution into a wide range of diffraction distance, because there is no approximation toward propagation distance in this formula. However, in discrete numerical calculation it is not adapted to near-field and far-field diffraction simulation simultaneously due to sampling limitation. In this study, the traditional angular spectrum method of diffraction simulation is improved. By introducing band-width limitation, a new method is put forward, which is suitable for diffraction simulation both in far and near field. Simulating examples are presented in the paper to validate the proposed method with band-width limit.

7848-65, Poster Session

Glasses-free 3D display system using grating film for parallax image separation

M. Kuwata, K. Sakamoto, Konan Univ. (Japan)

A liquid crystal display (LCD) recently comes into common use. The left and right half regions provide the stereoscopic images for left and right eyes. However both stereoscopic images are not in the same position because the center of left and right regions has an interval, then it is difficult for the observer to view the 3D image by the stereoviewing. One of the solutions to this problem is to use the 4-mirror stereoscope. This 4-mirror stereoscope is an easiest way to see stereoscopic images. But this paper describes another solution.

To overlap left and right images, the authors use an optical film. This optical sheet is a flexible film with prisms designed to transport and diffuse the light. This sheet has interesting characteristics as follows; the prismatic phenomenon is observed and the doubling can be visible through the sheet like the Calcite. This doubling phenomenon occurs because the prism sheet diffracts two beams. These beams are called as the first order diffracted beam and the second order diffracted beam. This interesting thing reminds us of method to superimpose left and right stereoscopic images. A grating diffracts or scatters a light beam with a designed angle. Using the doubling phenomenon, the authors shift the images for superimposing stereoscopic images by adjusting the interval between an optical sheet and image plane.

To deliver left and right images into appropriate eyes though you wear no glasses, we use a new grating film with view control effect. Using this film, you can see through the film from the left, but not from the right. One of the miraculous features is that it can be either transparent or grating sheet, so that it looks either like transparent glass or prism, depending on the angle of sight. It is useful characteristics for 3D viewing that you can control what can and what cannot be seen depending on which side the viewer is on, or what angle the viewer is looking from. Using the miracle of this visibility control, it enables us to perceive left images by the only left eye and right images by the only right eye.

7848-66, Poster Session

Fabrication of photonic crystals using holography and study for the lattice constant changes

J. Han, H. Zhang, T. Zhao, Capital Normal Univ. (China)

A simple optical path for fabricating photonic crystals is presented. It is convenient to change the number of beams and its angles. Then photonic crystals of different lattices can be gotten. And the recording material is home-made water-resisting photopolymer. After testing, the material has properties of high diffraction efficiencies, high resolution and simple later development, ect.

The fabrication of photonic crystals with holography is simulated by matlab, and the theory is introduced in this paper. In the theory, by changing the number of beams and its angles, triangular, square and circular structures of photonic crystals are obtained. When polarization states of beams are changed, photonic crystals of different refractive index modulation can also be obtained. Via the simulation, the refractive index modulation of linearly polarized light is the highest.

In the experiment, different exposures are set. In this paper, the best exposure using water-resisting photopolymer is obtained, and the time is 20s, which is less than before. In this paper, photonic crystals using four light beams and five light beams are fabricated. The fabricated photonic crystals are large-area, bulk-mass and high-strength 3-D. Then, compare the simulated results with the experimental results and they are in substantial agreement. So the experimental method can be used to fabricate 2D photonic crystals. And the same method applies to the fabrication of 3D photonic crystals. As well as, photonic crystals with defects can be fabricated using this experiment device.

7848-67, Poster Session

Multi-mode Laser beam uniformizing using phased Dammann grating

C. Zhou, Y. Li, Institute of Optics and Electronics (China)

Laser in medical applications is becoming more mainstream. Since 2003, worldwide sales of lasers used for aesthetic applications have doubled. Among the medical applications, laser-skin-treatment is very important. In order to operate the laser to treat skin conveniently, the multi-mode fiber is used to transmit high-power laser pulse beam, so the mode of the treat output laser is dependant on that of the multi-mode fiber. In general the mode of the multi-mode fiber is very complicated and random, so the output laser beam is very terrible. The common distribution of a Nd:YAG laser is not uniform and its center intensity is low and the edge is high, just as in Fig.1, In order to guide the Nd:YAG laser beam to the need-to-be treated skin part, a visible LD laser with wavelength of 650nm is used to be guide light, which is co-axial transmitted with Nd:YAG laser. But the 650nm pointed part is the center part, the energy is weak not to satisfy treat need. If we increase the energy of the output laser, the healthy skin on the edge spot would be burn out. In order to overcome the problem, many optical elements are used to re-shape laser beam from multi-mode fiber. Micro-optical element is best among these elements for its unique characteristics such as more design parameters. Since the laser wavefront and the intensity distribution are not stable, the traditional diffractive optical elements(DOEs) by G-S algorithm design or an aspherical optical group can not be used to shape the laser beam.

Dammann grating is a kind of DOE, and the intensity of its spots are not dependant on the input laser beam distribution, so the Dammann grating is used to uniformize the multi-mode laser beam in this paper. First, the quality factor M2 of the laser beam is large, i.e. the classic is more 100, so the spot is bigger than to fill the gaps between the neighbor spots; Second, the intensity distribution of the spot is super-Gaussian, so by optimizing the pitch of the spot-to-spot to super-position the neighbour spots correctly, the whole intensity of the focus plane is becoming uniform, just as in Fig.2. The design method is put forward and equation is deprived and the calculation results are given in this paper, and the non-uniformity is less than 10%, which satisfy the application need.

7848-68, Poster Session

Design of diffraction optical element for homogeneous and quadrupole illumination in lithography system

Y. Li, C. Zhou, Y. Feng, X. Wang, Institute of Optics and Electronics (China)

In lithography system, the illuminator is composed by profiler, uniformizer and relay. The uniformizer can control the exposure while

the relay can generate off-axis illumination (OAI) which enhances the resolution of the system. Quadrupole illumination is one of OAI. The tradition methods to produce OAI usually reduce the efficiency of the energy. Diffraction optical element (DOE) can be used for OAI and has the advantage of improving the efficiency of the energy. At the same time, DOE have been widely used in uniform illumination .The common methods for design of DOE are iterative algorithm and search algorithm like simulated annealing algorithm(SA) which need search within entire zone so that much time is needed. Iterative algorithm is quicker but it may be stagnation in some algorithms as G-S (Gerchberg-Saxton) algorithm. These algorithms are compared in this paper especially between the adaptive addition algorithm and the gradient search algorithm. In this paper, the adaptive addition algorithm is used to optimize the OAI-DOE because it can quickly get the optimum result without the stagnation, it is quicker than other iterative algorithm. In the design, only less than 30 times iterative are needed while the initial phase comes from the G-S algorithm of 30 times iterative. The energy efficiency is more than 90%, pole balance is less than 1% and uniformity is less than 5% . The results satisfy the request of the illumination system in lithography system. Besides, the influence to the results is discussed while the input is an oblique incident and the input laser beam has a small divergence angle.

7848-69, Poster Session

Research on eliminating zero-order diffraction interruption for wavefront reconstruction of digital holography with adjustable magnification

Q. Song, Kunming Univ. of Science and Technology (China)

In the study of wave-front reconstruction with adjustable magnification digital holography, applying the spherical wave as the reconstruction wave, and wave-front is reconstructed with the angular spectrum diffraction formula is an effective method. However, this method usually accompanies very intense zero-order diffraction interruption. In this paper, there are three methods for eliminating zero-order diffraction interruption. The experimental results demonstrated that the mean subtracted from a hologram is an effective method.

7848-70, Poster Session

Application of the angular spectrum diffraction transform in the design of binary optical element

Y. Wu, The Academy of Equipment Command & Technology (China); J. Li, Kunming Univ. of Science and Technology (China)

It is an important subject that binary optical element is designed to transform beam in the diffraction optics. At present, there are manifold design methods by using Fresnel diffraction integral. However, Fresnel diffraction integral is only the paraxial approximate solution to diffraction problem. According to scalar diffraction theory, Kirchhoff formula, Rayleigh-Sommerfeld formula and diffraction's angular spectrum transmission formula are accurate solutions to Helmholtz equation. And these formulae can be solved by FFT. Therefore, it will be obtained better result if using the formulae of de-paraxial approximation to design diffraction element. FFT is a fast algorithm of discrete Fourier transform. In order to obtain the accurate result, the sampling theorem must be met according to the theory of discrete Fourier transform. But there are few discussions about the calculation conditions of Kirchhoff formula, Rayleigh-Sommerfeld formula, and diffraction's angular spectrum transmission formula. So the sampling conditions using FFT to calculate the angular spectrum diffraction transform are deduced in the paper. Combining the Gerchberg-Saxton (GS) algorithm with the angular spectrum theory of diffraction, the design method of binary optical element to realize beam transformation is advanced. And a design example of the diffraction element in marking pattern is also provided.

The paper is organized as follows: Section describes the common design methods of binary optical element and provides the idea of using angular spectrum diffraction transform to design binary optical element. Section discusses the angular spectrum diffraction transform and its sampling conditions. Combining the Gerchberg-Saxton (GS) algorithm with the angular spectrum theory of diffraction, the design method of binary optical element is put forward in section . Section shows the design example. Discussion and conclusion are given in Section .

7848-71, Poster Session

4-views flat tabletop display using prism film for viewing angle control

T. Honda, K. Sakamoto, Konan Univ. (Japan)

Papers or displays show us an image. The direction to observe these views generally is determined. If you watch the view from opposite side, you perceive an upside down image. In this paper, the authors propose the optical technique for 360 degrees all-around viewing. Using our new technology, you always perceive a correct image even if you see a printed material or an electronic display on the tabletop from opposite side.

The authors have researched an interactive tabletop display system. We think that the electronic display system is applied to collaborative tasks on the round table. We would like to realize the computer supported collaborative working environment using the tabletop display. The goal of our researches is as follows: Suppose this system is in the science and technology museum. This display can provide some images according to the user's request. When kids put objects on the table, the display system gives users virtual 3D images and the observers can touch these floating images.

Assuming that two users sit around a table and do collaborative tasks. When the user-2 sits down opposite the user-1, for example, each user must view the different image so as not to perceive upside down images.

In this paper, the authors propose the displaying system for co-operative working among four users. As the all users are surrounding the table, the view screen of a display needs to be viewed from any directions. In our new display system, the imaging plate is laid on the table at a level with the tabletop. This plate delivers one screen view to each user so as to generate all-around viewing zone which can be viewed from any directions. This unidirectional screen is attached to the surface of a display plate. This special screen is designed so that each observer always faces the view screen on the table. The unidirectional screen works as an optical device for controlling the direction of emitted rays from the display. By an effect of the special optical sheet, you can perceive a correct image without upside down from any directions.

7848-72, Poster Session

The scattering characteristic of diffractive optics

W. Jia, Y. Wang, F. Huang, C. Zhao, J. Hou, Mechanical Engineering College (China)

The analysis of scattering characteristics of diffractive optics based on Finite-difference time-domain method is presented. And its scattering pattern along the surface is gotten. It shows that the scattering intensity in the discontinuous surface is much higher than the continuous surface. This causes the decrease of diffractive efficiency. Binary optics with multilevel relief can cause more scattering than micro optics with continuous relief, so it is not suitable for being used in the situation where phase varies rapidly.

7848-73, Poster Session

Analysis on light intensity distribution of diffraction of unequal slit width gratings

Z. Hong, Shandong Normal Univ. (China); X. Wang, X. Li, Beijing Technology and Business Univ. (China)

Taking gratings with periodically varying slit width as two groups of diffraction hinge unit, light radiates on the gratings, each diffraction unit produces diffraction respectively, and then it is equivalent to interference of two beams of coherent light. Using the theory of light diffraction and interference, by means of the diffraction light intensity distribution function of equal slit width, the light intensity distribution law of Fraunhofer diffraction is analyzed for transmission grating of periodically varying slit width. Based on the discussion of general results obtained, the diffraction light intensity distribution and light-shade stripe conditions are obtained for gratings with special slit width and nick width, the diffraction pattern and light intensity distribution curves are plotted through computer simulation.

7848-74, Poster Session

Design and analysis of waveguide grating coupling with gradually changing periods for optical interconnection

X. Feng, National Univ. of Defense Technology (China)

Waveguide grating couplers with gradually changing periods has good focusing effect to diffraction light, it can provide a compact, efficient coupling mechanism for optical interconnection. In this paper, a polymer waveguide grating couple to vertically couple and focusing for optical interconnection is proposed and designed. The light in waveguide propagates into the grating region, and the diffraction light is focused outside the waveguide by way of focusing of light from the gradually changing periods grating.In order to estimate the coupling performance of the proposed waveguide grating couple, the diffraction characteristics of waveguide grating with a gradually changing periods as an in/out out-of-plane couple are investigated. The non-uniform grating region can be divided into a number of small sub-grating regions with a uniform grating period. The coupling efficiency and the intensities of the diffracted beams as functions of the grating periodicity, grating groove depth, and excitation direction are analyzed efficiently by solving the Helmholtze equation and the method of transfer-matrix. The overall coupling efficiency of the proposed polymer waveguide grating couple can be calculated by adding the coupling efficiencies of all sub-grating region. Their corresponding numerical simulation results are given. With the optimized structure parameters showing the high coupling performance, the design of a waveguide grating coupling to vertically couple and focusing simultaneous for optical interconnection is obtained.

7848-75, Poster Session

Modeling and characterization of tunable photonic crystal waveguides based on two-dimensional periodic arrays of silicon pillars

Q. Dai, H. Butt, T. D. Wilkinson, Univ. of Cambridge (United Kingdom)

Highly dense two-dimensional periodic arrays of nano-scaled silicon pillars present the capacity of acting as photonic crystals which can mould, manipulate and guide light. We demonstrate finite element modelling of silicon pillars based photonic crystals and their effective use in applications like waveguides, dividers wavelength splitters and switches. The optical wave propagation through these structures was thoroughly simulated and analysed, confirming their high efficiency.

Later the fabrication of highly periodic two-dimensional arrays of silicon pillars through the process of etching is also explained. High quality of the fabricated silicon pillars is displayed in various scanning electron microscope images. The arrays with pillar radius of 50 nm and lattice constant of 400 nm were successfully utilised as optical waveguides with sharp turns. The experimental results are presented showing an excellent match with the simulation results. Finally we also present the concept of utilising liquid crystals as an anisotropic medium around the silicon nano-pillars to establish tuneable photonic crystals waveguides. The cell geometry for such a hybrid device is suggested in which by application of voltage the dielectric constant of liquid crystals can be controlled and essentially the waveguides can be tuned. The simulated results, with liquid crystals as anisotropic media in the silicon pillar arrays, demonstrate that liquid crystals can be successfully be utilised for this purpose.

7848-76, Poster Session

Study on multi-image hiding method based on polarization multiplexing digital holography

Z. Zhu, J. Zhang, S. Feng, S. Nie, T. Gan, W. Dai, Nanjing Normal Univ. (China)

This paper presents a novel algorithm of Multi-Image hiding method based on polarization Multiplexing digital holography(PMDH). Previous Multi-Image hiding methods, either in spatial or frequency domain of the content image, failed to solve embedding Multi-Image in the same location. More embedding area is correspondingly needed, when desired to embed more information. Therefore, the cost of robustness decrease will be paid for expanding embedding area.

For the shortages of the traditional Multi-Image hiding methods, a novel method based on polarization Multiplexing digital holography is proposed. In our PMDH scheme based on Mach-Zehnder interferometer, a linearly polarized light from a laser source is divided into two beams which pass through two PBS (Polarized Beam Splitter) respectively and two pairs of beams with orthogonal state of polarization are formed with single wavelength. The s-polarized object beam and p-polarized object beam illuminate the different objects respectively and the two orthogonal polarized reference beams propagate off-axis with the lights focused from the 2-D objects. The compound Fourier digital holograms are captured by CCD simultaneously. Therefore, two objects information can be acquired from a digital hologram with proper incident angle between two reference beams. Furthermore, if adopting dual-wavelength interference additionally, a digital hologram can store four images by changing incident angles of reference beams properly. The proposed PMDH technology is applied in the image hiding region, which the hologram stored Multi-Image is superposed on the discrete-cosine-transform (DCT) domain of the content image, and the extraction process only requires the watermarked image without content image.

The proposed method can implement Multi-Image hiding in the same location and the application of digital holography will increase the algorithm robustness, esp. against the attacks of cropping, compression and brightness variations. Simulation results also demonstrate that the embedded Multi-Image can be successfully extracted under different kinds of attacks.

7848-77, Poster Session

Single-exposure color digital holography

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In this paper, we report a method for color image reconstruction by recording only single multi-wavelength hologram. In the recording

process, three lasers emitting in the red, green and blue regions are used to illuminate on the object and its diffraction fields will arrive at the hologram plane simultaneously. Three reference beams with different spatial angles will interfere with the corresponding object diffraction fields on the hologram plane, respectively. Finally, a series of sub-holograms generated by different wavelengths incoherently overlapped on the CCD to be recorded as a multi-wavelength hologram. Angular division multiplexing is employed to reference beams so that the spatial spectra of the multiple recordings can be separated in the Fourier plane. In the reconstruction process, the multi-wavelength hologram will be Fourier transformed into its Fourier plane, where the spatial spectra of different wavelengths are separated and can be easily extracted by employing frequency filtering. The extracted spectra should firstly be shifted to the centre of the Fourier plane and then be inverse Fourier transformed to get three monochromatic sub-holograms. After padding zeros to the three monochromatic sub-holograms, we can reconstruct three monochromatic images, which are not only identical in size but also superposed precisely. The final color image can be reconstructed by synthesizing the three reconstructed monochromatic images. For single-exposure recording technique, it is convenient for applications on the real-time image processing fields. However, the quality of the reconstructed images is affected by speckle noise. How to improve the quality of the images needs for further research.

7848-78, Poster Session

Improved algorithm for diffraction calculation

X. Wang, C. Li, Kunming Univ. of Science and Technology (China)

An improved algorithm for diffraction calculation is proposed, which is suitable for near-field and far-field diffraction simulation simultaneously. Angular spectrum method (AS) used frequently in diffraction calculation is based on Rayleigh-Sommerfeld integral formula. It is adaptable to a long range of diffraction distance, because there is not approximation of propagation distance in this formula. However, in numerical calculation the sampling problem of transfer function makes it not adapt to near-field and far-field diffraction simulation simultaneously. In this study, this method is improved by limiting the spatial frequency range of object wave. By using the improved method, the problem existed in far-field diffraction simulation with AS is resolved. Simulating examples are presented to validate the proposed method with band-width limit in the paper.

7848-79, Poster Session

Optimization of multiplexed holograms for tomographic imaging

L. Song, Z. Jiang, Z. Xu, J. Yang, Beijing Univ. of Technology (China)

Volume holographic gratings have narrowband spectral and spatial transmittance filtering properties that enable to obtain spatial-spectral information within an object. The multiplexed volume holographic gratings can achieve simultaneously three-dimension imaging of an object according to their Bragg selectivity. In this paper, two holographic gratings are multiplexed within the same volume of recording material that is a 2-mm thick LiNbO3:Fe:Cu crystal, and they are recorded with collimated reference beam and signal beam at the wavelength of 532nm. Each holographic grating corresponds to both the signal beam with a given angle and the position of the point source of spherical reference beam dependent on the different deep position of 3D object. Each multiplexed grating in the holograms is Bragg matched with different depth within the object and diffracts in a direction specified by the corresponding recording signal beam. To avoid image overlap and cross talk between multiplexed gratings, we theoretically calculate the angular spacing of different signal beams for recording two holographic gratings, and experimentally demonstrate it by changing the angle of the signal beam to recording two multiplexed gratings. The angular spacing calculated theoretically agrees well with the experimental result. Moreover, we adjust the distance between each point source location corresponding to each holographic recording to obtain the appropriate distance for reducing the cross talk between the multiplexed gratings. The optimized holographic gratings are used to simultaneously image the different depths information of a tiny object. The results demonstrate that the optimized volume holographic gratings can enhance the performance of imaging.

7848-80, Poster Session

Subwavelength focusing of nanopatterned photon sieves

Y. Xue, W. Ge, C. Wang, Soochow Univ. (China)

Subwavelength focusing, deep-subwavelength pattern generation, beam shaping and manipulating of beam propagation based on nano-structured patterns have attracted much attentions recently. Wu demonstrated a subwavelength focusing using nanoholes in a transparent thin film in which the focusing spot coming from the constructive interference of diffracted beams near the nanoholes. Zhang et al proposed a deep-wavelength pattern generation from diffraction-limited masks using metal-dielelctric multilayer structures. The mechanism of most of those devices is based on the surface plasmonic polaritons(SPPs). However, obtaining a subwavelength spatial resolution for a propagation distance on micrometer scale with SPP-based structures only is difficult because the SPPs is an evanescent wave and will decay rapidly. Very recently, Fu et al proposed a zone-plate-like plasmonic nanostructure consisting of a quartz substrate coated with Ag thin film which enables beam focusing in the near-field or region with a propagation distance ranging from to 8 or even longer. The plasmonic micro-zone-plate (PMZP) can realize subwavelength focusing at a working distance on the micrometer scale and a resolving power around hundreds nanometers. Kim et al further proposed a metal/dielelctric multilayered zone plates(MDMZP) to enhance the transmitted optical intensity. The focal spots of the proposed PMZPs or MDMZPs, are, however, found to be spatially non-isotropic in X and Y directions, and the sidelobes of the both X and Y direction are as high as 40% of the peak intensity which is far beyond the acceptable level of utilization. In this paper, we propose a subwavelength focusing using a nanohole patterned structure or nano-photon sieves(NPSs). By employing a nanohole array instead of the ring pattern in PMZP or MDMZP, and incrporating a density modulation function on the nanoholes, it is found that the sidelobes of the NPS can be effectively suppressed and the focal spot exhibits spatially symmetry (isotropic) behavior. The focusing performance can be further improved by introducing a multi-layer system, which makes the propagation distance of the transmitted beam effectively increased and the sidelobes further decreased.

7848-81, Poster Session

Tunable volume holographic filter based on the photorefractive grating

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In wavelength division multiplexing (WDM) systems tunable optical filters are needed to manipulate or select a desired wavelength from the band of available channels. Volume holograms offer the important advantage of a very high wavelength selectivity of the filter. The aim of this work is to demonstrate a method to record tunable narrow-bandwidth thick holographic reflection gratings for telecommunication wavelengths near 1550 nm.

Our approach makes use of the photorefractive effect in a single lithium niobate crystal. Photorefractive grating is produced using two-beam

interference with CW 532nm laser in the bc-plane along the c axis. The read-out beam is focused onto the surface normal to the c axis of the crystal (ab-plane). The diffracted beam is measured by a photo-diode. The tuning is achieved by simultaneously changing the angles of the two recording beams. Tuning of two wavelengths (1550.12nm and 1551.72nm) is obtained.

Firstly, the wavelength selectivity of our dynamic grating filter is studied, from which the channel bandwidth of the filter is observed in the order of ~0.1nm. Secondly, the tuning times of the holographic reflection grating were determined by measuring the diffracted signal while changing the grating's Bragg wavelength. Tuning time in the order of a few hundred microseconds is achieved. Tuning time of the holographic reflection grating as a function of the average total recording intensity at the crystal surface is also studied.

7848-82, Poster Session

Controlling the propagating features of light through a two-dimensional coupled-cavity photonic crystal waveguides

S. Feng, Minzu Univ. of China (China)

Coupled cavity waveguide is a series of adjacent optical resonator structure, the weak coupling between the localized modes in the adjacent cavities makes electromagnetic waves propagate along the waveguide with a jumpy way, which can greatly reduce the propagation velocity of electromagnetic waves. Photonic crystal waveguide is considered as an attractive solution for realizing slow light, since it could allow ultra-small components and low group velocity. The propagation characteristics of the electromagnetic waves in a two-dimensional square-lattice photonic crystal coupled-cavity waveguides is studied in the paper. The photonic crystals studied are composed of a square array of dielectric rods immersed in the air environment, which are usually circular rods. By partially changing the circular rods with oval rods adjacent to the cavities, the length of whose long axis is one point five times of the short axis and its area is the same as that of the circular rods, the frequency range of the transmission modes can be adjusted by changing the rotation angle of the ellipse columns. When the adjacent oval rod's rotation angles are set to be equal for one cavity, but are different for the two adjacent cavities, the group velocity can be greatly reduced and high transmission efficiency of light transmission is insured without increasing the distance between the adjacent two cavities. This gives one way to slow down the transmission velocity of the light and choose the particular frequency include in the incident light, and may be utilized in the all-optical integrated circuits in the future.

7848-83, Poster Session

Research of microspectrometer based on flat field holographic concave grating

C. Li, Soochow Univ. (China)

A method to research and produce a micro-spectrometer with flat field holographic concave grating is introduced in the paper. The flat field concave grating as the core component of optical spectrometer is researched in two aspects, spectral resolution and energy efficiency. The flat field concave grating is designed by using ZEMAX optical design software. By optimizing the recording parameters the flat field concave grating aberration is corrected. The holographic concave grating has significant effects in both flat field and high resolution aspects. The micro-spectrometer wavelength range is from 400nm to 800nm, the system F / # = 5, slit width is 30um, and theoretical resolution can be better than 0.5nm. The diffraction efficiency of Concave grating as an important indicator in spectrometer, which shows the weakest spectrum can be detected. With grating coupled wave theory, the relationship between diffraction efficiency and the shape of grating is discussed and calculated, which provides the necessary theoretical guidance for the process of fabricating holographic concave grating. Using holographic recording and ion beam etching technology, the flat field holographic concave grating is fabricated. The results show that the spectral resolution and diffraction efficiency are consistent with the theoretical analysis.

7848-84, Poster Session

Position of virtual image formed by bi-grating imaging

W. Zhang, T. Luo, G. Huang, Y. Xiao, Guangxi Univ. (China)

Two gratings can make up a bi-grating imaging system for transmitting images. With this system, we can see an object in the distance with obstructions blocking our direct view. And we only need to illuminate the object by non-monochromatic light. The bi-grating imaging has a wide prospect of application, and is worthy of a deeper research.

In recent years, we have reported the research achievements of bi-grating diffraction imaging successively. These research achievements are mainly consist of a discovery about the phenomenon of bi-grating diffraction imaging, the equation that relates the two gratings' spatial frequencies, diffraction orders and positions necessary for obtaining the bi-grating diffraction imaging. But on the practical position of the virtual image, we have only analyzed the lateral position relative to the original object.

This paper will research the virtual image formed by bi-grating system. Firstly, we will analyze the longitudinal and the lateral deviation between the virtual image and the object theoretically. Then, study the discipline of deviation of the virtual image. And last, do an experimental verification for the discipline. The content in this paper has the practical guiding significance for the location (relative to original object) of the virtual image

7848-85, Poster Session

Dual wavelength interferometry for micro-nano structure topographic measurement

G. Cheng, Z. Jiang, D. Wang, H. Cui, Beijing Univ. of Technology (China)

Digital holography in microscopy imaging has tremendous applications. Reflection digital holographic microscopy is a useful method to measure the topography of MEMS or other sub-nanometer object. Conventional methods may meet the phase wrapping problem. If the step height is more than half of the single wavelength, it will appear the 2π ambiguity, so the phase map is wrapped. The prior knowledge of the general shape of the object is needed before removing the 2πambiguity in many phase-unwrapping algorithms. In the actual measurement, there exist some problems such as that the phase noise is high, and the surface profile is discontinuous, which are unable to be solved with the prior phase-unwrapping algorithm. In this paper, we discuss dual wavelength interferometry by using the two wavelengths at 533nm and 633 nm to obtain the effective wavelength. Fresnel off-axis diffracting theory is used to obtain expressions for phase-imaging of the reflective resolution target' surface, and to quickly reconstruct the real surface topography with our algorithm been optimized. The ordinary optical microscope imaging and single-wavelength and dual wavelength imaging of the surface structure are compared experimentally in this paper. The results show that the dual wavelengths measurement technique has obvious advantages than the single wavelength measurement, and in particular, the dual wavelengths technique can quickly and accurately obtain the mirco-nano structure's phase images. In the experiment, the noise is greatly reduced, and the problem of unwrapping phase-imaging ambiguity is nearly solved.

7848-86, Poster Session

Label stacking of the time stacked SAC labels in optical packet switching with a simple label recognition based on FWM

Y. Shi, Q. Zhang, C. Yu, X. Xin, Beijing Univ. of Posts and Telecommunications (China)

Label stacking has been proposed to avoid the complex table-look-up process. In the edge nodes of optical network, the packets are assigned with all labels needed in the routing path from source to destination, one label for each node. According to the corresponding label for each node, the forwarding decision will be made so as to avoid the complexity of optical swapping by moving the table look-up process to the smart edge nodes at the expense of stacking large number of labels in the edge nodes and obtain a simple, practical, economical, and ultra-fast optical backbone.

In this letter, the label stacking of two spectral amplitude codes (SAC) labels has been demonstrated by simulation. The two labels are encoded by weight-2 codes represented by only two wavelengths, and stacked in fixed-length time slots in chronological order, transmitting simultaneously with the optical payload at the packet rate. Due to the two different wavelengths in each label, label recognition is achieved by filtering its corresponding unique FWM tone . Based on this principle, at the forwarding nodes, the time-stacked labels are recognized simply by a label processor based on the four-wave-mixing (FWM) in semiconductor optical amplifier (SOA) and selectively filtering. The rest labels and the payload do not need to be processed and are forwarded for the next node according to the output of the label processor. The forwarding of the packet with two time-stacked labels for two nodes and an error-free (bit-error rate< 10-9) 80 km single-mode fiber (SMF) transmission for the packet have been implemented.

7848-87, Poster Session

A new method of calculating the diffraction efficiency for diffraction/refraction infrared hybrid system

T. Wang, Zhejiang Univ. (China)

A new method of calculating the diffraction efficiency for diffraction / refraction infrared hybrid system is given. By using this method, an automatic measurement system is designed. This system covers the wavelength range of 1~3 m, 3~5 m and 8~12 m. We use a blackbody as the energy source, put the lens which is to be measured above a computer controlled turntable in order to gain different results in different filed of view. We also have several relay lenses to cope with long or negative focal length. We use two types of detectors to deal with wavelength range of 1~3 m and 3~12 m .Both the detector and preamplifier are assembled together so we can easily change them for different wavelength ranges. To improve the accuracy of the measurements, a new theory of measuring the main energy is developed to minimize the negative impacts of other diffraction orders and the environment. We use an adjustable slit cooperating with a two-axis stage to scan the focal point and by adjusting the width of the slit we can reduce the energy of other diffraction orders and the environment that may come into our detector. During the experiment process we can manually control the slit and two-axis stage to improve the efficiency and use our computer program to improve the accuracy. The energy modulator and lock-in amplifier also help to improve the accuracy of our system. We designed two standard lenses for the 3~5 m wavelength range. Both of them are made of the same material, have the same focal length of 200mm and their shape is almost the same. The only difference between them is that one of them is pure refraction piece which acts as a reference and the other one has a diffraction surface to achromatic aberration. The result fits our theory well and the possible causes of the differences are discussed. This system has a practical meaning in the quality evaluating of infrared hybrid system.

7848-88, Poster Session

Air impurity in holographic photonic crystals made with dichromated gelatin

Z. Ren, S. Li, North China Electric Power Univ. (China); D. Liu, Beijing Normal Univ. (China)

The physical mechanism of the air impurity in volume holographic photonic crystals was investigated in this paper. The photonic forbidden band with the air impurity was analyzed and calculated by the transfer matrix method. Verifications were carried out using one dimensional holographic photonic crystals made with Dichromated Gelatin (DCG), and the impurity modes were observed.

7848-89, Poster Session

Diffraction intensity analysis of a transmission prism grating

X. Liu, Harbin Engineering Univ. (China); G. Zhang, Beijing Institute of Graphic Communication (China)

As very important optical diffraction elements, gratings have broad application in fields of optical communication, optical information processing and optical precise measure, etc. Usually gratings are divided into amplitude type and phase type, or transmission type and reflection type, etc. But no matter what kind of most common gratings, they will produce an unexpected loss about 50% of the input signal because of their inherent structures. Considering that, a new design of grating with many periodical micro isosceles prisms is proposed in this paper. The new design employs the characteristics of prisms to split the signal into two groups, both of which can transmit through the gratings and contribute to the output signal.

Diffraction characteristic is one of the key performance parameters for gratings. For the vector pattern of electromagnetic wave, to strictly study the diffraction have to consider the vector diffraction theory. But for the case that the space frequency of the grating is small and the observer is not so close to the grating, the scalar diffraction theory is also suitable to obtain a correct solution. So based on the scalar diffraction theory, the mathematical model of the proposed grating is established. The transmittance is derived from the definition of an optical path when a parallel light passes through a singular prism element. And according to the multi-slit Fraunhofer diffraction, the expression of light intensity distribution for the prism grating on the frequency plane is deduced by means of Fourier transform.

7848-90, Poster Session

Characteristics analysis of a transmission prism grating based on blazed gratings

G. Zhang, Beijing Institute of Graphic Communication (China); X. Liu, Harbin Engineering Univ. (China)

Gratings, usually divided into amplitude type and phase type, or transmission type and reflection type, etc, are very important optical diffraction elements. Different type of the gratings can periodically modulate the amplitude or the phase of the incident light, or periodically modulate both of them, so gratings have broad application in fields of optical communication, optical information processing and optical precise measure, etc.

But because of the characteristics in structure, most common gratings will produce an unexpected loss about 50% of the input signal.

Considering that, a new design of grating with many periodical micro isosceles prisms is proposed in this paper. The new design employs the characteristics of prisms to split the signal into two groups, both of which can transmit through the gratings and contribute to the output signal.

Diffraction characteristic is one of the key performance parameters for gratings. For the vector pattern of electromagnetic wave, to strictly study the diffraction have to consider the vector diffraction theory. But for the case that the space frequency of the grating is small and the observer is not so close to the grating, the scalar diffraction theory is also suitable to obtain a correct solution. At the same time, considering that each periodical element of the new design looks like a combination of two periodical elements of a blazed grating, and the space frequency of the grating is small (20), so based on such an equivalent, and according to scalar diffraction theory, the expression of diffraction intensity of the prism grating is deduced and analyzed in this paper.

7848-91, Poster Session

A novel structure photonic crystal fiber based on bismuth-oxide for optical parametric amplification

C. Jin, X. Sang, J. Yuan, W. Li, C. Yu, Beijing Univ. of Posts and Telecommunications (China)

The heavy metal oxide glasses containing Bismuth such as Bi2O3 show the unique high refractive index. In addition, the bismuth-oxide glass does not include toxic elements such as Pb, As, Se, Te, and exhibits better chemical, mechanical and thermal stability. Thus, it can be used to fabricate the highly nonlinear fibers for nonlinear optical application. Although the bismuth-oxide highly nonlinear fibers have above advantages and can be fusion-spliced to conventional silica fibers, it suffers from larger group velocity dispersion because of the material chromatic dispersion. To solve this problem, the micro-structure was introduced to adjust the dispersion characteristics of bismuth-oxide fiber in the telecommunication band around 1550 nm. We developed a hexagonal solid-core photonic crystal fiber based on bismuth-oxide, and it well balanced between dispersion and nonlinear coefficient. The simulation and calculation results show that the bismuth-oxide photonic crystal fiber (Bi-PCF) has near zero dispersion around 1550 nm where the optical parametric amplification can be validly carried out. Moreover, the dispersion slope of such Bi-PCF is also relatively smaller in the telecommunication band. The confinement loss, nonlinear coefficient and mode filed distribution were simulated at the same time, respectively. After that, this fiber was used in optical parametric amplification. It is well known that the phase-matching condition between the signal and pump is very important in parametric amplification based on four wave mixing, and it's difficult for maintaining in a longer length of fiber due to larger group velocity dispersion. The solution by adopting the bismuth-oxide photonic crystal fiber decreases the fiber length greatly, the four wave mixing effect can take place in a wider wavelength range, and the propagation loss is also reduced. It indicates that better performance in signal amplification was achieved compared to the silica highly nonlinear fiber.

7848-92, Poster Session

Study of sub-wavelength metal polarization gratings array used in polarization imaging

P. Sun, J. Wu, Q. Liu, Soochow Univ. (China)

Polarization imaging is a powerful tool to observe hidden information from an observed object, for instance, degree of polarization, polarization azimuth and polarization ellipticity. It has significant advantages, such as high accuracy rate, abundant information and can be easily applied by adding a polarizer in front of a camera. The existing technologies mostly need to rotate the polarizer to get the different polarization state. The application of CCD push-broom imaging technology is the development direction of the polarization imaging technology. This technology doesn't need to rotate the polarizer, but use a polarizer array to get the different polarizations at the same time.

The polarizer is the key device for polarization imaging. There are several devices which can be used as polarizer, for example, birefringent prism, film, photonic crystals, and sub-wavelength gratings. The sub-wavelength metal gratings has the characteristic of small volume, compact structure, easy to integrate, and is widely used in the area of optical communication, LCD and so on.

This paper designs a metal sub-wavelength polarization gratings array which is composed by micro polarization gratings, and two micro polarization gratings compose one unit. The two micro polarization gratings are orthogonal. It is integrated into CCD detectors, and every micro-grating is corresponding to one pixel. The effects of different grating materials and grating shapes on the TM and TE polarization transmission efficiency as well as the extinction ratio was analyzed by using the FDTD method. The best parameters were obtained: the period is 160nm, the groove depth is 160nm, and the duty cycle is 0.5. The influence of finite size of micro-grating on the TM and TE polarization transmission efficiency and the extinction was studied at last.

7848-93, Poster Session

Study on thermal fixing of holographic grating in paraelectric potassium tantalate-niobate crystals at large modulation depths based on the finite element method

Y. Song, J. Ji, W. Dou, C. Wen, National Univ. of Defense Technology (China)

A solution of the thermal fixing of holographic grating in paraelectric KTa1-xNbxO3 (KTN) crystals based on Flex-Partial Differential Equation (FlexPDE) program has been proposed to solve the problem at large modulation depth. The Kukhtarev equations are rigorously solved by the algorithm of finite element method under the existing of nonlinear coupling effect. The distributions and time evolvement curves of space charge filed, light excitated electrons, ionized donors, compensating ionic species and crystal refractive index are presented. The modulation of gratings becomes smaller along the propagating direction of writing beams because of the coupling effect. Calculation indicates that, the finite element method is advantageous to reduce the difficulty of solving the Kukhtarev equations, FlexPDE can display the forming of the fixed holographic grating dynamically on real time, with visualization.

7848-94, Poster Session

Reference wavefront reconstruction based on spatial light modulator

N. Liang, Xi'an Institute of Technology (China)

Aspheric optical elements have been widely used now. However, the aspheric technology has been largely restricted by testing methods. In particular, the acquisition of the reference wavefront with the different tested aspheric surface is still a challenge. The reconstruction of the reference wavefront based on spatial light modulator (SLM) is studied in this paper. Computer-generated hologram (CGH) interferograms encoding method has been selected. Then the hologram is been loaded into the SLM and the standard wavefront is reconstructed. Considering the effect of the SLM grid structure, the methods named stacking of dislocated messages of the grid structure has been proposed. The above methods also have been simulated and optimized. The result shows that the RMS of reconstruction wavefront is improved nearly 4.45 times. The research works provide a reliable theoretical basis and

experimental evidence for aspheric measurement based on SLM.

7848-95, Poster Session

Characteristics of subwavelength photolithography based on surface plasmon polaritons

W. Ge, C. Wang, Y. Xue, Soochow Univ. (China)

The rapid progress in the nanoscale science and technology has increased the demand for fabrication of nanoscale patterns. Photolithography has remained a useful microfabrication technology because of its ease of reproduction and suitable for large-area fabrication. The diffraction limit, however, restricts the fabrication resolution of the conventional photolithography. To improve the photolithography resolution, one straight forward approach is to reduce the wavelength of the illumination light into deep UV, extreme UV, or even x-ray wavelengths. The main drawbacks of these approaches, however, are the drastically increased instrument complexity and the corresponding cost. Recently, Luo et al proposed a technique of surface-plasmon polaritonic lithography (SPPL) which can produce sub-half-wavelength periodic patterns phenomenally by the coherent illumination of a standard photo-resist with ultraviolet or visible light. A resolution of 50nm, i.e., about of 432nm illumination light was achieved with a silver grating of 50nm thickness in comparison to the conventional diffraction limited resolution of, i.e., 216nm. The quality of the generated patterns in terms of uniformity and intensity is, however, low. Xiong et al proposed a technique which uses multiple pairs of metal and dielectric layers to generate 1-D and 2-D subwavelength periodic patterns. The fabrication of the multilayer metal/dielectric thin film stack system is complicated which may restrict the applications of this technique. In this work, the characteristics of the subwavelength patterning through periodic metal gratings are discussed. By incorporating different structures of metal gratings, the quality improvements in the generated subwavelength patterns are observed in terms of pattern uniformity and visibility. The physical mechanism of the quality improvement based on SPP theory is discussed. Finite-difference time-domain analysis method is used in the simulation.

7848-96, Poster Session

Security enhancement of double random phase encryption by phase extraction

Y. Shi, Y. Wang, Graduate Univ. of the Chinese Academy of Sciences (China); Y. Yang, Beijing Univ. of Technology (China); J. Zhang, Graduate Univ. of the Chinese Academy of Sciences (China)

Phase extraction is proposed to break up the linearity of a double random phase encoding system, which is usually vulnerable to a chosen or known plaintext attack. We directly extract the phase distribution of the complex amplitude in the transformed plane to be modulated by the second random phase mask. Since the amplitude term is discarded and the phase term is maintained, the original linear system becomes incomplete. That is, as a result, the nonlinearity of the system is achieved. As the price of the declined quality of the decrypted image due to the lost amplitude, the system security is enhanced. Further, the corresponding much simpler optical setup is suggested, in which only once transformation instead of two ones is needed. A series of computer simulations demonstrate the feasibility of the proposed technique.

7848-97, Poster Session

Multiple-image encryption with spatial information prechoosing and cascaded blocks scrambling

Y. Yang, Beijing Univ. of Technology (China); Y. Wang, Y. Shi, J. Zhang, Graduate Univ. of the Chinese Academy of Sciences (China)

Multiple-image encryption by spatial information prechoosing and cascaded blocks scrambling is proposed. The spatial information of secret multiple-image is pre-chosen in advance to effectively reduce the capacity burden of following encryption system. It is conveniently achieved by selecting or compressing the spatial information of multiple images to meet practical demands. Spatially pre-chosen multiple images are divided into several blocks that are scrambled and then reformed to a new image. Cascaded double random phase encoding system is used to encrypt the new image, and the blocks scrambling is operated at the input of each sub-encoding system. Two main advantages are obtained: 1. Since the spatial information prechoosing enables the whole system to afford much larger information capacity, the effective multiplexing capacity is improved greatly; 2. The combination of blocks scrambling and cascaded random phase encoding not only ensure the much higher system security, but also save the key space compared with the methods by each pixel scrambling. Computer simulations have shown the effectiveness of this method.

7848-98, Poster Session

Comparative research on the crosstalk characteristics of acoustic-optic tunable filters with different bandwidth used in the communication

W. Liu, Capital Normal Univ. (China); Y. Sun, Beijing Institute of Technology (China)

The optical add/drop multiplexer (OADM) is an important device to realize an auto optical exchange in optical transport network, and tunable filters are its central part. The acousto-optic tunable filter (AOTF) has not only a large wavelength tuning range (more than 100nm), low optical loss (less than 5dB) and a narrow filter bandwidth (about 1nm), but also dynamic and reconfigurable characteristics. Thus, the acousto-optic tunable filter (AOTF) is one of powerfully several potential candidates. In the paper, the main works are to test and analyze the sidelobes characteristics of TeO2 AOTF with different bandwidth and its influence on the crosstalk between the neighbor channels, according to the acousto-optic interaction theory and the device design principal. The experimental results are corresponded with the calculating ones. The new structure of OADM based on the AOTF is designed to lower the influence of signal crosstalk.

7848-99, Poster Session

Research of bi-grating imaging by computer simulating

W. Zhang, Y. Xiao, X. Huang, L. Wan, Guangxi Univ. (China)

The multicolor light from an object can form a virtual image of the object when the light diffracted twice by two gratings. This is the effect of bi-grating diffraction imaging we have reported. The bi-grating imaging has a wide prospect of application, and is worthy of a deeper research.

We recently have reported the research achievements of bi-grating diffraction imaging successively. These achievements are mainly

the outcome of experimental research and theoretical analysis. One important outcome is the relation formula among the two gratings' spatial frequencies, diffraction wave orders and positions necessary for obtaining bi-grating diffraction imaging. The coefficient w of the formula is an approximation only under special condition. The value of w is still to be studied.

This paper will research the phenomenon of bi-grating imaging by the computer simulation method. According to grating formula, we will simulate the procession that sampling wavelengths get through the grating G1 and G2 in the systems with different bi-gratings. After setting the grating G1 and diffraction light orders, we will calculate the position of grating G2, then fit out the bi-grating imaging relation equation with a specific coefficient and analyze the formula.

7848-100, Poster Session

A study of OCDMA over WDM PON system using DQPSK modulation and balanced detection

F. Deng, Q. Zhang, C. Yu, Beijing Univ. of Posts and Telecommunications (China)

Optical code division multiple access (OCDMA) technique is an attractive candidate for next generation broadband access networks. The optical code division multiple access (OCDMA) over wavelength division multiplexing (WDM) passive optical network (PON) is a potential technique for gigabit-symmetric fiber-to-the-home (FTTH) services. In this paper, a multiuser, asynchronous coherent OCDMA over WDM PON transmission with differential quadrature phase shift keying (DQPSK) and balanced detection has been analyzed. Comparing with conventional OCDMA system, the proposed scheme has better multiuser capacity, enhanced security and simpler threshold setting in the receiver.

The principle and architecture of asynchronous OCDMA/WDM PON system and its optical en/decoding have been described. There are four different wavelengths used as four channels' carrier waves in the system and several asynchronous users access the system in each channel. The en/decoder selected in this paper is a coherent phase en/decoder. Balanced detection is chosen as the receiver because of its simpler threshold setting. Here, DQPSK has been used as a new modulation, which has some distinct advantages, such as narrower spectrum width, higher spectrum efficiency and better tolerance for optical fiber nonlinear effects. At the same bit rate, the capacity of DQPSK modulation is twice larger than that of DPSK. Comparing with On-off keying (OOK) modulation, the DQPSK's receiver sensitivity has been raised by 3dB. Besides, the system's performance has also been analyzed, including the multiuser number, security, receiving sensitivity and so on. A bit-error-rate of 10-9 has been achieved with up to eight users in each channel at the bit rate of 10 Gbit/s.

7848-101, Poster Session

Design and simulation of a polarized color filter based on sub-wavelength metal gratings

Y. Zhang, Y. Zhou, L. Chen, Soochow Univ. (China)

The color filter is one of the key devices for liquid crystal displays (LCD). It can turn the incident white light into three colors, red, green and blue. Recently, color filters based on one dimensional (1D) and two dimensional (2D) sub-wavelength metal gratings have raised much concern. One problem remains that these color filters can not get a high extinction ratio in the short wavelength such as green or blue light. In this paper a color filter which is also a polarizer with good performance is proposed. This device consists of a transparent substrate, one bottom metal grating, a low refractive index dielectric layer, a high refractive index dielectric layer and a top metal grating. The bottom metal grating has a small period which is mainly for polarization, and the top metal grating has a large period for light-filtering. The parameters that affect the transmission and polarization properties of the structure have been simulated and analyzed by utilizing the finite-difference time-domain (FDTD) method. The polarized color filter has been designed as a broadband, high transmission and high extinction ratio device. The peak wavelengths and the corresponding transmittances are as follows: 650nm and 78% for red, 550nm and 79% for green, 450nm and 78% for blue. Extinction ratio above 1000:1 has been achieved along the full width at half maximum (FWHM) range of all the three colors. This device has a high extinction ratio and is suitable to liquid crystal displays.

7848-102, Poster Session

Application of digital holography in temperature distribution measurement

Y. Li, Beijing Univ. of Technology (China)

The temperature measurement can be used in the temperature control of the element manufacturing, the security monitoring and the online diagnosis for the equipment etc, which are involved in many engineering technology and research fields. The traditional sensors such as thermocouple and thermistor can't acquire the full-field temperature distribution because of its contact and single-point properties, and they can hardly detect the precise temperature in the adverse condition like the strong electromagnetic field. So in recent years, the digital holography is adapted to realize the non-contact temperature measurement for the whole temperature field distribution. The reason is that there is a certain relationship between the temperature field distribution under investigation and the phase distribution of the light waves passing through, while the digital holography can quantitatively recover the high-resolution phase distribution. In this paper, the reflection lensless Fourier transform (LFT) digital holography is established to record the hologram, and the complex amplitude distribution information of the complete object wave field can be reconstructed by using the Fresnel reconstruction algorithm. A reflection heat source including a radiator as well as an aluminum plate is designed, and the temperature field of the aluminum plate is used as the tested object. The digital holography system is applied to inspect the phase distribution of the aluminum plate in different time. Then the temperature distribution can be obtained according to the relationship between the phase information and the temperature. Finally, the experimental data obtained by the digital holography and thermocouple methods are compared, and the result shows that the data are in good agreement, which demonstrates the feasibility and effectiveness of the digital holography method. It is concluded that digital holography provides a fast full-field measurement method for the temperature.

7848-103, Poster Session

Study on diffraction spectrum of variable line space plane grating at oblique incidence

Y. Luo, J. Lou, Y. Liu, W. Tian, China Jiliang Univ. (China)

Holographic variable line space (VLS) grating has the advantage of self focusing and aberration-reduced. They play an important role in spectrograph and synchrotron radiation facilities. It becomes more and more imperative to study the diffraction spectrum of the variable line space grating thoroughly. In this paper, a general scalar model to analyze the diffraction spectrum of holographic VLS plane grating at oblique incidence is proposed. The analytic expression for the diffraction spectrum of a VLS plane grating at oblique incidence with a parallel and uniform beam was obtained on the basis of Fraunhofer diffraction theory. And the applied scope of the analytic expression is that the grating period is much larger than the incident wavelength.

Then some computing examples are given in the condition of single wavelength incident. This oblique incidence model can provide a theoretical reference for the real distribution of diffraction spectrum of holographic VLS plane grating. In future work, the diffraction efficiency and polarization state will be considered.

7848-104, Poster Session

High-resolution digital holographic imaging technology of digital microscope image plane holography

H. Wang, W. Gong, Hebei Univ. of Engineering (China)

On the basis of Fresnel diffraction and micro holographic theory, this paper has further studied the imaging technology of digital microscope image plane holography(DMIPH), derived the point spread function expression of DMIPH system, analyzed the recording conditions of the DMIPH. The second phase factor which caused by the microscope objective lens can be eliminated through choosing the proper position of the reference point source when DMIPH is recorded by spherical waves. Two experiment optical systems which are recorded by plane waves and spherical waves respectively were built, which used the resolution test plate as experimental samples. The recorded hologram was reconstructed by angular spectrum algorithm, and the two different methods and experimental results were compared. The results show that: if it meets the condition that the distance from equivalent of lighting point source to CCD equal the distance between the recorded reference point source and CCD when the DMIPH is recorded by spherical waves, then the second phase distortion which is introduced from the microscope objective lens can be removed. DMIPH avoids the process of finding recorded distance by using the auto-focus approach. The recording and reconstruction process of DMIPH is simple, the renewal rate is fast and the reconstructed image is clear. The technology is superior to common micro holographic technology and can be successfully used on the measurements of micro-object phase distribution.

7848-105, Poster Session

Analysis of diffraction spectrum of holographic variable line space plane grating based on rigorous vector theory

J. Lou, Y. Luo, Y. Liu, W. Tian, China Jiliang Univ. (China)

Analysis of diffraction spectrum of holographic variable line space plane grating based on rigorous vector theory is proposed. We know that the previous mathematical expressions of diffraction spectrum of holographic variable line space plane grating are mostly derived on the basis of the scalar diffraction theory. There are different descriptions for the applied scope of the scalar theory under different situations. Generally speaking, the applied scope of the diffraction expressions is that the period of the diffraction screen is much larger than the incident wavelength. It is obvious that there are some restrictions on the application of the scalar diffraction expressions. Nevertheless, we realize that grating diffraction field is an electromagnetic field, which satisfies the Maxwell equations and the grating periodic boundary conditions. Therefore we can use the rigorous vector theory to calculate the diffraction spectrum to avoid considering the limitations of the scalar diffraction theory. In this paper, the diffraction spectrum of holographic variable line space plane grating is calculated by means of the electromagnetic finite-difference time-domain (FDTD) method, and simulated with various grating parameters and incident conditions. The diffraction efficiency is also obtained in our study.

7848-106, Poster Session

Cell imaging techniques based on digital image plane holography

Z. Chen, Handan College (China); H. Wang, W. Gong, Hebei Univ. of Engineering (China)

According to the holographic theory and light diffraction theory, this paper has further studied the imaging technology of digital microscope image plane holography(DMIPH), and careful analyzed the implementation methods and recording conditions of DMIPH, then two optical systems of DMIPH were built: one was recorded by using plane waves as reference light, the other was recorded by spherical light. A transmission optical was used and fresh scallion epidermal cells were selected as tested samples in the experiment, and the recorded hologram was reconstructed by angular spectrum algorithm. Then used the discrete cosine transform which is based on least squares phase unwrapping algorithm to unwrap the phase of the digital holograms, and can obtained the quantitative phase distribution and three-dimensional shape information of cells. Finally, different methods and experimental results were studied to compare the affect on the microscopy image plane holographic resolution by using different reference light. The results show that: DMIPH avoids the process of finding recorded distance by using the auto-focus approach. The recording and reconstruction process of DMIPH is simple, the renewal rate is fast and the reconstructed image is clear. In addition, the DMIPH which is recorded by spherical light waves is better than that recorded by plane waves, it can eliminates the the second phase factor which is caused from microscope objective lens in theoretically. The DMIPH can be applied to the microscopic imaging of cells more effectively.

7848-107, Poster Session

Studies on the unweighted least-squares phase unwrapping algorithm

H. Wang, Z. Zhang, Hebei Univ. of Engineering (China)

Two-dimensional phase unwrapping algorithm is the important step and key technology of three-dimensional shape measurement. In order to obtain more accurate morphology characteristics phase information, a new phase unwrapping algorithm based on unweighted Least-squares is presented in this paper, which is a improvement of Discrete cosine transform phase unwrapping algorithm. Singular point which are contained in digital holograms (shadow, fracture, holes and noise etc.) result phase jumping and interruption, the phase unwrapping algorithm model is established. The advantage of this method is not only because of the global algorithms, processing the image as a whole, each pixel's value in the image is uniquely determined by solving the Discrete Poisson equation with Newman boundary conditions which makes the least-squares solution of the wrapped and unwrapped phase difference minimum, while a local solution does not have these advantages, but also can reduce the noise effectively and quickly. Built lensless Fourier transform digital holographic optical system, recorded and reconstructed the information of onion epidermal cells, emploied this improved method to unwrap the phase of the reconstruction phase holograms, and compared with the original algorithm, the results show that: the improved algorithm can eliminate the noise of the phase diagrams more effectively, reconstruct the phase information of the digital hologram more accurately, and have higher efficiency,which is more acceptable in digital holographic microscopy.

7848-108, Poster Session

Computer generated holograms of 3D objects with reduced number of projections

S. Huang, D. Liu, J. Zhao, Shanghai Univ. (China)

A new method for synthesizing computer-generated holograms of 3-D objects has been developed based on reduced number of projections. According to the principles of paraboloid of revolution in 3D Fourier space, spectra information of 3D objects is gathered from both several real projection images recorded under incoherent white-light illumination by circular scanning method and interpolated projection images by motion estimation between adjacent real projection images. We extract the information of the projection spectra in circles form and encode into CGH. Our method does not require any approximation in the synthesizing process, unlike other similar methods, and significantly reduces the number of required real projections without increasing much of the computing time of the hologram and degrading the reconstructed image. Experimental results both numerically and optoelectronically validate the proposed method and show its good performance.

The advantage of the method is that the number of real projections needed for generating the hologram is significantly reduced. At first, a series of projections of the 3D object from different points of view can be obtained by scanning the objects around the z-axis. Then, the view synthesis algorithm is integrated into the holographic acquisition in a way that significantly reduces the number of observed projections needed for recording a hologram. In the process, we proposed a new motion estimation algorithm with estimation accuracy and the efficiency of motion vector processing. To be more specific, we differentiate moving and static region based on equal determination, and find out the best matching block of moving region by comparing the minimum SAD (Sum of Absolute Difference) between the current and the candidate block in a certain window. Once the motion vectors are obtained, we can get projections between adjacent real projections using motion compensation algorithm. At last, we extract the spectra information of all the projections in circles form and encode into CGH based on computer-generated holography using a conjugate-symmetric extension. Both numerical reconstruction and optoelectronic reconstruction based on spatial light modulator from CGH show good results.

7848-109, Poster Session

Reduction of speckle noise in digital holography by using of multiple holograpms

H. Wang, Z. Guo, Hebei Univ. of Engineering (China)

In order to obtain high resolution images, the reduction of the noise is very important. The speckle noise effects the resolution of reconstructed image seriously in digital holography. At present, there are many studies on the reduction of speckle noise. Wavelet transform, Wiener filter and median filter are popular in these methods. In this paper, a method for the reduction of speckle noise in digital holography was proposed. This method can suppress the speckle noise effectively. It does not require classical filter technique, instead of it utilizes multiple holograms of an object by altering the spreading dirction of an illuminating light. First, a series of digital holograms are recorded with different titled plane wave illuminations. Then the every complex amplitudes are reconstructed, and the speckle noise is suppressed by incoherent superposition of the reconstructed image fields. The resolution of the reconstructed image is enhanced effectively. The important advantage of this method is that the speckle noise is suppressed effectively by incoherent superposition of the reconstructed intensity fields. An optical system of Fresnel off-axis digital holography is setted up in the experiment. And multiple holograms of a die with different title plane wave illuminations are recorded and reconstructed. The experimental results are shown and demonstrated that this method is superior to other methods of reducting the speckle noise.And the more digital holograms,the better the reduction of speckle noise.

7848-110, Poster Session

Theory analysis and numerical simulation of multi-pumps wavelength conversion solution with different wavelength spacing and different polarization in photonic crystal fibre

R. Xu, C. Yu, D. Hsu, Beijing Univ. of Posts and Telecommunications (China); H. Hu, Henan Institute of Engineering (China)

In all-optical network, multi-pump wavelength conversion systems which are based on four-wave-mixing processes have been researched on theory and application. Usually only the first order sideband wave were derived and used in consideration of wavelength conversion efficiency, noise et al. By controlling the pump power, pumps wavelength spacing can be equal or double, even triple. Specific wavelength would be enhanced while others decline. It's been widely recognized that polarized wave should be the pump wave since they'll obviously improve the conversion efficiency when polarization were properly set. Nonlinear equations explain the processes in using the high-nonlinear polarized photonic crystal fibre, then numerical simulations for 3, 4 or 5 pumps confirm the feasibility.

7848-111, Poster Session

Cells of Chinese herbal medicine measuring with digital holographic microscopy

Z. Chen, Handan College (China); H. Wang, F. Liu, Hebei Univ. of Engineering (China)

Traditional Chinese medicine plays an important role in the medical field and daily life. With the recent technological advances,there is an increasing need for measuring cells of Chinese Herbal Medicine. We show here that Digital Holographic Microscopy (DHM), a new method that implements digitally the principle of holography, is particularly well suited for obtaining cells information.We presented the measuring of the characteristics of cells of Chinese Herbal Medical using a Off-axis Lensless Fourier-transform optical system which is sample, convenient and enable to capture the whole cells information by a single image acquisition, through using Fresnel numerical reconstruction algorithm, we obtained the amplitude contrast image and aberrant phase image. In order to correct the aberration,in this paper we also done the corresponding theoretical recarch and computer simulation, through using automatic phase compensation method and Manual phase compensation method,the results show that it is a effective way to get an accurate phase distribution by combining the two methods. Finally we using improved methods reconstructed phase of hologram which is the cells of Chinese Herbal Medicine, getting an accurate phase distribution.

7848-112, Poster Session

Applications of the filter designed by fdatool in digital holography

P. Xie, H. Xia, M. Tang, Soochow Univ. (China)

For the eliminating the zero-order image of digital holography, the traditional digital filters have such defects as complexity of the design process, difficulties of adjustment of filter characteristics, heavy calculating workload and etc. This paper describes a design method of

digital filter, which is designed by signal processing toolbox of matlab. Detailed steps of using matlab to design program and using fdatool of signal processing toolbox to design interface are given. With filter designed by using matlab, we can immediately compare with the design requirements, adjust the parameters of filter characteristics and greatly reduce the workload. Digital off-axis holographic experiment system based on Mach-Zehnder inferometer is established, and the holograms recorded by the Charge Coupled Device (CCD) are processed by using the traditional filter and the filter designed by fdatool. It turns out that the running time is greatly reduced by using the filter designed by fdatool. Experiments verify the advantage of the filter designed by fdatool on eliminating the zero-order image of the digital holography.

7848-113, Poster Session

Performance of transmission volume phase holographic gratings recorded in DCG

M. Li, H. Xia, M. Tang, Soochow Univ. (China)

The volume phase holographic gratings recorded in dichromate gelatin (DCG) have advantages of high diffraction efficiency and resolution, low noise, strong wavelength selectivity and angular selectivity. They have been used in a variety of applications such as astronomical spectroscopy, Raman spectroscopy, ultrafast lasers, wavelength division multiplexers (WDMs), photo-voltaic concentrators and solar thermal energy conversion. Based on Kegenike's coupled wave theory, the transmission volume phase holographic gratings made in DCG with different spectral bandwidths have been designed and their performances have been analyzed theoretically. The gratings are manufactured and their characteristics are also measured experimentally. By adjusting and controlling the preparation conditions of DCG plates, the exposure conditions of the grating and processing conditions after exposure, the transmission volume phase gratings accord with the design requirement are obtained. The diffraction efficiency, the bandwidth, the angular and spectral selectivity of the gratings has been measured experimentally and the results were analyzed and compared with that of the theoretical ones. According to the experimental results, a modified model of the refractive index modulation in the transmission volume phase holographic gratings recorded in DCG is put forward.

7848-114, Poster Session

40-Gbit/s PON over OCDMA uplink using DQPSK/OOK orthogonal remodulation

J. Chen, Q. Zhang, F. Deng, C. Yu, X. Xin, Beijing Univ. of Posts and Telecommunications (China)

A novel 40Gbit/s PON over OCDMA uplink using DQPSK/OOK orthogonal remodulation and time-spreading phase en/decoder scheme has been proposed. The simulation setup with 40Gbit/s DQPSK downlink data and 2.5Gbit OOK remodulated uplink user data, which is secured by 320Gchip/s time-spreading phase en/decoder, have been demonstrated for this proposed scheme. The bit-error rate of both the high-speed downlink DQPSK data and asymmetric uplink remodulated OOK user data have been researched, respectively. In addition, the security performance and MUI (Multi-User Interference) property of the OCDM-coded uplink user data have been investigated. The results show that with DQPSK/OOK orthogonal remodulation, the PON system is more cost-effective with little power penalty. Besides, due to a unique OCDM code for every ONU and its excellent correlation property, a burst-mode transmission of data from ONUs can be implemented in the uplink, and a number of channels can be multiplexed on a single wavelength and within the same time slot, which can increase the bit-rate and user capacity of the system substantially.

7848-115, Poster Session

Study on the polarization grating working in 1053 nm wavelength

Q. Liu, P. Sun, H. Wang, J. Wu, Soochow Univ. (China)

The polarizer is a useful optical device that can split an incident beam into two orthogonally polarized beams. Therefore it is widely used in the high-power laser system. For example the optical isolator in the National Ignition Facility is a combination of a polarizer and a Faraday rotator. The natural birefringent crystal and multilayer dielectric coating can be used as the polarizer, but they are very expensive. Gratings with subwavelength period exhibit interesting polarizing properties, and it is easy to realize polarization, beam splitting, antireflection, high - reflection, phase delay, and etc. Generally speaking, polarization gratings have advantages over other conventional polarizers: miniaturization and integration. Moreover, they are athermal elements with low insertion losses. In this sense the substrate of the polarization gratings is the fused-silica because of its intrinsic high laser damage threshold.

In this paper, we designed a fused-silica polarization grating at a wavelength of 1053 nm. To achieve a high extinction ratio and efficiency, the grating period and groove depth were optimized by using rigorous coupled-wave analysis. The results showed: when the grating period and groove depth of polarization grating were at 610nm and 1350nm respectively, the extinction ratio could reach the maximum 5170, the efficiencies of the TE-polarized wave in the -1st order and the TM-polarized wave in the 0th order were 88.3% and 98.3% respectively. We also analyzed the effects of the deviations of the period and depth from optimized parameters on the extinction ratio and efficiency. The holographic lithography and the ion beam etching will be applied to fabricate a prototype polarization grating in late 2010.

7848-116, Poster Session

Eight-channel Fourier transform computer generated holograms

R. Guo, Xi'an Technological Univ. (China)

Abstract: A method of encoding eight objects simultaneously in a Fourier transform computer generated hologram (CGH)of detour phase type is proposed. In the method, we divide eight objects into two groups and encoding synthesized spectrum of multiple objects of each group using four free parameters in each encoding cell of Lohmann type. The experiment demonstrated the effectiveness of the method. In the reconstruction two groups of objects were reconstructed around the same diffraction order along x, y directions, respectively. Then to achieve the separation of information channel. Together with coordinate transformation of spectrum, it is onvenient for obtaining various forms of reconstructed images. The results showed that the method can improve the information capacity in a CGH efficiently.

7848-117, Poster Session

Measurement of Stress Field among Inclusions by Digital Holography

H. Xia, R. Guo, Z. Fan, B. Yang, Kunming Univ. of Science and Technology (China)

Inclusions widely exist in materials and the stress field among inclusions is an important factor to the damage process of materials. So it is an important content in materials research to measure and analyze the stress field among inclusions. In this paper the phase variation of object wave through PMMA(transparent) specimens with inclusions subject to uniform tensile force is measured by digital holography.

Phase unwrapping method based on least-squares and iteration of phase difference is used to unwrap the phase variation measured. The relation between phase and the thickness deformation and stress of specimens is given. So the stress field among inclusions is acquired by digital holography. The measured stress field of a specimen with a hole is accordant with the theoretical stress field. Which means this method is correct.Then the stress fields of specimens with multi-inclusions are measured by this method.

7848-118, Poster Session

The Monte Carlo simulation of focused Gaussian beam for aberration system

S. Li, X. Cui, Y. Niu, D. Zhang, J. Zhu, Y. Zhang, F. Li, Tibet Nationalities Institute (China)

In optical systems that employ lasers, it is important that the propagation properties of the focused Gaussian beam through the optical systems is investigated, many studies have been done for perfect optical systems that do not exhibit aberrations. If the optical systems exhibit some aberrations, few studies deal with focusing Gaussian beam. However, these studies focused on the solution of the Fresnel-Kirchhoff diffraction integral for optical systems with primary aberration system. In this paper, we are thus led to the study of the focused Gaussian beam by using Monte-Carlo method on the basis of both ray-tracing and diffraction. This treatment takes into the images affected by the primary even higher orders aberration

7848-119, Poster Session

Application of fractal masks to determination phase discontinuities in transparent objects.

A. A. Zinchik, Y. B. Muzychenko, S. C. Stafeev, Saint-Petersburg State Univ. of Information Technologies, Mechanics and Optics (Russian Federation)

The homogeneity of the refractive index and the phase is one of the fundamental qualitative properties of the transparent films. Methods of nondestructive checking play an important role in detection of phase and refractive index discontinuities, some of them based on optical image processing. In this paper we propose the new method of nondestructive checking, based on application of the fractal masks photographed through the objects under study. Coherent optical image processing of the fractal masks allow to receive the separate information about components of the refractive index gradient and phase discontinuities.

Application of the masks (filters) consisted of two-dimensional periodic structures has some disadvantages because of rapidly decreasing power of the spatial spectrum of the masks in radial direction.

The main reason of using fractal masks instead of periodic structures is the greater power of high spatial frequencies. In this case it appears possible to register not only more precisely small refractivity gradients of the object, but also automatically to select the characteristic periods of its discontinuities.

As a result of the study it was shown, that the power of high spatial frequencies of the fractal mask spectrum is three times greater in comparison with spectrum of regular mask. The analysis of results of the inverse Fourier transform of the distorted spectrum of regular and fractal masks shows that the fractal mask is more sensitive and allows to obtain more precisely the value of distortion of the initial object.

7848-120, Poster Session

Study of focusing properties of fractal phase-type zone plates.

Y. B. Muzychenko, A. A. Zinchik, S. C. Stafeev, Saint-Petersburg State Univ. of Information Technologies, Mechanics and Optics (Russian Federation)

The concept of fractals has found an application in many branches of science. Recently, the zone plates with fractal Cantor-like profile, designed on the basis of conventional Fresnel zone plates, have been introduced in optics. The axial irradiance provided by fractal zone plates presents sequence of foci, similar to conventional zone plates, but each focus has an intrinsic fractal structure, that depends on the level of generation of fractal and fractal dimension of the object. Around each focus occur an additional focal points and this fact makes the fractal zone plate potentially useful optical and photonic element in the optical imaging.

The paper describes the results of analytical and computer simulation of Fresnel diffraction from fractal zone plates with variable dimension and level of generation. It was shown that with growth of fractal level the number of focal points increases and the axial distribution of intensity exhibits self-similarity properties. It was demonstrated that intensity distribution becomes more complicated with reduction of the fractal dimension of the object; number of additional focal points and theirs relative intensities are increased.

Existence of additional focal points and fractal behavior of the axial irradiance from fractal zone plates allows to put forward an idea about reduction of chromatic aberrations under white-light illumination. Computer simulation has shown that the axial irradiance from the fractal zone plate is characterized by one maximum which corresponds to the middle of visible band of a spectrum and sharp decrease of intensity for other wavelengths.

7848-121, Poster Session

An FPGA based controlling and data acquisition scheme for the demodulation of quasi-distributed FBG sensing system

R. Yu, Y. Wang, K. Wang, Beijing Univ. of Posts and Telecommunications (China)

This paper propose a well-coordinated demodulation scheme with a high speed data acquisition system for large scale Quasi-Distributed Fiber Bragg Grating Sensor System using FPGA and USB interface, aiming to multiplex a large amount of sensors while maintaining precise control and accurate monitoring over all sensors on a small-sized embedded module.

Quasi-distributed sensing is acquired by using a combination of wavelength division multiplexing (WDM) and Spatial Division Multiplexing (SDM), while demodulation is implemented by a Fabry-Perot (F-P) filter as a wavelength selection element. A Xilinx Spartan-3 FPGA and a 16 bit DAC is used to control a PZT, which drives the F-P filter to sweep across the spectral range of multiple Fiber Bragg Gratings, thus the wavelength shift is detected and sent back to FPGA through a 14 bit ADC. The collected data is then transmitted into a high speed USB interface, which is realized by the same FPGA and a Cypress FX2 68013 USB controller with slave FIFO mode, and finally into PC for the refinement and calculating of sensing information. While the FPGA is adopted as the core of controlling scheme, the 48MHz clock in 68013 is used as the global clock of the whole embedded system for the convenience of dividing frequency in sampling and signal processing. With the combination of FPGA technology and USB bus, accurate and convenient demodulating control with a rapid and real-time transmission of over 400Mb/s is realized, through which a system with up to several hundreds sensors can be achieved and coordinated easily on a handy embedded module.

7848-122, Poster Session

Design And Fabrication Of DCG-based Reflection Volume Holographic Grating

C. Fang, M. Tang, M. Li, Soochow Univ. (China)

Dichromate gelatin (DCG) as a holographic recording material with excellent performance, high resolution, high diffraction efficiency, high signal to noise ratio and low absorption characteristics, has gained a good application in the holographic display, holographic optical elements, holographic storage, laser protection, and so forth. This article from the start of volume holographic principle, designs and analysis the DCG-based reflection holographic gratings using rigorous coupled-wave theory and discuss the influences of reflection volume phase holographic grating parameters on the diffraction efficiency. In this experiment we made reflection holographic gratings based on DCG recording medium, discussed the grating post-processing in detail and problems in the process, and at last we made experimental measurements of the grating diffraction efficiency, angle selectivity and bandwidth, and compared and analyzed them with the theoretical calculations.

7848-124, Poster Session

Analysis and control of thin film stresses during extreme ultraviolet lithography mask blank fabrication

L. Zheng, Harbin Institute of Technology (China)

Extreme Ultraviolet Lithography (EUVL) is the leading candidate for Next-Generation Lithography (NGL) in the sub-45 nm regime. The ITRS Roadmap has proposed the implementation of extreme ultraviolet lithography (EUVL) for the sub-45 nm nodes since the early years of this twenty-first century. However there are still quite a lot technical problems to be solved before EUVL can be commercialized. One of the key problems is the control of the image placements during the EUVL mask blank fabrication. This paper focuses on the characterization of image placement errors induced by the thin film stresses during the EUVL mask blank fabrication process. Through the analysis and control of thin film stresses, we try to minimize the image placement (IP) errors during the process.

In general, the thin film layers utilized for EUVL have relatively large intrinsic stresses causing the mask to bow. Such out-of-plane distortions (OPD) inherently cause in-plane distortions (IPD). In this paper, we developed the modified Stoney's Equation to reveal the relations between the thin film stresses and the OPD (and consequently) the IPD of the EUVL mask. Therefore, the analysis and optimization of these thin film stresses could directly affect the final image placement accuracy.

For this research, a full three-dimensional finite element (FE) model was developed to simulate each step in the fabrication process of the EUVL mask. During the simulation process, the optimal values of the thin film stresses were input in the FE models. OPD and IPD were tracked for each process step of the EUVL mask fabrication. Then the numerical results are compared with the analytical results to validate the FE model. Comparison indicated that the numerical results and theoretical results agree very well with each other. With the optimal values of the thin film stresses, the maximum OPD and IPD of the EUVL mask are 1221 nm and 50 nm, respectively. Further mounting and chucking can keep IP errors within the allotted error budget as well as provide the necessary flatness.

7848-125, Poster Session

Investigation and prediction of image placement errors in Extreme Ultraviolet Lithography masks

L. Zheng, Harbin Institute of Technology (China)

According to the latest ITRS Roadmap, extreme ultraviolet lithography (EUVL) is expected to be one of the principal carriers for the IC production at sub-45 nm technology nodes. One of the most challenging tasks to fulfill EUVL is the fabrication of the EUVL mask. The EUVL mask fabrication process generally consists of mask blank fabrication, e-beam writing, pattern transferring, and e-beam chucking. During the mask fabrication process, image placement errors are induced due to various reasons such as pattern transferring and chucking. The control of image placement errors is the most important issue during EUVL mask fabrication. In this paper, the EUVL mask fabrication process was analyzed and image placement errors due to the fabrication process were investigated. A theoretical analysis was also conducted to validate the investigation.

Finite element (FE) models were established to simulate the EUVL mask fabrication procedures. During FE simulations, a line-and-space pattern layout was employed and an electrostatic chuck was applied at both e-beam tool chucking and exposure tool chucking. For the EUVL mask, the actual features in the repeated patterns are on the order of nanometers while the patterned area containing these features is on the order of millimeters, thus it is essentially infeasible to generate and implement FE models of the entire mask incorporating the actual features. Therefore, in this research, a new modeling technique called "equivalent modeling technique" was developed to predict the global distortions of the mask and the local distortions of the pattern features.

First, global FE models of the EUVL mask were generated employing equivalent material properties and the mounting and pattern transfer load steps were simulated to acquire the global distortions of the entire mask. Then the submodeling technique was employed to investigate the local distortions of the actual features inside the unit cells. Results indicate that for the EUVL mask with the line-and-space pattern (pattern coverage of 50%), the maximum image placement error is only about 10 nm, which is largely due to the application of the electrostatic chuck in both e-beam mounting and exposure chucking. With this new technique, not only the global distortions of the mask but the local distortions of pattern features (at any location in the mask) can be predicted while circumventing the time and intense computational requirements.

A theoretical analysis was conducted to validate the numerical models. FE results were compared with the analytical results. Comparison indicated that numerical results and theoretical results agree very well with each other. It should be noted that all the results obtained in this paper assume the use of a perfectly flat EUVL mask and electrostatic chuck during the fabrication process. Nonuniformities of either the mask or the electrostatic chuck will add to the final image placement errors of the mask.

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7849-01, Session 1

Developments in optical coherence microscopy

J. P. Rolland, Univ. of Rochester (United States)

Optical Coherence Microscopy (OCT/OCM) is a technology capable of depth sectioning of biological tissue at the micron level. In this talk we will discuss the development of an emerging technology developed in the Optical Diagnostics and Applications Laboratory (ODALab), Gabor Domain Optical Coherence Microscopy (GD-OCM), whose innovation is two fold: (1) A high lateral resolution optical design of a dynamic-focusing optical probe with no axially moving parts; (2) An acquisition scheme (using the probe) that is capable of performing automatic data fusion to render an in-focus high resolution image throughout the depth of the sample. We will further highlight related research efforts in functional OCM imaging and 3D visualization of the data.

7849-02, Session 1

Optical design rules of a camera module with a liquid lens and principle of command for AF and OIS functions

E. Simon, B. Berge, F. Fillit, H. Gaton, M. Guillet, O. Jacques-Sermet, F. Laune, J. Legrand, M. Maillard, N. Tallaron, Varioptic SA (France)

We have developed a miniature liquid lens component based on electrowetting. It is designed to be plugged on a fix focus camera module lens to provide both optical image stabilization (OIS) and auto-focus (AF) functions without any mobile mechanical parts. The OIS/AF liquid lens component features a conical shape supporting the liquid interface in order to maintain a stable optical axis and a multi-electrode design enabling to induce an average tilt of the liquid interface when a bias voltage is applied to the different electrodes. The miniature size of the OIS/AF liquid lens component is well adapted to the imaging applications with 1/3 inch sensor or ¼ inch sensor size and with a typical f/2.8 numerical aperture. We will present general rules for the optical design with an OIS/AF liquid lens. In this context, we will describe a simple calculation, based on the well known Maréchal criterion, to estimate the optical wave front error requirement of an optical component positioned in the aperture stop plane of an imaging lens design to perform images with a pixel resolution quality. We will also present the principle of command of a multi-electrode liquid lens in order to perform AF and OIS functions with an optimal image quality.

7849-03, Session 1

The design of nonsymmetrical optical system in the detection of laser echo

H. Xie, H. Lin, H. Yu, R. Gong, Tianjin Univ. (China)

With the development of the science technology, there is a high requirement for the performance of optical systems in lots of areas.And a solution of the nonsymmetrical system about the collection of laser beam is put forward which is based on imaging optics and non-imaging optics in this paper. The aperture of the system is 14 cm2 in this paper, meanwhile, the angle of one feild is ±30°. Then the beam should focus on two detector whose sizes are 2*10 mm2. The difficulty in the design of the large field and large aperture optical system used to collect the laser echo is analyzed. And the influence of the aberration and cylindrical lens to the system is illuminated. The whole system is initially designed by CODE V, in order to make the beam focus on the object. Then the transmittance of system should be analyzed by LightTools, and the result shows that the transmittance for rays of any direction is more than 80%, and the system is feasible in practice.

7849-04, Session 1

Modeling anamorphic optical surfaces in the MOEMS-based zoom lens

X. Cheng, Tsinghua Univ. (China); Q. Hao, Beijing Institute of Technology (China)

MOEMS (Micro-opto-electromechanical systems) based zoom lens is a kind of optical system combining the off-axis reflective DM (deformable mirrors) and the on-axis refractive elements. It usually has two deformable mirrors. The magnification of one DM would be variable while its surface profile is changed by controlling the actuators, which results in a focal shift in the image space of the zoom lens. To compensate the variation of the focal plane position, the surface profile of the other DM is varied. Therefore the focal length of the whole optical system would be varied and have a stabilized image position.

In this paper, modeling anamorphic optical surfaces in the MOEMS-based zoom lens is described. The anamorphic profile of the DM is designed to satisfy the following requirements. First, the aberration coefficients of the DMs and the refractive surfaces are composed in the vector space to achieve the coefficients of the system. The parameters of the DMs anamorphic profile are selected and designed to calculate the aberration coefficients. And the initial configuration of the refractive elements is determined to fulfill the system requirements and specifications at the wide angle and long focal length positions. Then the anamorphic parameters of the DMs are optimized and varied to minimize the aberrations in the zoom range. The values of the paraxial radii of the DMs in the tangential and sagittal plane are also constrained to optimize the astigmatism. It is verified by the design of the MOEMS-based zoom lens with zoom ratio of 1:3.

7849-05, Session 2

Incorporating field dependence into the FRINGE Zernike polynomial

K. P. Thompson, Optical Research Associates (United States)

As optical testing methods expand from the testing of individual optical surfaces during fabrication to quantifying the alignment state of optical systems by measuring the wavefront at multiple field points, it becomes advantageous to know how a Zernike polynomial coefficient depends on the field point at which a measurement of the coefficient is made. Particularly with the new challenges of understanding the state of alignment of three (and more) mirror anastigmats (TMAs), having an expression for the field dependence of individual Zernike polynomial terms enables extracting a complete understanding of the state of alignment from a sparse sample of field points. This talk will present the analytic expression for the field dependence of the first 25 terms in the FRINGE Zernike polynomial, which can then be used to describe the state of alignment of most reflecting optical systems. Predicted field dependence based in nodal aberration theory will be compared to real ray based wavefront data numerically fit to the FRINGE Zernike polynomial.

7849-06, Session 2

Corrective, deterministic, and/or generative?: sub-aperture finishing

K. Tanimura, K. Hori, N. Sugimoto, T. Dohi, OptiWorks, Inc. (Japan)

Sub-aperture finishing is applied for the correction of the optical surface.

Most important issue is how to keep stabilized sub-aperture tool contact(the foot print) and control a removal rate and a dwell time. Magnet Rheological Finishing is one of most advanced finishing process. This paper shows MRF is able to “generate” a desired optical profile from existing surface under completely controlled finishing condition.

7849-07, Session 2

Design of optical stress sensor using single electrooptic and photoelastic crystal

C. Li, BeiHang Univ. (China)

Optical stress sensors as well as accelerator sensors have been widely used in mechanical engineering, stress analysis and measurement, and inertial system, etc. Some of them are based on photoelastic effect and optical polarization modulation. In previous literatures, such type of stress sensor usually consists of prism polarizers, a photoelastic element and an electrooptic modulator to generate polarization modulated probing light. To our knowledge, there is no report concerning the optical stress sensor by use of single crystal which is used as both sensing element and modulator.

An optical stress sensor using single electrooptic and photoelastic crystal is designed and numerically simulated. There are many types of crystal exhibit both electrooptic effect and photoelastic effect, e.g. 42m and 3m class crystals. The common feature of the two effects is the existence of field-induced refractive index change, or linear birefringence. In some crystals, stress-induced birefringence and electrooptic birefringence can be compensated with each other, thus external stress applied to crystal can be measured by compensating the birefringence using square-wave electrooptic modulation. For example, a static normal stress of 1 MPa applied to a bulk lithium niobate crystal on its y axis can produce a birefringence of 3.791 times 10 to the -6th, which can be compensated by an electric field of 46.68V/mm applied along the same axis, and its birefringence deviation is about 10 to the -10th, azimuth deviation of dielectric axis is 0.0013 degree. This novel sensing scheme doesn’t need additional electrooptic modulator, and closed-loop or phase-locked measurement can be conducted by use of square-wave electrooptic modulation.

7849-08, Session 2

Seperating misalignment from misfiguare in stigmatic null tests of conic mirrors

Q. Chen, M. Zhen, Y. Li, Xi’an Institute of Optics and Precision Mechanics (China)

In autocollimation test for off-axis mirror of conic section at its focal point, misalignment of the mirror under test will generate aberration that are not easily distinguish from the fabricating errors. accurate polishing and figuring of the off-axis mirror will not be possible. The errors caused by misalignment are the displacement of the parent conic section of the mirror under test and the rotations about the parent coordinate axes. And their influence on the wave aberration is found by an application of optical path methods. The resulting formula is then used to specify the sources of misalignment. This procedure allows the metrologist to unambiguously identify surface correction profiles needed in the fabrication of off-axis aspheric segments.

7849-09, Session 2

MTF measurement and imaging quality evaluation of digital camera with slanted-edge method

C. Xiang, X. Chen, Y. Chen, J. Zhou, W. Shen, Soochow Univ. (China)

Modulation Transfer Function (MTF) is the spatial frequency response of imaging systems and now develops as an objective merit performance for evaluating both quality of lens and camera. When MTF of a digital camera is measured and as usual gratings used as targets, its tested MTF value is uncertain, since there is inevitable registration error between the line of the grating image formed by its lens and the spatially discrete pixels of focal plane array. So it is difficult to accurately measure the MTF of digital camera with the traditional method. In addition, measurement with a chosen grating can only give one or a few of MTF values at its fundamental or lower-order harmonic frequencies. In order to obtain a whole MTF curve, many grating targets with different frequencies and corresponding measurements should be adapted and repeated.

Slanted-edge method and its principle for measuring MTF of digital camera are introduced in this paper. Compared with traditional method, it can effectively increase the sampling frequency and reduce the effect of registration error on measured MTF of digital camera. The setup and software for testing digital camera is respectively established and developed. Measurement results with different tilt angle of the knife edge are compared to discuss the influence of the tilt angle. Also carefully denoise of the knife edge image is performed to decrease the noise sensitive of knife edge measurement. Comparisons have been made between the testing results gained by slanted-edge method and grating target technique, and the result deviation is analyzed.

7849-10, Session 2

The ground calibration system of vacuum ultraviolet imaging spectrometer

Y. Wu, T. Yi, G. Ni, Beijing Institute of Technology (China)

The far ultraviolet imaging spectrometer (FUIS) is used to measure the composition and distribution of the main molecules and atoms in the Earth’s upper atmosphere. It is an important instrument in investigation of the physical and chemical processes in the Earth’s upper atmosphere.

This paper describes a kind of ground calibration system for the far ultraviolet imaging spectrometer. The FUIS works between 120nm to 180nm, its spectral resolution is better than 1.0nm and its spatial resolution is 0.1°. The calibration facility includes the FUV light source, the infinite target simulation system, the FUV array detector and the vacuum chamber which can provide high vacuum environment.

Deuterium lamp with MgF2 window is used as FUV light source. It illuminates a special collimator which is produced to imitate the infinite target. The imaging mirror focus FUV radiation into FUIS through the entrance slit. Image receiver is a windowless FUV CCD array detector. All of the above equipments are set in a vacuum chamber to simulate the condition of the Earth’s upper atmosphere.

The spectrum calibration of FUIS is accomplished with the linear interpolation method. As we know the light source’s radiation curve and the detector’s response curve, we can test the radiation transfer function of the collimator. Then, the radiation calibration of FUIS can be calculated by the parameters mentioned above.

All work must be done in high vacuum and the FUV light is invisible,

so the optical components are inaccessible for adjustments during the measurements. The radiation calibration uncertainty is about 15%, not as well as the similar equipment in visible.

7849-11, Session 3

In the era of global optimization, the understanding of aberrations remains the key to designing superior optical systems

J. Bentley, Univ. of Rochester (United States); R. N. Youngworth, Light Capture, Inc. (United States); C. Olson, L-3 Communications Sonoma EO (United States)

Historically, a thorough grounding in aberration theory was the only path to successful lens design, both for developing starting layouts and for design improvement. Modern global optimizers, however, allow the lens designer to easily generate multiple solutions to a single design problem without understanding the crucial importance of aberrations and how they determine the full design potential. Compared to pure numerical optimization, aberration theory applied during the lens design process gives the designer a much firmer grasp of the overall design limitations and possibilities. Among other benefits, aberrations provide excellent insight into tolerance sensitivity and manufacturability of the underlying design form. We explore multiple examples of how applying aberration theory to lens design can improve the entire lens design process. Example systems include simple UV, visible, and IR refractive lenses; reflective triplets; much more complicated refractive systems requiring field curvature balance; and broadband zoom lenses.

7849-12, Session 3

Why are there so many system shapes in lens design?

F. Bociort, Technische Univ. Delft (Netherlands)

No abstract available

7849-13, Session 3

A simulation imaging method for actual optical system and results analysis

F. Neng, Z. Cen, X. Li, Q. Liu, H. Shang, Zhejiang Univ. (China)

The output images of real optical systems at working conditions indicate the imaging quality of the systems directly. In optical industry some standard pictures such as resolution char, star point are usually imaged by lenses for lens testing. The existing simulation methods for optical imaging can be divided into two categories. One is to simulate the imaging process of perfect optical systems instead of the lenses with actual parameters, aberrations and errors caused by manufacture and assembly. The other is to calculate the spot diagrams, point spread functions and module transfer function by optical design software. The latter is widely used for optimization design and image restoration. In this paper, the actual optical system is simulated by our self-developed simulation software, the target object expressed by a picture is input, the ray tracing method is used and the simulated image of the object output by the actual optical system with aberrations is received. Taking an optical system with given parameters as an example, the simulated image is obtained and compared with real photograph. As shown by the comparison that the images with a sense of reality including colors and luminance information can be obtained at the stage of optical design. The more sampling rays are traced, the more fields are calculated, the simulated image much closer to the real. The errors caused by optical system manufacture and assembly, such as decentration, tilt and surface errors can be considered in the software, and the simulated image we get is affected by these factors. So that we can give the reasonable tolerances, increase the development efficiency and reduce cost. In addition, the image processing researchers can also take the simulated images as source image for the image restoration algorithm research and verification.

7849-14, Session 3

Several factors affecting self-thermal radiation of cryogenic infrared optical system

L. Lin, Beijing Institute of Technology (China); B. Du, Luoyang Institute of Electro-Optical Equipment (China)

Self-thermal radiation is dominant stray radiation and key factor of reducing image quality of cryogenic infrared system. How to suppress this radiation becomes a critical work in design process of cryogenic infrared system. Take a space remote sensor as an example, distribution change of self-thermal radiation on the detector surface when the sensor under different temperature, emissivity or surface state is presented in this paper. Phenomena of self-thermal radiation is also researched from two aspects of self-radiation of emitting sources and transmission of thermal radiation in optical system. Consequently, several key factors of making thermal radiation of detector surface change are found. Therefore, corresponding measures of suppressing thermal radiation are proposed. And self-stray radiation of cryogenic infrared optical system has been effectively suppressed and the performance of the space remote sensor has been ensured within its technical requirement.

7849-15, Session 3

Analysis methods for polarization state and energy transmission of rays propagating in optical systems

C. Liu, Q. Liu, Z. Cen, X. Li, Zhejiang Univ. (China)

Polarization state of only completely polarized light can be analyzed by some software, ZEMAX for example. If the transmission and reflection coefficients of each optical surface are given, the energy transmission of rays can be calculated by some software, ASAP for example. Based on principles of geometrical optics, novel descriptions of the light with different polarization state are provided in this paper. Binary trees are well used for saving the polarization states, amplitudes and optical paths of sampling rays when ray tracing. The polarization state changes are analyzed in terms of several typical circumstances, such as Brewster incidence, total reflection, and etc. Partially polarized light is discussed as an important aspect. Further more, a computing method including composition and decomposition of sampling rays at each surface is also set up to analyze the energy transmission of the rays for optical systems. Adopting these analysis methods mentioned, not only the polarization state changes of the incident rays can be obtained, but also the energy distributions can be calculated. Since the energy distributions are obtained, the surface with the most energy loss will be found in the optical system. The energy value and polarization state of light reaching the image surface will also be available. These analysis methods are very helpful for designing or analyzing optical systems, such as analyzing the energy of stray light in high power optical systems, researching the influences of optical surfaces to rays' polarization state in polarization imaging systems and so on.

7849-16, Session 4

Adaptive intensity stabilization of ultra-short optical pulse for optical measurement and metrology

T. Konishi, K. Kawanishi, Osaka Univ. (Japan)

Nonlinear optical effects such as multi-photon absorption, Raman effect etc. have been attracted a considerable attention and used in various fields such as light source development, optical measurement, optical metrology, optical communication, optical fabrication and so on. Since, however, nonlinear optical effects are very sensitive to intensity fluctuation of input pulses, intensity stabilization of a light source is a very important issue for their applications. In this talk, the current progress on an all-optical limiter for intensity stabilization is reviewed and some achievements by using a SPM-based optical limiter are demonstrated.

7849-17, Session 4

Experimental simulation and parameters measurement of the atmospheric Turbulence

X. Qiang, Xi'an Jiaotong Univ. (China); F. Zong, Y. Li, J. Zhao, J. Liu, Northwest Institute of Nuclear Technology (China); J. Song, Xi'an Jiaotong Univ. (China)

Atmospheric optical turbulence is a principal factor that has effects on laser beams propagation through the atmosphere, so, measurement of parameters of atmospheric optical turbulence is a important research in the field of atmospheric optics. A device was set up in laboratory for simulating and measuring atmospheric optical turbulence. Under the approximation of geometrical optics, the parameters of atmospheric optical turbulence were given by measurement of irradiance fluctuations and arrival-of-angle fluctuations of laser beams after propagation through simulated-turbulence. The uncertainty in measurement was given by analysing the experimental data, and the experimental data was compared with the results presented in the literature.

7849-18, Session 4

Extraction and analysis of the image in the sight field of comparison goniometer to measure IR gratings

Z. Wang, Beijing Institute of Technology (China) and Henan Univ. of Technology (China); Y. Zhao, Z. Li, L. Dong, Beijing Institute of Technology (China)

There are too many kinds of old inspection devices and instruments which are playing important role in real application. Some of the optical angle gauges, parabolic collimators which ware made in 30 years ago are yet serving many purposes in the laboratories. In the research work, a special knockdown grating to reflect infrared will be fabricated and measured. Cool Stick Technique is used to connect the gratings to the support plate, the comparison goniometer is used to inspect the parallelism character between the single prism.

The common manner to read a comparison goniometer is to check the ocular of the goniometer by one eye of the operator. The ocular's size is quite small, it is not easy to read and to recognize for a long and heavy checking work. A new technique to read the comparison goniometer is consequently proposed in this paper. The image-based reading technique proposed in this paper will deal with the image of the sight field which includes scale lines, coordinates lines and the reflection image of two infrared grating prisms. The aim of appropriate technique is to analyze the light intensity distribute curve to get information which includes the size of scale lines and the position of reflection image, finally get the angle difference between the two prisms.

One set of lens, digital camera, common goniometer is built up to obtain the view image which includes scale lines, coordinates lines and the reflection image of two infrared grating prisms that needs to be checked. The procedure to process Meter Dial image is designed customized.

7849-19, Session 5

Free-form Kohler nonimaging optics for photovoltaic concentration

P. Benitez, J. C. Miñano, P. Zamora, Univ. Politécnica de Madrid (Spain); M. M. Hernandez, A. Cvetković, Light Prescriptions Innovators Europe, S. L. (Spain); M. Bulyan, Univ. Politécnica de Madrid (Spain)

Concentration Photovoltaics (CPV) is one of the most promising areas for competitive solar electricity production. This promise relays on the use of high-efficiency triple junction solar cells (which have already proven efficiencies over 41%) and on advance optics designs, which allow for high concentration and high manufacturing tolerance, both key elements for low cost in mass production..

In this paper we will presented the progress in the development of most advanced CPV optical designs at present. They are based on free-form optics using Kohler homogenization. The degree of freedom of using free-forms allows introducing multiple functionalities in only two optical elements, which provide the required concentration with high tolerance and excellent light homogenization. Even though the designs are complex, they can be manufactured with the same techniques as classical designs (typically plastic injection molding, embossing and glass molding) and that their production cost is the same.

Different families will be introduced. A first group will use Fresnel lens as a primary optics (called FK concentrator and F-RXI concentrators) and a second group using mirrors as a primary (the XR and XXR). Comparison between them (both optical performance and practical module design differences) will be given, and also the comparison with classical designs will be discussed. The first being introduced to the market (the FK) has already experimentally proven module electrical efficiencies over 30% with no AR coatings at a concentration of 625x with high tolerance angle (1.2º). These experimental results will be shown.

7849-20, Session 5

Study on SMS design method for LED illumination

H. Wang, Q. Zhang, H. Wang, South China Univ. of Technology (China)

A 3D optical design method called SMS 3D method (Simultaneous Multiple Surface 3D)was present. 3D means here that the prescriptions and the results of the problem are given in 3D geometry.In general the results of a 3D design method are non-rotational, non-linear asymmetric surfaces. Free-form optical surfaces can presently be manufactured with optical precision thanks to the development of multiple-axis high-accuracy diamond turning machines. The SMS design method has proven to generate simple ultra-compact high-efficiency devices.

7849-21, Session 5

Endoscope illumination system based on freeform lens

S. Yan, China Jiliang Univ. (China); L. Wang, Zhejiang Univ. (China)

Endoscope has been applied widely in the diagnoses of digestive system disease, which can capture visual information of tissue in vivo. To relieve patients, endoscope is thinner and thinner. This benefits mainly from increasingly small image sensor, which is generally CCD. Recently, CMOS was also used in endoscope. Compared with CCD, CMOS has smaller dynamic range, which gives poor image quality. Endoscope objective lens has a wide field of view, which is generally more than 120°. For wide angle objective lens, central field is greatly brighter than margin field. Due to the two reasons above, an illumination system matching the objective lens is appreciated. In this paper, an illumination system producing gradient illuminance for endoscope is presented, which is based on freeform lens. The requirement for illuminace distribution was decided by the encircled illumination performance of endoscope objective lens. The freeform lens' shape was computed reversely based on vector refractive law. With a MatlabTM program, rise of the freeform lens was achieved iteratively point by point from center to edge. For the size of light source, the illumination result departs from the perfect target value a little. It can be settled by adjusting the target distribution advisedly. With optical raytracing software, the imaging performance of the endoscope objective lens under the freeform lens illumination was analyzed. The result shows a uniform illuminance distribution in the image plane and enhanced dynamic range of imaging.

7849-22, Session 5

Different illumination modes in microlithography illumination system

H. Xing, L. Lin, Beijing Institute of Technology (China)

Illumination system is one of the most important parts of the micro-lithography object lens. Its performance can greatly affect the lithography machine's etching graphic quality. In this paper, we discuss a DUV micro-lithography illumination system which can achieve high uniformity and a large illuminated area on the mask. According to the large numerical aperture requirement, a refractive illumination system is designed and optimized with software ZEMAX. The system also meets the requirement of large illumination area on the mask, and no aspherical lens is used. Characters of different illumination structures and mode are introduced here. Then by using the software of TracePro, illumination system with different kinds of aperture is modeling and illuminace is analyzed. We research effect of illuminace on the mask which bring by different kinds of aperture. Also in this paper, we make a study of relationship between different illumination mode and different graphics. Finally, we compare the results and give suggestion about how to choose illumination mode. That is meaningful for choosing different aperture in illumination system of micro-lithography.

7849-23, Session 5

Temporal shaping of the femtosecond pulse by deformable mirrors and spatial light modulators

Y. Nie, X. Li, J. Yang, W. Hu, S. Luo, National Univ. of Defense Technology (China)

A programmable femtosecond pulse shaping is designed by using a micro-machined deformable mirrors (MDM) and a liquid crystal spatial light modulators (LCSLM). The shaping apparatus contains two 4f optical subsystems which modulate the phase and the amplitude of the pulse respectively, and the MDM and the LCSLM are located in the spectral plane of each subsystem. According to the fact that the time domain signal f(t) and its corresponding frequency domain signal F( ) are Fourier transform pair, and the Fourier transform of the delayed signal f(t-) is F( )exp(-i), the pulse can be delayed or advanced by imposing a linear phase change onto its spectrum. In the shaping system, the LCSLM is used to modulate the amplitude of each frequency component of the pulse, and the reflecting MDM with low loss (less than 4%) can modulate the phase of each frequency component smoothly. The excellent characters of LCSLM and MDM make the dispersion caused by pulse chirping well compensated for, and the temporal feature of the pulse effectively modulated. Theoretically, any temporal pulse shape can be obtained through the system if the phase and the amplitude of the pulse are perfectly modulated. The results of our experiments indicate that a temporal flattop pulse with fast rising time is generated, and the fluctuating of the flattop district is less than 5.1%. Moreover, we also obtain a high repetition rate pulse trains by the shaping system. All the results above show that the shaping system has some potential applications to the areas of optical computing, optical communication and quantum control.

7849-24, Session 6

Depth-fused multi-focal plane displays enable accurate depth perception

H. Hua, College of Optical Sciences, The Univ. of Arizona (United States)

Many different approaches to three-dimensional (3-D) displays have been explored, most of which are considered to be the stereoscopic-type. The stereoscopic-type displays create depth perception by presenting two perspective images, one for each eye, of a 3D scene from two slightly different viewing positions. They have been the dominant technology adopted for many applications, spanning the fields of flight simulation, scientific visualization, medicine, engineering design, education and training, and entertainment systems. Existing stereoscopic displays, however, lack the ability to produce accurate focus cues, which have been suggested to contribute to various visual artifacts such as visual fatigue. This paper will review some recent work on vari- and multi-focal plane display technologies that are capable of rendering nearly correct focus cues for 3D objects and these technologies have great promise of enabling more accurate depth perception for 3D tasks.

7849-25, Session 6

Free form optical system design with differential equations

D. Cheng, Beijing Institute of Technology (China) and College of Optical Sciences, The Univ. of Arizona (United States); Y. Wang, Beijing Institute of Technology (China); H. Hua, College of Optical Sciences, The Univ. of Arizona (United States)

The general Wassermann-Wolf differential equations were derived to design an off-axis free form surface (FFS) prism head mounted display (HMD) system. A FFS prism HMD system with 20° degree, 8mm exit pupil and 15mm-effective focal length was designed and the image qualities were analyzed.

7849-26, Session 6

The design of light pipe with microstructures for touch screen

Y. Bo, K. Lu, L. Fei, X. Wei, Univ. of Shanghai for Science and Technology (China)

Touch screen has a very wide range of applications. Most of them are used in public information inquiries, for instance, service inquiries in telecommunication bureau, tax bureau, bank system, electric department . Touch screen can also be used for entertainment and virtual reality applications too. Traditionally, touch screen was composed of pairs of infrared LED and correspondent receivers which were all installed in the screen frame. Arrays of LED were set in the adjacent sides of the frame of an infrared touch screen while arrays of the infrared receivers were fixed in each opposite side, so that the infrared detecting network was formed. While the infrared touch screen has some technical limitations nowadays such as the low resolution, limitations of touching methods and fault response due to environmental disturbances. The plastic material has a relatively high absorption rate for infrared light, which greatly limits the size of the touch screen. Our design use laser diode as source and change the traditional inner structure of touch screen by using a light pipe with microstructures. The geometric parameters of the light pipe and the microstructures were obtained through equation solving. Simulation results prove that the design method for touch screen proposed in this paper could achieve high resolution and large size of touch screen.

7849-27, Session 6

Carrier feed-through analysis of heterodyne lidar system

J. Wang, Shandong Academy of Sciences (China)

A novel heterodyne continuous wave lidar system based on single-mode fiber (SMF) components and instruments is reported. In order to improve the signal-to-noise ratio(SNR) of heterodyne lidar system, the four causes producing carrier feed-through are presented, including (1) the return loss of optical antenna; (2) the direction of fiber circulator; (3) the extinction ratio of acousto-optic frequency shifter (AOFS); (4) close object's reflection. Then theoretical analysis and experimental study for the methods of eliminating carrier feed-through are conducted. The results demonstrate that carrier feed-through is mainly arising from the non-ideality of optical components. By improving the traditional heterodyne optical structure and enhancing the performance of optical components, the carrier feed-through power can be decreased by more than 20dB. And the effect of carrier feed-through can be basically eliminated by adopting the suppression technique with phase compensation.

7849-28, Session 7

Principles of optical and software development in document scanners/readers applications

I. L. Livshits, M. Pashkovskiy, V. Vasiliev, Saint-Petersburg State Univ. of Information Technologies, Mechanics and Optics (Russian Federation)

Optical scanners and readers are among the most frequently used opto-electronic devices.Engineers are constantly trying to improve existing schemes, as well as to create new principles and solutions for these products. Publication is devoted to analysis of existing scanners/readers schemes from two different points of view - from the side of optical designer and software engineer. It is shown that only close cooperation of apparatus and software design can lead to a successful result.

Modern scanners/readers have to satisfy the followings criteria:

- High resolution;
- Small size;
- Light weight and minimum number of components;
- Possibility for mass production;
- Working in real time;
- Low cost.

Example of two scanners/readers designs are presented - one is implemented using conventional optics, and in the second design we used the lens array as optical system. Both variants can find their applications,but in case of mass-production lens-array system will have lower cost.

For both types of scanners software is described. Software solves several problems: image processing, text recognition and document validation.

7849-29, Session 7

optical Design of non-CaF2 of middle and low power flat-field apochromatic metallographic microobjective

Z. Xiao, J. Cao, X. Ran, P. Li, Guilin Univ. of Electronic Technology (China)

Flat-field apochromatic microobjective has both the best quality and the highest grade among the microobjectives. The ordinary way to correct the axial chromatic aberration and secondary spectrum is putting the optical crystal into the pluslens, for example, using CaF2 as the material of optical glasses. Recentely, in view of cost and manufacturability, using special type glasses are used for insteading of CaF2 wholly or partely in the designing of flat-field apochromatic microobjective. There are superiority in lowing cost and improving technique. Designing flat-field apochromatic microobjective with large NA(numerical aperture) and field, the traditional way is seeking for the original structure among the typical types. But these structures basically contain CaF2. To design higher performance price ratio flat-field apochromatic microobjective which only contains optical glass, the medium and low power apochromatic metallographic microobjective are constructed by basing the optical system theory on apochromatic, referencing photographic objective to making similar innovation and using special type optical glasses. For designing objective of 2.5× and 5×, triplet type of photographic objective including positive lens, negative lens and positive lens is transplanted and applied for low power objective. The same kind glasses are used in front and back lens. With the use of drumlens, satisfactory results of achromatism of d,c,F and flat-field are attained in the structure. We can design middle power flat-field apochromatic of 8×and 10× successfully by using iterative optimization in OSLO through complicating triplet type of photographic objective and referencing parameter of Orthometar photographic objective.

7849-30, Session 7

Conceptual design of airborne daytime infrared star cameras

Y. Zhou, W. Shen, F. Wu, Soochow Univ. (China)

Star camera is a kind of sensitive attitude sensors used for navigation of space vehicles. It has the advantages of high precision, light weight, and low power dissipation over other navigation systems, such as sun sensor, inertial gyro, and infrared earth sensor. However, it is difficult for the conventional and current star camera to be effectively used on

aircrafts that fly in daytime, since the star image, which is formed by such visible camera, is flooded by the intense sky background scatter light. The conceptual design and the principle of airborne daytime infrared star cameras are proposed and introduced in this paper.

In fact, there is enough number of stars in near infrared band to be used as reference of a star camera for calculating attitude. From the 2MASS star catalog, it is known that there are 3243 stars brighter than 2.5 magnitude within near infrared H-band. Based on recent developed InGaAs focal plane detector (FPA), conceptual infrared daytime star cameras, including a star tracker and a star sensor, is proposed. Similar to visible star camera, the proposed daytime infrared star cameras consist of a lens, a FPA and corresponding electronics, and guidance star catalog and associative software. In order to be suitable for air vehicles, these infrared star cameras should be as compact as possible and then their lens should have small optical aperture. Through analyzing the atmospheric scattering background light intensity for different altitudes, observing angles, and solar angles with Modtran software, and considering FPA performance, shot noise and the required star magnitude for daytime star trackers and sensors, the optical system parameters, i.e. field of view, entrance pupil diameter and effective focal length, are determined according to the required SNR. Both proposed airborne daytime star cameras have the advantages of compactness, easy implementation, and low cost.

7849-31, Session 7

Design of a multi-channel quasi-optical front-end at terahertz bands

Z. Lou, S. Shi, Purple Mountain Observatory (China)

This paper presents a proposal for the quasi-optical design for a terahertz band multi-channel front-end that can be used to couple quasi-optical beams from the antenna to the detectors in a telescope or radiometer system. The front-end splits the input beam from the antenna into three channels: Channel 1 is a 4 by 1 pixels SIS receiver array at 350 micron band, Channel 2a is a single-pixel SIS receiver at 200 micron band, and Channel 2b is a single-pixel HEB receiver also at 200 micron band. The quasi-optical front-end provides quasi-optical beam coupling from the antenna to the detector horns of channel 1~3 simultaneously. Gaussian optics is used as the design tool and physical optics simulation is performed for the numerical verification of the design. Apart from optical performances, engineering considerations such as system miniaturization and the effect of extreme temperature changes on the system alignment are also taking into account during the design. The proposed front-end design has the potential application in China's future 5 meter terahertz telescope in Dome A, Antarctica.

7849-32, Session 8

LED lighting module design based on a prescribed candle-power distribution for uniform illumination

J. Chen, C. Wang, T. Wang, National Changhua Univ. of Education (Taiwan); Y. Wang, National Tsing Hua Univ. (Taiwan); S. Wu, National Changhua Univ. of Education (Taiwan)

Owing to the advancement of LED technologies, high-power LEDs have reached a development stage that affords them many feasible applications to general indoor/outdoor lighting. However, the direction-dependent characteristic of their candle-power distribution, particularly the half-space light-ray spread, let them cannot be directly applied to provide an adequate and uniform illumination. Therefore, at least a well-designed optical element is usually required to produce the desired uniformity or prescribed illumination.

This paper presents a simple approach to design an LED lighting module, which contains a reflector with freeform surface, to provide a uniform lighting. The reflector is designed based on a prescribed candle-power distribution to achieve a perfect uniformity of illumination on a target surface. Both the design methodology and the construction of the reflector are stated in detail. The optical efficiency and illumination uniformity of the lighting module are calculated according to a ray-tracing result by using a TracePro program. In addition, the effects of the reflector's aperture and the LED chip size on the optical efficiency and uniformity are also investigated that the result can provide a reference to LED-luminaire designers and manufacturers. The computer simulation result shows that the total optical efficiency of the single lighting module can achieve above 85% with illumination uniformity greater than 0.89 on a target surface of radius 2.5 m at 2.5-m away from the LED light source. For further practical applications, we employ this method to develop a reflector with a square aperture to produce a uniform lighting-distribution of square shape.

7849-33, Session 8

The design method of tailored-intensity distribution lens based on LED

W. Wang, S. To, W. B. Lee, The Hong Kong Polytechnic Univ. (Hong Kong, China)

The design method of tailored-intensity distribution based on LED is demonstrated in this paper. Two kinds of LED light sources are adopted to test the design method for the tailored-intensity distribution lens based on LED. The high power White LED Light source is adopted in this method. The lens can be easily designed according to the intensity distribution requirement. And the designed lens is fabricated by direct single diamond turning or by mold injection. The results show that this tailored-intensity lens is of high performance which is available to satisfy special light intensity distribution requirements in the manufacture of LED light luminaries, and is of great practical value in the LED lighting industry.

7849-34, Session 8

Lens design of street lamp for integrated high power LED

H. Liu, L. Jiang, L. Hu, Zhejiang Univ. of Technology (China)

LED light source has obvious advantages and wide application, and lamps and lanterns with integrated high power LED light source are the study hotspot. Integrated high power LED light source could gives idea high intensity of luminous energy, but at the same time it brings out a dazzling problem because of concentrated luminous beam. It has high demand for photometric design to get the uniform radiation at appointed area, for example rectangular uniform radiation shape for street lamp luminance. The paper studies photometric design method of integrated high power LED light source using lens of free surface, and puts forward a photometric design way of free surface lens for integrated high power LED street lamp. According to the characteristic of LED light source and road surface luminance demand, which is rectangular uniform radiation shape, the paper gives out the two dimensional curve governing equations for lens of free surface, and on this base it obtains governing parameters for lens of free surface. The paper discusses the method of photometric patch design for street lamp, i.e., divides lens surface into several corresponding patches according to the road sub areas; and on this base it adjusts the radiation shape through adjusting governing parameters of lens of free surface to control luminous beam to the appointed area. And it optimizes the governing parameters using orthogonal experimental method. In this way the paper gets an idea lens, which could give rectangular radiation shape for street lamp luminance. The lens has good uniformity and idea average luminance, and could satisfy the relational national standards about street and road luminance.

7849-35, Session 8

Multi-segment free form surface LED lens for large scale uniform illumination

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The application of the high power light emitting diode (LED) is limited due to the ununiformity of the emitting light. To meet the requirement of the large scale uniform illumination, a secondary optical lens constituted by multi-segment free form surfaces is proposed in this work. The energy conservation law is utilized to build the corresponding relationship of the illumination region and the source, and the free form surface of the lens is obtained by the refractive law, then the uniform illumination in the desired region is realized. Simultaneously, to resist the reflection loss happened inner the lens for large scale illumination, this lens is combined reasonably by multi-segment free form surfaces, accordingly the reflection loss is controlled and the energy efficiency is enhanced.

7849-36, Session 9

Frequency tunable electromagnetic metamaterial based on mechanical movement method

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A frequency tunable electromagnetic metamaterial was proposed based on mechanical movement method. Two rings are etched against each other on the two sides of the substrate and both can be adjusted mechanically to slip slightly relative to the substrate. Thus, the resonant frequency can be modulated due to the changed coupling capacitance between the rings according to equivalent circuit theory. Simulation results show that the transmission can be continuously adjusted and retrieved effective parameters based on simulated scattering parameters show that the tunable permittivity can be realized by slipping the rings either along the gap or perpendicular to the gap's direction. By combining frequency modulations in the two directions, electric resonant frequency can shift from 6.2GHz to 8.7GHz, which realized a broad frequency range modulation. The proposed tunable metamaterial has potential applications to design dual band and multi-band antennas.

7849-37, Session 9

Plasmonic analogue of atom systems with two-level to four-level configurations in metamaterials

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Electromagnetically induced transparency (EIT) arises from destructive quantum interference such that zero absorption probability at line center of an absorptive optical medium. Group velocity control using EIT has been intensively studied for fundamental physics as well as various applications of nonlinear quantum optics. Plasmonic EIT, as the classical counterpart of conventional EIT, has also been studied in metamaterials. Although plasmonic EIT roots in different physics from that of conventional EIT, the exploration is of great interest because of its own advantages in a plasmonic system. In this work, we analyze the plasmonic EIT as a classical analogues of EIT in various geometric configurations of metamaterials. For this, we use the finite-difference time-domain (FDTD) method and the density-matrix approach for numerical calculations. We show that geometrical shape of metamaterial elements is fully mapped with the physical quantities in an atomic system, such as decays, detunings, and Rabi frequencies. Our study provides fundamental understanding and useful guidelines of the plasmonic EIT, and paves the way for the plasmonic EIT applications such as delay lines and all-optical switching. Furthermore, we illustrate geometrical relations to the plasmonic EIT for the transparency enhancement, in asymmetric matematerial structures. More interestingly, a simple modification of geometry can excite dual-dark resonance as in an atomic system, where plasmonic switching is applicable.

7849-38, Session 9

Emission enhancement of an organic light-emitting by localized surface plasmons

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We report an organic light-emitting device structure which is formed by an organic layer deposited thermally close to a periodic metallic array with a several nanometer thick SiO2 spacer. In this structure, the localized surface plasmon (LSP) was introduced by the periodic metallic array, which was fabricated by the sub-diffraction-limited photolithography based on the self-assembled polystyrene nanosphere (PS) array. The experiment has been done to demonstrate a strong coupling generated between the LSPs and the organic emitter when choosing the suitable period of the metallic array. Simultaneously, comparing with the structure without the metallic array, a strong enhancement of the photoluminescence (PL) can be observed.

7849-39, Session 9

LC Parameter based analysis of coupled gold nanorods

K. B. Mehta, N. Chen, National Univ. of Singapore (Singapore)

Metal nanoparticles provide unique optical properties due to the collective oscillation of free electrons in them, popularly known as Plasmon resonance of particles. Due to Plasmon resonance in metallic nanoparticles they have enhancement in scattering and absorption cross sections. This property has been widely used to generate contrast in various coherent imaging modalities. With advancement in nanofabrication now it is possible to fabricate various unique shaped nanoparticles. But before fabricating them it is necessary to predict and understand their behavior using simulations.Except for some very simple shaped nanoparticles like sphere, it is very difficult to derive analytical functions to characterize the optical properties. Various numerical methods like the Finite different time domain (FDTD) method, Finite element method (FEM), Discrete dipole methods have been used to characterize the optical properties of complicated shaped particles, or coupled nanoparticles.In this paper we have used a simple analytical model based on LC circuit parameters to model the Plasmon resonance, based on the circuit theory approach and concepts from antenna theory, we have calculated the far-field scattering pattern of coupled gold nanorods. The results have been compared with the FDTD based simulations.

7849-40, Session 9

Performance analysis of wavelength conversion in SOI waveguides

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The flexibility of very high bandwidth optical fiber networks solely depends upon all-optical wavelength conversion. Among many wavelength conversion schemes, exploiting FWM in silicon waveguides has gained considerable attraction due to its transparency against modulation formats and bit rates, along with very short excitation lifetime. The silicon waveguides are the perfect choice for FWM applications due to considerable reduction in cost and size of silicon photonic devices. The parametric process of FWM in silicon waveguides is the result of nonlinear response of bound electrons to an applied field. The inherent properties of very high nonlinearity and tight light confinement of silicon waveguides enable it to provide silicon compatible chip scale wavelength converters ready to replace the long highly nonlinear silica fibers (HNLSF).

In this paper the wavelength conversion in a 1cm long silicon-on-insulator (SOI) waveguide has been investigated numerically using coupled wave equations. The influences of dispersion, pump power and nonlinear absorption on the conversion efficiency and noise figure are discussed. Different pump parameters are considered to optimize the conversion efficiency. In order to achieve high conversion efficiency, the pump wavelength is to be operated in anomalous GVD regimes. Conversion efficiency decreases with the increasing pump power due to the two-photon absorption (TPA) and TPA-induce free-carrier absorption (FCA) at the higher pump power. The high conversion efficiency and low noise figure can be achieved by choosing suitable pump power in the silicon waveguide.

7849-41, Session 9

The high numerical aperture photonic crystal fibers and application in the astronomy

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In astronomy, the range of the protostars is very aboard and because the effect of the atmosphere of the earth and so on, the light of the protostars is so weak to detect. In order to solve these problems, we demonstrate a high numerical aperture detector has photonic crystal cladding. The core of high numerical aperture fiber is 256 m; a ring of air holes is arrayed around the core. The diameter of the air holes is 32 m, the big air holes not only make the effective index of the cladding is very low to rise the numerical aperture but also make more protostars light confined into the central core to reduce the loss. The material of the central core is SiO2 or other high index material, thus it can also raise the numerical aperture. Through the theoretical arithmetic, it can find that the numerical aperture is 1.05; the loss is less than 0.1dB/km. So this kind of high numerical aperture fibers has the strong ability to collect light and the loss is very low.

7849-42, Session 10

An asphericity definition for aspheric surface testing

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In order to fit the requirements of aspheric surface testing, slope asphericity capable of representing asphericity gradient accurately is proposed. First the application of min-max slope asphericity in CGH and laser defectometry is analyzed. According to mass simulations, the formulas of min-max slope asphericity and relative best-fit sphere are given. Then the effect of aspheric surface parameters on calculation result is analyzed. The results indicate that the min-max slope asphericity is directly relative to the manufacture difficulty of CGH and the testing difficulty of aspheric surface, and the corresponding best-fit sphere can be used to reduce the testing error of laser deflectometry. Slope asphericity can represent the testing difficulty of aspheric surface, thus is suitable for aspheric surface testing techniques.

7849-43, Session 10

White light interferometry for fast area surface measurement based on GPGPU

J. Wang, K. Wang, J. Bai, Zhejiang Univ. (China)

The performance of industrial products are mostly determined by the quality of the surface. It is thus crucial to effectively evaluation the surface quality of products including shape, waviness, roughness. As a popular surface inspection tool, white-light interferometry has the advantages of non-contact, high-precision and quantitative analysis. However, in order to obtain the requried areal surface profile, tens to hundreds of interferograms have to be processed. Compared with the several seconds processing time for laser interferometry that based on phase shifting, the white light interfermetry is farily time consuming. Algorithms such as filtering, Fourier transform, and correlation have to be carried out in order to acquire the optical path difference distributions of the interferometer. At present, it takes up to several minutes for commercial white-light interferometer to complete a single measurement. GPGPU, short for general purpose graphic processing unit, is now not only used for video accelerating, but also used for scientific computing during recent years. In this paper, we propose a fast white light interferometry based on GPGPU in which the interferograms are processed in parallel. By using GPGPU as an acceleration tool, the data processing time of white light interferometry has been reduced to five percents that of conventional method.

7849-44, Session 10

Accurate alignment error removal for interferometry spherical surfaces testing

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Laser interferometric testing of spherical surfaces is the most frequently used and effective approach for ultra-precision surface quality evaluation. In practice, the measurement results usually represents the combination of information of the surface to be tested, the system aberration, and the alignment error of the surface such as tilt and defocus. In order to effectively evaluate the surface quality, system aberration and alignment errors have to be removed. A three-measurement absolute testing technique is usually implemented to remove system aberration. Traditionally, the alignment errors are removed by removing their corresponding Zernike terms. However, in this paper, we report that the conventional method suffers notable residual error when testing a surface with small F-number. This would be problematic for ultra precision surface testing. Different alignment errors found in laser interferometric were analyzed by using a strict model. To demonstrate the theoretical analysis, a spherical surface with small F-number was tested and both the traditional and our proposed method are used to remove the defocus error. The defocus error is effectively eliminated by using our method with a peak-to-peak residual error of 0.001 wavelength, while a residual error of 0.03 wavelength remains when using the traditional method.

7849-45, Session 10

Single-shot two-dimensional dispersive interferometric profilometer

P. Zhu, K. Wang, Zhejiang Univ. (China)

Traditional interferometric profilemeters suffers from phase ambiguity problem and sensitivity to environmental disturbance, thus preventing their applications for on-line surface inspections. We propose a new method to obtain the object surface's two-dimensional profile in a single shot using a dispersive interferometer. An air-spaced Fabry-Perot etalon was applied in order to decompose the light from the broadband source into discrete monochromatic constituents with equal wavelength interval. A blazed grating is implemented to effectively separate the interferograms of difference wavelength. As a result, the interference patterns of different wavelengths distributed separately on the CCD camera. We applied an absolute optical path acquisition algorithm based on fast Fourier-transform to calculate the phase information. Factors which influence the accuracy of the measurement are also discussed in this paper. Compared with traditional white-light interferometry and wavelength scanning interferometry, the key advantage of the proposed technique is that two-dimensional surface profile can be acquired in a single shot, at the price of scarifying some measurement area. It is thus highly insensitive to environmental noise and can be used to measure surfaces with large steps or optically rough surfaces without vibration control.

7849-46, Poster Session

Comprehensive performance analysis of popular odd-symmetric phase masks used for wave-front coded imaging system

H. Zhao, Xi'an Institute of Optics and Precision Mechanics (China)

Since proposed by Dowski and Cathey in 1995, wave-front coding has been paid much attention because of its amazing capability in extending the depth of field (DOF). As is widely known, the phase mask is the key element to generate the magic of large DOF and many kinds of phase masks have been designed so far. Among all phase masks, odd-symmetric types are not only dominant in quantity, but also perform better in extending the DOF. Therefore, several popular types, such as cubic, logarithmic, exponential, high-order, and polynomial and so on, are what we focus on here. In order to make the subsequent performance analysis reasonable, optimization should be the first step because randomly selected parameters will degrade the performance of any phase mask. With the minimum acceptable MTF (modulation transfer function) as the uniform criterion, simulated annealing (SA) algorithm is first used to obtain the global optimum parameters and then performance analysis is carried out by considering four important factors: DOF extension capability, sensitiveness to elementary aberrations, PSF (point spread function) shifting effect and restorability of intermediate blurred images. Based on the numerical results, these masks can be actually divided into three groups and this will help users select appropriate type when they determine to use wave-front coding technique. To our knowledge, nearly all masks are just proposed in a one-by-one way and no comprehensive performance analysis has been made among them. So, the work reported here will be a good complementary part to this research field.

7849-48, Poster Session

Measuring focal length of microlens-array by grating prismatic interferometry

X. Zhu, X. Cao, S. Wu, P. Zhang, Institute of Optics and Electronics (China)

Microlens-arrays have been used in many field, it's difficult to measure the focal length by traditional method. This paper introduces a new technique for the focal length measurement. Place the grating close-by the focal point and make the +1 order and 0 order rays from the grating interfering, from the number of interference stripe we can get the defocusing, ulterior finish the focal length testing. In this paper, we enumerate the expression between the defocusing and the number of interference stripe. At the same time, we make an experiment to prove the feasibility; we also get different kinds of micro lens-array in the experiment to compare their testing accuracy. The experiment result shows that this technique has a higher accuracy and efficiency as opposed to traditional method, and the small f number lens have a higher testing accuracy.

7849-49, Poster Session

Index profile of gradient refractive index ball lens using the nondestructive measurement method

H. Lv, Xiaogan Univ. (China)

In this paper, the polynomial which is used to calculate the gradient refractive index profiles of gradient refractive index ball lenses is given, and the gradient refractive index profiles of gradient refractive index ball lenses can be measured using shearing interferometer rapidly, automatically and nondestructively. Comparing the measuring results with the previous reports, we find the gradient refractive index profiles of gradient refractive index ball lenses are precisely measured using the shearing interferometer.

7849-50, Poster Session

Design of x-ray array detector based on S8865

X. Liu, C. Miao, F. Rong, Tianjin Polytechnic Univ. (China)

This paper presents a new approach to design X-ray array detector which used to detect whether the high strength conveyor belt is broken inside. Based on the S8865 module, the paper designs hardware of detector, does circuit simulation. This detector accepts X-ray penetrated the conveyor belt, then generates different voltage signals of varying size. The signals are transferred to far end controller after they were amplified and differenced. This design has high speed, ECCM capability and strong extensibility. It can also been applied to the field of industrial or non-destructive testing and security checks.

7849-51, Poster Session

Analysis of nanostructures with Near-Zero Refractive index in mid-infrared region

H. Dong, C. Qiu, Institute of Optics and Electronics (China)

The near-zero-index metamaterials (NZIMs) have been extensively studied in recent years. In this letter, we show that a NZIM can be achieved in metallic nanostructures in Mid-IR region. The structure is composed of parallel metal stripes arrays, so it can be easily fabricated.

By scaling the dimensions of the structure, the effect can be tuned over a large bandwidth. Analysis is carried out to study the influence of the NZIM on infrared transmission in 28.3THz (10.6μm). The multilayer homogeneous medium model is employed based on the effective medium theory. Additionally, the theoretical analysis also provides a new method of determining the effective thickness of metamaterials, which is usually complicated. The results suggest that the ratio of the power after the light beam propagates through the NZIM to that before it is about 80%, and there is a negative variation in the phase of the light transmitted through the NZIM, which is in agreement with numerical simulation. Simulation also indicates that there is a strong enhancement of the electric field between the metal stripes arrays, which plays an important role in the phase delay. This metamaterial has the potential to be used in some devices such as in waveguides.

7849-52, Poster Session

Optimization design and error analysis of moiré deflection system

L. Song, S. Wu, X. Cao, L. Kuang, Institute of Optics and Electronics (China)

Moiré deflectometry is used for the measurement of focal lengths of optical lenses and systems in this paper. Detailed uncertainty analysis is done, and achievable accuracy is discussed. To increase the measurement accuracy, we propose two useful ways by changing the two systemic parameters (angle and space between two gratings). Firstly, we find that the space between two gratings affect the error from the tilt angle of moiré fringe greatly. And optimum space between two gratings for minimum error is referred to. In the other hand, enhancing the angle between the two grating's ruling's lines moderately can reduce error from the angle of two gratings greatly. Theoretical analysis and experimental results indicate that, higher measurement accuracy (twice above) can be achieved by changing the systemic parameters (angle and space between two gratings) reasonably.

7849-53, Poster Session

The design of foveated optical imaging system based on reflective liquid crystal SLM

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S. Feng, Changchun Institute of Optics, Fine Mechanics and Physics (China)

Based on reflective liquid crystal SLM, a new foveated optical imaging system (FOS) is proposed. Good quality imaging can be realized at any region of interest (ROI) within the field-of-view (FOV) by utilizing the SLM with variable resolution. A more rational optical structure is proposed, which is designed, optimized and matched with the reflective SLM to construct a more practical optical foveated imaging system that can achieve high resolution imaging and a wide field of view. We also simulate and analyze the tolerance of the system in order to control the fabricate work. This kind of FOS can be applied in wide FOV imaging aspects to reduce bandwidth and optics complexity, and to achieve weight reduction and miniaturization.

7849-54, Poster Session

The research on optical mirror's thermal characteristic in aerospace working condition

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The optical system used in aerospace must work under a very difficult aerospace condition. The temperature between the mirror sides which one is facing the sun and the other one is opposite the sun can reach about 200°. These temperature grids can bring thermal deformation to the optical components and then influence the whole system's image or detect results. To measure and analyze the deformation, we first use the finite element method to establish a heat exchange model to simulate the thermal distribution situation of an optical mirror, and the thermal imager is used to measure the temperature distribution on the surface of the mirror with time to correct the simulation model .Finally we provide an optical mirror's thermal characteristic in aerospace working condition. And the results are useful for the practical applications of the optical mirror in the aerospace environment.

7849-55, Poster Session

Design and analysis of a sub-aperture scanning machine for the transmittance measurements of large-aperture optical system

Y. He, P. Li, National Institute of Metrology (China)

For measuring large-aperture optical system transmittance, a novel sub-aperture scanning machine with double-rotating arms (SSMDA) was designed to obtain sub-aperture beam spot. Optical system full-aperture transmittance measurements can be achieved by applying sub-aperture beam spot scanning technology. The mathematical model of the SSMDA based on a homogeneous coordinate transformation matrix is established to develop a detailed methodology for analyzing the beam spot scanning errors. The error analysis methodology considers two fundamental sources of scanning errors, namely (1) the length systematic errors and (2) the rotational systematic errors. As the systematic errors of the parameters are given beforehand, computational results of scanning errors are between -0.007~0.028mm while scanning radius is not lager than 400.000mm. The results offer theoretical and data basis to the research on transmission characteristics of large optical system.

7849-56, Poster Session

Numerical analysis of SPP interference lithography based on prism coupling

X. Guo, Univ. of Electronic Science and Technology of China (China)

The continuing size reduction of integrated circuits to nanometer scale dimensions requires the development of new lithographic techniques. It is becoming increasingly complex and costly to use the established method of optical projection lithography at the short optical wavelengths required to reach the desired feature sizes. Some of other techniques include nanoimprint lithography, electronic beam lithography, scanning-probe lithography, and near-field optical techniques. However,they are greatly limited by challenging leveling,high ineffiency or low exposure depth.

In recent years, the use of surface-plasmon polaritons(SPP)instead of photons as an exposure source was rapidly developed to fabricate nanoscale structures, which greatly enhances the decay depth of evanescence wave in conventional near-field lithography. Grating-assisted SPP interference nanolithography successfully fabricated a sub-100nm interference pattern. To overcome the fabrication of fine periodic grating, a large-area SPP interference lithography based on prism coupling was proposed in 2006, which can obtain 60nm feature size at incidence wavelength of 441nm. The method offers a feasible way for nanodevice fabrication.

In this paper, we focus on the study of nanolithogrpahy based on prism

coupling and discuss the dependence of the spatial resolution on the related influence factors in detail,which is expected to provide optimal structure parameters for high quality lithography. Furthermore, the method to enhance the image quality is presented.

7849-57, Poster Session

Research on part-compensation aspheric surface testing via slope asphericity

F. Xie, Q. Hao, Q. Zhu, Beijing Institute of Technology (China)

In order to effectively analyze part-compensation testing of aspheric surface, a research method based on slope asphericity is proposed for wavefront transmission. First a predetermined reference sphere is beneficial to evaluate the compensation ability of aspheric wavefront to aspheric element by comparing the normal of aspheric element with the sphere normal and comparing the normal of aspheric wavefront with the sphere normal. Then the correlation among the slope of residual wave aberration, the density of system interference pattern and the selection of detector is analyzed. The way to search a best-fit sphere of aspheric wavefront under min-max slope asphericity is to find min-max spot diagram. The calculation methods of slope asphericity and reference sphere of aspheric element are given. The effect of different best-fit sphere positions to the compensation ability of part-compensation lens is analyzed and the compensation abilities of the part-compensation lenses with different slope asphericity distributions are compared. The results indicate that the research of part-compensation aspheric surface testing via slope asphericity is intuitive and effective, thus is beneficial to the development of related works.

7849-58, Poster Session

Research on special type vertical illumination system of metalloscope

X. Ran, Z. Xiao, J. Cao, Guilin Univ. of Electronic Technology (China)

Kohler illumination is the typical concentrated illumination system of microscope, and is widely used in all kinds of microscopes. Because the conjugate distance of large NA(numerical aperture) kohler illumination system is long, the application of it in general metalloscope is restricted. With the purpose of coordinating the contradiction between them, a kind of large NA and special type vertical kohler illumination is explored according to the optical principle of kohler illumination. Practice has proved that the system can get the same good performance with traditional kohler illumination system. However, the conjugate distance and the number of lens of the system are about half of that of the typical structure, and they have higher performance-cost ratio. Meanwhile, the illumination system can be converted expediently between the bright field and dark field. This paper also introduced a creation design of focal distance offset character of the annular lens light group using OSLO optical software, and it can be used for dark light group critical lighting systems through the method of calculating annular lens. The light group has fairly good adaptability with optical properties of the objective, providing a maneuverability practical method of designing refractive dark field critical illumination.

7849-59, Poster Session

Tip-tilt adaptive correction based on stochastic parallel gradient descent optimization algorithm

H. Ma, J. Zhang, P. Zhang, C. Qiao, C. Fan, Anhui Institute of Optics and Fine Mechanics (China)

Adaptive optics correcting technique based on stochastic parallel gradient descent (SPGD) control algorithm is an alternative approach which is independent of wavefront sensor and optimizes the performance metric directly. In this paper we establish a simulation model of tip-tilt adaptive optics system, where stochastic parallel gradient descent optimization algorithm is applied to correct the tip-tilt aberration induced by dynamic turbulence. The distance between the measured centroid of a blurring image and the demarcated centroid of the ideal image is used as the system performance metric, and then signals that is applied to compensation of the drifting atmosphere are generated for tip-tilt mirror. The sensitivity of the performance metrics is investigated, and the convergence rate and the stability are analyzed. By means of this optimization algorithm, the centroid of the image is changed in real time, which results in the improvement of the long exposure image.

7849-60, Poster Session

Thermal difference analysis and athermalization design of infrared optical system

X. Ai, Changchun Institute of Optics, Fine Mechanics and Physics (China); B. Liu, Changchun Institute of Optics, Fine Mechanics and Physics (United States)

When infrared optical system works in a large temperature range, the thermal effect of optical lens and optical tube will produce image plane shift and lead to imaging quality deterioration. In order to eliminate the thermal aberration, the athermalization design principles of infrared optical system were introduced, and some commonly used methods of thermal difference compensation were described. Proceeding from single lens, the thermal difference caused by temperature changing was analyzed. When the temperature changed, the refractive index of optical materials and the surface radius of lenses changed as well,and the relationship between temperature and focus shift was obtained. Considering optical tube thermal expansion, a set of equations to estimate the thermal difference of lens group was given. Finally, an infrared optical imaging system that can work under the temperature range of -40° to 60° was design according to athermal technique, in which a new mechanical passive temperature compensation was proposed. Through simulation, the athermalization design could make imaging plane shift the smallest. The simulation results coincided with the theoretical formula, and the design had reference value in engineering.

7849-61, Poster Session

Comparison of two algorithms for annular subaperture testing method based on Hartmann Shack sensor

H. Xu, H. Xian, Y. Zhang, Institute of Optics and Electronics (China)

Annular subaperture testing method based on Hartmann Shack sensor is proposed in this paper. Comparing with Interferometer, Hartmann Shack sensor is a wavefront sensing instrument by measuring the wavefront gradient with larger measurement dynamic range. So the annular subaperture testing method based on Hartmann Shack sensor can testing aspheric surface with less annular subapertures in bad measuring environment.

The whole-aperture wavefront reconstruction algorithm from subaperture measurement data has played a vital role all along the application of the subaperture testing methods. Two whole-aperture wavefront reconstruction algorithms are proposed in this paper for annular subaperture testing method based on Hartmann Shack sensor.

One algorithm is that the whole-aperture wavefront is joined together from the subaperture wavefront data which is reconstructed from annular subaperture gradient data in advance. Another algorithm is that the whole-aperture wavefront is reconstructed directly from the annular subaperture gradient data.

The precision of the algorithms is a major concern. The purpose of the paper is to establish the two algorithms and compare the performance of the two algorithms for annular subaperture testing method based on Hartmann Shack sensor. The principle of the two algorithms is described, and the performance of the two algorithms is evaluated in different cases. By abundant simulations, the precision of the two algorithms is analyzed in some pertinent cases such as different annular subaperture configuration, different annular subaperture misalignments and different gradient measurement noise level. The whole-aperture wavefront reconstruction algorithm directly from annular subaperture gradient data performs better in different pertinent cases.

7849-62, Poster Session

Design of IR correctors for ground aspheric surface

Y. Wu, Y. Zhang, Institute of Optics and Electronics (China)

The use of aspheric optical surface is becoming more popular because they can give improved performance with a reduced number of elements and consequent less weight. But with the expanding of diameter and relative aperture, the asphericity of primary mirror will increase evidently. The primary mirror required removal of several hundred microns relative to the best-fitting sphere. So they cannot be aspherized by polishing alone. Because the efficiency of grinding is about 10 times higher than polishing, lapping would be a good choice of systematic aspherizing. But we need an accurate test method. There are many difficulties in measuring the large primary mirror in grinding process. The questions to be solved are how to test the large ground mirror in reasonable time and how to reduce the measuring error in the range of the visible interferometry. The far-infrared interferometer we present can meet on that point. The wavelength of the interferometer is 10.6μm. At this wavelength, the lapped surface is optical “smooth”. But we also need an additional instrument to test the aspherical surface. It is the task of this paper to improve IR corrector that makes it meet the test requirement of large ground primary mirror.

This report gives the optical design and analysis of IR correctors for ground aspheric surface. The optical system assumes an interferometer that consists of a point source. The aberration of the IR correctors is PV0.008 .An optical test for measuring the correctors is presented in this paper.

7849-63, Poster Session

Test for optical systems in laser projection imaging for PCB

O. Qin, J. Y. Zhou, Q. Lin, Guangdong Univ. of Technology (China)

Projection imaging is one of the most important steps in the fabrication of printed circuit board. In order to meet the increasing demand for finer resolution, higher speed and larger area of imaging, a novel laser projection imaging (LPI) has been developed to take the place of the conventional Hg lamp exposure. We set up a system with resolution 10μm over large exposure area of 460mm×610mm on substrate materials. The system is available by the combination of three main parts: an XeF excimer laser with a wavelength of 351nm and single pulse energy of 120mJ, an illumination system with numerical aperture (NA) value of 0.02, and a double telecentric optical projection lens with NA value of 0.025. Such designs can theoretically meet the demand of actual lithography. However, experiments have shown that the propagation loss ratio of laser power from the light source to the substrate can be up to 50% or more so as to hardly achieve the expected results. In this paper, we present our results of experiments under different conditions on laser projection imaging equipment, and meanwhile, parameters such as gas lifetime, pulse repetition rate, exposure dose, scanning time, aperture position and diaphragm size as well as the optical lose of quartz microlens array are analyzed. Finally, we acquired the optimum exposure parameters.

7849-64, Poster Session

Design of a testing compensator for F/3 hyperbolic mirror

Y. Y. Yuan, J. Hu, J. Pan, Soochow Univ. (China)

The design principles of three familiar compensators are introduced. They are null lens compensator, refractive offner compensator and reflective mirror compensator. Based on the three different theories, four different kinds of compensators for the testing of F/3 hyperbolic mirror are designed. The initial parameters of every compensator are analyzed in detail. The residual wavefront error, RMS diameter of the spot diagrams and the tolerance of the four compensators are presented respectively. Due to the residual wavefront error consisted in these compensators themselves, higher order aspheric terms will be introducted when using these compensators to test the hyperbolic mirror during the process of the fabrication. These higher order aspheric terms will influence the image quality of R-C system which primary mirror is hyperbolic mirror. The simulation of this influence is analyzed by Zemax. The analysis and comparison of four compensators are given. Two optimum configurations which can be used for practical testing are determined after comprehensive consideration. The residual wavefront error of two final designs are both less than /30.The RMS diameter of the spot diagrams are both less than 0.76μm. The calculation and design method of the two compensators are universal which can be correspondingly extended and used to the compensator design for similar hyperbolic mirror.

7849-65, Poster Session

The invariance of statistical law for aerosol scattering pulse signal modulated by random noise

Z. Yan, Nanjing Univ. of Science and Technology (China)

For studying the effect of the statistical distribution character for the aerosol scattering pulse signals after adding the background noise of the photoelectric sensor to it in the laser airborne particle counter, a mathematical model that the random background noise acts on the particle signals is established. The results show that the statistical distribution of the particles’ measurement result will broaden caused by noise. Further numerical calculation indicates that the output signal amplitude still has the same distribution when the measured particles with the lognormal distribution are modulated by the random noise which has lognormal distribution. Namely, it has the statistics invariance. Then, the counting distributions of the background noise signal and aerosol’s random scattering pulse signal are obtained and analyzed by using a high-speed data acquisition card PCI-9812. Based on this, it can be seen that the experiment results and simulation results are well consistent.

7849-66, Poster Session

The figure error separation modeling and simulation of optical measurement

X. Qiao, L. Li, Hebei Univ. of Engineering (China)

While testing aspherical mirror with zero compensation method, the changes of structure parameters affect the test result of interference pattern.Several errors are induced due to the misadjustment among compensator, interferometer and tested mirror. It is important for optical processing, testing and the actual alignment process to distinguish between the aberrations arising from surface error and the aberrations arising from misadjustment of the null compensation testing set-up. The purpose of this paper is to obtain the real aspheric surface error during optical polishing. The work includes establishing the error separation model with the least square method, and separating the errors due to misadjustment of test set-up from the test results. Finally, the result of analysis and simulation show that high precision figure error can be obtained, and calculation precision of misadjustment is better than Zemax.

7849-67, Poster Session

The analysis of the wave front aberration caused by gravity of the tunable-focus liquid-filled membrane lens

W. Zhang, Univ. of Shanghai for Science and Technology (China) and Xi'an Institute of Optics and Precision Mechanics (China); X. Wei, S. Zhuang, Y. Bo, Univ. of Shanghai for Science and Technology (China)

Liquid lens is a novel optical device which can implement active zooming. With liquid lens, zoom camera can be designed with more miniature size and simpler structure than before. It is thought that the micro zoom system with liquid lens has a very wide potential applications in many fields, in which the volume and weight of the system are critically limited, such as endoscope, mobile, PDA and so on. There are mainly three types of tunable-focus liquid lens: liquid crystal lens, electrowetting effect based liquid lens and liquid-filled membrane lens. The liquid-filled membrane lens is usually made of a cavity and at least one deformable membrane surface. Its focal length changing can be controlled by hydraulic pressure, air pressure or other mechanical ways. Comparing with the other two kinds of liquid lens, the liquid-filled membrane lens has the advantages of simple structure, flexible aperture and high zooming efficiency. But its membrane surface will have an initial shape deformation caused by the gravity when the aperture of the lens is at large size, which will lead to the wave front aberration and the imaging quality impairing. In this paper, the initial deformation of the lens caused by the gravity was simulated based on the theory of Elastic Mechanics, which was calculated by the Finite Element Analysis method. The result showed that when the diameter of the lens is less than 5mm, the wave front aberration caused by the gravity can be ignored according to the rayleigh's criterion. And the Optical path difference produced by different liquid density was also analyzed in this paper.

7849-68, Poster Session

Using different interpolation techniques in unwrapping the distorted images from panoramic annular lens camera

G. Yu, L. Fu, J. Bai, Zhejiang Univ. (China)

The camera using panoramic annular lens (PAL) can capture the surrounding scene in a view of 360-degrees horizontally and -10 to +60 degrees vertically without any scanning component. Due to the severe distortion, the image formed by PAL should be unwrapped into a perspective-view image in order to get agreed with the human's visual custom. However the unfilled pixels would exist in the process of unwrapping as a result of the non-uniform resolution in the PAL image, hence the interpolation should be employed in the phase of the forward projection unwrapping. Then we have designed a simulating scheme to evaluate the performance of different interpolations during proceeding the unwrapping algorithm on a series of frequency-patterned images at different frequencies as a simulation by using three image quality indexes: MSE, SSIM and S-CIELAB. The performances of different interpolation have been exhibited in a variety of FPIs at different frequencies. The experiment result revealed that those interpolation methods had better capability for the low frequent PAL images. The Bicubic, Ferguson and Newton interpolations worked relatively better at higher frequencies, while Bilinear and Bezier could achieve better result at lower frequency. Besides, the Nearest method had poorest performance in general and the Ferguson interpolation was excellent in both high and low frequencies.

7849-69, Poster Session

Design of the structure parameters of the photo-resist grating

X. Chen, Soochow Univ. (China)

The pulse compressed grating (i.e. PCG) is the key optical element in high power laser system. In order to obtain the PCG with high diffraction efficiency, it is necessary to design the required structure parameters of the photo-resist grating which is used as the mask of fabricating the PCG in process of etching. The rigorous couple wave theory is adopted to study and search for the suitable structure parameters of the PCG with the 1740lp/mm space frequency and particular basement of dielectric stack films which could produce more than 97% diffraction efficiency. Consequently the required structure parameters of the photo-resist grating which is corresponding to those suitable structure parameters of the PCG are determined under some etching technological conditions. In studying the relationship between the diffraction efficiency of the photo-resist grating and its structure parameters, it is found that the -1st order diffraction efficiency of the photo-resist grating mask will be more than 5% if the depth of grating is more than 250nm, the duty cycle is from 30% to 50% and the residual thickness of photo-resist is null when the laser with 1064nm wavelength incidences with 65° angle. Then a simple and practical method which can estimate the structure parameters of the photo-resist grating according to its diffraction efficiency is proposed. The measuring setup based on this method is built and the veracity of this method is verified by experiment. The experiment result is present in the paper.

7849-70, Poster Session

A multispectrum fish-eye lens for rice canopy detecting

H. Zhi, J. Bai, X. Hou, Zhejiang Univ. (China)

In the past few years, a number of systems which measure fractional light penetration through canopy have become commercially available, like LAI-2000, DEMON and SunScan etc. The value of optical LAI (leaf area index) measurements by means of hemispherical photography has already been demonstrated. But the performance of these instruments as reported in the literature is suitable for plants in forests, rather than commercial plants with small size, like rice. In addition, most of these instruments cannot distinguish different wavelengths. In this paper, a fish-eye lens used for detecting rice canopy is presented. It is a small lens with a length of about 70 centimeters and a diameter of 45 centimeters with 12 spherical lenses and a plate glass. The full field of

view is 180°. The spectrum designed for detecting rice growth is about 486nm to 780nm. The lens is fit for a standard 1/2 inch CMOS/CCD camera. The image quality is excellent that the MTF is more than 0.5 at 153lp/mm. The lens is composed of two parts, with three changeable optical filters between them. The filters can be changed automatically by stepper motor. The first sample lens shows its good performance of image quality and portability for outdoor operation.

7849-71, Poster Session

A method of video analysis in vehicle based on a single PAL camera

Y. Yang, Zhejiang Univ. of Science and Technology (China); G. Yu, J. Bai, Zhejiang Univ. (China)

Driver distraction and fatigue are important factors that cause accidents. We developed a novel machine vision system which can provide the driver's face pose and eye status information as well as the driver's viewing scene. The driving original video information was obtained simultaneously by a Panoramic Annular Lens (PAL) camera in the system. The PAL camera can capture its surroundings with a field view of 360-degrees horizontally and -10 to +60 degrees vertically without any scanning parts. The PAL camera was properly configured on the vehicle to not only capture the scene in front of the vehicle but also the driver status information including face and eye. A rapid face detection lgorithm was proposed based on Bayes classification of the skin color. Once the face detection had been completed, template projection was used to detect eyes in a narrow area of the face. Besides, a cascade yielded from training was used to detect the vehicle object and a novel object localizing algorithm was proposed which is insensitive to the shake of the vehicle. Our contribution was that it was possible to research the vehicle and driver information at the same time with a single panoramic camera. Meanwhile the system was very simple.

7849-72, Poster Session

Compact mid-wavelength infrared zoom system with positive zoom lens

S. Li, Huazhong Institute of Electro-Optics (China)

In this paper,a compact mid-wavelength continual infrared zoom system with posive zoom lens has been designed. The focal length of this zoom system is from 35mm to 350mm with a zoom range of 10:1,and the narcissus of the long focal length and the short focal length is analysed.Because of the previous fixed groups ahead of the zoom lens has compress the light aperture,so the mechanical design with zoom groups and compensated groups is small than the normal continual zoom system with the negtive zoom lens.The continual zoom system with posive zoom lens have small volume,smart mechanism,so it can be used in the high thermal imager widely.

7849-73, Poster Session

Narcissus analysis in DFOV scanning infrared zoom system

C. Yang, S. Li, Huazhong Institute of Electro-Optics (China)

In this paper,two results of serious Narcissus effect in scanning dual-field-of-view (DFOV)infrared system is introduced. Optical method of restraining narcissus in optical design is reviewed. According to the principle of the methods, a DFOV scanning zoom system is designed. It has small Narcissus effect in both long effective focal length and short effective focal length of the zoom system.This DFOV scanning zoom system is applied to long wavelength infrared thermal imager successfully,and the better real image of DFOV thermal imager is given.

7849-74, Poster Session

Improved azimuthal alignment technology of polarization maintaining fiber based on side-viewing image

J. Zhang, W. Gu, Z. Chen, J. Yu, D. Guo, L. Huang, Jinan Univ. (China)

It is very important to exactly align the polarization axis for the polarization maintaining fiber (PMF). So the aim of this paper is to discuss the alignment method. First, the simulation model of PMF has been specifically designed by ASAP software. The PMF is irradiated by parallel ray from lateral side. The observation plane is set on the other side of PMF. And then the light-intensity distribution image can be gotten after the ray tracing. The light-intensity distribution image is called side-view image (SVI) in the paper. A list intensity value of SVI is curved and called intensity distribution curve. The result shows that when the azimuth angle of PMF's polarization axis is changeless, the SVI is changed with the distance between the fiber and the observation plane (DBFOP). When the DBFOP is changeless, the SVI is changed with the azimuth angle of polarization axis (AAPA). Second, the SVI is divided into two parts from the center according to the intensity distribution curve. The correlative coefficient is calculated between the two parts of SVI. And the correlative coefficient is interrelated with AAPA of PMF. That is to say, the AAPA of PMF can be aligned by the correlative coefficient of SVI. The method is called correlative method. The precision of alignment is improved when the correlative method is combined with the five finger method.

7849-75, Poster Session

Gimbal displacement errors analysis on an electro-optical seeker

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It is essential to analyze the gimbal displacement errors for a seeker due to the importance for cueing of targets and tracking for the final approach. Otherwise, for a seeker electro-driven with a concentric glass dome, the large errors will decrease the picking, pointing, and tracking precision rooted from the displacement errors existing between the rotation center of the optical system and the gimbal. And the gimbaled camera system displacement errors are never eliminated but reduced due to the geometric errors consists of geometric tolerances of gimbal structure, manufacture, installation and vibration coming from working environment.

In this paper, the gimbal displacement errors in an electro-optically stabilized platform resulting from geometric errors and environment errors were analyzed and shown in detail. The mathematical modal of the gimbal displacement errors created based on multi-body dynamics demonstrated the connection between the gimbal displacement errors and the stabilized platform. Taking a visible light image seeker as a case, the diameter is 120mm, and the geometric tolerances came from the values of primary design and the vibration data came from the environmental vibration test on the pitch-yaw seeker, and at the same time, the errors resulting from installation were considered too. Based on calculating, the maximum gimbal displacement error will reach to 0.2mm for pitching angle smaller than 40°and yawing angle smaller than 60°. However, the critical parts have been found out according to the probability theory and the reliability analysis successfully used in the

paper, and finally, the maximum gimbal displacement error reduced to 0.1mm, which is acceptable corresponding to the picking, pointing and tracking precision for an optical imaging seeker.

7849-76, Poster Session

The design of a laser transmittance measurement system

Q. Wang, M. Li, Beijing Institute of Technology (China)

A laser transmittance dynamic measurement system designed to measure the transmittance of laser passing through propellant plumes with wavelength 0.808μm, 1.06μm and 10.6μm is introduced in this paper. The transmission method is applied as the measurement method. By measuring the laser intensity before and after passing through the plume, the laser transmittance of the plume can be calculated. In order to get higher signal-to-noise ratio, the laser is modulated with certain frequencies. A microprocessor is applied in this measurement system for system controlling and data processing. The measurement results can be corrected automatically and shown in real time. Meanwhile, the measurement results are transmitted to a computer through the serial port. As a result, the data can be saved and printed for future analysis. Based on the results of system performance trial, this system fulfills the accuracy, stability requirements as designed.

7849-77, Poster Session

Development of a real time MTF test bench for visible optical systems

X. Chen, Y. Chen, J. Fan, C. Xiang, W. Shen, Soochow Univ. (China)

The concept of modulation transfer function (MTF) is now used widely in optical design and fabricating process to assess the optical system's imaging quality. A real-time MTF test bench for visible optical systems is presented in this paper. This test bench can perform quick on-axis and off-axis MTF measurement of optical systems whose aperture are less than 200mm in visible wavelength. A high quality off-axis parabolic collimator is used as object generator of this test bench. The image analyzer is a microscopy with CCD camera installed on a multi-axis motion stage. With this camera, star image of the under test optical system can be acquired and displayed in real time, which is very convenient for assembling and quick test of optical system. The software of this MTF test bench, which is programmed with Visual C++, provides a good interface for the operators to set measurement parameters and control this bench. Validation of this test bench, performed with a 50mm plano-convex audit lens, shows that MTF measurement error of this bench is within 0.04. Besides MTF measurement, this bench can also perform effective focal length (EFL), back focal length (BFL), and field of view (FOV) without any hardware modification. Transmittance of optical system can also be performed on this bench with an integrating sphere.

7849-78, Poster Session

Numerical study of fluid properties in opening-up optical fibers

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The Finite Element Method (FEM) analysis about fluid properties in opening-up optical fibers which are designed for gas and liquid is demonstrated. The opening-up fiber has advantage in time-vary sensing, but this ability is limited by its fluid characters. A FEM fluid-optical interacting model is founded by combining the Navier-Stokes equations and Maxwell equations. The analysis focuses on the relationships between fundamental field distributions and fluid characters in the wagon wheel opening optical fiber which has one opening cladding holes. The opening fiber in our simulation has core size below 1 micron and several tens micron hole size. The Monte Carlo Method (MCM) is adopted for fluid and gas distribution simulation. 2D and 3D models are found for time-vary sensing analysis. The time-vary simulations show that the fundamental field distributions in dynamic fluid deviate from its static state. When the opening up optical fiber is exposed in high-speed drag flow, its fundamental field distributions have severe distortion. Some results under difference stickiness and speed fluid are achieved. The opening-up optical fibers expose in liquid have more distortion than gas exposing. The fundamental field distributions come into fluctuation noise in sensing result. The high speed flowing of fluid distort fundamental field distributions the too. Simulation about high-speed fluid show optical sensing result could not match the true value of fluid refractive changing in some opening structure. If the slot for cladding hole is longer than the threshold, the drag flow and motion noise could be restrained partially. Bigger cladding hole is preferred for better fluid motion, but the fluorescence sensing efficiency decrease according WW structure. Based on the analysis above, we present some propose about opening-up optical fiber sensing design.

7849-79, Poster Session

Testbed for an adaptive secondary of 1.8-m telescope

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Adaptive secondary is a device which acts not only as secondary of telescope but also as wave-front corrector of adaptive optical system for the telescope. Compared with traditional adaptive telescope, telescope equipped adaptive secondary has simpler configuration and better performance. An adaptive secondary which is composed of reflective mirror, piezoelectric actuators and reference structure has being designed for 1.8m telescope. Since reflective mirror of the adaptive secondary is a convex hyperboloid glass shell, it can't be tested with Meinel testbed which has been used successfully to test passive secondary of the 1.8m telescope. Testbed for the adaptive secondary is a system originates from Simpson-Oland-Meckel method. Since the adaptive secondary is good at correcting low order wave-front errors, partial correction range of the adaptive secondary is assigned to correct wave-front errors coming from fabrication, alignment and materials asymmetry to reduce the requirement of tolerance in order to reduce cost. Because most of errors coming from these aspects are corrected by the adaptive secondary, the precision calibration process of Simpson-Oland-Meckel method will no longer be required. The testbed is composed of hindle element, Hartmann-Shack wave-front sensor and far-field analysis element. Light from Hartmann-Shack wave-front sensor passess through the hindle element and reflects off of the hyperboloid. It then is reflected by the second surface of the hindle element. After reflecting off of the hyperboloid again it passes through the hindle element and return Hartmann-Shack wave-front sensor. A beam splitter is placed between Hartman-Shack wave-front sensor and hindle element to reflect partial of the output light to far-field analysis element. The testbed is a low cost simple system that allows testing the convex hyperboloid adaptive secondary. It also could be used to calibrate the adaptive secondary as well as investigating high performance control loops. Optical setup design, tolerance of fabrication, alignment and material asymmetry are presented.

7849-80, Poster Session

Method of noiseproof wavefront testing in time- and spatial-domain

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The noiseproof wavefront testing method in both time- and spatial-domain mentioned in this papar, which neither equal step-length phase-shifting nor accurate step-length calibration is necessary in this method. Active phase-shifting works associated with passive phase-shifting caused by the environmental vibration and air turbulences. Large amount of sequentially acquired interferograms are analyzed for the phase distributions corresponding to each interferogram, and then all the phase distributions are averaged to produce a wavefront free from various random noises in time- or spatial-domain. During the measurement, the phase shifts introduced by environmental vibration and active phase-shifting are the same for all the measured points, so they will not change the wavefront. The phase shift brought in by air turbulence is eliminated through averaging. The active phase-shifting can also help in speeding up the measurement to avoid long-time waiting for the phase-shifting caused by slowly varying air turbulence. The problems in most available anti-vibration phase-shifting interferometry can be avoid. Large-aperture optical elements testing with high accuracy can be achieved with this method.

7849-81, Poster Session

Analysis of heat dissipation for integrated high power LED lamp

L. Jiang, H. Liu, Q. Zhao, L. Hu, Zhejiang Univ. of Technology (China)

LED light source, which has many advantages such as high light efficiency, low power consumption, long lifetime, no mercury and radiation, is considered as one of the important way for power saving and environmental protection. It has begun to play an important role in application of lighting area. Due to its particularity, heat dissipation is a key problem needed to be solved in engineering application. In this paper, a heat dissipation method for integrated high power LED lamp was investigated to solve its heat dissipation problem. First, the demand of heat dissipation of LED street lamp and the heat generation characteristic of integrated high power LED light source were analyzed, and then a heat dissipation analytical model was set up. Secondly, modeling parameters of fins of radiator were extracted, and the maximum temperature after the system reaching thermal equilibrium state, which was also the working temperature of LED light source, was fixed as experimental index, to study the effect of shape and layout of fins of radiator on heat dissipation by use of orthogonal experimental method to arrange the numerical simulations. Optimal analysis result was obtained. Thirdly, the optimization analysis was applied to guide the radiator design of high power LED lamp. The modeling design of LED street lamp and radiator were also gotten. The result of numerical calculation of radiator shows that the design of LED street lamp and its radiator satisfied the demand of heat dissipation. It is of importance to guide the heat dissipation design for LED Lamp.

7849-82, Poster Session

Research and analysis of edge backlighting light guide panel for handset

J. Zhang, H. Wang, Z. Chen, J. Yu, D. Zhou, C. Chang, Jinan Univ. (China)

LCD and edge backlight light guide panel (LGP) are one of the main parts of handset or mobile phone et al. The design of LGP is vital technique to the design of backlight module. The aim of this paper is to design a handset LGP with LED as the light source. Three design qualifications are simulated and analyzed with ASAP software. The three qualifications are rough surface, diffusion-dots and microstructure. The analysis result shows that the factor of diffusion-dots is the most important ingredient. The surface brightness, the luminance distribution and the light efficiency of LGP are determined by the density of diffusion dots. The total light loss is also affected by the factor of diffusion-dots to the LGP whose diffusion dots are printed. A handset LGP is designed according to the research in the paper. The simulation result is satisfying as good as the practical outcome. The paper is useful to increase the brightness and uniformity of handset LCD.

7849-83, Poster Session

The design of auto thermal-structural-optical integrated analysis software based on MATLAB

Y. Liu, X. Chen, G. Ni, Beijing Institute of Technology (China)

The high-Resolution imaging technology of the space camera has been paid more and more attention with the development of modern satellites. The thermal environment has noticeable influence to the imaging accuracy for the camera in space. Thus, the thermal-structural-optical (TSO) integrated analysis of the space camera is very important to the optical design and optimization. But there is no such software that can analyze automatically as so far. If the thermal-structural-optical Integrated Analysis is adopted, the engineer must be accomplished in optical design software, finite element analysis software and other basic knowledge on mechanics and so on. This means the researchers must have many advanced skills. An auto TSO integrated analysis software based on MATLAB is designed in this paper. CODE V will be taken as the example of optical design software, and ANSYS as the finite element analysis software in this paper. The auto TSO integrated analysis software can build three-dimensional model automatically according to the optical system in CODE V. This three-dimensional model will be imported into ANSYS to mesh and analyze in the next. The coordinate before deformation and the calculated deformation under the thermal load of each node will be automatically saved into a text file. MATLAB will convert the lens' deformation data to zernike polynomial which could be imported into CODE V directly. The auto TSO integrated analysis software will invoke CODE V to update lens' surface according to zernike polynomial. The lens' data after thermal deformation are obtained by CODE V then. The MTF and other performances of the optical system under the given thermal environment are revealed at last according to the result of the ray tracing in CODE V. The software and its GUI are developed with MATALB. All the functions could be done automatically or semi-automatically, which reduces requirements of operators, and predigests the simulation of the space cameras' design and optimization.

7849-85, Poster Session

The concept of constructing system for adaptive-selective assembly of optical devices

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It is proposed to develop a system design and manufacture of optical instruments, covering the calculation of optical systems, engineering, technological production preparation and production of devices. The basis of the method is expected to lay the adaptive-selective assembly as a system of constructing the model development of scientific and technical product at all stages of problem solving with absolute ensuring an integrated approach.

7849-86, Poster Session

The manufacture of rectangle aperture off-axis ellipsoidal aspheric mirror

X. Yao, P. Guo, J. Ren, C. Xi, Soochow Univ. (China)

The testing and processing of rectangle aperture off-axis ellipsoidal aspheric mirror in the process of grinding and polishing is presented. Based on the third-order aberration, the initial configuration parameters of Offner compensator were obtained for manufacturing rectangle aperture off-axis ellipsoidal aspheric mirror, optimized by Zemax Optical Design Software, the residual wavefront error is better than /1000 (= 0.6328 nm). The final parameters of Offner compensator are determined by analyzing and comparing of the residual wavefront error, tolerance and manufacturing process exactly. In addition, the manufacturing process and control method of off-axis magnitude are described and analyzed with the rectangle aperture off-axis ellipsoidal aspheric mirror. Then, the finite element model of the support-gimbal in processing is built by using the finite element analysis Software. Finally, the polishing surface error of the off-axis ellipsoidal aspheric mirror is better than /60 (= 0.6328 nm), and the off-axis magnitude error is less than 0.2mm. The design method is universal and the design method can be used in the compensator design for other aspheric mirror. The optical manufacture and testing technology are described and analyzed with this aspherical surface and the corresponding surface figure, it is the basics of the off-axis aspheric manufacture process and optical testing.

7849-87, Poster Session

Smart high ratio zoom optics with global optimization

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To achieve the transforming in multiple fields of view, the approaching to system efficacy limit in theory and improving smartness, pure diffractive optical system is chosen. The top idea and main strategy is developed. Some correlative model is established. In optimized design, global optimization algorithm is used to achieve wider spectrum range, multi field view, lower distortion and appropriate MTF. A kind of result works mainly in 3-5μm and 8-12μm with high ratio more than 30:1 is evaluated. And this integrated multi-sensor electro-optical system satisfies the applied requirements on some criterion, such as MTF, RMS and PSF etc., and achieves remarkable advantages in volume, weight, system efficiency and so on.

7849-88, Poster Session

The wavefront sensorless wide field of view adaptive optics correction based on SPGD algorithm

X. Zhang, J. Guo, Y. Xin, X. Han, Beijing Institute of Technology (China)

The space adaptive optics system used for space remote sensing system to improve the image quality will face the challenge from the wider field of view. In this paper, the SPGD algorithm is present to realize the wavefront sensorless adaptive optics correction for a wide field of view optics system. Giving the traditional TMA optics system as the example, the image quality of different field of view is analyzed when there are some different surface and position errors in the optics system. The gradient evaluation method and convergence of SPGD is analyzed in detail. The issue of parameter such as the gain and step selection for SPGD is discussed. Computer simulation of a remote sensing AO system based on SPGD is studied. The primary mirrors of this optics system are the whole mirror and segmented mirror separately. The SPGD algorithm is realized in MATLAB, and an AO system is modeled in optical design code ZEMAX. Communication between MATLAB and ZEMAX is established via ActiveX technique. MATLAB computes the control voltage and sends it to ZEMAX; ZEMAX alters the shape of the deformable mirror (DM) according to the received voltage, and calculates the point spread function (PSF) data, which is then sent back to MATLAB. This iteration goes on and on, until the termination condition is satisfied. The results show that wavefront sensorless wide field of view adaptive optics correction based SPGD algorithm for the whole primary mirror system is better, and the wavefront error is within 1/10 rms.

7849-89, Poster Session

Design of imaging spectrometer based on Czerny-Turner in FUV

J. Liu, T. Yi, Beijing Institute of Technology (China)

Imaging spectrometer is a new generation of optical remote sensing instruments which can obtain both the two-dimensional spatial information and one-dimensional spectral information at the same time. It is widely used in atmosphere, ocean and land. However, it is still difficult to obtain high spatial and high spectral resolution images at the same time. And most of imaging spectrometers are used in the visible and infrared wavelength bands, very few in UV and FUV bands. In this paper the aberration of traditional Czerny-Turner imaging spectrometer is analyzed, and the conclusion is that astigmatism generated by surface tilt is the main reason results in great difference between space dimension and spectral dimension of the quality of spectral image, and the grating generates large FOV which leads to large coma. So the toroidal mirror is presented in order to correct the astigmatism, and the aberration caused by the large FOV is correct by optimizing the surface tilt. Then both of the spatial and spectral resolutions are improved. Finally a Czerny-Turner imaging spectrometer working in FUV(120~180nm) with 2.5° FOV is designed, and its focal length is 148.95mm, its F/number is 3.76. After ray tracing and optimizing the optical system with Zemax, MTF of this imaging spectrometer is more than 0.3 at 15lp/mm in the total wavelength band of total FOV, which satisfies the requirements of imaging spectrometer working on satellite in FUV.

7849-91, Poster Session

The optical system design and application of micro 2D barcode

Y. Zhu, L. Li, Q. Chen, Z. Liang, Nanjing Univ. of Posts and Telecommunications (China)

We show an optical system of micro visual tag which is based on the principle of microscope, the property of QR Code and the camera out of focus. Unlike current optical tag, such as barcodes, must be read within a short rang and the codes occupy valuable physical space on products, the new tags can be shrunk to several millimeters and captured from a distance of over 0.5 meters. We integrate LED, microlens and the barcode array to form the active signal transmitter. Taking using of the camera out of focus, the users are able to detect small optical tags from a relatively large distance to get an amplificatory image which is decoded to access to information. We design the transmitting terminal according to the parameters of camera lens. We also take the detection range and the apertures into account, meanwhile we conduct simulations and experiments. For the virtues of QR Code such as High-Speed omnibearing reading and high-efficiency coding Chinese character, we select it as the mode of information encoding. The results show that: in this optical system, the microlens of the transmitting terminal restricts the luminous energy of receiver, at the same time the camera lens determines the field. As the distance

increases, the energy and the field will reduce both of which decide the maximum detect range. The ascendancies of the tag such as large amount of information, security and cheapness make it possible to provide an effective supplement to radio frequency tags (RFID).

7849-92, Poster Session

A new algorithm for compensating misalignment in optical spherical surface testing form State Key Laboratory of Modern Optical Instrumentation

J. Zhang, K. Wang, J. Bai, Zhejiang Univ. (China)

Misalignment (tilt, defocus,) problem always exists in every spherical surfaces testing process. Traditional method compensates misalignment by removing the corresponding Zernike terms from the measurement result. It works well for most cases when the surface to be tested has a relatively large F-number. However, the residual errors can't be ignored when the spherical surface has a small F-number. To solve this problem, we propose a new approach for misalignment compensation called Best Fitting Sphere Algorithm(BFSA). In this algorithm we find a best fitting nominal surface including the best fitting radius and localization of the surface to compensate misalignment. Thus theoretically there wouldn't be any residual error which happens in traditional methods. The best fitting surface is found by minimizing the deviations from the original surface to one nominal surface. In order to demonstrate the validity of BFS, we test it by numerical experiments and then apply it to real data, finally compare the result with that of traditional method (used in ZYGO interferometer). Both the numerical and real data experiments prove the validity of BFSA. The real data experiments demonstrate that the performance between BFSA and traditional method is almost the same when only tilt exists. However when the misalignment is mainly caused by defocus, the difference is notable, especially when the defocus cause several interference fringes. BFSA has a better performance when the misalignment is considerably large.

7849-93, Poster Session

Design of lunar-based common aperture multi-spectrum solar telescope

Z. Zhang, L. Zhang, J. Wang, H. Zhu, J. Zhang, Beijing Institute of Technology (China)

Since the absorption of ultraviolet radiation by atmosphere is strong, it is difficult to photograph solar UV radiation using ground-based telescopes. While, lunar which has no atmosphere has stability geological structure and low magnetic field. So observing solar on lunar is more suitable than observing solar on the earth. This paper describes the design of lunar-based solar telescope. This solar telescope can photograph the solar in three wavelength: long-wave IR (8-11μm), visible (400-900nm) and UV(100-400nm). This telescope is composed of two parts: reflective object lens and splitting system. This design effectively avoids the material restrictions of IR and UV imaging optical systems. The effective focal length is 277.3mm, while, the F Number is 3.7. The ground-based prototype has successfully been developed. A series of experiments have been done with this prototype. The rationality of the optical system design of the common aperture multi-spectrum telescope was proved by comparing the results with the images got by single spectrum solar telescopes all over the world. Compared the experiment images under different weather, the proposition of lunar-based devise is proved. Combined the different splitters and the special detectors, the UV, visible and IR can be separated and imaged by different detectors, which is the main innovation of the device.

7849-94, Poster Session

Optical design of objectives with forced performance for metallographic light microscopes

A. D. Frolov, Saint-Petersburg State Univ. of Information Technologies, Mechanics and Optics (Russian Federation)

Results of optical lenses with special design features for the accelerated completion of metallographic light microscope. Presented lenses satisfy the requirements of the linear field, the correction of aberrations

7849-95, Poster Session

Optimal design of optical lens based on metallic nano-slits using Yang-Gu algorithm

Q. Zhu, Capital Normal Univ. (China)

Firstly, we design the optical lens with focus length of f=650nm. The wavelength of the incident TM polarized light is 650nm and the metal used is silver. The distance between two adjacent slits is 160nm. The Yang-Gu algorithm is managed to optimize the nano-metallic structure till achieved objective. We adopt the Green function in the iterative procedure and utilize the FDTD method to check the validity of the optimized nano-structure. The field distribution demonstrates that the focus spot appears at 668nm away from the exit surface, which agree with our design. The full-width at half maximum of the focus spot is 226nm. Then the optical lens with two focus spots is design. The focusing length is still 650nm. The optimized structure simulated by the FDTD method and the filed distribution clearly shows that there are two focus spots appear about 680nm away from the exit surface. The designed result agrees well with our objective and the full-width at half maximum of the focus spots are 280nm.

In conclusion, the Yang-Gu algorithm is employed to directionally design two kinds of nano-metallic optic lenses. One of them can perform one spot focusing and the other one has two focus spots. The FDTD checking of obtained structures shows that the designed elements can perform the preset functions well. The optimal design is not only save our time but also can solve some problem which is difficult to achieve by original method. It will make a new way to design the subwavelength optical devices.

7849-96, Poster Session

A sub-aperture scanning method for detecting wavefront of long-focus lens from State Key laboratory of Modern Optical Instrumentation, Zhejiang Univ.

Y. Li, J. Wang, C. Hou, J. Bai, Zhejiang Univ. (China)

Lens whose Focal length greater than 10m play an important role in high-power laser systems. In order to get an effective way to measure its wavefront, a new method is proposed. It is based on two dimensional sub-aperture scanning and model method re-construction with Zernike polynomials. Through sub-aperture scanning of the stripes generated by two Ranchi gratings, the wavefront slopes are achieved as the initial data. The used grating contains two parts of grid lines. The two parts are orthogonal. Stripes generated by the vertical and horizontal part stand for the x and y direction's information, respectively. The number of stripes moved from one sub-aperture to another has a relationship with the wavefront slope. In most case it can be approached to linear relation. Then with the initial slope data, the wavefront is reconstructed by model method with Zernike polynomials. Singular value decomposition is used in the process of solving the matrix equation.

A simple prototype is established. Engineering feasibility reliability and cost are considered. To make the prototype smaller, the mechanism is improved. The method's precision is validated after comparing it with laser interferometer. It also works in some situation that interferometer will not be suitable to detect a long-focus and large-diameter lens.

7849-97, Poster Session

Flat surface measurement on fiber point diffraction phase-shifting interferometer

J. Li, L. F. Chen, Y. Ren, Beijing Institute of Technology (China)

A technique with a fiber point diffraction interferometer (FPDI) for measuring the quality of flat surfaces is presented. It requires only two-step program for point-by-point flat surface measurements rather than the traditional method which is limited by the accuracy of the reference surface.

The spherical wavefront, diffracting from the measurement fiber, is reflected by a flat mirror under test. It is an aberrated spherical wavefront carrying the surface information of the flat mirror, and its sphere center is at the virtual image point P of the end of the measurement fiber in the flat mirror. After passing through an auxiliary positive lens, it is reflected by the oblique end of the reference fiber and becomes the measurement wavefront. It interferences with the reference wavefront diffracted directly from the reference fiber. Thus the aberrations of the flat mirror and the auxiliary lens are measured in the first measurement.

Then, the flat mirror tested is removed, the end of the measurement fiber is placed at the point P, and all other optics are kept in exactly the same positions. The measurement wavefront, passing through the auxiliary lens, is reflected by the oblique end of the reference fiber and interferences with the reference wavefront diffracted from the reference fiber. The aberrations introduced by the auxiliary lens can be evaluated in the second measurement.

The figure of the flat mirror can be got point-by-point after subtracting the aberrations of the auxiliary lens from the aberrations got from the first measurement. Because this method employs the nearly perfect point diffraction wavefront, it can assure accurate flatness measurement on the optic under test.

7849-98, Poster Session

Optical design used in Z-stack imaging based on liquid lens

T. Yang, L. Wang, Zhejiang Univ. (China)

Z-stack imaging system drives microscope scans one image plane, changes the depth of the focus, and then scans another plane, last gets the data of examination sample. The curvature of liquid lens can be changed according to changes in the characteristics of voltage. It leads to achieve miniaturization and simply structure of focus imaging system. This article uses CODE V to design a microscope objective which employs an Arctic 416 liquid lens. It proposes architecture of 5 groups of lens with 40× microscope objective lens with 0.65 numeral aperture and 0.52° field of view (FOV). By CODE V automatic design, the microscope objective lens achieves a continuous focus adjusting up to 120μm depth. And then a better center FOV MTF value with the same continuous focus range can be obtained by reducing one of lens group. Lastly by replacing the high index material of glass, the center FOV achieves higher MTF and the continuous focus range increases to 130μm.

7849-99, Poster Session

Measurement of the radius of curvature of a mini spherical surface with virtual grating phase shift technique

Y. Xu, Nanjing Univ. of Science and Technology (China)

Radius of Curvature (ROC) is an important geometric parameter as it influences the imaging and transmission property of the corresponding optical spherical surface. In this paper, the technique of virtual grating phase-shift interferometry (VGPI) is adopted for measuring the ROC of a convex spherical template, which is provided for an Askania spherometer and has a nominal ROC value of 17.92 mm. Firstly, a spatial carrier interferogram (SCI) is taken, and by Fourier' s transform, the spatial carrier frequency is obtained. Secondly, with a computer, four virtual gratings are made, the phases of which being shifted 0, $-\pi/2$, $-\pi$, $-3\pi/2$ in turn. To obtain four moiré fringe images, the four virtual gratings are separately multiplied with the original SCI. And thirdly, by spatial low-pass filtering, a group of four phase shifted interferograms are obtained. Thus finally, by using four bucket phase shifting and Gauss-Newton nonlinear iteration algorithms, the ROC of the test spherical surface is obtained. The experimental result, ROC=18.07 mm with a relative error of 0.84%, verifies the practicability of VGPI in the measurement of the ROC of a spherical surface.

7849-100, Poster Session

Research of the optimum operating modes of combined acousto-optic and electro-optic modulator based on beam steering theory

Z. Pang, Hebei Normal Univ. (China)

A novel design of anisotropic Lithum Noibate (LiNbO3) modulator combined acousto-optic and electro-optic effects based on beam steering thoery is presented and studied. By the judicious design with beam steering theory, which utilized multipieces tranducers instead of one piece tranducer, can realize realtime tracking of the ultrasonic wave vector that satifsfied the condition of momentum match and achieve a higher diffractive efficiency simultaneously. The optimum operating modes of this device, including the electro-optic operating modes and the acousto-optic operating modes, are systematically studied and determined respectively. Furthermore, the optimized design parameters of the modulator under different number of transducers are also given.

7849-101, Poster Session

Optical systems design of Surface Roughness photoelectric inspection instrument

Z. Xiao, P. Li, J. Cao, X. Ran, Guilin Univ. of Electronic Technology (China)

Basing on the surface roughness measurement of light-section method is one of the most classical measuring methods. According to light-section method which combine visual observation with photomicrography to test surface roughness, domestic type of 9J is a traditional device. The surface roughness photoelectric inspection instrument which designed by author also based on the theory of light-section, and it integrate subjects of optics, mechanical, electronics and calculation. Surface roughness of object image can be obtained on the light sensor of CCD by the optical system. Through the PC and display, and rely on using of autonomous software in the computer, the average height of workpiece unevenness Ra value can be measured and read in the monitor. Therefor, level of surface roughness will be

obtained. In order to design the optical system of device, there are three main aspects which should be finished: Start with requirements of detective object, according to the detective range from Ra12.5 to Ra0.04 ruled by CNS(China National Standards) GB3505-83 the Surface Roughness Term Surface and the Parameters, parameters on (magnify power), NA(numerical aperture), W.D(work distance), filed of object etc are defined and optimized. Meanwhile, good complementation and compatibility are noticed among three kinds magnification objectives. Special type infinity image distance double telecentricity optical system are constructed. The main point is designing a set of objectives of long W.D and infinity image distance flat field semi-apochromat. How to match and optimize image sensor of CCD and lens.

7849-102, Poster Session

Research on the surface reflectance measurement of optical elements with transparent substrate

X. Guo, X. Gong, L. Cheng, F. Yu, Zhejiang Univ. (China)

In reflectance measurement of transparent optical elements, the substrate back surface reflectance occurs between the second surface of the element and the air. In most reflectance measurements the substrate back surface reflectance is usually approximated or neglected. In low reflectance measurements, the approximation or neglect will lead to obvious error. Theoretically, reflectance is always normal to the optical elements, but in practice the achievement of the reflectance measurement is quasi-normal, which makes impossible to obtain accurate substrate back surface reflectance. In this paper, the differences between normal and quasi-normal substrate back surface reflectance are analyzed for the first time. Because of the quasi-normal reflectance, not all of the back surface reflectance can be collected by the receiver,this will result in loss of the back surface reflectance. The loss is determined by several uncertain factors, for example: substrate thickness, substrate material, measuring distance and so on.Secondly, for the loss to compensate, the detailed study of how the back surface reflectance is influenced by these factors was proposed, and a computational expression of these influences was given. Based on the analysis achieved, a compensation model of the back surface reflectance measurement was proposed. Finally, a common reflection measuring system based on microfiber spectrometer and reflection probe was setup to verify the derivation. Simulation analyzed by TracePro optical software and experimental results show the correctness of the compensation model and this model can be used in the surface reflectance measurement of optical elements with transparent substrate.

7849-103, Poster Session

Frequency-tunable cloaking with external control

P. Li, Y. Liu, Nanjing Univ. of Aeronautics and Astronautics (China)

Cloaking an object with metamaterials and artificial structures has recently attracted a great deal of attention. Typical approaches involve coordinate transformation techniques [1], scattering cancellation methods [2], anomalous localized resonances [3], and so on. These cloaks are usually designed to work at a single operating frequency. In this contribution, three techniques are proposed in order to tune the cloaking frequencies based on the scattering cancellation method. The first is an electrically-controlled frequency-tunable cloak with a single shell of ferroelectric material. The second is a temperature-controlled frequency-tunable cloak with a single shell of superconductor material. The last is also temperature-controlled frequency-tunable cloak with semiconducting constituents. The scattering cross sections (SCS) of the composite structures are solved analytically and calculated by the means of the Mie scattering theory. For a typical structure composting with a cylindrical object (epslon=3, mu=3, radius a1=10 μm)surrounded by a semiconducting shell with the internal and external radii of a2=18 μm and a3=20 μm, the cloaking frequencies are 1.212 THz, 1.673 THz, 2.138 THz at T=250K, 275 K, 300 K, respectively. Frequency-tunable properties may be realized in the above-mentioned structures.

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2. A. Alù, and N. Engheta, Achieving transparency with plasmonic and metamaterial coatings, Phys. Rev. E. 72, 016623 (2005).

3. G. W. Milton, and N. A. Nicorovici, On the cloaking effects associated with anomalous localized resonances, Proc. R. Soc. A 462, 3027 (2006).

7849-104, Poster Session

System tolerance analysis of dual-advantage spectrographic system Based on coded aperture

L. Cheng, X. Gong, F. Yu, Zhejiang Univ. (China)

The performance of traditional dispersive spectrographic system is greatly constrained by the entrance slit, which can ensures a remarkable spectral resolution but a loss of system throughput and vice versa, thus this kind of instrument can't achieve dual-advantage simultaneously and statically. A novel high gain model for dispersive spectrographic system appears, and the traditional entrance slit is replaced by a coded aperture based on orthogonal independent column codes. The extended aperture lets more energy enter the system, increases system's throughput and SNR dramatically. While the independence of the codes helps to avoid the degradation of the spectral resolution. In this case, traditional spectrographic system based on dispersive elements can achieve dual-advantage consequently. On the basis of the derivation of the system model, this paper emphasizes on the analysis of system tolerance, to find out the key elements which affects the realization and performance of the system model. As the core of the system model, the coded aperture greatly affects system performance. Simulations were carried out to study the influence of several abnormal situations of the coded aperture on system performance, which included the existing of the error fabrication and insufficient illumination of the coded aperture. Furthermore, the influences of inaccurate system adjustment and calibration on system performance were studied. The analysis result shows that the system can still work properly when the coded aperture has a fabrication error rate of 20% or insufficient illumination of the coded aperture, while inaccurate system adjustment and calibration will severely affect system performance. According to the analysis result, fabrication of the coded aperture will be much easier as the system performance doesn't greatly suffered from its error. An error rate below 10% of coded aperture can reduce fabrication difficulty and the cost without much degradation of system performance. On the other hand, adjustment and calibration of the system should be well done, because it may lead to obvious deviation to the correct result. Finally, specific theoretical system model for each abnormal situation was studied respectively to demonstrate and verify the analysis result and the system theoretical model.

7849-105, Poster Session

Three-channel off-axis three-mirror system design and analysis

X. Li, Z. Fang, X. Li, Shanghai Institute of Technical Physics (China)

This paper analyzes the structural and imaging features of off-axis three-mirror system, discusses the multi-channel off-axis three-mirror

system design method. By analyzing, we can conclude how to choose the initial configuration of the optical system. In this paper, we design a three-channel off-axis three-mirror system. The following are the system parameters : aperture is 300mm, cover three spectral bands, large field of view coverage, achieve channel spectral. According to the system parameters and requirements, we can calculate to obtain an appropriate initial configuration of the optical system. By optimizing the initial design, we get an optical system which meets the technical requirements. The design of relay lenses is also considered, The ultimate design goal is to complete the design of each channel with the least number of lens.

7849-106, Poster Session

Large area two-dimensional scanning model and image rotation analysis

X. Li, X. Li, Z. Fang, Shanghai Institute of Technical Physics (China)

With the development of aerospace technology, now remote sensing instruments have a greater field of view coverage, a higher LOS pointing accuracy requirement. The traditional scanning model has a relatively small scanning area. If the scan area increases, the image rotation of traditional scanning model will increase rapidly. The traditional two-dimensional scanning model has failed to meet the growing demands of remote sensing instruments. To solve the problems, this paper analyzes and compares the differences of all kinds of two-dimensional scanning model, considering different ways to place and rotate two-dimensional scanning mirror. Finally, through analysis, we obtain a kind of two-dimensional scanning model which meets the large area two-dimensional scanning requirements. At the same time, the image rotation of large area two-dimensional scanning model is analyzed, which provides data support for image processing.

7849-107, Poster Session

Design of a four-mirror optical system with wide fields of view

S. Liang, Xi'an Institute of Optics and Precision Mechanics (China) and Graduate School of the Chinese Academy of Sciences (China); J. Yang, B. Xue, Xi'an Institute of Optics and Precision Mechanics (China)

Reflective optics is used widely in space optical systems for their achromatization, large aperture and lightweight compared with refractive systems. Four-mirror system especially off-axis system is desired for its excellent imaging performance and compact structure. Aberration theory of coaxial four-mirror system based on PW method is analyzed and the design process is proposed to get the initial four-mirror system. A large field off-axis four-mirror system is designed based on the theory and the design process. The system contains four conic aspheric mirrors. It has a 2°×0.32° rectangular field of view. MTF of the system is diffraction-limited and the distortion is less than 0.1%. The structure of the system is compact and the ratio of total axis length to focal length is about 1/4.5. The excellent imaging performance and compact structure makes it adaptable to space remote sensing systems.

7849-108, Poster Session

Research on measuring optical transfer function

S. Lu, Xi'an Technological Univ. (China)

Optical transfer function (OTF) of optical system is an important character to show optical system's imaging quality. It is important to accurately obtain the OTF in optical measurement. But traditional methods encountered some difficulties in high-precision measurement. A new approach based on digital image processing technique (DIP) is proposed in this paper. An experiment is done to acquire the image of a pill and a CCD is used to acquire digital images. Optical-electronic focal plane fixing technology is adopted to obtain a more accurate image. Then the images are done by digital image processing, including filtering and fast fourier transform, and the 2-dimension modulated transfer function (MTF) is obtained. The MTF of this detected lens derived from this way is compared with a higher accurate equipment to measure the OTF of the same lens, their similarity identify the correct of this method. This method will be widely used in optical inspection.

7849-109, Poster Session

Study on testing resolution of optical system

S. Lu, Xi'an Technological Univ. (China)

To measure the resolution of optical system has become more and more important in optical test. Traditionally, the method of evaluating the resolution of optical system is mainly subjective which is simple and intuitive but likely to introduce subjective error. To solve this problem, an approach to objectively measure the limited resolution is brought out in this paper. This way is based on the Rayleigh criterion and digital image processing technique. The experiment is done by illuminating a resolution panel with a light source of stable intensity and well-distributed radiation. A CCD is used to grasp the image, and the digital image is stored in a computer. Then MATLAB id used to get the gray curves and distinguish which fringe can be identified according to the gray curves. Finally the limited resolution is obtained. It shows that this way has almost the same result as calculation.

7849-110, Poster Session

The optical design and simulation of multi-chip LED array package structure

H. Wang, L. Chen, F. Ye, South China Univ. of Technology (China); L. Wang, South China Univ. of Technology (United States)

Based on the non-imaging particularities of LED optical sources, considering the impact of several factors such as the distribution of chips, the size of the reflector and the refractive index of packaging material, the packaging of multi-chip LED array source is designed and simulated by using geometrical modeling for optical components and Monte Carlo non-sequence ray tracing method. In this paper put emphasis on the optical design of the packaging structure to the 2 × 2 LED array source, and get the different emitting efficiency and light intensity distributions by changing the packaging parameters of the model. The results showed that the distributions of light intensity under the different parameters have certain regularity. These laws have the practical guidance to the multi-chip LED lighting system design and production, and these are also helpful to reduce the experiment costs in LED packaging manufactures.

7849-111, Poster Session

Design and fabrication of a two-beam prism-interferometer

M. Abolhassani, M. Esmaeili, Arak Univ. (Iran, Islamic Republic of)

In this paper an amplitude-division two-beam interferometer is introduced that, with some limitations, works similar to Michelson or

Twyman-Green interferometer. A prism operates as a beam-splitter and one of the two mirrors. Any plane parallel plate is not employed, and any of its surfaces doesn't need to anti-reflecting or semi-transparent coating. It doesn't produce spurious fringes.

It produces fringes with high visibility comparable with Michelson interferometer's one in similar conditions.

In comparison to Michelson or Twyman-Green interferometer, it has some advantages and some disadvantages as follows:

(a)Disadvantages

1- Since one arm of this interferometer is fixed, limitation of source temporal coherency limits the displacement of mirror M. Thus it is suitable only for testing components like prisms and low focal length lenses. This is not suitable for testing large optics, while Twyman-Green interferometer can be used for testing the components that needs an interferometer with long arms

2- Because lacking a compensator, it cannot be used to spectrometry of sources with continues and broad spectrum.

3- Departed beams width become smaller than the incoming one.

(b) Advantages:

1- The number of beams incidences to interfaces (2 times) is less than the one (4 times) in the two interferometers. Thus the errors occurred due to imperfections of involved surfaces is less the one in the two interferometers.

2- There are no spurious fringes when it is well-adjusted.

3- The number of its optical and mechanical components is less. Thus its adjustment is easier.

4- No antireflection or semi transparent coatings are necessary.

7849-114, Poster Session

A 3D numerical study of pinhole diffraction in visible-light point diffraction interferometer

J. Xu, Institute of Optics and Electronics (China) and Graduate School of the Chinese Academy of Sciences (China); F. Xu, T. Xing, Institute of Optics and Electronics (China)

A three dimensional (3-D) electromagnetic field simulation, based on Finite Element Method (FEM), is used to modal the propagation of visible-light (632.8nm) through pinhole in a metal medium, a part of the visible-light point diffraction interferometer (PDI). By changing several parameters, such as diameter and thickness of the pinhole, deviations from diffracted wavefront to the perfect spherical wavefront are analyzed to estimate the possible accuracy of the interferometer. Error induced by beam spot placement is also discussed.

7849-115, Poster Session

Optical design of high resolution and large format CCD airborne remote sensing camera on un-manned aerial vehicle

Y. Qian, X. Cheng, Zhejiang Normal Univ. (China)

Unmanned aerial vehicle remote sensing (UAVRS) is lower in cost, flexible on task arrangment and automatic and intelligent in application, it has been used widely for mapping, surveillance, reconnaissance and city planning. Airborne remote sensing missions require sensors with both high resolution and large fields of view, Large format CCD digital airborne imaging systems are now a reality. A refractive system was designed to meet the requirements with the help of code V software, It has a focal length of 150mm, F number of 5.6, waveband of 0.45-0.7um, and field of view reaches20°. It is shown that the value of modulation transfer fuction is higher than 0.5 at 55lp/mm, distortion is less than 0.1%, image quality reaches the diffraction limit. The system with large format CCD and wide field can satisfy the demand of the wide ground overlay area and high resolution. The optical system with simpler structure, smaller size and lighter weight, can be used in airborne remote sensing.

7849-116, Poster Session

Research on calibration of three-mirror reflective space remote sensor using wavefront sensorless method

X. Han, Y. Xin, X. Hu, Beijing Institute of Technology (China)

Position errors of three-mirror reflective space optical system will affect the whole system badly, so we have to calibrate these errors in orbit. This paper proposes a new method for the first time, which is: we can use Stochastic Parallel Gradient Descent algorithm to calibrate three-mirror reflective remote sensor, this method don't need wavefront sensor to calibrate position errors. It uses root mean square of radius of image as system merit, through controlling the six position of second mirror to compensate system error. This method is suitable for the calibration of three mirror reflective space optical system for its needless of using wavefront sensor. Results of the simulation show that compared with traditional sensitive matrix inversion algorithm, this method increases the dynamic range of initial position errors, and it can improve wavefront error from about 1 wave rms to lower than 0.04 wave rms in the center field of view.

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7850-01, Session 1

Research on combinational image stabilization technology based on MEMS IMU

Y. Zong, X. Jiang, X. Wang, Z. Liu, Academy of Armored Force Engineering (China)

As a result of unexpected attitude variation or random shaking of the camera, the image sequences would become blurred and instable. High performance stabilization platform adopting precise gyros is usually dear and complex. Electronic image stabilization technique is cheap and low power dissipation, but the intricacy of algorithm substantial increase considering camera intentional motion and moving objects. Designing a cheap stabilization platform using a small MEMS IMU, limiting the range of variation of the camera attitude;pixel coordinate conversion model related to the camera attitude variation is deduced and simplified. Then utilizing the IMU angle rate and acceleration value to compensate the frame deviations, and realizing stable video output.

7850-02, Session 1

Portable electronic endoscopic imaging system

L. Du, L. Wang, B. Ye, H. Duan, Zhejiang Univ. (China)

The paper presents a low-power, inexpensive and portable imaging system for laparoscopy or industrial application. A 1.3 million pixels COMS sensor is considered as an image capture. The sensor and the lens system are designed to minify the cannula diameter of the endoscope and therefore minimize the incision size for insertion. LVDS (Low-Voltage Differential Signaling) is used for image data transmission between the sensor and CPU to get a long distance, high speed and low noise system. An ARM 920T based microcontroller is employed as the control core for the image transmission module, display module and other modules. The camera interface and LCD controller are integrated in the microcontroller and both have a dedicated DMA supports to transmit image data though AHB (Advanced High performance Bus) to or from frame buffer located in system memory without CPU intervention. The image is displayed on an 8 inch LCD screen with 800 * 600 resolution and 16 bits of color depth. With the maximum capture and display rate of 30 fps, this system can provide a clear image enough for laparoscopy or industrial application. And with integrated camera, light source and video display function, it can also be used as a portable, miniature and inexpensive endoscope.

7850-03, Session 1

New photoacoustic imaging modality for imaging internal organs based on single focus ultrasonic transducer

W. Xie, H. Li, Z. Li, J. Zhang, Z. Zeng, Fujian Normal Univ. (China)

Photoacoustic imaging is a promising technique in practical medicine to image biological tissue's function and diagnose internal organs. In this paper, a new photoacoustic imaging modality for imaging internal organs was presented. The system mainly consisted of optical fiber and focus ultrasonic transducer. A laser which wavelength is tunable was coupled into a multimode optical fiber. And the fiber was inserted into the inner tract of the samples to deliver light for exciting photoacoustic signals. The outgoing PA signal was detected by a focus ultrasound transducer which was placed on the surface of the samples. By transducer scanning, we obtained a 2D cross-section photoacoustic image. Finally, we evaluate this system's performance and demonstrate its capabilities by imaging both phantoms and an excised intestine of a rat.

7850-04, Session 1

Quantification and elimination of the CCD dark current in weak spectrum measurement by modulation and correlation method

Z. Cai, X. Wei, J. Ju, J. Wu, Soochow Univ. (China)

Charge coupled device (CCD) has become the prevailing spectroscopy detector for its high sensitivity and fast multi-channel data acquisition ability. However, in case of weak spectrum measurement, the dark current of CCD could be very large and thus affect the proper application. It's essential to suppress the dark current and other noises to get high quality spectral data. In this paper we proposed a modulation and correlation method to quantify the CCD dark current and further to eliminate it for weak spectrum measurement. In this method, a compact camera shutter is to be mounted in front of the entrance slit of the spectrometer and will be controlled by the application software. Using the CCD light integral-time control and shutter control functions of our home-made spectrometer system, we could modulate the CCD's integral-time and the shutter's open/close status independently. With the shutter closed and the light integral-time modulated by a periodic sequence, the dark current can be quantified by correlation algorithm. In order to measure weak spectrum, the shutter is modulated by a binary pseudo-random sequence with integral time fixed, and the correlation processing of the resulting spectra can produce high quality data where dark current is eliminated. In this paper, the system setup and the brief analysis of the modulation-correlation method were introduced, computer simulation was presented and the weak spectrum measurement results were provided. It showed that the proposed method can effectively eliminate the dark current of CCD, suppress the random noises and extract the weak spectrum signal from strong noise background. Compared with other dark current suppression techniques like CCD cooling, this method is easer to implement and requires little modification on the existing spectrometer system, which makes it suitable for low cost portable spectrometer design.

7850-05, Session 1

Design and fabrication of a fiber optic image inverter based on a new high numerical aperture glass system

J. Pan, Changchun Univ. of Science and Technology (China)

A fiber optic image inverter is a special type of fiber optic plate that rotate an image through a 180 degrees angle, an image inversion can be accomplished in an image intensifier tube, by means of attaching the phosphor to a fiber optic image inverter as the output window of image intensifier tube, to minimize the length of which to the eyepiece lens, providing the miniaturization necessary for a helmet-mounted night vision goggle system. Development of fiber optic image inverter

is used to concentrated on the heat twist process experiments based on the existing glass system for production of a high numerical aperture (N.A.) fiber optic plate, but which is hardly capable of withstanding a fast heat twist operation without the billet broken, due to the thermal shock property was neglected in these historical design. To prevent the billet from broken during twist operation, a long time heat twist cycle process was adopted in domestic fiber optic industry, caused low yield efficiency and other shortages. In response, a program of design and fabrication of a high N.A. image inverters which address to develop a new glass system with improved thermal shock property and optimized index of refractive of glass system. This program has yielded a new high numerical aperture glass system which is capable of suffer a fast heat twist operation without the billet broken, and has been demonstrated to produce a high numerical aperture image inverter with higher transmission than existing materials. In this paper we review fiber optic fundamental, glass system properties, heat twist process, and properties and performance of the fiber optic image inverters from a pilot run.

7850-06, Session 1

A configurable distributing high performance computing framework for satellite's TDI-CCD imaging simulation

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This paper renders a configurable distributing high performance computing(HPC) framework for TDI-CCD imaging simulation. It uses strategy pattern to adapt multi-algorithms. Thus, this framework help to decrease the simulation time with low expense.

Imaging simulation for TDI-CCD mounted on satellite contains four processes: 1) atmosphere leads degradation, 2) optical system leads degradation, 3) electronic system of TDI-CCD leads degradation and re-sampling process, 4) data integration. Process 1) to 3) utilize diversity data-intensity algorithms such as FFT, convolution and LaGrange Interpol etc., which requires powerful CPU. Even uses Intel Xeon E5440 processor, regular series process method takes more than 30 hours for a simulation whose result image size is 1024 * 1024. With literature study, there isn't any mature distributing HPC framework in this field. Here we developed a distribute computing framework for TDI-CCD imaging simulation, which is based on Web Service, uses Client/Server (C/S) layer and invokes the free CPU resources in LAN. The server pushes the process 1) to 3) tasks to those free computing capacity. Ultimately we rendered the HPC in low cost.

In the computing experiment with 4 symmetric nodes and 1 server, this framework decreases 70% simulation time. Adding more asymmetric nodes to the computing network, the time decreased namely. In conclusion, this framework could provide unlimited computation capacity in condition that the network and task management server are affordable. And this is the brand new HPC solution for TDI-CCD imaging simulation and similar applications.

7850-07, Session 2

A grayscale image color transfer method based on region texture analysis using GLCM

Y. Zhao, W. Jin, L. Wang, Y. Luo, J. Li, Beijing Institute of Technology (China)

Gray level pseudo-color encoding method can get colorized images displaying luminance distribution by direct viewing colors, but the sudden and blunt color appearance is not conducive to long time observation. The color transfer method arising in recent years is able to colorize grayscale images with natural color sense. Its greatest strength is the use of the image texture information, so the description of image texture has an important influence on the effectiveness of color transfer. Gray Level Co-occurrence Matrix (GLCM) method proposed by Haralick et al. in 1973 can very effectively describe image texture, and it is suitable for natural scene images. In this study, we analysis the region texture characteristics of image luminance channel using GLCM, and propose a novel method to accurately transfer color to grayscale images. First, according to the grayscale image's content and scale, we choose an appropriate chromatic reference image, and then both the grayscale image and the chromatic image are transformed to de-correlated opponent color space. Second, after doing linear transformation and grayscale compression to the luminance channel of two images, we describe their pixel neighborhoods' texture characteristics using GLCM, and match the pixels between images according to their texture value difference. Third, the color values of the best matching pixel of reference image are transferred to corresponding pixel of grayscale image. Finally the original luminance channel of grayscale image is restored. Experimental results showed that, in some regions of resulting images, conventional color transfer method may get color differing greatly from scenes' real color, because it only uses mean and standard deviation as matching parameters; our method can significantly improve pixel matching accuracy by texture analysis, and get much better color transfer performance than conventional method.

7850-08, Session 2

An efficient parallel processing approach to fractal image compression

X. Xie, R. Wu, Minjiang Univ. (China)

Time complexity is one of the biggest problems for fractal image compression algorithm which can bring about high compression ratio. However, in generally, there is data parallelism for fractal image compression algorithm. Naturally, parallel computation scheme would be used to deal with it. This paper proposes a fractal image compression algorithm with high data parallelism, and then "equal division load" balancing algorithm is designed to implement the fractal image compression. "Equal division load" balancing algorithm distributes computation tasks to all processors equally. According to "equal division load" balancing algorithm, load in every node is divided into smaller tasks based on all power of nodes on network, and then these smaller tasks are sent to corresponding nodes to balance the load among nodes. This approach not only can be used in homogeneous parallel computation system, but can be used in heterogeneous distributed computation system. The algorithm has lower time complexity, and the algorithm shows its efficiency when system is to allocate load initially or when the system's load is extremely unbalanced. However, the amount of the transferred load on the network will be considerable when the system's load is approximately balanced. But there is no major problem to use the algorithm in practice, because, frequently, balancing load is required only when the system's load is quite unbalance. The experiments show that the algorithm greatly reduces the component task execution time, and the specific parallel implementation is beneficial for the execution speed of the fractal image compression algorithm.

7850-09, Session 2

An image threshold estimation model

R. Wu, X. Xie, Minjiang Univ. (China); Z. Song, Fuzhou Univ. (China)

It is important to accurately fit the unknown probability density functions of data from practical applications for designing more efficient signal processing systems. The generalized Guassian distribution model is often used to characterize the statistical behavior of a multimedia signal,

and applied in fitting probability density functions of a signal. But, in practically, the probability density functions of lots of data source may be inherently non-Gaussian. So simply using the generalized Guassian distribution model cannot describe the data accurately. This paper considers the distribution family to estimate the unknown parameters and approximate the empirical distributions, and then to resolve the estimation difficulty in the generalized Guassian distribution mixture model. The first reason we choose Johnson distribution system is that the family covers most of the common distribution types and the frequency curves provided by the family are as wide as in general use. Moreover, the parameters of Johnson transformation can be calculated from the first four sample moments or from the sample percentile points which can be obtained easily in practice. Finally, the standard normal distribution is one of the most common distributions and it is convenient for practical application. The method uses the first four moments to calculate the skewness and kurtosis. Then right distribution can be selected on the basis of the skewness and kurtosis, and we can use this frequency curves fitting the unknown probability density function. The experimental results show that the fitted model could depicts quite successfully the Gaussian and non-Gaussian probability density function of image intensity, and the method has low computing complexity.

7850-10, Session 2

A windowed phase correlation algorithm for subpixel motion estimation

Y. Chen, J. Wu, Q. Li, Z. Xu, H. Feng, Zhejiang Univ. (China)

This paper presents a windowed phase correlation algorithm for subpixel motion estimation. The proposed registration algorithm has superior precision for images that differ by translation and uniform changes of illumination. The algorithm is used for motion estimation in visual servo and can achieve subpixel precision when images contain aliasing errors due to undersampling.

Image registration algorithms can be used in visual servo to estimate image motion with high precision. In this field, images are often undersampled in order to collect enough photons in the short exposure time. Conventional phase-based correlation registration algorithms usually have reduced precision or bias error due to aliasing errors when images are undersampled. The average subpixel precision may be affected by the aliasing artifacts and the discrete fast fourier transformation. Some algorithms may even fail to estimate pixel-wise image displacements.

A window function is applied to images in the spatial domain before fourier transformation to suppress frequency leakage. Further more, unreliable frequencies due to aliasing errors are removed in the frequency domain before phase correlation or frequency by frequency multiplication. We have analysed how aliasing errors and FFT affect motion estimation accuracy and examined many different kind of window functions to find a better solution. We applied the Kaiser window to the images in spatial domain. The Kaiser window has narrower main lobe width and relatively low side lobe amplitude with a proper parameter.

Experiments show that the proposed approach yields improved accuracy and superior precision for motion estimation in the presence of aliasing compared to conventional phase-based correlation algorithms.

7850-11, Session 3

Experimental determination of the system parameter of oil thickness measurement

Q. Lu, B. Ge, W. Yao, Y. Zhang, Tianjin Univ. (China)

We present a method for the measurement of the thickness of transparent oil film on water based on laser trigonometry, and the oil film thickness can be obtained by use of the displacement of imaging spot and the configuration parameter of the imaging system. So calibration is needed to achieve the geometrical parameters of the system. We complete the calibration experiment for optical planar ground glass and the system parameters the object distance of the imaging system and the incident angle of the laser beam are acquired and the uncertainty is ±1.7mm for 1.5mm optical planar ground glass. The experiment is conducted with diesel oil and engine oil. The research results show that the method presented in this paper is feasible, and applicable to dynamic on-line measurement of oil film thickness of oil spill on sea surface.

7850-12, Session 3

Automatic seal imprint verification by quantifying edge difference

H. Zhang, Tianjin Univ. (China); J. He, Tianjin Univ. of Technology and Education (China)

To automatically verify the genuinity of seal imprints in Chinese bank checks, we proposed an image based algorithm that can identify highly intimated seal imprints by quantifying the edge differences between model seal imprints and sample seal imprints. A model seal imprint and a sample seal imprint were registered according to their SIFT (Scale Invariant Feature Transform) features. The edge difference (non-overlapped edge pixels) reflected the similarity between two imprints. One challenge of seal imprint verification is differences between a model seal imprint and a highly-intimated fake sample seal imprint may be subtle, while there always were differences between the model seal imprint and a genuine sample seal imprint due to the variety of imprinting conditions. To distinguish these two kinds of difference, edge difference was quantified by two parameters: the distance between non-overlapped corresponding edges and the length of non-overlapped seal edges. According to these two parameters, the sample seal was verified as true, false or doubtful. In the experiments, 2000 sample seal imprints in bank checks were tested (1000 were genuine and 1000 were fake). All highly-intimated fake seal imprints were verified accurately. 27 genuine seal imprints were misclassified due to some serious distortions. False-acceptance rate was 0%. False-rejection rate was 2.7%. The overall recognition accuracy was 98.65%.

7850-13, Session 3

Obtain the fingerprint on a transparent fragment by using optical filtering method

C. Jia, China Criminal Police College (China)

Objective Fingerprints on transparent materials are regarded as phasic objects so that their development with method is studied. Method Spatial filtering is applied by dark field lighting method with 4f optical system and the developed fingerprints are compared with those lifted with transmission lighting. Results Latent sweat fingerprints on transparent materials are developed and the results are quite satisfactory. Conclusion Spatial filtering It is concluded from the spatial filtering experiment that fingerprints on partial transparent flakes can be developed and further study is needed in the future.

7850-14, Session 3

A new intelligent method of people counting based on the principle of optical triangulation

Y. Hou, P. Wei, Beijing Institute of Technology (China)

In this paper we present a new intelligent method of people counting. The system is based on optical triangulation principle, using the image sensor and infrared LED light source, collecting image information by the exposure of both being strictly synchronous. This can effectively reduce the interference of background light, with high accuracy, good real-time. The experimental results show that even in the large density of the flow experimental condition, the accuracy of this method can achieve more than 90%, verifying the feasibility and effectiveness.

7850-15, Session 3

An aerial composite imaging method with multiple upright cameras based on axis-shift theory

J. Fang, X. Liu, Q. Tong, Institute of Remote Sensing Applications (China)

Several composite camera systems, such as DMC, SWDC, and MADC, were made for wide coverage by using 3 or 4 oblique cameras. It is very difficult for geometrical correction with different projecting angles caused by oblique cameras. A virtual projecting center and image was used for geometrical correction and mosaic, because of the different projecting angles and different spatial resolutions. An imaging method based axis-shift theory is proposed to acquire wide coverage images by several upright cameras.Four upright camera lenses have the same wide angle of view. The optic axis of lens is not on the center of CCD, and each CCD in each camera covers only one part of the whole focus plane. Oblique deformation caused by oblique camera would be avoided by this axis-shift imaging method.

A prototype camera system is constructed by common DLSR (digital single lens reflex) cameras, and the principle and parameters are given and discussed. The angle of view could exceed 90 degrees along the flight direction, and the ratio of base line to height could exceed 0.7 when longitudinal overlap is 60%. Experimental results of image test show that the upright imaging method can effectively avoid the oblique deformation and meet the geometrical precision of image mosaic. This axis-shift imaging method could be applied to construct high performance aerial photographic system. When some large format CCDs (such as 9K*7K) are adopted, the final output image would exceed 30K*14K, which is larger than DMC and UCX.

7850-16, Session 4

Hyperspectral image data compression based on DSP

J. Fan, J. Zhou, W. Shen, Soochow Univ. (China)

The data volume of hyperspectral image rapidly expands as the increase of spectral channels, spatial pixels, and digitized bits, the huge data cube will certainly lead to difficulty in its transportation and store. It is necessary to find an effective method to compress the hyperspectral image. Through analysis and comparison of current various algorithms, a mixed compression algorithm based on prediction and integer wavelet transform is proposed in this paper. First, an optimal inter-band predictor is designed for de-correlating the spectral redundancy of hyperspectral image. Next, its spatial redundancy is removed with an efficient integer wavelet transform. Then, an improved embedded zero-tree wavelet (EZW) encoder is employed for encoding the obtained transformed coefficients. The proposed algorithm can be used to implement not only lossless compression, near-lossless compression, but also lossy compression.

For the necessity to compress the image data cube in real time from the hyperspectral imager on space and/or air platform, this paper adopts a high-powered Digital Signal Processor (DSP) of TMS320DM642 to realize our proposed mixed algorithm. Since the data volume of spectral image is so huge that it is impossible to be processed in the internal memory of DM642 one-off, it is partitioned into several blocks of same size and then each of the them is encoded by the internal CPU. The effective means to solve the problem is to use DMA and CACHE for high speed transportation and read of the image data in the memory. Through modifying the mixed algorithm and optimizing its algorithmic language, the processing efficiency of the program was significantly improved, compared the non-optimized one. Our experiment show that the mixed algorithm based on DSP runs much faster than the algorithm on personal computer. Our proposed method can achieve the real-time compression with excellent image quality and compression performance. The work of this article has founded a real-time hyperspectral image compression platform.

7850-17, Session 4

Design and FPGA implementation of graph cuts for fast image segmentation

G. Hou, P. Wei, Beijing Institute of Technology (China)

Recent graph-based image analysis methods have been achieved exciting results in Markov Random Fields (MRF's), Graph Cuts is one popular algorithm among these. Many simulated experiments of Graph Cuts have been implemented on personal computers, but none papers are represented about the results of Graph Cuts on embedded system for some real-time applications, and mobile computation has attracted much attention as a future research tendency due to rapid development of modern integrated circuit. In this paper we design and implement a fast Graph Cuts based on Field Programmable Gate Array (FPGA) for image segmentation in complex embedded mobile environments. Image are process in MAP-MRF framework and Graph Cuts as global minimization methods are used to achieve the solution. Our algorithm is verified on embedded system based on Xilinx Spantan-6 platform with Verilog hardware design language, and the performance of the final hardware implementation is practically the same as that predicted by computer simulations. Through the results Graph Cuts are proved it can be applied in embedded system for more versatile mobile applications.

7850-18, Session 4

A new two-point correction algorithm for non-uniformity correction combined with the information of scene

R. Zou, Beijing Institute of Technology (China)

The paper proposed a new non-uniformity correction algorithm based on the two-point correction combined with the information of scene. Which can eliminate the non-uniformity response of the IFFPA arrays, time drift, and also restrain salt&pepper noise too.

Assuming the response of each IFFPA unit keep a linear relationship with the infrared radiation, the non-uniformity can be corrected by the gain coefficient and the bias coefficient, to eliminate the most non-uniformity of the IFFPA, but in the actual scene, the linear model cannot describe the real situation. In this essay, the IFFPA is still corrected by the two-point correction but the the ideal value of the focal plane correction is the intermediate value of the image point, while the course of amending the bias coefficient is divided into two phases, with different step length, respectively to overcome the drift and the salt&pepper noise. The algorithm was achieved based on the FPGA, which showed its better virtues than the traditional two-point correction algorithm.

7850-19, Session 4

Region labeling algorithm based on boundary tracking for binary image

C. Li, Z. Cen, Zhejiang Univ. (China)

Extracting objects from background and analyzing the geometrical characteristics of each object are widely used in machine vision and pattern recognition. And connected component region labeling is one of the common methods.

Several region labeling algorithms for binary image is introduced at the beginning of the paper. Conventional algorithms often cannot meet the demands of processing image at real-time because of the limit of processing time and memory space. For the special use of small and multi-objects labeling, a new region labeling algorithm based on boundary tracking is proposed in this paper. The basic principle and experiment operations such as the real-time test of the algorithm are shown in detail. The concrete steps of this algorithm are generally as follows: after searching and finding a pixel of a new connected component region, do the boundary tracking around it, get the boundary pixels information, label the inside pixels of the connected component region, finish one of the labeling and start a new labeling with the same way. At last, a comparison between this algorithm and conventional algorithms is given and necessary improvements are proposed.

Because only one time scanning is needed for each image, the algorithm above avoids the repetitive labeling and operates with higher efficiency obviously in theory. Simultaneously, tracking each object is based on the boundary, and the internal pixels of each object are labeled together, these make the algorithm much better for reducing the noise effects on small and multi-objects.

7850-20, Session 5

3D image registration and fusion of intensity and range data

Y. Hou, P. Wei, Beijing Institute of Technology (China)

We can obtain range images, including depth information and shape of the exterior from scanning the object by laser beam. The kind of laser radar imaging is active and can obtain accurate 3D point from the information, but it does not depend on external light conditions. However, due to the factor of imaging speed and distance of the laser radar imaging, the resolution of the range image are lower relative to the camera images, and laser radar can only get gray image, can't get the texture and color, was bad to the target identification.

Meanwhile, the intensity image of the object is captured under illumination light. In contrast, high resolution and being targets of texture and color information to identify a good target, but the image of instability, a strong dependence on the environment, and can't provide distance information.

Therefore, range and intensity images are complementary in nature and provide a richness of description which is not possible with either source in isolation. After accurate registration, we aim to build a 3D model of fusion of intensity and range data. The combination of range (dense depth estimates) and image sensing (color information) provides data-sets which allow us to create geometrically correct, photorealistic models of high quality. Compare with the traditional image, the 3D fusion image can reflect the object more completely and more truly.

7850-22, Session 5

An embedded three-dimensional profilometry based on a combination of gray-code and phase shifting method

D. Li, J. Tian, Shenzhen Univ. (China)

An embedded three-dimensional(3-D) profilometry system based on a combination of gray-code and phase shifting method for industrial applications is proposed. This system consists of a single-chip digital light processing (DLP) projector, a high-speed CCD camera and an embedded digital signal processing hardware system based on DSP. During the measurement procedure, seven gray-code patterns and three sinusoidal fringe patterns are projected by the DLP projector onto the object sequently, and a high-speed CCD camera synchronized with the projector acquires the images at a frame rate of 180 frames/s. The gray-code patterns are exploited to detect without ambiguity even for the discontinuity surface, whereas the phase-shift patterns allows the measurement of fine surface details. Because of the characters of gray-code and the pipeline measurement mechanism, a embedded system based on DSP is suitable for this kind of procedure especially. The hardware system is developed mainly for taking full advantage of DSP parallel processing capability for real-time phase retrieve and 3-D reconstruction. Experimental results show that this system can implement fast 3-D shape measurement at a speed of 18 frames/s with a resolution of 800×600 points per frame. It is particularly favorable for 3-D real-time measurement applications.

7850-24, Session 5

The effect of the status of aircraft on detection accuracy of airborne scanning lidar

J. Liu, T. Lan, Y. Zhang, G. Ni, Beijing Institute of Technology (China)

Airborne scanning lidar is a new type remote sensing system which consists of several high-tech systems containing global positioning system (GPS), inertia navigation system (INS), laser scanning range system (LSRS), aerial camera system etc. The accuracy of its data is limited by many factors such as GPS, INS, LSRS, target surface gradient, the status of aircraft in flight and so on. In flight the status of aircraft is subject to the meteorological factors. And it affects the accuracies of scanning angle, aircraft attitude angle, detection accuracy of orientation in airborne scanning lidar. After giving the detection principle and geometric model of airborne scanning lidar briefly, this paper analyzed the existent error sources in detection process, and established the correction equation of positioning error. According to the attitude changes and aircraft vibration in frequency induced by meteorological factors, the simplified models of vibration and attitude changes are developed. Based on the simplified models, computer simulation is carried out. The outcome of simulation is analyzed. Finally a few elementary conclusions are obtained and some suggestions are offered for improving detection accuracy and for error compensation of airborne scanning lidar data. The results of this paper are of reference value in research on the improvement of detection accuracy of airborne scanning lidar in the future.

7850-25, Session 5

Research on Stereo Vision odometry

X. Zhang, B. Zhang, Tianjin Univ. of Technology (China)

In the navigation and localization of ALV(Autonomous Land Vehicle), the technology of the odometry is more important to get the distance and

direction information of moving robot. The problem of the conventional odometry based on wheel encoder must compute is the miscount error when the wheel-slip can not be overcome, and the dead reckoning error will rapidly accumulate with the moving distance increasing. So, auxiliary navigation and localization technology must be adopted to obtain location and attitude estimation of ALV more accurately.

The stereo visual odometry technology in robot navigation system is proposed in the paper. The stereo visual odometry can obtain the motion data to implement the location and attitude estimation of ALV.

Two key technologies in the stereo vision odometry are dissertated. The first is using SIFT to extract suitable feature, match points pairs in the feature, and track the feature of fore and after frames of the same point. The second is using matching and tracking technology to obtain the different 3-D coordinate of the selected feature points during the movement of ALV, and to estimate the relationship of position and orientation of moving ALV at the time of fore and after frames gathered, and then to compute the motion parameter of ALV by motion estimation.

The unknown outdoor environment is adopted in the experiment. The results show that the stereo vision odometry is more accurate, and the measurement error is not increase with the moving distance increasing. It can be described as an important addition of conventional odometry.

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7850-26, Session 6

Realtime multispectral imaging-based blood stain seeker

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In some dangerous locations, it is necessary that the search and collection for forensic evidence must be performed quickly and during daytime only. In this paper, we propose a real-time multispectral imaging-based blood stain seeker. Our key idea is to illuminate an interesting area with a full spectrum visible light and then analyze the selected reflectance spectra via digital image processing techniques. In this way, the blood stains are highlighted back onto the live video screen on the computer's monitor so that the investigator can readily see the areas of evidence in real time on the screen while performing search and collection. This paper will also highlight our experimental proof of the concept.

7850-27, Session 6

An improved segmentation algorithm to detect moving object in video sequences

J. Li, X. Sang, Beijing Univ. of Posts and Telecommunications (China)

The segmentation of moving object in video sequences is attracting more and more attention because of its important role in various camera video applications, such as video surveillance, traffic monitoring, people tracking and so on. Conventional segmentation algorithms can be divided into two classes. One class is based on spatial homogeneity, which results in the promising output. However, the computation is too complex and heavy to be unsuitable to real time applications. The other class utilizes change detection as segmentation standard to extract moving object. The typical approaches include frame difference, background subtraction and optical flow. A novel algorithm based on adaptive symmetrical difference and background subtraction is proposed. Firstly, the moving object mask is detected through the adaptive symmetrical difference, and connection of adjoining pairs on the contour of the mask. The adaptive background subtraction is carried out in the acquired region to extract accurate moving object. Morphological operation and shadow cancellation are adopted to refine the result. Experimental results show that the algorithm is robust and effective in improving the segmentation accuracy to detect the moving object in the video sequences.

7850-28, Session 6

A phase congruency based corner detector for images under different illuminations

S. Wang, Y. Zhang, X. Zhang, Nanjing Univ. (China)

Reliable corner detection is extremely important for applications such as 3D scene reconstruction, image registration and motion tracking. There are many kinds of corner detector which have been wildly used. However, the image's changing contrast and brightness under different illuminations may considerably influence these traditional detectors' response, which makes the setting of universal threshold very difficult. In this paper, a phase congruency based corner detection method is proposed. The new operator finds the corner points within an image through searching the maximal phase congruency in frequency domain. The phase information is obtained by wavelet transform with Log-Gabor filter. The result of detection is highly localized and invariant to image's illumination. Contrast experiments between the proposed detector and the widely used Harris detector have been made on both synthetic and natural scene images. The experimental results have shown that accuracy of detection and localization of corner points can be achieved with the proposed method.

7850-29, Session 6

An airport runway centerline location method for one-off imaging system

S. Ge, T. Xu, G. Ni, X. Shao, Beijing Institute of Technology (China)

Airport runway centerline location plays a key role in automatic track recognition in aerial images. In high resolution images from one-off imaging system, the details of airport runway and objects around are presented clearly. For runway detection and recognition, its long straight line character is the best feature, so a centerline location method is proposed for airport runway recognition in images from one-off imaging system. This method has three steps: edge detection, straight line extraction and runway centerline location in distance histogram. A self-adaptive Sobel edge detection method is developed for detecting salient edges from side stripes of runway. This method could effectively detect edges from airport runway and suppress the irrelative weak edges. Straight line extraction is carried out by Hough transform in polar coordinates. In Hough space, the dominating angle is corresponding to the angle of edges from runway. The runway has two side stripes and dashed line stripe at the center, and these stripes generate parallel lines, which is an angle extreme in Hough space. There are always other parallel lines generated from surrounding structures, so a distance histogram location method is developed to cope with these disturbing lines. A reference line is chosen at the dominating angle, and distance of each point in edge map to this line is calculated to build a one-dimension histogram. In this histogram, airport runway shows a three-peak pattern, and the center peak is produced by its centerline. Experiments of the proposed method with images of several airports show it could precisely locate runway centerline.

7850-38, Poster Session

A wireless video monitoring system base on 3G communication technology

Z. Xia, Yangtze Univ. (China)

With the rapid development of the electronic technology, multimedia technology and mobile communication technology, video monitoring system is going to the embedded, digital and wireless direction. In this paper, a solution of wireless video monitoring system based on WCDMA is proposed. This solution makes full use of the advantages of 3G, which have Extensive coverage network and wide bandwidth. It can capture the video streaming from the chip's video port, real-time encode the image data by the high speed DSP, and have enough bandwidth to transmit the monitoring image through WCDMA wireless network. The experiments demonstrate that the system has the advantages of high stability, good image quality, good transmission performance, and in addition, the system has been widely used, not be restricted by geographical position since it adopts wireless transmission. So, it is suitable used in sparsely populated, harsh environment scenario.

7850-39, Poster Session

Real-time panoramic infrared imaging system based on FPGA

H. Zhang, Shanghai Institute of Technical Physics (China)

During the past decades, the signal processing architecture, which is based on FPGA, conventional DSP processor and computer, is popular for infrared or other electro-optical systems. With the increasing processing requirement, the former architecture starts to show its limitation in several respects. This paper elaborates a solution based on FPGA for panoramic imaging system as our first step of upgrading the processing module of infrared system to System-on-Chip (SoC) solution. Firstly, we compare this new architecture with the traditional to show its superiority mainly in the video processing ability, reduction in the development workload and miniaturization of the system architecture. Afterwards, this paper provides in-depth description of the imaging system, including the system architecture, function, signal processing flow and addresses several related issues about how to raise the maintainability and reliability of the logic design followed by the field test data and future system development.

New system architecture demands for new design methodology. FPGA has developed so rapidly during the past years, not only in silicon device but also in the design flow and tools. In the end, we discuss the limitation of the traditional FPGA design methodologies and propose some relative strategies. The advanced design flow through Simulink and System Generator has been introduced, which enables engineers to develop sophisticated DSP algorithms and implement them in FPGA more efficiently. It is believed that this new design approach can shorten system design cycle by allowing fast prototyping and refining design process.

7850-40, Poster Session

Earth elevation map production and high resolution sensing camera imaging analysis

X. Yang, Changchun Institute of Optics, Fine Mechanics and Physics (China); J. Li, Jilin Univ. (China); G. Jin, D. Lu, K. Xu, Z. Liu, Changchun Institute of Optics, Fine Mechanics and Physics (China)

The Earth's digital elevation which impacts space camera imaging has prepared and imaging has analysed. Based on matching error that TDI CCD integral series request of the speed of image motion, statistical experimental methods-Monte Carlo method is used to calculate the distribution histogram of Earth's elevation in image motion compensated model which includes satellite attitude changes, orbital angular rate changes, latitude, longitude and the orbital inclination changes. And then, elevation information of the earth's surface from SRTM is read. Earth elevation map which produced for aerospace electronic cameras is compressed and spliced. It can get elevation data from flash according to the shooting point of latitude and longitude. If elevation data between two data, the ways of searching data uses linear interpolation. Linear interpolation can better meet the rugged mountains and hills changing requests. At last, the deviant framework and camera controller are used to test the character of deviant angle errors, TDI CCD camera simulation system with the material point corresponding to imaging point model is used to analyze the imaging's MTF and mutual correlation similarity measure, simulation system use adding cumulation which TDI CCD imaging exceeded the corresponding pixel horizontal and vertical offset to simulate camera imaging when stability of satellite attitude changes. This process is practicality. It can effectively control the camera memory space, and meet a very good precision TDI CCD camera in the request matches the speed of image motion and imaging .

7850-41, Poster Session

Design of ground-based physical simulation system for satellite-borne TDI-CCD dynamic imaging

Z. Sun, Changchun Institute of Optics, Fine Mechanics and Physics (China)

As it is known, the existence of image motion has a bad effect on the image quality of satellite-borne TDI CCD camera. Although many theories on image motion are proposed to cope with this problem, few ground-based simulations are done to justify the proposed theories, and consequently it becomes very necessary to test the validity of the theories by simulations on ground. And thus, in this paper, a ground-based physical simulation system for TDI CCD imaging is developed and specified, which consists of a physical simulation subsystem for precise satellite attitude control based on 3-axis air bearing table, and an imaging and simulation subsystem utilizing area-array CCD to simulate TDI CCD. The designed system could realize not only a precise simulation of satellite attitude control, whose point accuracy is above 0.1° and steady accuracy above 0.01°/s, but also an imaging simulation of 4-stage TDI CCD with 0.1s its integration time. This paper also gives the mathematical model of image motion of this system analogous with satellite-borne TDI CCD and detailed descriptions on the principle utilizing area-array CCD to take place of TDI CCD. Such a designed system could test the validity of image motion theory. It is shown that experiment results are in accordance with mathematical simulation, and that the image quality deteriorate seriously when the correspondence between the image velocity and signal charges transfer velocity is broken out, which suggest not only the validity of the system design but also the validity of image motion theory of TDI CCD.

7850-42, Poster Session

A big screen projection system based on reflective mirrors with Zernike polynomial surfaces

M. Liu, Harbin Normal Univ. (China)

The first mirror is concave to reduce the size of the second mirror and obtain high contrast ratio. The second mirror and the third mirror are convex to achieve a shorter projection distance and correct major aberration such as spherical aberration, coma aberration and distortion.

Experimental results show that at the same conditions the optical performance of projection system based on Zernike polynomial surfaces is superior to that based on aspheric surfaces, under the condition of F-number=2.5 and angle of view=1300, the MTF is more than 55% at 60lp/mm and distortion is less than 2.2%, which can satisfy the requirement of the high definition projection display system.

7850-43, Poster Session

A novel method for real-time edge-enhancement and its application to pattern recognition

H. Ge, Donghua Univ. (China)

Real-time optical image processing such as edge-enhancement has been widely investigated in recent years because of its unique property. As yet, the relevant study on it has mainly concentrated on filtering out low spatial frequency component via high-pass filter. Here we present a novel optical system for image edge-enhancement without the loss of useful information.

In the first part of the paper, the coupling gain coefficient g is redefined and deduced based on two-wave coupling theory. The variant of coupling gain coefficient g for different TL and r is analyzed.

In the second part, a novel optical system is proposed for image real-time edge-enhancement. It recycles the back signal to amplify the edge signal, which has the advantages of high throughput efficiency and brightness. The optical system is designed and built, and the edge-enhanced image of hand bone is captured electronically by CCD camera using the optical system.

Finally, the principle of optical correlation is demonstrated, 3-D correlation distribution of letter H with and without edge-enhancement is simulated, the discrimination capability I and the full-width at half maximum intensity (FWHM) are compared for two kinds of correlators. The analysis shows that edge-enhancement preprocessing can improve the performance of correlator effectively.

In summary, the paper redefine and deduce the coupling gain coefficient g, discuss the effect of TL and r on g . A novel optical system for edge-enhancement is proposed and built, the theoretical analysis are demonstrated by experiments. At last we demonstrate that optical correlation discrimination capability I can be improved greatly by using the technique of optical edge-enhancement preprocessing.

7850-44, Poster Session

Adaptive optics image restoration based on wavelets and curvelets

B. Chen, Guilin Air Force Academy (China)

In this paper, a novel deconvolution algorithm, based on both the wavelet transform and the curvelet transform (NDbWC). Using these two different transformations in the same algorithm allows us to optimally detect in tire same time isotropic features, well represented by the wavelet transform, and edges better represented by the curvelet transform. Adding a regularization penalization term avoid the presence of ring patterns around the edges which may appear when using multi-scale methods.The NDbWC algorithm is applied to the restorations of point source images of astronomical star and images of expanded object. Experimental results prove that this algorithm works well not only for short exposure images of point source star, but also for long exposure images of expanded object. The NDbWC algorithm works better than classical wavelet-regularization method in deconvolution of the turbulence-degraded image with low SNR.

7850-45, Poster Session

PSF estimation for defocusing blur of remote sensing image based on quantum back-propagation neural network

K. Gao, Beijing Institute of Technology (China)

During remote sensing imaging procedure, one of the main image blurring reasons is caused by defocusing of lens. The precondition of restoring the degraded image is to estimate point spread function (PSF) of the imaging system as precisely as possible. Because of the complexity of the degradation process, the transfer function of the degraded system is often completely or partly unclear, which makes it quite difficult to identify the precisely analytic model of PSF. Considering the similarity between the quantum process and imaging process in the probability and statistics fields, a novel algorithm is proposed by using multilayer quantum back-propagation neural network (QBPNN) trained with back-propagation learning to estimate PSF of the degraded imaging system. Different from the classical artificial neural network (ANN), quantum neuron of our proposed QNN neuron introduces 2 adjustable parameters of weight connection coefficient and phase coefficient during learning stage. By establishing different training sets, this method can overcome the limitation in the aspect of dependence on initial values and large amount of computation. Test results show that this method can achieve higher precision, faster convergence and stronger generalization ability comparing with the traditional PSF estimation.

7850-46, Poster Session

A real-time monitoring system for night glare protection

J. Ma, X. Ni, Zhejiang Univ. (China)

When capturing a dark scene with a high bright object, the monitoring camera will be saturated in some regions and the details will be lost in and near these saturated regions because of the glare vision. This work aims at developing a real-time night monitoring system. The system can decrease the influence of the glare vision and gain more details from the ordinary camera when exposing a high-contrast scene like a car with its headlight on during night . The system is made up of spatial light modulator (The liquid crystal on silicon: LCoS), image sensor (CCD), imaging lens and DSP. LCoS, a reflective liquid crystal, can modular the intensity of reflective light at each pixel as a digital device. Through modulation function of LCoS, CCD is exposed with sub-region. With the control of DSP, the light intensity is decreased to minimum in the glare regions, and the light intensity is negative feedback modulated based on PID theory in other regions. So that more details of the object will be imaging on CCD and the glare protection of monitoring system is achieved. In experiments, the feedback is controlled by the embedded system based on TI DM642. Experiments shows: this feedback modulation method not only reduces the glare vision to improve image quality, but also enhances the dynamic range of image. The high-quality and high dynamic range image is real-time captured at 30hz. The modulation depth of LCoS determines how strong the glare can be removed.

7850-47, Poster Session

A novel small area fast block matching algorithm based on high-accuracy gyro in digital image stabilization

P. Wang, Y. Zhao, Y. Fei, W. Zhu, G. Lang, L. Dong, Beijing Institute of Technology (China)

In electronic image stabilization, when we use high-accuracy Gyro to estimate the motion vector, the error is less than 3 pixels. So the true motion vector is in a small range near the estimate value. If we use common method of digital image stabilization(DIS), most of resource will be wasted. In order to improve the problem above, in this paper a novel small area fast block matching algorithm based on high-accuracy Gyro is proposed. First, estimate the motion vector from Gyro. Secondly, determine searching initial position using this motion vector, in that case the searching window reduces to the size of 7×7. And then we divide the image motion into three modes of small, medium and large based on the size of motion vector. Finally, we design the fast block matching algorithm for this three modes. For the small mode in which the error is less than 1 pixel, we search only 9 points close to the initial position. And in the medium mode, the error is between 1and 3 pixels. We improve four types of templates(square, diamond, hexagon, octagon), and then choose diamond and hexagon to form the core algorithm after comparing. The large mode is designed to avoid abnormal condition, in which the error is more than expected. Experimental result shows that this algorithm can speed up at least 70% over common method (such as NTSS, FSS, DSD) and maintain the same accuracy.

7850-48, Poster Session

A fast star image extraction algorithm for autonomous star sensors

X. Zhu, F. Wu, Changzhou Institute of Technology (China)

Star sensors have been developed to acquire accurate orientation information in recent decades. An important step to acquire attitude knowledge is to compare the features of the observed stars in the maps taken by a star camera with those of the cataloged stars. Before this step, it is required to extract star image from the star maps in advance. In this paper, a novel star image extraction algorithm is proposed. By scanning star map, the pixels brighter than the gray threshold are found and their coordinates and brightness are stored in a cross-linked list. Data of these pixels are linked by pointers, while other pixels are neglected. Therefore, region growing algorithm is used by choosing the first element in the list as a starting seed. New seeds are founded, and the last seed is deleted from the list. Next search continues until no neighboring pixels are in the list. At that time, one star image is extracted, and its centroid is calculated. Likely, other star images may be extracted, and then the examined seeds are deleted which are never considered again. A new star image search always begins from the first element for avoiding unnecessary scanning. The experiments have proved that the presented algorithm is efficient.

7850-49, Poster Session

The electronic image stabilization system based on MEMS gyroscope

G. Lang, Beijing Institute of Technology (China)

Digital image stabilization (DIS) is a new generation of image stabilization technology. It obtains the information of relative motion between frames of dynamic image sequences through the method of digital image processing.Motion compensation is completed according to the information and the steady video is displayed finally. Digital image stabilization can produce stable video output, and create favorable conditions for follow-up image processing, such as image mosaic, image enhancement, information fusion, object tracking, target recognition. Meanwhile, the DIS system has many advantages over other traditional image stabilization technology, including smaller size, easy to handle and design. As to the technology of electronic image stabilization, this paper provides a method that makes use of the palstance which the MEMS gyroscope is sensitive with to stabilize image sequences. A real-time electronic image stabilization system is designed. With LabVIEW an application program is designed to control the system's operation and realize the algorithm.The two MEMS gyroscopes' data is transferred via NI USB-6008, after the A/D transform, and input into the computer. Then we transform the palstance to the number of pixels at X and Y directions by using CCD's parameter. At the same time, image data that is garbed by CCD is transferred to the same computer through NI PXI-1409 frame grabber. We use the number of pixels which has been transformed to shift the current image towards X and Y directions and finish the image stabilization. The experimental results show that this method is effective.

7850-50, Poster Session

Measurement for opto-electronic conversion functions(OECFs) of digital still-picture camera

H. Wu, P. Li, Y. Wang, National Institute of Metrology (China)

The opto-electronic conversion function(OECF) is defined as relationship between input luminance and digital output levels for an opto-electronic digital image capture system. It is fundamental parameter to evaluate the performance of digital still-picture camera. An experiment device was set up to measure OECFs by using test charts with twelve neutral patches stepped in different visual density increments and a integrating sphere uniform illuminator. To determine the camera OECFs, images of the test charts were captured under controlled conditions for computer to calculate. For each trial, the mean digital output level shall be determined from a 64 by 64 pixel area located at the same relative position in each image. Several digital still-picture cameras were selected as test samples and their OECFs were different under a larger range of illumination. Besides, the dynamic range, linearity, incremental gain and SNR also can be calculated using the OECF test charts images data.

7850-51, Poster Session

A LED-array-based range imaging system used for enhancing 3D imaging

H. Wang, Institute of Intelligent Machines (China); J. Xu, D. He, T. Zhao, H. Ming, Univ. of Science and Technology of China (China); D. Kong, Institute of Intelligent Machines (China)

A LED-array-based range imaging system is proposed for three-dimensional (3D) shape measurement. The range image is obtained by time-division electronic scanning of the LED Time-of-Flight (TOF) range finders in array, and no complex mechanical scanning is needed. By combining with a low cost CCD/CMOS sensor for capturing the two-dimensional (2D) image, the proposed range imaging system can be used to accomplish a high quality 3D imaging. A sophisticated co-lens optical path is designed to assure the natural registration between the range image and 2D image. Experimental tests for evaluation of the imaging system performance are described. It was found that the 3D images can be acquired at a rate of 10 frames per second with a depth resolution better than 5mm in the range of 50 - 1000mm, which is sufficient for many practical applications, including the obstacle detection in robotics, machine automation, 3D vision, virtual reality games and 3D video.

7850-52, Poster Session

Gimbal displacement degrades the optical axis pointing precision in an image seeker

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Fine Mechanics and Physics (China)

Concentric glass spherical dome has been utilized in the image seeker successfully attributed to relieving the difficulty of the optical system design and fitting the ability of manufacture and testing method existed. However, optical ray has to change its direction when propagating through the dome because of refraction unless passing through the center of the dome, which demand gimbal point coincide with the center of the dome exactly. In fact, gimbal displacement can not be eliminated due to fabrication, assembly, vibration and so on, therefore the optical axis pointing errors is generated.

In this paper, the optical axis pointing errors in an image seeker resulting from gimbal displacement is demonstrated. The theoretical expression of the optical axis pointing errors is derived based on geometric optics and the errors dynamics is explored by numerical. Take a visible light image seeker as a case, the concentric glass spherical dome thickness of which is 8mm and the inner radius is 72mm, the optical axis pointing errors varying dynamically with look angle and gimbal displacement are shown in graph. When the gimbal displacement is 0.11mm, the maximum optical axis pointing error is 0.054mrad that is equal to the instantaneous field of view (IFOV) corresponding to the camera system whose focal length is 120mm and pixel size is 6.5μm at the look angle that is perpendicular to the gimbal displacement vector. Furthermore, with the gimbal displacement increasing, the optical axis pointing error increases linearly. The analyzed results provide a theoretical basis for the displacement range, which has to be carefully considered in the design phase.

7850-53, Poster Session

A new efficient method for color image compression based on visual attention mechanism

X. Shao, K. Gao, G. Ni, L. Lv, Beijing Institute of Technology (China)

One of the key procedures in color image compression is to extract its region of interests (ROIs) and evaluate different compression ratios. Human visual attention system has the capability of concentrating an attentive location in an input scene and selecting interesting visual information to process in the brain. A new non-uniform color image compression algorithm with high efficiency is proposed in this paper by using a biology-motivated selective attention model for the effective extraction of ROIs in natural images.

Firstly, the effective extraction of ROIs based on the Itti model is implemented by using the saliency-based model of bottom-up attention. For a color input image, the model computes feature maps for luminance, color and orientation contrasts at different scales.

Then some of the feature maps are selected to transform in their conspicuity maps achieved by a “difference of Gaussians” filter. The conspicuity maps are integrated together, in a competitive way, into a saliency map. Taking into account that there may be two or more salient objects in an image, a local iterative method is adopted instead of global strengthen.

At last, a winner-take-all (WTA) neural network scans the saliency map for the most salient location and returns its position. When the ROIs have been extracted and labeled in the image, the subsequent work is to encode the ROIs and other regions with different compression ratios via popular JPEG algorithm.

The final experiment results and quantitative and qualitative analysis show that our method has perfect performance comparing with other traditional color image compression approaches.

7850-54, Poster Session

3D position measurement using square marker for automatic mobile robot control

K. Ohmori, K. Sakamoto, Konan Univ. (Japan)

Our developed mobile robot can move itself to indicated goal point by an operator. A trial robot system provides us two indication methods. One is how to indicate as the operator put a marker as a goal point on the floor. The other is a remote control through closed-circuit television like the operator indicates the goal point on a video monitor. The mobile robot decides a route to the goal according to a behavior decision algorithm. The automatic mobile robot moves itself so as to shorten a distance from current residence to goal in consideration of a direction to the goal.

The authors have developed a mobile robot system using a commercial radio control car and an additional controller. This robot is made utilizing a frame of the radio control car and attached with a marker in order to measure its position on the floor. The radio controller is also reconstructed so as to operate a motion from Windows PC. The operator indicates a goal using the marker.

To control the mobile robot automatically, a camera fixed on the ceiling shots the markers which are robot and goal positions. The maker is used for three dimensional space measurement and it is invisible for human’s eyes. The maker card is designed like an operator can easy understand and recognize. The maker for 3-D measuring consists of a black square frame filled with some kind of a pattern. Thus 3-D measuring maker lacks the design sense. Then the authors utilize an infrared printing. Our designed card involves two printed symbol patterns which are a visible symbol and an invisible pattern. The visible symbol shows a function or a role as the man can easily understand. The invisible pattern is used for 3-D position recognition by the vision system. Moreover we draw the invisible marker pattern onto the body of a mobile robot in order that the operation system can also measure the position of a remote controlled robot. The human can only perceive visible symbol and color design of robot’s body. The camera only shots the invisible pattern because its lens is covered the infrared passing filter. The direction and distance from current residence to goal are calculated after the operation system recognizes markers and measures spatial positions. To get relation between markers, we used the software library which is called ARToolkit. ARToolkit involves a video capture, a 3D graphics generator, a spatial measuring and an overlay imaging for the creation of augmented reality applications. ARToolkit calculates three coordinate axes from a captured camera scene. The video tracking libraries calculate the real camera position and orientation relative to physical markers in real time.

Suppose that two 2D markers are laid on the floor. One is the marker which indicates a goal position. The rest shows the position of the mobile robot. The tracking library calculates each three coordinate axes on the two markers. Since our system program can detect a difference between two coordinate systems, we can know the direction and distance from current residence to goal. After a decision of the direction and distance to the goal, the automatic mobile robot judges a next action itself according to an algorithm of the motion behavior decision. After slight movement the robot again judges where a goal marker is on the floor. To perform a series of slight movement reaches the goal.

7850-55, Poster Session

Virtual vision system with actual flavor by olfactory display

F. Kanazawa, K. Sakamoto, Konan Univ. (Japan)

The authors have researched multimedia system and support system for nursing studies on and practices of reminiscence therapy and life review therapy. The concept of the life review is presented by Butler in 1963. The process of thinking back on one’s life and communicating about one’s life to another person is called life review. A therapist must keep a

record of sessions for inspection of methods and ways of valuation on reminiscence and life review therapy, but it is trouble for the therapist to record. The aim of research is to develop the support system which can automatically give an optimum topic and write down a session report about the activity. This life review is often assisted by aids such as videos, pictures, objects, archives and life story books, in order to make an opportunity of talking. We want to develop an omni-directional display system for cooperative activity on a round table to enable all-around viewing and unification of media contents by an electronic form. There is a famous episode concerning the memory. It is called as Proustian effects. This effect is mentioned on the Proust's novel as an episode that a story teller reminds his old memory when he dipped a madeleine in tea. So many scientists research why smells trigger the memory. The authors pay attention to the relation between smells and memory although the reason is not evident yet. Then we have tried to add an olfactory display to the multimedia system so as to the smells become a trigger of reminding buried memories.

Involuntary memory is a concept articulated by the French writer Marcel Proust in his novel "In Search of Lost Time." The most famous example is the "episode of the Madeleine." In this novel the narrator experiences an awakening upon tasting a madeleine dipped in tea. Involuntary memory is a conception of human memory in which cues encountered in everyday life evoke recollections of the past without conscious effort. Thus the smell is implicated with the memory. The authors developed a prototype olfactory display system. Our developed olfactory display system consists of an air blower, ten aromatic tanks and valves. Airs flow into the aromatic tanks from the blower and smell goes out through the valve. This ten valves system can output nine flavors because one air valve is used for making no smell so as not to block an air flow. Each valve is controlled by a signal from the Windows PC through RS-232C serial interface. Thus the olfactory display is a device that can generate smelled air with a trigger of reminding a forgotten memory, and deliver it to an observer's olfactory organ.

Generally, we can get the 3D information such as the position of an object using the stereovision measuring method. However it is possible to measure the 3D position by the captured scene of the single camera when the measuring system has already known the parameter such as an interval of eyes in this case. In this paper, the authors show the geometric analysis of single camera method and the results of measuring system. Assume that the pin-hole camera captures the face of a user and let define three space coordinate which shows the relations between the camera's position, a film image plane and an actual face position. The face in the real world translates to the perspective image of a user's face on the plane of a film. Assume that the points A, B, C and D show the interest points of the eyes and the points A', B', C' and D' on the image plane show the corresponding points of the eyes(A and B's or C and D's are both sides of eye). Moreover, the positions of eye ER and EL are the midpoints of the side AB and CD respectively. The followings are assumed at capturing: 1) The interval of eyes (the length of the side ELER) is R. 2) AB : BC : CD = k : 1 : k. The authors prove that it is possible to calculate a magnification between norm(vector OX) and norm(vector OX') (Here X is indication instead of A, B or C). Then it is possible to measure the distance from the camera to the eye and to determine the direction using the camera image captured by the single camera.

The detecting process and image processing go along the step as follows. The image processing software firstly determines the regions of the observer's face and hands from the video frame image of the single camera using the skin color detection. At the skin detection, we utilized the image processing using the HSV space. Secondly it needs to choose only the face area from detected regions. This process is performed by the hair-color detection using the RGB space and the histogram approach. The part of hair is attached to the face area and thus it enables the system to choose the region of the face. And the parts of black colors are extracted from the selected face region. Next, parts of the hair are eliminated. This operation is the image processing using the RGB space. Countering the numbers of connected pixels with black colors, the eyes and eyebrows are only extracted. Finally, it chooses the eyes from this image after analyzing the alignments of parts on the face and the intervals between the parts. If we get the positions of eyes then it is easy to estimate the nose position.

7850-56, Poster Session

Laser range profile of the sphere

Y. Li, Z. Wu, Xidian Univ. (China)

The range profile is studied first in the microwave band. With the advent of the lidar technology, the range profile is studied from microwave band to the laser band, which is the laser range profile (LRP). The outstanding feature of LPR is that it can obtain the 3-D shape and the range information of the target by one pulse without optical scanning system. In this paper, Laser range profile theory and simulation is investigated. Laser range profile simulation is studied based on the theory of beam scattering by rough object, pulse wave scattering theory and the radar equation, the calculated formula of laser range profile is obtained. This equation is, in part, dependent upon the target's scattering strength which is quantified by its radar cross section. Consider the engineering application, the pulse laser radar equation with narrow pulse illumination is found. As examples, the laser range profile simulations are done for the sphere. It is indicated that the influence of pulse width, beam parameters, transmit-receive angle and target roughness on the simulation results is also analyzed. The peak position of laser range profile curve act in accord with radial dimension, and the peak value is contain the information of geometric shape, viz. the peak length of laser range profile curve act in accord with radius for the sphere and the shape of range profile curve act in accord with lateral surface profile. This paper is offer theory bases and simulation method for abstraction and identification target feature on laser waveband.

7850-57, Poster Session

System simulation of two-dimentional synthetic aperture imaging ladar

N. Yi, Z. Wu, Xidian Univ. (China)

For conventional imaging laser radars, the resolution of target is constrained by the diffraction-limited which includes the beamwidth of the laser in the target plane and the telescope's aperture. Synthetic aperture imaging Ladar(SAIL) is a new imaging technique which employs aperture synthesis with coherent laser radar to overcome the limit. Theoretically, the resolution is determined by the total frequency spread of the source and is independent of range. With the measurement of phase history of returned signals throughout the synthetic-aperture time, we can achieve fine resolution in long range.

We employ a linear frequency chirp as the transmitted signal, and the echo signal is the heterodyne of local oscillator(LO) path and signal path.However, the chirp bandwidth of laser is so large that we cannot find an analog-to-digital converter whose digitizing sample meets Nyquist limit. We adopt five paths, the target signal path, the target LO path, the reference signal path, the reference LO path, and the hydrogen cyanide(HCN) path in the system. The target paths are used to receiving the chirp bandwidth, the reference paths generating an intermediate frequency(IF) and reducing the sampling rates, the HCN path helping us to synchronize the starting frequency of each pulse.

Recent synthetic aperture imaging Ladar (SAIL) demonstrations are performed at laboratories, so the detection range and velocity are small. Here, the long range system simulation is carried out with actual parameters, whose results show that the SAIL can support better resolution.

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7850-58, Poster Session

The application of principal component analysis in sequence image hiding

W. J. Shuai, S. Nie, S. T. Feng, Nanjing Normal Univ. (China)

Principal component analysis(PCA) has an advantage over data compression and it's often used to reduce the redundancy of data information. In this paper, a hiding method is proposed to store vast quantities of information based on PCA. It's different from previous work, which embedded secret images into the carrying image directly.

In order to hide sequence images of objects in a carrying image, eigenimages are obtained by using principal component analysis method. We can take advantage of the most important eigenimages to reconstruct the objects. Then we project the object images onto the eigenimages to obtain a set of decomposition coefficients. The decomposition coefficients are used as secret keys to ensure information security. Wavelet transform is frequently used in information hiding because of its multi-resolution and the secret images can be stored in the low-frequency domain. By using a hiding algorithm, wavelet coefficients of eigenimages are embedded into the wavelet domain of the carrying image.

When the hiding information need be extracted, we can obtain the eigenimages by using the opposite approach with the hiding approach. Based on the relationship of extracted eigenimages and decomposition coefficients, a series of images are reconstructed.

The proposed method does not store all of the objects directly, but store the eigenimages which contain most of the information. The experimental results show that the features of objects are effectively embedded into the carrying image, and the proposed algorithm has a high capacity.

7850-59, Poster Session

A novel method for eliminating the ICA uncertainties in blind source separation

J. Zhang, S. T. Feng, S. Nie, Nanjing Normal Univ. (China)

Independent Component Analysis (ICA) is a signal analysis for blind source separation (BSS); it can estimate original source signals using only the information of the mixed signals observed in each input channel. In view of the strong BSS capability of ICA, this technique is utilized in watermark, separating source images from watermarked and reference images. But as the lack of priori information, the blind uncertainty of separated signals, such as amplitudes, phase and orders remain unsolved.

In this paper, firstly, we analyze the reasons of the ICA blind uncertainty in the process of BSS. Since the ICA technique chooses maximization of non-Gaussian as the criterion to distinguish whether the separated signals is an independent component, that is, the separated signals are arranged in order of non-Gaussian. But, on account of non-Gaussian proximity between input signals, the original watermark methods based on ICA failed to solve the uncertainty problems. By observing non-Gaussian difference of source signals, also with analysis of observed and estimated signals, in this paper, a novel method for the revision of ICA estimation was proposed based on criterion of separated signals non-Gaussian order. In virtue of watermark pre-processing (time-frequency transformation) and the unique selection of frequency embedding region in content image, the extent of separated signals non-Gaussian was increasing remarkably. Therefore, the blind uncertainty of ICA estimation was eliminated effectively. This improved ICA watermarking method was applied to the frequency domain watermarking and achieved blind watermark extraction.

Experimental results show that the proposed algorithm has good robustness against the various watermark attacks of Checkmark benchmarking software.

7850-60, Poster Session

Brightness adaptive algorithm for image mosaic seamless fusion

H. Yu, Beijing Institute of Technology (China) and Huangshi Institute of Technology (China)

When digital images are mosaicked, brightness difference between to-be-mosaicked images will result in mosaic artifacts in the final mosaicked image due to non-uniformity caused by optical system vignetting as well as gain changes automatically caused by scene changes. An brightness adaptive algorithm for image mosaic seamless fusion has been studied in this paper. The process of the method are as follows;1) estimating significant degree of stitching traces according to brightness differences between to-be-mosaicked images;2) adjusting the brightness of the image to be mosaicked in order to reduce the brightness difference untill stitching traces can not be perceived by human visual system;3)blending the images to be mosaicked based on based on multiscale analysis method. The experiment indicates that the method is adaptive to adjust brightness for seamless blending based on multiscale analysis. Mosaic image quality can meet the requirements of human vision.

7850-61, Poster Session

An image enhancement effect objective assessment method based on visual information fidelity

X. Liu, Huangshi Institute of Technology (China)

Assessment of image visual quality is of fundamental importance to numerous image and video processing applications.

Visual information fidelity is a novel criterion that is based on modeling of natural scene statistics,image distortion and the human visual distortion. Traditionally, image QA algorithms interpret image quality as fidelity or similarity with a "reference" or "perfect" image. we apply the VIF method on image enhencement effect which takes distorted image as "reference" image instead of "perfect" image to assess the quality of enhenced image.It provides clear advantages over the traditional approaches because VIF index is combined with HVS features under certain conditions. In particular, it can be measured only rely on the original image and enhenced image. We validate the performance of our method with an extensive subjective study to show that it outperforms current methods in our testing.

7850-62, Poster Session

Signal processing and correction implementation for modulation transfer function test bench

Y. Chen, X. Chen, C. Xiang, W. Shen, Soochow Univ. (China)

The signal processing flow for the MTF test bench that is based on Fourier analysis method is presented.

The signal processing flow mainly consists of three parts that are Fourier analyzing, background correction and system attenuation elimination. The center of the pinhole area is recognized automatically and the line spread function (LSF) of both sagittal and tangential directions is calculated. Second-order fast Fourier transform is executed so that a primary two-direction MTF result is gained. Either auto Fourier-domain background correction or manual time-domain manual background correction is executed. The attenuation of the tested MTF result that is mainly caused by the effort of the detector and pinhole is eliminated finally.

A commercially available 50-mm plano-convex audit lens is tested as the sample to validate the accuracy of the signal processing flow of the MTF test bench. The test error is below 0.04 under 200lp/mm.

7850-63, Poster Session

An improved centroid detection method based on higher moment for Shack-Hartmann wavefront sensor

A. Xia, C. Ma, Xi'an Institute of Optics and Precision Mechanics (China)

The accuracy of the Shack-Hartmann wavefront sensor (SHWS) for measuring the distortion wavefront is mainly dependent upon the measurement accuracy of the centroid of the focal spot. Many methods have been presented to improve the accuracy of the wavefront centroid measurement by weakening the influence of various noises, such as the photo noise, the read-out noise, the background noise, unevenness and instability of the light source, etc. In general, these methods mainly use first moment centroid algorithm to calculate the centroid in the whole sub-aperture. In this paper, we present an improved centroid measurement approach that calculate the centroid of the focal spot more precisely using the higher moment centroid method in an optimized detection window. Firstly, we obtain the approximate center of the focal spot by first moment centroid algorithm in the whole sub-aperture. Secondly, we set up a rectangular window including the focal spot, whose center is just the obtained approximate center. Finally, we again calculate the centroid of the focal spot by higher moment centroid algorithm in the rectangular window. Based on the improved method, the effects of various noises out of the optimized detection window are almost eliminated; furthermore, the noise influences in the optimized detection window are also weakened due to the more contributions of the focal spot intensity. The experimental results demonstrate that the precision, repeatability and stability of focal spot centroid are more prominent than the results obtained via other commonly centroid methods.

7850-64, Poster Session

Implementation of realistic image rendition algorithm based on DSP

L. Lv, K. Gao, G. Ni, L. Zhou, X. Shao, Beijing Institute of Technology (China)

Realistic image rendition is to reproduce the human perception of natural scenes, where "realistic" means providing machine vision with the ideal images according to human visual system. With the algorithm proper processing, the camera system can provide better than human-observed imagery particularly during poor visibility conditions, such as rain, fog and snow. In this paper, the developments of realistic image rendition are investigated, human visual system structure and characteristics are described in detail and some excellent algorithms are studied and discussed, especially the classical Retinex series algorithms. Retinex is an image enhancement algorithm that simultaneously provides high dynamic range compression contrast and color constancy of an image. It has been used widely in various applications ranging from aviation safety to general purpose photography.

Retinex algorithm contains a large number of complex computations and data transfers, so it is difficult to achieve with general purpose processors. In this paper we discuss a design of a digital signal processor (DSP) implementation of the single scale monochromatic Retinex. The target processor is a Texas Instruments TMS320DM642, a 32-bit fix floating point DSP which is clocked at 720 MHz. This DSP hardware platform designed is of low power consumption and powerful video image processing capability. PAL video data streams are captured by camera, and transfered and stored in external memory, then Retinex processed with DSP, at last displayed on a standard monitor. In order to achieve the real-time processing performance, we discuss some feasible optimization measures. In the end, the performance of the algorithm executing on DSP platform is shown.

7850-65, Poster Session

Research on signal processing techniques for a chirped amplitude modulation imaging laser radar

Q. Wang, Y. Wang, Beijing Institute of Technology (China)

Due to some significant advantages such as high space resolution, three-dimensional imagery (including intensity image and range image) acquiring, and so on, an imaging laser radar is helpful to improve the correct recognition ratio being as a sensor in a target recognition system. A chirped amplitude modulation imaging ladar is based on the frequency modulation/continuous wave (FM/cw) technique. The target range is calculated by measuring the frequency difference between projected and returned laser signal. The design of a signal processing system for a FM/cw imaging ladar is introduced in this paper, which includes an acquiring block, a memory block, a communication block, and a FFT processor. The performance of this system is analyzed in detail in this paper.

7850-66, Poster Session

Fusion of 3D imaging ladar and binocular stereo vision for improved 3D measurement

H. Jiao, National Univ. of Defense Technology (China)

3D imaging ladar and binocular stereo vision are two typical 3D scene geometric information measurement methods. But these methods have their own limitations such as ladar has lower spatial resolution and stereo vision has poor disparity maps estimation in long distance. To overcome these limitations we introduce a fusion of two 3D measurement techniques: 3D imaging ladar and binocular stereo vision. By mapping the ladar-depth images to stereo images the correspondence between ladar images and stereo camera pair are found so the ladar depth measurements can be linked to the image pairs. Also in the same framework a method is developed to constrain stereo matching algorithm and make it time efficient. Experiment results show that in this way higher spatial resolution is gained than by only using the ladar and higher quality dense stereo disparity maps than using standard stereo methods.

7850-67, Poster Session

Experimental research for broadband spatial heterodyne spectroscopy

Y. Feng, Xi'an Institute of Optics and Precision Mechanics (China)

Spatial heterodyne spectrometers have been used in multiple scientific studies since their invention and early development. Broadband spatial heterodyne spectrometers also have the advantages of large etendues, high spectral resolving powers, and high data collection rates as tradational spatial heterodyne spectrometer. Basic theory, design and performance parameters, breadboard experiment for a broadband, high-resolution spatial heterodyne spectrometer are reported. The experimental spatial heterodyne spectrometer achieves continuous spectral coverage of 450nm to 650nm with a design resolution 0.325cm-1. There are three aims for the breadboard

experimental research. Firstly, it will be demonstrated that broadband spatial heterodyne spectrometer have the advantages of wide spectral coverage and high spectral resolving power simultaneously; secondly, the optical tolerances of the system will be tested; thirdly, to examine the effects of the mask used to select spectral orders on the recovered spectral radiance. Two dimensions interference data procession will be mentioned.

7850-68, Poster Session

Fuzzy synthetic evaluation method for laser jamming to CCD imaging performance

Y. Xu, Electronic Engineering Institute (China)

With the wide application of CCD (Charge Coupled Devices) in many fields and the rapid development of researches on laser jamming or destructing effect, how to evaluate the laser jamming effect reasonably has become more and more significant. When CCD is jammed by laser, its imaging performance will be influenced too. The influenced imaging performance will lead to low detection or recognition ability and furthermore will influence reconnaissance or tracking ability of the whole imaging system. Therefore, the effect of laser jamming to CCD can be evaluated from the aspect of imaging performance. However, evaluation of laser jamming to CCD can be a synthetic process which combines different factors. These factors usually have the characteristics of uncertainty and complexity. Hence, research on fuzzy synthetic evaluation method of laser jamming to CCD is feasible and necessary. The advantages and disadvantages of traditional evaluation methods for laser jamming effect are analyzed and the feasibility of fuzzy synthetic evaluation method is explained. Process of fuzzy evaluation is shown and evaluation parameters like factor set, evaluation set, membership function and weight function are chosen. Combined with different parameters of CCD imaging performance, fuzzy synthetic evaluation method is proposed. In the method, several performance evaluation parameters are calculated, like signal to noise ration (SNR), contrast, definition, information, luminance and uniformity. Hence, single factor evaluation result is obtained. Then the evaluation parameters are normalized respectively and suitable weights are selected. Through fuzzy relation matrix, single factor evaluation results are synthesized and analyzed. Under different jamming conditions like different powers, divergence angles and distances, the fuzzy synthetic evaluation results are obtained. Experimental results show that this method not only can overcome limitation of single factor evaluation, but it also can reflect the effect of laser jamming to CCD imaging performance.

7850-69, Poster Session

Simulation of laser jamming and its influence on CCD imaging performance

Y. Xu, Electronic Engineering Institute (China)

With the characteristics of small volume, light weight, high sensitivity and resolution, CCD has been widely used in many fields such as reconnaissance, guidance, identification and so on. However, CCD can be easily jammed or damaged when it is illuminated by laser and its imaging performance will also be influenced. The influenced imaging performance will lead to low detection or recognition ability and furthermore will influence reconnaissance or tracking ability of the whole imaging system. In practical working environment, CCD can be influenced by many other factors under laser illumination and some of these factors are difficult to analyze. Therefore, research on the simulation of laser jamming and its influence on CCD imaging performance will be quite significant.

Firstly, the situation of researches on laser jamming in imaging detectors is analyzed and there are few researches in literature references which are aimed at changes CCD imaging performance under laser illumination. Then saturation effect of CCD when it is illuminated by laser is briefly introduced and this effect will be useful for further simulation of laser jamming. Meanwhile, combined with characteristics of CCD, diffraction limited point spread function (PSF) is applied to analyze the saturated laser spot in image system and the process of simulation is also demonstrated. Hence, simulated jammed image is obtained and it is compared with actual jammed image. Finally, under different laser jamming conditions, like different powers, divergence angles and distances, imaging performance parameters of both simulated and actual images are analyzed, such as signal to noise ratio (SNR), gray variation, definition, uniformity and so on. Experimental results show the feasibility and validity of laser jamming simulation. As a result, major factors of laser jamming influence on CCD imaging performance are summarized. Moreover, changes of imaging performance parameters can provide useful references for further evaluation of laser jamming effect.

7850-70, Poster Session

Interactive image segmentation by constrained spectral graph partitioning

H. Zhang, Tianjin Univ. (China); J. He, Tianjin Univ. of Technology and Education (China)

A new interactive image segmentation algorithm is presented which can deal with incorrectly labeled user constraints. Analogous to image segmentation being formulated as spectral graph partitioning, such as normalized cuts, we formulate interactive image segmentation as a constrained spectral graph partitioning problem. Furthermore, we prove it equals a supervised classification problem, where the feature space is formed by rows of the eigenvector matrix that is computed by normalized cuts based spectral graph analysis. v-SVM (support vector machine) is preferred as the classifier due to its good generalization performance as well as clarity and simplicity on parameters. Some incorrect labels in user constraints can be tolerated by being identified as margin errors in v-SVM. This algorithm can handle single labeled interactive segmentation due to the capacity of v-SVM in single class classification. Experiments on real color images are reported.

7850-71, Poster Session

An algorithm for computing extrinsic camera parameters for far-range photogrammetry based on essential matrix

H. Cai, K. Li, Beijing Institute of Technology (China); M. Liu, Beijing Institute of Technology (China) and Beijing Technology and Business Univ. (China); P. Song, Beijing Institute of Technology (China)

In this paper, we present a technique for accuracy stereo photogrammetry for observation and measurement of the drop point of a high speed object. Two digital cameras are set on a ground base line so that the space between the centers of the two cameras is almost 1 km. Due to large distance and other practical problem, we can't measure the actual location and direction of the two cameras. We set a large planar landmark whose geometry information is precisely known which can image clearly in both two cameras. We can use Zhang's method to obtain the intrinsic parameters in the lab. The landmarks and epi-polar constraint can be used to construct a minimum estimation of the essential matrix. From the essential matrix, the rotation and translation parameters can be easily computed. The main contributions of this paper are two fold. One, we development and present theoretical analysis that how to get an accuracy solution for location and orientation of the cameras in large scale scene. Second, we use this method in our project and the measurement error of the stereo vision system whose surveillance area is about 80000 square meters is below 2 m.

7850-73, Poster Session

Research on automatic multispectral images synthesis of space camera

X. Wu, J. Liu, H. Zhou, Changchun Institute of Optics, Fine Mechanics and Physics (China)

Multilinear CCD Sensor was often used on space cameras to obtain multispectral images with each line representing different band channels. However images of different band channels obtained at the same time didn't coincide as there were spaces between lines. Pixel numbers to be adjusted between images of different channels varied when the space camera worked by swaying forward or adjusted row transfer period to compensate image movement. An automatic muti-spectral images synthesis algorithm of space camera was put forward on the basis of analysis of such phenomenon. In this algorithm a new evaluation function was used to determine pixel numbers to be adjusted and the image regions of each band channel to be clipped. In this way images of different band channels could be synthesized automatically to obtain an accurate colorful image. This algorithm can be used to dispose a large mount of images from space camera directly without any manual disposal so that efficiency could be improved remarkably. In validation experiments the automatic muti-spectral images synthesis algorithm was applied in synthesis of images obtained from outside scene experiment of a muti-spectral space camera with AT71547 as the sensor. Result of validation experiments proved that the automatic muti-spectral images synthesis algorithm can realize accurate muti-spectral images synthesis of space camera and the efficiency can be improved markedly.

7850-74, Poster Session

Depth measurement using monocular stereo vision system: aspect of spatial discretization

X. Zheng, C. Li, X. Zhao, J. Chen, Soochow Univ. (China)

The binocular stereo vision system widely used in 3D reconstruction e.g. for tracking and surveillance, could be too large for some applications. In some cases there is neither enough room for the required length of base line, a distance between two cameras. In these cases, a monocular stereo vision system, consisting of a single camera with controllable focal length, can be a suitable solution. Images obtained for at least two focal lengths are fused to obtain a depth perception of the 3D space. Applying the monocular stereo vision system for 3D reconstruction, must consider effects caused by digital camera for instance spatial discretization.

There are two possible methods to make the monocular stereo vision system based on bifocal imaging. First one supposes that the distance between the target object and the camera sensor plane is constant and lens moves. The second method assumes that the lens position is constant and the sensor plane moves in respect to the target.

In this paper mathematical modeling of these two approaches is presented. We focus on iso-disparity surfaces to define the discretization effect on the reconstructed space. These models are implemented and simulated on Matlab to verify them. Then a physical experiment is performed to validate these models and simulation.

The analysis is used to define application constrains and limitations of these methods. The results can be also used to enhance the accuracy of depth measurement.

7850-75, Poster Session

Study on image registration and spectral construction based on eight-channel imaging spectrometer

J. Wang, N. Liao, Y. Lian, Z. Liu, Beijing Institute of Technology (China)

This paper describes an eight-channel imaging spectrometer based on the narrow band multi-spectral imaging technology, which can obtain spectral information and spatial information simultaneously. After acquiring eight images in real time, the spectrometer processes image registration and spectral construction, and finally the color image is compounded. Focus is on methods of image registration and spectral construction. The experiment indicated the point mapping and the cubic spline interpolation are effective, and the color image is close to the real image. The system has high spatial resolution, strong real-time character and can be widely used in the field of moving target recognition.

7850-76, Poster Session

Spectral images browsing with JPEG2000

L. Ma, Shenyang Institute of Automation (China)

Spectral imaging technology have been used mostly in remote sensing, but have recently been extended to new area requiring high fidelity color reproductions like telemedicine, e-commerce, etc. These spectral imaging systems are important because they offer improved color reproduction quality not only for a standard observer under a particular illuminantion, but for any other individual exhibiting normal color vision capability under another illuminantion. A possibility for browsing of the archives is needed.

In this paper, the authors present a new spectral image browsing architecture. The architecture for browsing is expressed as follow:

(1) The spectral domain of the spectral image is reduced with the PCA transform. As a result of the PCA transform the eigenvectors and the eigenimages are obtained.

(2) We quantize the eigenimages with the original bit depth of spectral image (e.g. if spectral image is originally 8bit, then quantize eigenimage to 8bit), and use 32bit floating numbers for the eigenvectors.

(3) The first eigenimage is lossless compressed by JPEG2000, the other eigenimages were lossy compressed by wavelet based JPEG2000 algorithm.

For experimental evalution, the following measures were used. We used PSNR as the measurement for spectral accuracy. And for the evaluation of color reproducibility, E and ES-CIELAB were used.here standard D65 was used as a light source.

To test the proposed method, we used FOREST and CORAL spectral image databases contrain 12 and 10 spectral images, respectively. The images were acquired in the range of 403-696nm. The size of the images were 128*128, the number of bands was 40 and the resolution was 8 bits per sample.

Our experiments show the proposed compression method is suitable for browsing, i.e., for visual purpose.

7850-77, Poster Session

The research on image encryption method based on parasitic audio watermark

P. Gao, Y. Zhu, Nankai Univ. (China)

In order to improve image encryption strength, an image encryption

method based on parasitic audio watermark was proposed in this paper, which relies on double messages such as image domain and speech domain to do image encryption protection. The method utilizes unique Chinese phonetics decomposition algorithm to separate embedded audio information into prosodic phrase, obtains complete element set of initial consonant and compound vowel that reflects audio feature of statement. By sampling and scrambling the initial consonant and compound vowel element, synthesizing them with image watermark, and embedding the compound into the image to be encrypted in frequency domain, the processed image contains image watermark information and parasitizes audio feature information. Experiments show that any decryption method in image domain or speech domain could not break encryption protection, and image gains higher encryption strength and security level by double encryption.

7850-78, Poster Session

Vision measurement method for impact point in large planar region

M. Liu, Beijing Institute of Technology (China) and Beijing Technology and Business Univ. (China); K. Li, H. Cai, P. Song, Beijing Institute of Technology (China)

It is obvious that vision measurement is an effective method for precise location of impact point. To achieve higher calibration accuracy, the measurement area must be covered fully by calibration objects. So the traditional method of camera calibration is not applicable to location of impact point in large area. In this paper, we propose a new method to locate precisely the impact point in remote large area.

On the basis of summarizing the methods of camera calibration, a new method of direct geometric solution (DGS) based on calibration objects is proposed. It is required to establish some beacons in particular position with equal height in measurement area. Adjust camera carefully to ensure that the measurement plane is orthogonal to the image plane of the camera. The DGS model which is used to calculate the coordinates of points in measurement area is built with the pinhole imaging model and the coordinates of calibration objects. The comprehensive error caused by measurement error was simulated in MATLAB with DGS model, and the experiment of actual measurement was done. The experiment data was processed respectively by the DGS model and the DLT (direct linear transformation) model. The results show obviously that both the accuracy and error stability of DGS are better than ones of DLT. The average relative error of DGS in this experiment is 0.5%. The DGS model is better than the DLT model in locating the impact point in remote large area.

7850-79, Poster Session

3D modeling method for computer animate based on modified weak structured light

H. Xiong, Guangdong Univ. of Technology (China)

A simple and affordable 3D scanner is designed in this paper. Three-dimensional digital models are playing an increasingly important role in many fields, such as computer animate, industrial design, artistic design and heritage conservation. For many complex shapes, optical measurement systems are indispensable to acquiring the 3D information. In the field of computer animate, such an optical measurement device is too expensive to be widely adopted, and on the other hand, the precision is not as critical a factor in that situation. In this paper, a new cheap 3D measurement system is implemented based on modified weak structured light, using only a video camera, a light source and a straight stick rotating on a fixed axis. For an ordinary weak structured light configuration, one or two reference planes are required, and the shadows on these planes must be tracked in the scanning process, which destroy the convenience of this method. In the modified system, reference planes are unnecessary, and size range of the scanned objects is expanded widely. A new calibration procedure is also realized for the proposed method, and points cloud is obtained by analyzing the shadow strips on the object. A two-stage ICP algorithm is used to merge the points cloud from different viewpoints to get a full description of the object, and after a series of operations, a NURBS surface model is generated in the end. A complex toy bear is used to verify the efficiency of the method, and errors range from 0.7783mm to 1.4326mm comparing with the ground truth measurement.

7850-80, Poster Session

A dynamic model of plants' blossom based on L-system

R. Zhang, W. Zhang, Y. Zhu, Guilin Univ. of Electronic Technology (China)

The article study L-system theory to modeling a visualization system which can expresses plants' growth and blossom by the Delphi language. This is according to growth process in the topology evolution and fractal geometry shape of plant, which extracts plant's growth rules to establish blossom models. The simulation is aim at modeling dynamic procedures, which can produces the lifelike plant images and demonstrates animations of growth processes. This new model emphasizes various parts of plant between space's and time's relationships. This mathematical models use biology to produce plant compartments of blossoms on growth of plants with correct images which ranges from time to time, and provides the lifelike continual growth sequence and through the natural principles to imitates and controls plants' blossoms and plant's diseases.

7850-81, Poster Session

Effects of laser beam divergence angle on the airborne lidar positioning errors

L. Jiang, T. Lan, Y. Zhang, G. Ni, Beijing Institute of Technology (China)

Laser beam divergence angle is one of the main factors that affect positioning accuracy of airborne LIDAR. The existence of the laser divergence angle will lead to pulse broadening of echo signal detected by rangefinder, thereby increase the uncertainty of electronics timing precision and thus reduce the signal noise ratio. These will cause ranging error, and affect the coordinate accuracy of laser point. Taking linear scanning airborne LIDAR for example, this paper qualitatively and quantitatively analyzed the influence of laser beam divergence angle on the three-dimensional coordinate error of laser point. The research results showed that, no matter what kind of terrain surface, the positioning errors of airborne LIDAR increased with laser beam divergence angle. When the laser beam divergence angle is constant, positioning errors of airborne LIDAR also have relationship with scan angle and slope angle. The influence of scan angle on positioning errors was not really monotonically increasing, but also affected by surface terrain. For downhill of slope surface, when the sum of scan angle and slope angle was less than 90°, the positioning error of laser point increases with the increase of scan angle. For uphill of slope surface, when the scan angle was more than slope angle, the positioning error of laser point increased with the increase of scan angle. These results have an important guiding significance on real flight operations.

7850-82, Poster Session

Parallel computing rendering in specific remote sensing image processing

B. Mao, B. Xue, X. Chen, G. Ni, Beijing Institute of Technology (China)

For the more in-depth scientific research, remote sensing images often contain huge amounts of details. Therefore, remote sensing image always has features with multi dimensions of information and huge size. In order to obtain a more accurate picture of ground surface, the remote sensing image processing has several steps with the aim of better image restoring and refining of the image information.

Frequently this type of image processing faced to several issues such as calculating slowly or huge consume in resources. Therefore, the necessity of the parallel computing rendering in remote sensing image processing is essentially important. This paper proposed a parallel computing which did not require the original algorithm rewriting. This method allocated the original approach efficiently to the multiple computing cores in the processing computer. It would fully use the computing resources, reduce calculating time and can turely guarantee the integrity of the remote sensing image data.

In order to validate the feasibility of the method, this paper applied the parallel computing rendering into the simulation of remote sensing image processing algorithms, and conducted several experiments. We intergrated the parallel computing into the core of the original algorithm which could adapt data segmentation. The experimental results showed that the resulting computational efficiency improved. The number of computer calculating core is proportional related to the reduced rate of computing time. At the same time, the computing results were indentical to the original resluts.

7850-83, Poster Session

Analysis of adaptive optics imaging for extended object based on the frequency spectrum entropy

Z. Wu, H. Yang, Huaihai Institute of Technology (China)

The adaptive optics (AO) technique based on the image sharpness function appears more promising than the conventional AO for the imaging correction of extended object. The success of this technique depends on an appropriate system performance metric and a suitable control algorithm. Some classical image quality criteria are often used as system performance metric in imaging correction of extended object. But most of image quality criteria are not considering the existence of imaging noise. Practically, the observed object images are degraded not only by the atmospheric turbulence but also imaging system noise. The noise in image will affect the value of image quality criteria and further affect the correction capability of adaptive optics system.

From the imaging theory of Fourier optics, we know that the sharpness of an image is closely related to the high frequency content of the image, which corresponds to the image edge details. A clearer image often includes more high frequency content and the total energy is also relatively higher. The noise of image presents relatively small value of frequency in the frequency domain and this interference margin has less weight than that of in time domain. Therefore, the effect of noise on correction capability of adaptive optics system can be mitigated when the frequency spectrum entropy is used as the system performance function.

Based on stochastic parallel gradient descent algorithm and the frequency spectrum entropy, the correction capability of AO system is investigated through different images and different turbulence strength wave-front aberrations. Numerical simulation results verified the method is effective and the correction capability of adaptive optics is improved obviously.

7850-84, Poster Session

High dynamic range multispectral imaging using liquid crystal tunable filter

B. Tan, N. Liao, Y. Lin, L. Tian, Beijing Institute of Technology (China)

Using conventional camera to capture natural scenes with high dynamic range generally results in saturation as well as underexposure, because of their limited dynamic range. And moreover, the image of conventional RGB camera with RGB color filter lacks color accuracy. We present a promising solution - a high dynamic range multispectral camera placing a Liquid Crystal Tunable Filter (LCTF) between lens and gray level imaging sensor. For each bands, gray level images with different exposures are acquired separately and are combined into a multispectral high dynamic range image afterwards. The high dynamic range multispectral image has higher color accuracy and greater dynamic range than the images of the traditional RGB camera.

7850-85, Poster Session

Moment characters: Fourier descriptor applied in optoelectronic drop image recognition

Q. Song, C. Zou, Beijing Univ. of Posts and Telecommunications (China)

The droplet shape embodies the fundamental intrinsic properties of droplet that can be used to identify the characteristics of liquid types as an important way. Moment characters- Fourier descriptor, unite of Moment characters and Fourier descriptor, is a tool that can be used in shape recognition and especially be suitable for image processing in real-time.Data of the droplet profile changing is collected through the CCD camera in the process of droplet growth real-time and stored in image processing system. A series of preprocessing like image enhancement, image segmentation are used to process those target images, and then the shape of the graph boundary is refined by contour tracing. Moment characters sequence is calculated to represent the shape. The sequence is given Fourier counterchanges and normalized. At last, those treated feature descriptors sequence descriptor will not varied with rotation, scale and invariant. The feature descriptor carrying the liquid image features and unique information of liquid, so by distinguishing the differences between test liquid and sample liquid, the kind of test liquid can be known.

7850-86, Poster Session

The optimum configuration of the sub-aperture array based on compressed sensing

H. Wang, Y. Jiang, L. Liu, Y. Zhang, BeiHang Univ. (China)

Optical aperture synthesis imaging technology is one of optical imaging technology methods for high observation resolution. It brings the high astronomical observation resolution and research into reality. The optimum configuration of the sub-aperture array is the key of optical aperture synthesis imaging technology. Compressed Sensing(CS) theory is a novel data collection and coding theory under the condition that signal is sparse or compressible. This paper reviews the theoretical framework and the key technical problems of compressed sensing and introduces the latest developments of signal sparse representation, design of measurement matrix and reconstruction algorithm. Then this paper also reviews several open problems in CS theory and discusses the existing difficult problems . In the end, the application fields of compressed sensing are introduced. This paper mostly studies the

optimum configuration of the sub-aperture array, advances an extract method to the optimum configuration of the sub-aperture array based on compressed sensing.

7850-87, Poster Session

Photorealistic texture blending of 3D geometric model

X. Liu, X. Liu, A. Li, X. Peng, Shenzhen Univ. (China)

A photorealistic geometric model is of important in a variety of applications using three-dimensional (3-D) imaging and modeling, such as 3-D electronic games development and special effect generation of films. In this paper, we present an efficient texture blending algorithm that can be applied to register and combine multiple texture-mapped range images acquired from different view points, leading to a complete 3-D photorealistic texture blending geometric model. The proposed approach can be implemented as follows: we employ a home-made 3-D digitizer to capture the range image data and corresponding texture image of a portion of free-form object from different viewpoints, and further to build up a complete 3-D geometric model by means of range-image registration and integration techniques. The complete geometric model has been established using triangulating the adjacent vertices of the non-redundant range data points to determine the geometric and topological representation. Meanwhile, we can assign a color value to each of vertex with a RGB color attribute in order to construct a partial texture image for each corresponding range view. Furthermore, to construct a complete and fused texture image, we need to determine how the overlapped portion of those textured images can be blended. This can be done, with the aid of the built 3-D geometric model, through a novel identification, bi-linear interpolation and weighted averaged algorithms which will be described in detail in this presentation. Once the whole textured image is established, the texture blending can be achieved. Experiment results show the effectiveness of proposed approach.

7850-88, Poster Session

A universal noise filter based on neighborhood feature matching

Y. Liu, K. Gao, G. Ni, Beijing Institute of Technology (China)

In this paper, we introduce a new universal noise filter for removing the mix of Gaussian and impulse noise. Our new filter follows the basic concept of non-local means which was proposed by A. Buades and J.M. Morel at 2005. Most natural images have the property of non-local self-similarity, and the useful information for the de-noising of a reference pixel may be far away. By scanning a portion of the image in search of all the resemble pixels, and replacing the noisy value by a weighted average of all these resembling pixels, image self-similarity and information redundancy are adopted to suppress Gaussian noise. Non-local means is very effective in removing Gaussian noise, but is bad at the de-noising of impulse noise. By introducing the concept of neighborhood similarity evaluation and impulse noise detector, the universal noise filter based on neighborhood feature matching is built from non-local means. The filter scans for impulse noise free pixels with resemble neighborhood. By replacing the noisy value by a weighted average of all these pixels, the mix of Gaussian and impulse noise is suppressed effectively. Compared to most other spatial domain nonlinear filters, the universal noise filter consistently yields better results in removing the mix of Gaussian and impulse noise and maintain image texture effectively. Like the non-local means, the proposed filter easily extends to color image de-noising, and easily transplants to DSP/FPGA multi-processor platform.

7850-89, Poster Session

Indirect measurement of the penpoint used in an short throw interactive projection system

Q. Zhou, K. Ni, L. He, Y. Lu, L. Chen, H. Guo, J. Ma, C. Zou, Tsinghua Univ. (China)

Short throw interactive projection systems are widely used in education, training, commerce, and entertainment in recent years. Different interactive techniques have been developed. And among them, the infrared location technique is one of the attracting methods, because of the advantages such as independent of whiteboard and low cost, and so on. However, the main defect is that the infrared pen point is easy to be blocked by user's hand.

In this paper, we introduced our recent progress on indirect measurement of the pen point used in a short throw interactive projection system. Two infrared LEDs are fixed along the pen's body near the tail end. By separately measuring the position of the two LEDs, the location of the front end pen point can be calculated. Such placement can effectively avoid the LEDs from being blocked by user's hand. The mathematical model of this measurement scheme is given separately in the situations of infinite focal length and short focal length of the camera. Errors are analyzed by both analytical and numerical method. We used our position sensitive detector (PSD) based location system to test the effect of this method. The experimental results showed that the positioning accuracy does not visibly decrease compared to traditional measurement scheme with LED fixed on the front end.

7850-90, Poster Session

A location system based on two-dimensional position sensitive detector used in interactive projection systems

K. Ni, Q. Zhou, L. Chen, P. Sun, H. Xu, Y. Gao, J. Ma, Tsinghua Univ. (China)

The interactive projection systems have been widely used in people's life. Currently the major type is based on interactive whiteboard (IWB). In recent years, a new type based on CCD/CMOS sensor is greatly developed. Compared to IWB, CCD/CMOS implements non-contact sensing, which can use any surface as the projection screen. This makes them more flexible in many applications. However, the main defect is that the location accuracy and tracing speed are limited by the resolution and frame rate of the CCD/CMOS.

In this paper, we introduced our recent progress on constructing a new type of non-contact interactive projection system by using a two-dimensional position sensitive detector (PSD). The PSD is an analog optoelectronic position sensor utilizing photodiode surface resistance, which provides continuous position measuring and features high position resolution (better than 1.5μm) and high speed response (less than 1μs). By using the PSD, both high positioning resolution and high tracing speed can be easily achieved. A specially designed pen equipped with an infrared LED is used as a cooperative target. A high precision signal processing system is designed and optimized. The nonlinearity of the PSD as well as the aberration of the camera lens is carefully measured and calibrated. Several anti-interference methods and algorithms are studied. Experimental results show that the positioning error is about 2mm over a 1200mm×1000mm projection screen, and the sampling rate is at least 200Hz.

7850-91, Poster Session

Fuzzy measurement based image testing for oil particles contamination level

Y. Zhang, Chongqing Technology and Business Univ. (China)

The oil contamination level testing is important for its using and maintenance which is the basement of the oil contamination control is required higher by the developing device system, and the testing method is urgently needed to be studied for improving the process method and the maintenance quality of the contaminated oil. To classify the level of particles contamination in lubricant, CCD imaging technology is used to capture microscopic digital image of the oil particles sample . The digital image was processed and segmented in order that the computer can recognize and understand the particle targets by using image testing algorithm to measure the sizes, amounts and distributions of particles. The oil contamination level can be measured effectively by the economical and convenient method in which there is little air bubble and bead leading to false particle targets. To improve the influence produced by the false particle targets, One method is that a series of dynamical image samples from the multi-period and the multi-state contaminated oil are captured and used to test the particle targets, and the further method is to employ the fuzzy measurement using Gaussian subjection function, which describes the distribution of the standard evidences and the distribution of the testing data, and the testing probabilities of the evidence are weighed by the matching degree of the two distributions, which is used to classify the oil particles contamination level .The test shows that the oil particles contamination level diagnosis reliability is improved and the diagnosis uncertainty is reduced. This method combining with other testing methods by using the multi-information fusion method will be further studied later.

7850-92, Poster Session

Laser pulse scattering from a moving one dimensional rough surface

M. Wang, Xianyang Normal Univ. (China)

Abstract-Based on the Kirchhoff's approximation, analytical expressions for pulse scattering mutual coherence function (MCF) from moving rough random surface are presented. It is computed the Double Frequency Scattering Section (DFSS) change with the coherence bandwidth frequency difference and scattering angles in different incident angles incidence on laser (1.06) according to the mean of fluctuating heights and the semi-sphere reflectivity of the plating gild rough polyester moving film surfaces. Some important scattering characteristics of calculations based on the analytical solutions are be discussed in details.

7850-93, Poster Session

Digital camera auto white balance based on color temperature estimation clustering

L. Zhang, P. Liu, Y. Liu, F. Yu, Zhejiang Univ. (China)

Auto white balance is an important technique for digital cameras. Human vision system has the ability to recognize the original color of an object in a scene illuminated by a light source that has a different color temperature from D65-the standard sun light. However, recorded images or video clips, can only record the original information incident into the sensor. Therefore, those recorded will appear different from the real scene observed by the human. Auto white balance (AWB) is a technique to solve this problem. Traditional methods such as gray world assumption, white point estimation, may fail for scenes with large color patches. In this paper, an AWB method based on color temperature estimation clustering is presented and discussed. First, the method gives a list of several lighting conditions that are common for daily life, which are represented by their color temperatures, and thresholds for each color temperature to determine whether a light source is this kind of illumination; second, an image to be white balanced are divided into N blocks (N is determined empirically). For each block, the gray world assumption method is used to calculate the color cast, which can be used to estimate the color temperature of that block. Third, each calculated color temperature are compared with the color temperatures in the given illumination list. If the color temperature of a block is not within any of the thresholds in the given list, that block is discarded. Fourth, the remaining blocks are given a majority selection, the color temperature having the most blocks are considered as the color temperature of the light source. Experimental results show that the proposed method works well for most commonly used light sources. The color casts are removed and the final images look natural.

7850-94, Poster Session

Blind multiframe deconvolution algorithm for atmospheric turbulence degraded image

D. Shi, Anhui Institute of Optics and Fine Mechanics (China)

Blind deconvolution is a powerful technique to restore images which are degraded by atmospheric turbulence. We develop a novel blind multiframe image deconvolution algorithm and use it to restore images degraded by atmospheric turbulence. In order to overcome ill-conditioning of the estimation equations in the blind deconvolution, regularization is used. In this paper, we use the adaptive normalized convolution as anisotropic spatially adaptive regularization to filter the restored image and the point spread function (PSF). And the adaptive normalized convolution can also denoise the restored image. Degraded images of computer simulation and reality situation are used in the simulation experiment. The experimental results show that the algorithm developed by this article can restore a good clear image from the images degraded by the atmospheric turbulence.

7850-95, Poster Session

Image fusion using lifting wavelet transform with human visual features

X. Gu, Z. Peng, Univ. of Electronic Science and Technology of China (China)

Image fusion based on multi-source information is a new research field in image processing. It analyzes the characteristics of each fusing image by adopting image process method and information fusion theory, fuses these features by adopting appropriate strategy on the basis of image space registration in order to achieve a whole legible fusion image finally. It has been a hot research field and is widely used in many fields such as automatic target recognition, battlefield surveillance, medicine diagnosis, remote sensing, robotics and object detection and tracking, etc.

In this paper, we focus on the method of image registration and fusion and introduce all kinds of existing registration and fusion algorithm based on lifting wavelet in detail. Based on the characteristics of the infrared and visible images, this paper presents a registration approach using lifting wavelet transform to extract edge feature points, and improve the fusion algorithm based on features of human vision system (HVS). The methods refer much other knowledge such as lifting scheme, edge detection, affine transformation, HVS and fusion rules. A fast multi-resolution image fusion method based on visual features for infrared and visible images is proposed in this paper. The source images are decomposed using CDF9/7 lifting wavelet transform, respectively. Then it calculated the visual features of each sub-image and chose the different rule of fusion based on visual features. Finally, a fused image is reconstructed by using inverse lifting wavelet transform. Experimental

results demonstrate that the proposed method has apparent advantage in information preservation and resolution even if the source images have low signal to noise ratio (SNR), and the algorithm is more effective in computational speed.

7850-96, Poster Session

Noise influence upon detection precision for optical joint transform correlator

Q. Li, Z. Xu, H. Feng, P. Ge, Zhejiang Univ. (China)

Optical joint transform correlator (OJTC) is useful tools for detecting motion vector between frames, in a typical OJTC, two CCD sensor is necessary to acquire frequency spectrum image and correlation image respectively, so noise character of CCD sensor have important influence to motion detection precision. In this paper we constructed simulation process of optical joint transform correlator, and analyzed influence of noise. The joint image was inputted to a space light modulator (SLM) of the OJTC, and the frequency spectrum of joint image was grabbed in the first CCD. Then we introduced the frequency spectrum image, in which we added known-parameter noise, to another SLM, and correlation image appeared in the second CCD. The displacement in joint image is calibrated in advance, so distance between two peaks in correlation image is a constant without noise; with the noise increasing, precision of the distance will reduce gradually. According to the analysis results we found that OJTC can keep its detection precision when noise variance is smaller than 0.8 and correlation peaks will disappear when noise variance is larger than 1.29.

7850-97, Poster Session

Far-field focusing of laser beam based on digital image processing techniques

H. Zhang, Changchun Institute of Optics, Fine Mechanics and Physics (China)

In order to lead the laser beam transmit in the atmosphere convergently, an experiment of laser focus at the distance 450m and 300m has been operated in the outdoor place. The actual manipulations are as follows: Firstly, the laser was collimated by a beam expander, then the near-parallel laser beam was transmitted with a Galileo telescope system, and the distance between the concave lens and the convex lens can be tuned through a precise displacement platform, so the focus of the system changed due to the tiny displacement o f the concave lens. Secondly, the average power of the laser spot can be measured using power meter, the power is 47.67mW and the standard deviation is 0.67mW while the focal length is 450m. Thirdly, the energy distribution was found through the laser beam analyzer. The spot images were saved expediently using this beam analyzer, and the saved image can be processing with Matlab software afterwards. According the actual image in experiment, the function named EDGE and Sobel operator was used in the pre-processing. Then method of median filter was used in the course of image de-noising, then 53H filter was adopted in signal analysis. The diameter of laser spot was obtained by the method above under the selected edge threshold, the diameter is 5.56mm and standard deviation is 0.24mm. The spot center excursion is 0.56mm, it is 10.43% of the total diameter of the laser spot. At last, the key factors of the energy dissipation in the focusing system can be summarized as follows: restriction of the diffraction limit, attenuation in the atmosphere, geometrical aberration of optical system, and the diffraction limit and the geometrical aberration are significant in the three factors above, so we can reduce the impact of the both factors during the design of optical system. The reliable referenced data of the system design can be acquired through the primary experiment research .

7850-98, Poster Session

SOPC implementation for stereovision measurement system

X. Lou, N. Lv, W. Deng, Beijing Information Science and Technology Univ. (China)

Recently, stereovision technology has become a viable target for the implementation of industrial measurement applications. In order to recover three-dimensional information of a scene, image processing is necessary. Image processing typically requires very high computational power, and it is always bottleneck for real-time system. From this point of view,, a single FPGA with an embedded processor and DSP module is used to construct a SOPC system that fulfills image processing tasks parallel.

This paper focuses on the three aspects.

Principles of SOPC system designing are analyzed. Computational tasks of stereovision measurement system are divided into three types according to input data quantity and algorithm complicity. With system requirements under consideration, features of SOPC system are selected.

The realization of SOPC system is described in detail. The embedded processor, special IPs (Intelligent Properties), several custom logic modules are included in a single FPGA. All units are seamlessly integrated into the overall system using the system builder interface.

Simulation and debugging results of SOPC system are introduced. Result images of modules within SOPC system such as median filtering, impurity winkling, binarizing, edge detecting and coordinates obtaining are presented and compared with MATLAB and C programs. Elements that influence running time of SOPC system are analyzed and final results are given.

Experiment and test results show that all the functions needed were realized with much higher efficiency and processing speed in our SOPC system than conventional PCs.

7850-99, Poster Session

Measuring micro displacement based on Moiré fringe

S. Lu, Xi'an Technological Univ. (China)

It is important to accurately obtain micro displacement in industry, especially in numerical controlled machine. But traditional methods encountered some difficulties in high-precision measurement. A new approach based on moiré fringes digital image processing technique(DIP) is proposed in this paper. A smartly designed experiment is done to grasp moiré fringes from two same gratings, so complicated equipments are not necessary which has obvious advantages. A CCD is used to acquire digital images. Then the images are done by digital image processing, including filtering and gray-scale transformation, fringes identification. A smart way to calibrate the distance represented by each pixel is given in this paper with DIP technique. The distance of a certain fringe between two images is obtained to display the micro displacement of any object. The result of this approach is compared with a higher accurate micro displacement, their similarity identify the correct of this method. We are sure that the result will be more satisfactory if higher accurate equipment is applied in inspection.

7850-101, Poster Session

Automated centreline extraction of neuronal dendrite from optical microscopy image stacks

L. Xiao, Nanjing Univ. of Science and Technology (China)

In this work we present a novel vision-based pipeline for automated skeleton detection and centreline extraction of neuronal dendrite from optical microscopy image stacks. The proposed pipeline is an integrated solution that merges image stacks pre-processing, the seed points detection, ridge traversal procedure, minimum spanning tree optimization and tree trimming into to a unified framework to deal with the challenge problem. In image stacks pre-processing, we first apply a curvelet transform based shrinkage and cycle spinning technique to remove the noise. This is followed by the adaptive threshold method to compute the result of Neuronal object segmentation, and the 3D distance transformation is performed to get the distance map. According to the eigenvalues and eigenvectors of the Hessian matrix, the skeleton seed points are detected. Staring from the seed points, the initial centrelines are obtained using ridge traversal procedure. After that, we use minimum spanning tree to organize the geometrical structure of the skeleton points, and then we use graph trimming post-processing to compute the final centreline. Experimental results on different datasets demonstrate that our approach has high reliability, good robustness and requires less user interaction.

7850-102, Poster Session

An auto multi-threshold segmentation approach of PCB image based on iteration

J. Feng, M. Dong, Beijing Information Science and Technology Univ. (China)

Print Circuit Board (PCB) is an information carrier integrating various electronic components. It has been applied in different fields widely. Traditional detection method can not satisfy the large production. The Automatic Optic Inspection (AOI) based on image-processing had showed its advantages in inspection methods. Combing the traditional iterative algorithm and the Otsu's method, an auto multi-threshold image segmentation approach based on iteration is presented for the printed circuit board (PCB) image in this paper. The initial value for iteration is calculated firstly by using the Otsu's method. Then the iterative algorithm is applied twice to get the optimal threshold. Experiment is conducted on PCB image. The result shows that the algorithm is simple, efficient and it has good segmentation performance for PCB image.

7850-103, Poster Session

Improvement for exposure time measurement of microchannel plate gated framing camera

H. Cai, J. Liu, L. Niu, W. Peng, L. Gu, H. Niu, Shenzhen Univ. (China)

The method of exposure time measurement for the Microchannel plate gated framing camera is presented in this paper while the propagation on the microstrip line of gating pulse is considered. The delay time between two fiber images with neighboring number was analyzed, and found that the delay time between gating pulse encounter the neighboring fiber images was 2 ps,10 ps, or 18 ps in different situations. Considering the propagation of the gating pulse, we measured that the exposure time of the framing camera was 95 ps, comparing to 73 ps without considering. Finally, a method for the exposure time extension measurement is presented.

7850-104, Poster Session

Target classification using active laser polarimetric imaging technique

X. Zhang, Y. Jiang, X. Lu, Beijing Univ. of Aeronautics and Astronautics (China)

Laser polarimetric imaging has great potential application to classify targets which could not be realized by intensity imaging. A polarimetric imaging system is built to acquire two kinds of images, intensity and polarization degree coded images, simultaneously. By fusing the intensity and polarization degree images with pseudo-color encoding technique, we have achieved the classification of different kinds of targets with similar characteristics. Preliminary results show that higher contrast and better resolution images classified with polarimetric technique could be obtained after speckle reduction. Coherent speckle noise can be reduced with lowpass filter by treating it as high frequency noise. And lowpass filter outperforms the normally used median filter in speckle reduction.

7850-30, Session 7

A two-dimensional location method based on digital micromirror device used in interactive projection systems

L. Chen, K. Ni, Q. Zhou, X. Cheng, J. Ma, Y. Gao, P. Sun, Tsinghua Univ. (China)

Interactive projection systems based on CCD/CMOS have been greatly developed in recent years. They can locate and trace the movement of a pen equipped with an infrared LED, and displays the user's handwriting or react to the user's operation in real time. However, a major shortcoming is that the location device and the projector are independent with each other, including the optical system, the optoelectronic devices and the control system. This requires construction of two optical systems, calibration of the differences between the projector view and the camera view, and also synchronization between two control systems, etc.

In this paper, we introduced a two-dimensional location method based on digital micromirror device (DMD). The DMD is used as the display device and the position detector in turn. During the locating period, the infrared LED is imaged onto the DMD surface through the projection lens. By serially flipping the micromirrors on the DMD according to a specially designed scheme and monitoring the reflected infrared light energy, the image spot of the LED can be located in a very short time. By using this method, the same optical system as well as the DMD can be time multiplexed for both projection and location, which will reduce the complexity and cost of the whole system. Further more, this method can also achieve high positioning accuracy and sampling rates. The results of location experiments are given.

7850-31, Session 7

The research on the reconstruction of intensity image based on streak tube imaging lidar

C. Ma, Beijing Institute of Technology (China)

In the system based on the streak tube imaging lidar (STIL), the streak image on the salt screen captured by the CCD camera not only includes

the range information, but also provides the material attribute, the angle information of the target and so on, that is the intensity information. It is generally assumed that the image brightness on the salt screen reflect the laser intensity of the target. However, the brightness not only relates to the density of the electron beam, but also relates to the accelerating voltage. The relative intensity of the streak image will be distorted for reasons of the different accelerating voltage resulted by the different coming time. An amended method that there is a weighted processing for the intensity information based on the range information was proposed, a research on the reconstruction of the intensity image was processed, and some effects were achieved.

7850-32, Session 7

An algorithm of electronic image stabilization suitable for hardware implementation

P. Zuo, P. Wei, Beijing Institute of Technology (China)

In this paper, an electronic image stabilization algorithm for hardware implementation is proposed. Firstly, dithering image sequences are processed by two-valued methods based on various criterions before correlation matching, in order to make full use of image information. Then, instead of traditional block matching criterion, the simple XOR operation is adopted to process the binary images when doing motion estimation. Thus motion vectors under different criterions obtained. Secondly these estimated vectors should be judged by the statistical method on weighted, in order to gain the optimal motion vector. In addition, dithering image sequences are obtained by camcorder in order to soft simulate, and evaluate the performance characterization of algorithm designed in paper. The simulation results show that the algorithm is over 10 times more rapid than the traditional block matching, and its stabilizing precision approaches that. So this algorithm exhibits such advantages as fast running, high stabilizing accuracy. Lastly, a related module is designed, based on parallel processing of different two-valued methods, with the combination of the algorithm's operational structure. Based on that, this paper analyses the reliability to carry out this module in FPGA. So it lays the foundation of the product and miniaturization of the electronic image stabilization system.

7850-33, Session 7

Counter Sniper: a localization system based on dual thermal imager

Y. He, Z. Wu, W. Jin, B. Du, Beijing Institute of Technology (China)

Sniper tactics is widely used in modern warfare, which puts forward the urgent requirement of counter sniper detection devices. Now the existing single infrared detection system can only give the orientation of the sniper, this paper proposed the anti-sniper detection system based on a dual-thermal imaging system for detection and tracking of a bullet and exact location of the sniper. Combining the infrared characteristics of the muzzle flash and bullet trajectory of binocular infrared images obtained by the dual-infrared imaging system, and applying a detection technology which searches and tracks the significant infrared characteristics of a single bullet by the principle of binocular stereo vision, backtracks to the bullet trajectory, the exact location of the sniper was analyzed and calculated. This paper mainly focuses on the system design method. Based on the analysis of the bullets' infrared radiation characteristics, the selection of the thermal imager system's parameters is discussed, and the structure of the dual-infrared imager is designed. Then the detection performance is analyzed. The features of different perspectives of the bullet in the infrared image are considered to get the corresponding center position of the bullet in the same frame image of the two thermal imagers. Applying the binocular stereo vision on the corresponding images, the trajectory of the bullet can be calculated. Finally combining with the muzzle flash analysis, we can get the exact location of the sniper. At last, We discussed some feasible improvement to enhance the performance of this system.

7850-34, Session 7

Forensic inspection of document using visible and near-infrared spectral imaging

W. Huang, G. Wang, X. Xu, T. Yu, Z. Yang, Institute of Forensic Science (China)

In this study, the potential of visible and near-infrared spectral imaging as a technique of document inspection was examined. Doubtful documents are often found in economic cases, distinguished between original and added strokes and detected blurry characters are very useful for judgment. Burned, covered and rinsed documents in which the characters can't be identified with naked eyes were experimentally studied with a visible spectral imaging technique. Meanwhile, the same color inks were detected by both visible and near-infrared imaging spectrometers. Classification of spectral images was carried out in specialist spectral imaging software packager Misystem provided by Institute of Forensic Science. The technique significantly improved the detection of many documents, especially those that might be considered of poor quality or borderline characters. The visible spectral imaging was successful in detecting the burnt Chinese characters produced using pencils. It was possible to form spectral images showing the strokes even covered by Chinese ink by means of imaging at characteristic frequencies. As inks have very different spectral from the clothes, contribution and contrast of the rinsed lines and illegible seal words on clothes were clearly enhanced. By examining the spectral images from the inks, it was possible to determine whether the same color inks were written by the different pens. The results also show that the near-infrared spectrometer is better than visible one in distinguishing the same inks. In blind testing, spectral imaging was shown to achieve an average 85.1% chance of success. The results reveal the wide applications of spectral imaging in document evidence analysis. The potential of this technique in forensic science will be more apparent along with the further and deeper studies.

7850-35, Session 8

The research about the calibration of the spectral radiance at the exit of integral sphere

F. Zhang, Xi'an Institute of Applied Optics (China)

The spectral responses of a fiber spectrometer (200nm 1100nm) within 700nm 900nm and 400nm 700nm separately are obtained by measuring the spectral radiances at the exits of the standard blackbody at 1000 and the integral sphere source at some color temperature, in which there is a tungsten lamp with characteristics of blackbody. We not only get the spectral response of the spectrometer within 400nm 900nm, but also have the integral sphere source trace to the standard blackbody simultaneously. So we can obtain different radiance orders by changing the color temperature of the tungsten lamp in the integral sphere, avoiding using diaphragms. The calibration of the imaging spectrometer will also become more and more convenient.

7850-36, Session 8

Low cost web-camera based optical spectrometers

S. Sumriddetchkajorn, National Electronics and Computer Technology Ctr. (Thailand)

A low cost optical spectrometer is an important device needed for environmental monitoring, chemical sensing, and health care monitoring in developing countries. Today, a web-based camera is a popular device for communicating purposes via internet. It comes as an externally peripheral device or it is built into a portable computer. With this proliferation, this paper proposes low cost web-camera based optical spectrometers. In particular, we show how a web-based camera can be used to realize a single channel and a multichannel optical spectrometers. Our key idea is based on the use of an external dispersive element for separating different wavelength optical beams from each other in a two-dimensional (2-D) space and the use of the lens of the web-based camera for appropriately directing all separating wavelength optical beams onto the 2-D image sensor of the web-based camera. Our device implementation and its experimental test will be highlighted.

7850-37, Session 8

Interference efficiency of thermal infrared imaging Fourier transform spectrometer

X. Xiao, Xi'an Jiaotong Univ. (China) and Xi'an Institute of Applied Optics (China); J. Gao, Xi'an Institute of Applied Optics (China)

Theory about the Thermal Infrared Imaging Fourier Transform Spectrometer has been discussed, and then we found that Interference efficiency is an important factor related to SNR of Thermal Infrared Imaging Fourier Transform. The Interference efficiency involved in transverse shear splitting. After study of this kind of beam splitting, some formulas about Thermal Infrared Imaging Fourier Transform Spectrometer has been found, then the simulation modes was done. At the end, Interference efficiency of Imaging Fourier Transform Spectrometer was calculated. The relationship between interference efficiency and SNR was simply given.

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7851-01, Session 1

Development of the compact opto-electronic integrated neural (COIN) co-processor

C. Warde, W. Herrington, Massachusetts Institute of Technology (United States)

Compact Opto-electronic Integrated Neural (COIN) co-processors operate using neural network type methods employing the light emission properties of gallium arsenide and the processing properties of silicon VLSI circuits to provide a high density 2D array of pixels or neurons. The effectiveness of these co-processors has been tested. The co-processors are capable to synthesize and analyze large, parallel data set, through the interconnections made between the different processors. Each processor consists of a sheet of photodetectors, a sheet of threshold electronics, a sheet of Vertical Cavity Surface Emitting Lasers (VCSELs), and a hologram array. The Bragg grating of one co-processor is separated from the array of photodetectors of the next co-processor by a spacing plate which consists of a thin glass spacer.

7851-02, Session 1

Hyperspectral sensing and real-time pattern classification

T. Chao, Jet Propulsion Lab. (United States)

JPL has recently developed an compact electro-optic liquid crystal waveguide (LCW) based Fourier transform spectrometer that is capable of remote and in-situ sensing of gases and chemicals of critical importance to NASA's space exploration missions. We have also developed in parallel real-time pattern recognition and classification processor including a grayscale optical correlator (GOC) and neural network (NN). In this paper, we will report the technical details of the compact LCW based Fourier transform spectrometer as well as the associated real-time pattern classification processor algorithms. Experimental investigation results will also be provided.

7851-04, Session 1

Rotation-invariant scene matching with multi-sample parallel estimation in volume holographic correlator

S. Wang, L. Cao, X. Niu, Q. He, G. Jin, Tsinghua Univ. (China)

Volume holographic correlator has the characteristics of high-speed parallel multichannel processing. The target image can be located simultaneously in the scene matching by using the volume holographic correlator. To achieve the rotation-invariant correlation, we have proposed the synthetic discriminant function and wavelet filtering method, which mainly deal with the image preprocessing and filtering. In this work we will propose to use a new method to achieve the scene matching with rotation and get the rotation angel for the target image. The method of multi-sample parallel estimation can be used to get the rotation angel when the target image is rotated to the reference image. According to the characteristic of the stationary random process of remote sensing image, the method of curves fitting is used to derive the function of the brightness of the correlation spots, which varies with the two-dimensional translation volume and rotation angel. In this function, there are three variables with absolute value and then six equations can be used to derive solution. Based on the relationship, the six correlation spots, which describe the correlation results between the target image and template images, can be used to determine the location and rotation angel of the target image. More correlation spots can also help to improve the accuracy of the results. Compared with using both rotating and translational template images in traditional optical recognition, the method only used the translational template images to implement the rotation-invariant scene matching recognition, which saved much capacity of the volume holographic correlator, enlarged the recognition scope, and improved the recognition accuracy. Theoretical simulation and experiment results show the validity of the method, and the maximum rotation angel of the target image to be recognized is about ten degree.

7851-05, Session 2

Fiber sensors for molecular detection

C. Gu, Univ. of California, Santa Cruz (United States)

The demand for sensors for detecting chemical and biological agents is greater than ever before, including medical, environmental, food safety, military, and security applications. At present, most detection or sensing techniques tend to be either non-molecular specific, bulky, expensive, relatively inaccurate, or unable to provide real time data. Clearly, alternative sensing technologies are urgently needed. Recently, we have been working to develop a compact fiber optic surface enhanced Raman scattering (SERS) sensor system that integrates various novel ideas to achieve compactness, high sensitivity and consistency, molecular specificity, and automatic preliminary identification capabilities. The unique sensor architecture is expected to bring SERS sensors to practical applications due to a combination of 1) novel SERS substrates that provide the high sensitivity and consistency, molecular specificity, and applicability to a wide range of compounds; 2) a unique hollow core optical fiber probe with double SERS substrate structure that provides the compactness, reliability, low cost, and ease of sampling; and 3) an innovative matched spectral filter set that provides automatic preliminary molecule identification. In this talk, we will discuss the principle of operation of various building blocks, demonstrate our recent results, and highlight some potential applications.

7851-06, Session 2

A novel down-hole fiber optic sensors with high temperature and pressure based on Fabry-Perot cavity and fiber Bragg gratings

Y. Wang, China Univ. of Petroleum (China)

With the rapid development of fiber optic sensing technology, more and more monitoring programs related begin to play an important role in oil and gas exploration. In the past, down-hole monitoring of temperature and pressure is more dependent on pump partner, electronic pressure gauge or the capillary pressure gauge. However, such devices shows many disadvantages in stability, reliability, accuracy and so on.

In the interest of special anti-corrosion, seals, high temperature and high pressure treatment, and long life, we have developed a new fiber-optic temperature and pressure sensor based on Fabry-Perot Cavity and Fiber Bragg Gratings. The temperature and pressure resolution of this sensor can be as high as 0.5 and 0.05%, respectively. Meanwhile, the sensor work condition can cover the wide range of 0-15000psi and -25-300 . This paper describes the technical principles, characteristics and field application of the sensor in detail.

7851-07, Session 3

Comparison of two-dimensional phase retrieval methods from single interference fringe pattern

H. Lei, K. Qian, A. K. Asundi, Nanyang Technological Univ. (Singapore)

Accurate phase retrieval from single fringe pattern is significant for dynamic phase measurement.

Although it brings the issues of speckle noise and severe nonsinusoidal waveform, the interference fringe pattern by coherent light is still often used for profile measurement, especially for measuring target with low reflective surface.

Both simulation and experiment are carried out to study the performance of two- dimensional Fourier transform, windowed Fourier transform(including windowed Fourier filtering and windowed Fourier ridges), and wavelet transform methods.

The influence of the speckle noise and nonsinusoidal waveform for those phase retrieval methods is compared and discussed.

7851-08, Session 3

Holographic image encryption using random phase mask

J. Widjaja, Suranaree Univ. of Technology (Thailand)

Recently, much research has been devoted to digital-optical image encryption by using holographic technique. The reason for this interest is that holographic recording process can be considered as an encryption using a reference wave as a key, while holographic reconstruction is equivalent to a decryption process. Consequently, information of the encrypted object can be decrypted, provided a correct reference wave is used to read out the hologram. Since holographic technique allows recording of both amplitude and phase of the object wave, security of holographic encryption can be improved by manipulating its phase information. Since the phase of the object wave is now randomized, besides the reference wave, the correct phase mask and information of the locations of the object and the phase mask must be used as decryption keys of holograms. Owing to flexibility of setting recording distance and a resolution limitation of CCD sensor, Fresnel holography using Mach-Zehnder interferometer have been widely employed for this encryption. Based on this approach one arm of the interferometer is used to carry object wave, while the other arm is for a reference wave. The object wave is randomized by placing the phase mask at a distance behind or front of the image. The encrypted image is then holographically recorded by using a CCD sensor. Finally, the object wavefront is numerically calculated to retrieve the original image. In this paper, we discuss effects of the phase-mask position on the quality of the decrypted images.

7851-09, Session 3

Color image encryption based on joint fractional Fourier transform correlator and phase retrieval algorithm

D. Lu, W. Jin, Zhejiang Normal Univ. (China)

Abstract: Existing color image encryption techniques mainly adopt three-channel encryption. The color image is separated into RGB three components and encryption/decryption is performed individually in each channel. However, there are three channels in the optical setup, thus three lasers of different wavelengths will be needed. The deficiencies of the method were involved in system-complicated and many procedures. A novel single channel color image encryption technique based on joint fractional Fourier transform correlator (JFRTC) and phase retrieval algorithm was proposed here. The target color image is decomposed into three red(R), green (G), blue (B) components. A joint image is formed and encoded into two random phase masks (RPM) iteratively. In the decryption, a retrieved RGB components space-separated image with high quality was obtained when the designed two RPMs are matched. After synthesis the RGB components, the reconstructed color image is available. This method takes full advantage of parallel processing features of the optical system, and could realize single-channel color image encryption with the safety ensured. The system and the operation procedure are simplified. The design of the phase masks is flexible and the algorithm converges rapidly.

7851-10, Session 3

Optical image encryption with a polarization-selective diffractive optical element based on interference

N. Zhu, Y. Wang, J. Liu, J. Xie, Beijing Institute of Technology (China)

Data security techniques based on optical theories and methods have been proposed and widely developed in recent years. Compared with conventional mathematical encryption methods optical security system provides higher processing speed, more information volume, more encryption free-degree as well as its multi-dimension and parallel processing abilities. In this paper we proposed a novel architecture for optical image encryption with polarization-selective diffractive optical element (PDOE) based on interference theory. A target image is firstly encoded into two phase-only distributions and then these phase distributions are encrypted into the etched surface-relief pattern of a single PDOE mask. In the process of optical image decryption, when the working wavelength and the system configuration are correct, the PDOE mask with the encoded information for the target image can generate two desired polarized wavefronts by modulating the incident light beam. These two wavefronts interfere and then generate the decrypted image. The encoding algorithm to generate the phase-only distributions is simple and it does not need iterative process. The optical realization for image decryption also has the advantages of easier installation and collimation since all the optical elements are in a same optical axis. The employment of the PDOE mask in this optical security system will highly increase the information security and still maintain the parameter sensitivity in an acceptable region. Numerical simulation is performed to demonstrate the validity of this new proposed method.

7851-11, Session 3

Research on optical hash function

W. He, X. Peng, X. Meng, Q. Wan, Shenzhen Univ. (China)

Hash function is a one-way encryption scheme. It is widely used in the internet for the check of message integrity and the identification of the legal users. In this paper, we introduced an optical Hash function (O-Hash), which is constructed by the method of phase-truncated Fourier transforms. The O-Hash processes the arbitrary length message in 512-bit blocks, and finally generate a 128-bit (fixed length) hash value by adopting the cascaded Fourier transforms with phase-truncated operations, this method can be implemented either digitally or optically. Moreover, by way of embedding a key in the process of constructing O-Hash, we can then get the keyed optical Hash function (K-O-Hash), which can processes a message and a key (related to unique legal users) into a 128-bit long keyed hash value, also known as message authentication code, MAC. Finally, the avalanche effect is also evaluated to show the performance of constructed O-Hash and K-O-Hash with a set of numerical experiments.

7851-12, Session 4

Retardagraphy: a new polarization recording method and its applications

T. Yatagai, D. Barada, Utsunomiya Univ. (Japan)

An optical recording technique, called retardagraphy, has been proposed by the authors. In the retardagraphy, retardance distribution of a birefringent object can be recorded on a polarization-sensitive medium made of azobenzene copolymer. In other words, the phase difference distribution between two orthogonal polarization components of the wavefront to be recorded can be directly recorded. The multi-valued phase pattern recorded can be reconstructed by measuring retardation between two polarization components by an imaging polarimetry technique. In this paper, the optical recording and reconstructing methods in retardagraphy is presented. Its applications to optical mass data storage and optical diffractive elements are discussed.

7851-13, Session 4

Plasmonic technologies for data storage

B. Lee, S. Kim, I. Lee, D. Oh, Seoul National Univ. (Korea, Republic of)

In this paper, we review recent techniques of using plasmonics for data storage. Plasmonics (which is based on the phenomenon of surface plasmon resonance) can be used to generate subwavelength hot spots with power throughput larger than one. Various types of metallic apertures have been proposed for the purpose such as bow-tie apertures, C-apertures, and H- (or I-) apertures. Metallic nano-antennas such as rolly-pop structures are also promising for the purpose. We will discuss physics, characteristics and requirements for optical data storage or heat-assisted magnetic recording adopting plasmonic generation of subwavelength hot spots.

7851-14, Session 4

The feasibility research on phase-shift multiplexing for holographic storage

W. Song, S. Tao, Beijing Univ. of Technology (China)

Holographic storage technology has been studied becoming an attractive research topic because of its high storage capacity and fast data rate.In order to reach these two goals, many kinds of multiplexing techniques such as angular, phase-coding and wavelength-multiplexing, and speckle-shift multiplexing technique have been studied. Whatever any kind of multiplexing technique is selected for the storage system, the quality of the reconstruction results by the selected multiplexing technique shuold be maintained. In our previous work, the influence of the reference beams used corresponding to the selected multiplexing techniques on the reconstruction quality has been discussed. Because the great potential of the speckle-shift multiplexing for high density storage, the speckle reference beam has been paid a lot of attention in our previous work. However, the result of our work showed that the reference beam with randomly encoded phase arouses lots of scattering noise coming into the reconstructed images. In order to optimize the multiplexing method, we suggested in this paper a hybrid multiplexing method which incorporates orthogonal phase-coding multiplexing into shift-multiplexing in photopolymer recording materials.

We started the feasibility research with a numerical model of recording and reconstruction of Fourier transform holograms. According to the results of numerical simulation, holograms recorded by orthogonal phase-coded reference beams exhibite excellent phase-code selectivity. So orthogonal phase coding techniques is good for hologram multiplexing in a cmmon volume. On the other hand, if a hologram is recorded by a reference beam phase-coded with one of the orthogonal patterns, the quality and brightness of the reconstructed image is sensitive to the relative shift between the hologram and the pattern. The position selectivity can reach 40 m in both lateral directions. According to the results of the numerical simulation, this multiplexing method is feasible. And an experment has been set up with an LCOS-SLM as phase coder, and the validate experment is in progress.

7851-15, Session 4

Fabrication and properties of random phase-shifter for holographic speckle-shift multiplexing

Q. Zhai, S. Tao, Beijing Univ. of Technology (China)

Holographic disc storage in photopolymer has been a persistent hot topic of study. Considering the requirement for high storage density, speckle-shift multiplexing is a candidate multiplexing method which is practical and compact in terms of experimental configuration. Thus the generation of specified speckle reference light is worth for research. In this paper, we suggest a simple method of making specified random phase-shifter. The spatial speckle field, produced by using laser light to illuminate a common ground glass, was recorded in a photopolymer film to form the random phase shifter. Compared with other kinds of diffusers, this specified phase-shifter is easier to be made and designed to control the average speckle size. According to different recording conditions, such as the incidence aperture and the distance between the aperture and the recording plane, the average speckle size on the recording plane can be adjusted to meet the requirement of a specific speckle-shift multiplexing scheme. The experimental scheme of making the speckle phase-shifter and the theoretical calculation of the desired average speckle size are given. Moreover, the images of the speckle fields generated by different self-made speckle phase-shifters are acquired by a CCD camera. Then the actual speckle size can be obtained by calculating the width of the autocorrelation peaks of the image intensity distributions. The difference between the actual and theoretical speckle size is discussed. Finally the factors such as the shrinkage of photopolymer, which influence the performances of shift-multiplexing using the above scheme, are discussed, and the feasible solutions to those factors are given.

7851-16, Session 4

CLV control system for CBHD spindle motor

Y. Cui, X. Cheng, J. Ma, X. Hou, Tsinghua Univ. (China)

CBHD(China Blue High-Definition) is a high definition optical disc format announced in September 2007 by the OMNERC(Optical Memory National Engineering Research Center) of Tsinghua University in China. To keep CBHD data transfer rate to be constant,CLV (constant linear velocity) control system for CBHD spindle motor is essential.The CLV control system consists of data slicer,SYNC (Synchronous Data, unique in each frame,is used as CLV control feedback signal)protection, data PLL(Phase Locked Loop),spindle motor control and spindle motor driver. Hitherto few papers elaborate on the realization of the CLV control system which can work effectively and accurately in case of disk defects,scratches,figner prints, etc. In this paper,hardware circuit design and software flow charts for CLV Controller are given.An experimental platform based on FPGA is established to servo the burshless DC spindle motor . What is more,adoption of soft-core processors PLL and PWM embed in FPGA greatly simplify the hardware circuit,and the maximum spinning velocity error remains under 5% in the closed-loop system which can meet the requirement of CBHD adjusting Machine. All the experimental results show that the hardware and software are reasonable and possess very good reliability and real time performance.

7851-17, Session 4

Servo control system construction for CBHD radial and axial tracking

Y. Cui, X. Cheng, J. Ma, D. Chen, Tsinghua Univ. (China)

CBHD(China Blue High Definition Disc) is a high-definition optical disc standard with Chinese independent intellectual property. Compared with DVD optical pick-up, CBHD optical pick-up,key component of CBHD player, has significant improvement in the channel bit rate for 1 speed reading and certain reduction in acceptable tolerance range for disk tilt, etc. Servo Control principle for CBHD Radial and Axial Tracking follows that for DVD, but its implementation will cause greater hardship .This paper specifies the servo conrol system construction for the CBHD radial tracing and axial tracking. This servo conrol system should ensure the optical beam of OPU focusing on the Disc plane and following the track of CBHD channe accurately. Acorrding to the expected radial/ axial maximum accleration and the limitation of emax,an open-loop transfer function specifing the servo system for axial and radial tracking is introducted in the frequency range 36.9Hz and 10kHz. The servo control algorithm including IIR filters based on above-mentioned transfer function is theoretically analyzed and numerically simulated by MATLAB. Because the real systems are differnent in dynamic properties and exists quantization error, time dalay, nonlinearity, etc,the tuning of IIR parameters is laborious and time-consuming. In this paper, A hardware and software experimental platform for CBHD optical pick-up servo system are constructed,and an user-friendly solution to make IIR parameter adjustment convenient and efficient is given. Experimental results show that this servo control system can perform well with vertical deflection disc and center deflection disk.

7851-18, Session 5

SHOT: single-beam holographic tomography

G. T. Nehmetallah, P. P. Banerjee, Univ. of Dayton (United States)

We report on a non-intrusive technique for the recording and 3D shape reconstruction of high speed moving water droplets using a Single-beam HOlographic Tomography based multiplicative reconstruction technique (SHOT-MT). For each orientation, we reconstruct the corresponding digital hologram and compute the intensity on multiple planes around the distance d which corresponds to the middle of the test volume where the droplet(s) is/are located. Then after some coordinate transformations, we can reconstruct the droplets by multiplying the different reconstruction volumes. The method is extendable from a single droplet to multiple droplets such as in a cloud or rain. SHOT-MT enables us to visualize in 3D the shape of the droplet, as well as the Gaussian and the mean radii of curvatures on each point of the 3D shape, which is important for deformation characterization of the object on which it impinges. Also, this method allows us to quantify the number density of these droplets and the distance between them accurately.

7851-19, Session 5

Real-time measurement of the full spatiotemporal field of a single Terahertz pulse by pulsed digital holography

X. Wang, H. Zhai, Nankai Univ. (China)

Up to now, different methods have been developed for the single-shot THz detection, including spectral encoding technique, optical streak camera, non-collinear geometry spatial encoding, non-collinear cross correlation technique, retrieval algorithm based on in-line spectral interferometry, two-dimensional electro-optic imaging with dual echelons, tilted front collinear geometry, etc, which can be, however, only employed to measure the electric field of a single-shot THz either in its spatial or in its temporal domain, respectively, in real time.

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In this paper, we describe a method for a full spatiotemporal electric field, E(x, y, t), of a freely propagating single THz pulse, based on the electro-optic (E-O) sampling technique and the pulsed digital holographic approach. From a series of sub-holograms recorded digitally, the complete electric field E(x, y, t) of a single THz pulse can be recovered by the following digital reconstruction algorithm. Our analysis results show that the spatial and the temporal resolution of the measurements can be as high as micron and femtosecond order, respectively, limited only by the resolution of the detector array and the width of the probe laser pulse, respectively. Our new method offers a possibility for a three-dimensional characterization of the THz field E(x, y, t) with a single-shot model in real-time.

7851-20, Session 5

High efficiency THz wave generation and application

M. Cheng, Y. Gao, M. Hao, C. Wang, S. Yin, The Pennsylvania State Univ. (United States)

In this talk, we will review our recent work related to high efficiency THz wave generations and applications. Several types of THz wave generation methods, including employing multiple air plasmas, photoconductive semiconductor switch (PCSS), and nanostructured surfaces will be addressed. The advantages and limitations of each approach will be discussed. Finally, the applications of THz wave, such as remote sensing, will also be presented.

7851-21, Session 5

The generation of nondiffracting beams array with arbitrary order by phase holograms

M. Hu, R. Wang, J. Tian, D. Li, Shenzhen Univ. (China)

Nondiffracting beams are of interest for optical potential applications owing to their properties of smaller central spot, longer propagation distance and so on. Approximations to such beams can be experimentally realized using a range of different means. A phase-holograms-based method of generation nondiffracting beams array with arbitrary order is proposed in this paper. If a phase hologram is displayed on a phase-only spatial light modulator (SLM), when a collimated monochromatic plane wave illuminates it, a annulus with high concentration of energy is obtained in the Fourier plane. Then through the Fourier transform again, a nondiffracting beam will be generated. It is able to generate arbitrary order nondiffracting beams with high diffractive efficiency. More significantly, if a phase-hologram-array is utilized, a unique bright annulus will be obtained in the Fourier plane, because of the shift-invariance of Fourier transform and the consistency of phase hologram design. In this case, a nondiffracting beams array will be generated. Furthermore, the location and the order of any individual nondiffracting beam can be designed according requirement. Experimental results are presented to show the theoretical predictions. We experimentally generate different of nondiffracting beams array, and these results are in good agreement with the numerical simulation. This kind of nondiffracting beams array are helpful for optical metrology, optical tweezers, optical manipulation, optical vortices and so on.

7851-22, Session 5

Polarization readout characteristics of electric-controlled holographic Bragg grating in photorefractive crystal

Y. Wan, S. Tao, Beijing Univ. of Technology (China)

The application of the photorefractive crystals are getting more and more widespread owe to their characters in recent years. The photorefractive crystal is paraelectric phase when an applied electric field inflicts on it. In the paraelectric phase photorefractive crystal, the electro-optic effect, that is quadratic, result in a Bragg grating in the volume of the crystal. The reconstruction process and the diffractive properties of the grating, including diffraction efficiency and the polarization of diffractive beam can be governed by both the externally applied electric field and the polarization of input light. Dependence of electrically controlled Bragg grating in paraelectric phase KLTN: Cu crystals on reading beam polarization were experimentally investigated under different geometry configuration. The applied electric field ( ) perpendicular and parallel to the grating vector ( ) are investigated for a transmission and a reflecting holographic gating respectively. In different configuration, the quadratic effective electro-optic coefficients have distinct value, resulting in distinct diffractive properties. The results of experiments show that the Bragg condition is fulfilled for a specific applied electric field and both incident beam perpendicular and parallel to writing beam for a transmission grating. The diffraction efficacy is several times higher using parallel incident beam readout than that of using perpendicular to writing beam. However the polarization of diffractive beam is always same with the incident beam. The further experiments on the diffractive properties of transmission and reflecting holographic gating in the configuration of are ongoing. Some theoretical model was introduced and modified to interpret the experimental results.

7851-23, Session 6

Skin image reconstruction using Monte Carlo based color generation

Y. Aizu, T. Maeda, Muroran Institute of Technology (Japan); T. Kuwahara, T. Hirao, Shiseido Co., Ltd. (Japan)

We have already presented Monte Carlo simulation of spectral reflectance based on a multi-layered skin tissue model which can be used for fitting a spectrum to the measured result. In this paper, we propose a novel method of skin image reconstruction based on color generation using Monte Carlo simulation of spectral reflectance in a multi-layered skin tissue model. In a measuring apparatus, the RGB image and the spectral reflectance of human skin are obtained at the same time by RGB camera and spectrophotometer, respectively. The acquired skin image is separated into the color component and texture component. By fitting the measured spectral reflectance with a nine-layered skin tissue model, we determine expected values of optical parameters (absorption coefficient, scattering coefficient, anisotropy scattering parameter, and refractive index) and layer thickness for each of nine layers. This process is first started with certain given values for all the necessary parameters, which are published in literature. Modifying these parameters, an alternative spectral reflectance is generated by Monte Carlo simulation and is converted to skin color. This color component is then synthesized to the texture component to reconstruct a skin image under the modified conditions. This technique is able to visualize a skin image under various conditions of skin optical parameters. The results indicate that the method is promising for application to dermatology and cosmetics fields.

7851-24, Session 6

Lasers in light skin interaction

B. Chan, S. Jutamulia, Univ. of Northern California (United States)

Lasers have been used to collect information from human body. The information collected includes regular images, optical signals for optical coherent tomography, spectroscopic signals, signals of absorption/transmission through skin in a specific wavelength band, speckle and scattering signals, etc. On the other hand, lasers have also been used for medical treatments. In this paper, various lasers used in light tissue interaction, especially light skin interaction are reviewed. Specific wavelengths and required powers are discussed. In particular, the studies using low power and high power laser diodes are analyzed.

7851-25, Session 7

Fabricating triangular fiber Bragg grating using nonlinear one step method

Q. Zhou, T. Ning, J. Li, P. Li, X. Hu, J. Zheng, C. Qi, Beijing Jiaotong Univ. (China)

A new method which make use of the variable accelerated motion of servo Motor is presented to fabricate the triangular fiber Bragg grating. Considering the exponential relationship between the changes of grating refractive index and the exposure of UV laser, this method only requires one exposure, the variable accelerated motion of servo motor is controlled by computer program to control the increment of UV laser exposure and the linear change of grating refractive index on the fiber axial, then the edge of triangular fiber Bragg grating can be gained. The experiment result shows that the edge of triangular fiber Bragg grating has a good linearity, the bandwidth is 1.6nm, the linear bandwidth which can be used is 1nm, and the maximum reflectivity is 90%. As a fiber Bragg grating sensor demodulation device, triangular fiber Bragg grating will be more widely used in sensing fields.

7851-26, Session 7

Analysis of the transmission properties of mechanically induced long-period fiber grating

Y. Jiang, J. Zhao, D. Yang, D. Tang, Northwestern Polytechnical Univ. (China)

We experimentally studied the impacts of an assistant fiber, longitudinal pretension and fiber coating on the transmission properties of mechanically induced long-period fiber gratings (MILPFGs). The results show that the loss peaks of MILPFGs have a relationship of sin2(l) with the pressure, meanwhile, the central wavelengths have a blueshift, and the bandwidths change along a parabolic curve. But the pressure is smaller for the same loss peak when there is no assistant fiber. The loss peak is almost unchanged when the longitudinal pretension is increased. But the central wavelength increases linearly, and the bandwidth increases exponentially. The out-of-band loss will decrease by applying a small pretension, but this loss will increase linearly when the pretension is too large. The loss peak and the central wavelength of MILPFGs are all smaller when they are induced in coated fibers than that in uncoated ones under the same pressure, while the out-of-band loss is also smaller. So the MILPFGs should be induced in coated fibers while a assistant fiber is absence, meanwhile, a small pretension should be applied.

7851-27, Session 7

Tunable chromatic dispersion compensating in 40-Gbit/s system by an enhanced thermal chirped fiber Bragg grating

K. Zhong, N. Jia, T. Li, M. Wang, J. Chi, J. Sun, J. Wang, Beijing Jiaotong Univ. (China)

In this letter, a tunable chromatic dispersion compensating in 40Gbit/s system based on enhanced thermal chirping fiber Bragg grating is demonstrated. The dynamic dispersion is provided by a tunable dispersion compensator based on enhanced thermal chirping fiber Bragg grating. Fiber Bragg grating is glued onto a uniform AL channel, whose two ends are heated or cooled using two peltiers respectively. A linear temperature gradient is obtained along the AL channel. The fiber bragg grating is chirped by the thermal expansion of AL channel, the thermo optic effect and the thermal expansion of optical fiber. Controlling the linear temperature distribution of the uniform FBG performs the tuning of GVDs and center wavelengths. Tuning the group velocity delay (GVD) without changing the center wavelength is achieved by changing temperature difference between the two ends of AL channel and holding the temperature at the middle of AL channel. Tuning the center wavelength with a fixed group velocity delay (GVD) is achieved by changing temperature difference between the two ends of AL channel and holding the temperature at the middle of AL channel. The GVD can be tuned from -360ps/nm to -690ps/nm with a center wavelength at 1551.25 nm. On the other hand, the center wavelength can be shifted by 1 nm with a GVD value around -660ps/nm. At last, a 40Gbit/s OTDM system is demonstrated with dynamic dispersion compensating utilizing this device.

7851-28, Session 8

Faced folded rods as nano-antenna for optical devices

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We propose faced folded rods (FFR) as nano-antenna for light emissions. This FFR structure, which is composed of two folded gold rods, shows two different field enhancement modes depending on the polarization direction of feeding light. Under the incidence of x-polarized light, double hot spots are observed at gaps due to capacitive coupling between rods. Meanwhile, when y-polarized light is applied to this geometry, a single hot spot is achieved at the center of the structure which is due to the superposition of half-wavelength dipole resonance occurring at each folded rod. Strong resonance of several vertices, which is predicted to be 93 of E-field enhancement factor in FFRs, can be achieved for sensitive bio-molecular detection. Thus, we can manipulate the number and position of desired hot spots by way of controlling the polarization states of light. Since we can obtain up to four different hot spot areas in nano-meter scale, multiplexed bio-sensing can be possible using FFRs as the nano-antenna. To understand the physical mechanism behind the pair type of folded rods, a single folded rod is first simulated as a basic elementary structure and compared with the pair structure. Then, this FFR structure is fabricated with an e-beam evaporator and the focused ion beam lithography. The scattered light intensity is captured by a CCD camera and analyzed by a spectrometer and compared with the simulation data.

7851-29, Session 8

Analysis on divergence half-angle of Gaussian approximation for the far-field of planar waveguide

L. Li, F. Guo, Fujian Normal Univ. (China)

Since the advent of semiconductor lasers, they have developed quickly. It gives powerful impetus to technology innovation in our modern life as well as becomes the heart of the information industry. A three-layer planar waveguide is used as the cavity of semiconductor laser; in addition, planar waveguide is one of the most basic parts in integrated optics devices too. So research on its beam propagation rule has important meaning in practical applications.

The end diffraction of planar waveguide is researched first and results are not convenient for real application. For the sake of convenience, Gaussian approximation for the diffraction far-field is investigated. We begin by analyzing its rationality according to the theory on beam propagation factor and why the far-field can be approximated by a Gaussian field is clarified. Then, the most important thing is how to determine divergence half-angle for it. There are two kinds of definitions for the divergence half-angle, that is, the second-moment and differential operator divergence half-angle, but our further research indicates that they are not perfect enough through analyzing matching efficiency between the far-field and Gaussian field. As a result, a new definition of divergence half-angle is presented. It is redefined based on the maximal matching efficiency method. Numerical calculation shows that the maximal matching efficiency divergence half-angle is more precise than the other two. Furthermore, we also provide a simple series expansions for computing divergence half-angle with a pocket calculator based on solving linear equations.

7851-30, Session 8

Numerical simulation of slow light in the semiconductor optical amplifier

M. Hu, Z. Wang, L. Zhang, Tianjin Univ. (China)

Optoelectronic technology played a pivotal role in the unprecedented information revolution in the past two decades. One of the remaining grand challenges is the ability to store an optical signal in optical format. So slowing down the velocity of light have recently attracted substantial interest. In various mechanisms of slow light generation, semiconductor optical amplifier (SOA) attracts much attention because it offers the advantage of compactness, room temperature operation, electric-optical controllable, and easy integration with existing optical communication systems. In the SOA, Four Wave Mixing (FWM) effect is an important method to produce slow light. According to the light field propagation equation, the carrier concentration equation and refractive index modulation theory, the relationship between the signal light time delay with the outside control parameters (the current into SOA, pump power, the frequency loss harmonic between pump light and signal light) can be derived. And according to the relationship, simulate and analyze the dynamic changes of the signal light delay with these parameters in details. Finally, the numerical simulation of slow light based on SOA is carried out.

7851-31, Session 8

Study on the non-paraxial beam parameters of single-mode fiber

L. Li, F. Guo, Fujian Normal Univ. (China)

In recent years, fiber laser is one of the focuses of laser technology. It has developed quickly and gives powerful impetus to technology innovation in our modern life as well as becomes the heart of the

information industry. Thus, study on the beam propagation rule of fiber has important meaning in practical applications.

According to ISO 11146-1:2005 international standard, beam parameters are mode-field radius in the near-field, divergence half-angle and beam propagation factor. They provide a standard to evaluate the beam quality. Under paraxial approximation, they are researched widely. As for the non-paraxial beam parameters, study on them is often neglected. Actually, after laser outputs from fiber laser, it is not exact to approximate it by a paraxial beam. In addition, M2 factor must be greater than or equal to unity as the ISO standard, however, some researchers have presented that it can be smaller than unity.

The purpose of our study is to provide the comprehensive analysis and calculations for non-paraxial beam parameters. In this paper, the beam parameters of LP01 mode for single-mode fiber is analyzed and calculated based on the non-paraxial vectorial moment theory of light beam propagation and waveguide mode theory. Numerical calculations show that if both the core and cladding layer fields are considered, M2>1 is always obtained and neglect of the cladding layer field leads to M2<1. That is to say, the optical field outside the core layer influences the beam propagation factor. These conclusions may provide theoretical support for the proper design of fiber laser.

7851-32, Session 8

A novel Simultaneous demultiplexing and clock recovery unit for high speed OTDM system

K. Zhong, N. Jia, T. Li, M. Wang, J. Chi, J. Sun, J. Wang, Beijing Jiaotong Univ. (China)

In this letter, a novel simultaneous demultiplexing and clock recovery unit based on EAMs and clock recovery module is presented and experimentally demonstrated for a high speed OTDM system. This unit consist a pair of concatenated electro-absorption modulators (EAMs) and a 10GHz clock and data recovery module, which form a loop for simultaneously clock recovery and demultiplexing for 160Gbit/s optical signal. The first EAM driven by 10GHz clock signal generates <25ps (FWHM) temporal optical sampling windows with a repetition rate to10GHz. 40Gbit/s demultiplexed signal is obtained at the output of the first EAM. Due to the recovery clock is 10GHz and the second EAM works at 40GHz, the second EAM is connected to the output of two frequency doublers. The second EAM driven by 40GHz clock signal generates <5ps (FWHM) temporal optical sampling windows with a repetition rate to 40GHz. 10Gbit/s signal demultiplexed from 160Gbit/s signal is obtained at the output of the second EAM and is split into two parts. One is investigated by a digital sampling oscilloscope (Agilent DCA 86100 B), and another is injected into 10GHz data and clock recovery module for clock and data recovery. Comparing to other structure, just two EAMs are used and Simultaneous demultiplexing and clock recovery are realized. The performance is evaluated by BER curves and the power penalty is lower than 3dB with the error rate of 10-9. To our knowledge, this is the first demonstration report of simultaneous demultiplexing and clock recovery for OTDM systems utilizing the unit.

7851-33, Poster Session

Crosstalk cancellation of differential readout technology for Super-RENS disc system

W. Hu, X. Li, J. Yang, Y. Nie, National Univ. of Defense Technology (China)

The differential readout technology, which regards the difference of the high power and low power laser readouts as the final signal, improves the resolution of readout signal for Super-Resolution Near-field Structure (Super-RENS) disc system. Since the nonlinear property of super resolution (SR) layer, the high power and low power incident beams can cause different optical responses, and then the differential signal has an advantage of high resolution. In order to get more understanding of the technology, crosstalk analyses are conducted to show the reason of the high quality readout signal. We establish a simple model for Super-RENS ROM disc system. In this model, the role of SR layer is approximated as a special transmittance function which describes the nonlinear response to intensity distribution. Based on the model, the crosstalk for differential readout technology and normal readout technology are calculated by using scalar diffraction theory. Numerical analyses demonstrate that the crosstalk of differential readout technology is weaker than that of normal readout technology, which indicate that the differential readout technique is effective as a mean of crosstalk reduction. Further analyses are focused on discussing the effects of different Gaussian-weighted beams, focus error and track error on crosstalk for both normal and differential readout technologies. Simulations show that wide incident beam is preferable to gain low crosstalk, and the focus error and track error increase the crosstalk for both technologies. What's more, by comparing the two kinds of readout technologies, we find that the differential readout technology is robust to defocus and track error.

7851-34, Poster Session

Theoretical investigation of the fixing phase in two-center holographic recording

X. Li, Beijing Technology and Business Univ. (China); Z. Jiang, Beijing Univ. of Technology (China); D. Xu, H. Ju, B. Li, Beijing Technology and Business Univ. (China)

The charges transfer mechanism of the fixing pahse in two-center holographic recording is studied theoretically. In the fixing phase, while the hologram recorded in the shallower traps is erased by the illuamation of the reference beam, partial of the electron gratings in the shallower traps is transferred to the deeper traps via the conduction, thus the total space charge field in the crystal is a bi-exponential process. Based on the two-center model, the effects of the shallower traps concentration, the deeper traps concentration, the oxidation-reduction state of the crystals and the intensity ratio IR/IUV on the space-charge field of the deeper traps during the fixing phase are investigated by using the Runge-Kutta method. The results show that, to enhence the fixed space-charge-field in the fixing phase, it is available to use the weakly oxidized crystals with higher shallower traps concentration and lower deeper traps concentration.

7851-35, Poster Session

Theoretical studies for volume computerized tomography based on optical interferometry

N. Sun, Nanjing Univ. of Science and Technology (China)

Optical Computerized Tomography is a technique which is famous for real-time, stable and non-contact characteristics in various flow fields' diagnosis. As a result, it shows superiorities in many domains, including aerospace survey and the measurement of thermo physical parameters. Due to most of the traditional reconstruction methods of OCT are based on 2-D Radon Transform, they are pseudo three-dimensional in essence. That is to say, the measured flow field is divided into several parallel slices firstly, and then, the stack of tomogram slices is subsequently used to compute the three-dimensional representation. However, all the measured flow fields own true 3-D character. Therefore, in this paper, based on the 3-D Radon Transform, the optical interferometry is studied on the model of the volume CT. Meanwhile, the sufficiency condition of accurate reconstruction is studied. Besides, the transform reconstruction algorithm for volume OCT is also presented and is verified by simulated experiments. In a word, this study will be better to visualize and display the measured flow fields.

7851-36, Poster Session

Characters of reflecting holographic volume grating in photosensitive-refractive glass

L. Lin, Y. Wan, N. Yang, G. Liu, S. Tao, Beijing Univ. of Technology (China)

Holographic volume gratings (HVG) as diffractive elements have much practical and more potential applications, such as spatial filters, attenuators, modulators, imaging lens and so on. As it's well known whether a HVG is practical utility mostly depend on the performances of recording media. A new type of photosensitive-refractive glass, silicate glass doped with silver, cerium, fluorine, and bromine, was fabricated at our lab. The absorbance of the glass from 190nm to 1100nm was measured by Agilent 8453 UV-Visible Spectrophotometer. The absorbance were 1.42(AU) at 325 nm and 0.32(AU) at 442 nm. The glass was exposed to radiation of a He-Cd laser at 325 nm and 442nm respectively to produce holographic gratings under a reflecting geometry optical set-up. Holographic grating of approximately 6mm×6mm in size was recorded in the sample with thickness of 3.34 mm. The gratings were developed with thermal. The diffracted efficiency were measured real-time during the holographic grating formation and after thermal development respectively. The results of the experiments show the glass is more sensitive at 325nm than 442nm, and the maximum diffracted efficiency of exposed on ultraviolet is far more than that exposed on 442nm. The volume grating recorded by 325nm laser after thermal development was readout by 442nm and 532nm laser illumination in order to investigate the stability of the grating at long wavelength. The calculated results theoretically of diffraction efficiency, angular selectivity and spectral selectivity are compared with experimental measured data for reflecting HVG in a photosensitive-refractive glass.

7851-37, Poster Session

The error analysis of the discrete layer peeping algorithm for fiber Bragg grating synthesis

X. Yu, Harbin Institute of Technology (China) and Harbin Univ. of Science and Technology (China); C. Liu, Y. Yao, Harbin Institute of Technology (China)

The discrete layer peeping algorithm has been widely used to synthesize the fiber Bragg grating for the inverse scattering problem. The synthesis is useful both as a design tool and for characterization of already fabricated gratings with complex profiles. In the paper, the error sources of the discrete layer peeping algorithm, including the resolution (spacing of the detuning values), the bandwidth (range of the detuning) and the length of the fiber brag grating, are analyzed(measured reflectivity).. As an example, a dispersionless bandpass filter is designed. We choice different resolution and different bandwidth to calculate profiles of fiber Bragg gratings with different length of the fiber Bragg grating, separately. In order to compare the influence of the resolution and the bandwidth on the robustness of the algorithm, a deviation between the target reflection spectrum and the calculated reflectivity is presented. We find that the calculated reflectivity of the fiber Bragg grating can all be synthesized when the resolution is different, but the length of the fiber Bragg grating required to the calculate the reflectivity is longer as the resolution increases. For a target reflection spectrum, we also find that the length of the fiber Bragg grating required to calculate the reflectivity with different bandwidth is almost same, and a deviation between the target reflection spectrum and the calculated reflectivity decreases as the resolution increases. The resolution and bandwidth required for a certain level of accuracy will depend in general on the bandwidth and the fine structure of the initial target reflection spectrum, therefore our analysis are instructive meaningful.

7851-38, Poster Session

Optical implementation for adaptive beamforming of array antenna

M. Liu, Nanjing Univ. of Science and Technology (China)

It is difficult for a traditional phased array radar to process large array-element and high time-bandwidth-product signal in real time. In this paper, we present an electro-optic radar signal processor. Using Stimulate Photon Echoes(SPE) phenomenon, it provides a unique way of processing high bandwidth signals in both space and time, especially it has the ability of multiple-channel spatial-temporal signal processing. Firstly, the principle of how to implement a true time delay based on SPE phenomenon with its theory models is established. Then the method of how to implement variable time delays using laser beams modulated by linear frequency chirped pulses is discussed, the relationship between chirp bandwidth and delay step is demonstrated by simulation results. At last, an optical processing architecture based on SPE is proposed to implement true time delays for large-bandwidth adaptive beamformers. This architecture can adaptively store time delays of incoming waveforms for thousands of antenna elements, and can simultaneously perform signal processing during the readout of a time delay. As a result, it allows to filter thousands of simultaneous AOAs with 30 GHz dynamically in both spatial and spectral domains, which can be used to adaptively steer a large RF phased array antenna toward the direction of interest while minimizing the effects of unwanted interference signals.

7851-39, Poster Session

Analysis of holographic grating formation in photopolymer with a dynamic diffusion model

T. Zhang, Qiqihar Univ. (China); S. Tao, Beijing Univ. of Technology (China); Q. Li, Qiqihar Univ. (China)

Holographic photopolymers is a novel material for holographic storage, that exhibit a number of advantages over traditional volume holographic materials such as silver halides and photorefractive crystals. And it will become promising materials for future production of holographic devices. The mechanism of hologram formation in photopolymers has been broadly studied. In this paper a dynamic diffusion model is presented in order to describe the monomer diffusion and photopolymerization during the grating formation in photopolymers. Monomer concentration will decrease because of photopolymerization, and the polymerization rate of monomer will also change with the decreasing of monomer concentration. Then the polymerization rate of monomer is considered a parameter which changes with record time in this dynamic diffusion model. The differential equation of refractive index modulation is established base on this dynamic diffusion model, and solved numerically by the Runge-Kutta method directly. The time-dependence of refractive index modulation is obtained numerically and it is in good agreement with our experimental results. The parameters in the dynamic diffusion model are got by fitting experimental data. The concordance between theory and experimental result proves that this dynamic diffusion model can describe the process of grating formation in photopolymers accurately.

7851-40, Poster Session

Holographic storage characteristics of red-sensitive photopolymer sensitized by Azure II

J. Xu, J. Cheng, S. Wang, Y. Wang, M. J. Huang, Henan Univ. (China)

In recent years, the holographic data storage has been a focus in the world at all times. To make it practicable, the recording material is critical. In all kinds of materials, the photopolymer materials are perfect recording materials with many advantages: high diffraction efficiency, large dynamic range, relatively low cost and no wet chemical processing.

In this paper, the holographic characteristics of the photopolymer sensitized by azure II are investigated. The experimental result demonstrates that the sensitive spectral range of the material is from 550 nm to 700 nm, the maximum absorption peak is at 662 nm, so we can use the 632.8 nm wavelength of He-Ne laser as the recording and reading source. The inner uniformity of the material is better and little scattering appears, the maximum transmittance can reach to 90%. The maximum diffraction efficiency is 56% and the optimum adding amount of photo-sensitizer is 4 ×10-4mol/L when the intensity of incident beam is 1.1mw. From the formulas,we can calculate the maximum exposure sensitivity is 5.2×10-3cm2/mJ, and the maximum refractive index modulation is 1.6×10-3.

In addition, using the photopolymers, we successfully stored some holograms. We can see that there are few scatterings in the transmission and reconstruction images.The images have better contrast and fidelity.

7851-41, Poster Session

Analysis of wavelength margin and defocus margin for collinear holographic storage system

J. Li, L. Cao, X. Tan, Q. He, G. Jin, Tsinghua Univ. (China)

Collinear holographic memory has many advantages as one of the next generation massive optical storage system. Experimental studies show that the wavelength margin of collinear holographic memory is over three times larger than that of conventional 2-axies holography and the defocus margin of collinear technology is over six times larger than those of DVD's specifications. These wide system margins enable us to miniaturize the collinear holographic storage systems more easily. However, further theoretical discussion is necessary for explaining why the wavelength and defocus margin of a collinear holography is large. In this paper we theoretically analyze the wavelength margin and defocus margin for collinear holographic data storage system based on first Born approximation and scalar diffraction theory. Explicit expressions for the decay of the diffracted signal with the shift of the reading wavelength and with the defocus of the disc are presented. The expressions predict that the defocus margin is independent of the media thickness while a thicker disc leads to a narrow wavelength margin. The wavelength margin and defocus margin for collinear holography can be calculated based on these. The calculated result can explain why the wavelength margin is larger than conventional 2-axies. It also shows that even if the disc place in the reconstructing process is shifted 4um away from the focus of the objective lens, the diffracted signal efficiency holds about seventy percent of the peak efficiency.

7851-42, Poster Session

The intrinsic function theory of imaging system and its application in micro-projection display design

L. Wang, Y. Huang, G. Li, Y. Qiu, Fujian Normal Univ. (China)

A display projection system using an RGB laser source provides a wide color spectrum unachievable by commercialized light sources. Thus it generally has the advantages of presenting more realistic natural color on a huge screen, including a long lifetime. On the other hand, the laser display projection system has the disadvantage of introducing speckle by the long coherence of the laser beam, which is reflected from a diffuse surface, as is well known.

Many speckle-reduction techniques have been tried with varying degrees of success, including rapid movement of a single screen in its plane, the use of two stationary spaced screens, liquid-crystal screens, and the use of two closely spaced screens in slow relative orbital motion. However, considering the contradiction between speckle reduction and light utilization, increasing complexity of the structure and other factors, not many practical methods could be used.

This article describes a perfect way which can not only effectively suppress the speckle but also reduce the light loss .we analyze the principle of suppressing speckle with a moving diffuser, based on the intrinsic function theory of partially coherent optical systems. This method can easily provide a theoretical basic for choosing the diffuser production program and designing the illumination mode.

7851-43, Poster Session

Optical Hilbert transform using fiber Bragg gratings

J. Ge, C. Wang, X. Zhu, Soochow Univ. (China)

The Hilbert transform is an important tool for signal processing that can find important applications in modern radar and communications systems. The Hilbert transform (HT) is usually implemented in the electrical domain using digital electronics, but the processing speed is slow owing to the limited sampling speed of the digital circuits. Recently, it was found that the HT can also be implemented in the optical domain with a much higher speed and greater bandwidth. Asghari et al reported an all-optical Hilbert transformer based on a single phase-shifted fiber Bragg grating, in which the first order Hilbert transform was implemented using an uniform-period fiber Bragg grating (FBG) with a proper refractive index apodization incorporating a phase shift in the middle of the grating. Li et al proposed an all-fiber temporal photonic fractional Hilbert transformer based on discrete layer peeling (DLP) method, in which fractional HT can be implemented by properly designed FBGs based on the target response in the frequency domain. The refractive index profiles of the designed FBGs are, however, difficult to accomplish. In this paper, we demonstrate that a simple and practical phase-shifted fiber Bragg grating (PSFBG) operated in reflection can implement an all-optical Hilbert transform, including both integer and fractional. The PSFBG consists of two concatenated identical uniform FBGs with a phase shift between them. The phase shift of the FBG and the apodizing profile of the refractive index modulation determine the order of the transform. Both integer and fractional transforms show good transforming accuracy for arbitrary input optical waveforms when compared with the precise analytical results.

7851-44, Poster Session

Bandpass filters based on cascaded long-period fiber gratings and its application in laser mode locking in normal dispersive regime

X. Zhu, D. Liu, C. Wang, J. Ge, Soochow Univ. (China)

Mode-locked lasers have attracted great interests in fundamental science, commercial instruments and other applications. The cavity group-velocity dispersion (GVD) is a key parameter for mode locking of the laser to have the ability of produce stable, high-power, ultrashort pulses. The cavity group-velocity dispersion (GVD) is a key parameter for achieving the mode locking of lasers. For anomalous GVD, ultrashort pulses can be easily obtained where the GVD balances the self-phase modulation (SPM) to produce soliton-like pulses that are nearly bandwidth limited. However, the desire for higher-energy pulses suggests consideration of cavities with large and net normal GVD. By applying a spectral filter in the laser cavity, robust, high-

energy, ultrashort pulses can be generated at extremely large normal GVD. Some of the components are used for the spectral filter such as interference filter, birefringent filter, or CFBG, but all the spectral filters either are the discrete components which destroy the all-fiber structure or inserter circulator into the laser cavity. Recently, long period fiber gratings (LPFGs) have been used as band-rejection filters, fiber amplifier gain equalizers, mode converters, and broadband couplers for applications in optical because of it in an all-fiber low-loss version and operate in transmission system.

In this paper, we report a new method of using a cascaded long-period fiber grating (CA-LPFG) as the spectral filter in the ytterbium-doped mode locking in the normal dispersive regime. The CA-LPFG was fabricated in a single mode fiber at wavelength of 1064nm using a CO2 laser based system. A stable mode-locking laser output at wavelength of 1030nm was observed and measured in the normal dispersive regime. In comparison with the conventional interference filters or fiber Bragg grating filters, the CA-LPFB can provide not only an all-fiber low-loss but also a transmission mode.

7851-45, Poster Session

Simulation of tunable buffer and gain capability in 2D quasiperiodic photonic crystal slabs

X. Chen, Y. Wang, Minzu Univ. of China (China)

Micro-nano optical buffers, as one of the important components of the next generation of internet have become the research hotspot in recent years. In this paper, we design a novel optical buffer structure on quasiperiodic photonic crystal slab, which combines 1D defect photonic crystal waveguide and 2D annulus coupled cavity. This annulus buffer demonstrates the features of both time tunability and slow light. We investigate the existence condition of traveling waves in 2D photonic crystal ring, as well as the mode conversion and matching relation with the 1D defect photonic crystal waveguide. Due the high-loss propagation in photonic crystal, the lifetime of traveling wave is calculated about several nanoseconds, which seriously limits this buffer application. we dope the photonic crystal with effective activation in order to obtain the optical gain. The relations between optical gain coefficient and composition and concentration are also discussed.

7851-46, Poster Session

Correlation between the optical pickup electrical evaluator and spot aberration measurement system

X. Cheng, J. Ma, Y. Cui, Z. Zhang, H. Liao, Tsinghua Univ. (China)

The optical pickup unit is a kind of mass-produced product as well as a diffraction-limited micro-optical system. Thus the optical elements are assembled serially in the production line, and its assembling errors (mainly systematic and random errors) should be controlled to achieve a diffraction-limited focus spot on the disk. And the reflected light from the disk on the photo detector would be converted and processed in the servo control system and evaluated using the electrical evaluator. Thus a correlation between the electrical evaluator and the spot aberration should be considered when setting the testing standard for a production line.

In this paper, the optical pickup is measured using a spot aberration measurement system and a collimating light measurement device. Its electrical signals are described in the evaluator. The optical system in the optical pickup would be divided into two testing parts: base part and focusing part. The base part includes the laser diode, collimator, prism, quarter-wave-plate, beam splitter and reflective mirror; while the focusing part has objective lens, phase plate, wave-plate, and so on. The collimating beam from the base part is qualified using the light measurement device, while the focus quality is measured using the spot aberration system. Then the beam parameters and the aberrations are processed and simulated in the ZEMAX to achieve the intensity distribution on the photo detector to achieve the servo signals. Secondly, these optical pickups are processed to get the electrical signals directly from the evaluator. Then the parameters from these two system are compared and its correlation are calculated. This method is verified when designing a DVD production line and might be useful in establishing the standards for a new optical pickup.

7851-47, Poster Session

Signal quality improvement of holographic data storage by adaptive two-dimensional filter

Y. Takahata, Y. Kondo, S. Yoshida, M. Yamamoto, Tokyo Univ. of Science (Japan)

Recent research and development of holographic data storage has been targeted at practical use, where the challenge is to prevent the deterioration of the reproduced signal due to shrinkage of the recording medium, wave aberration in the optical system, or crosstalk with other images during multiplex recording. These deterioration mechanisms result in an increase in bit errors and optical interference between bits.

In this paper, we examine whether the use of a two-dimensional finite impulse response (FIR) filter in two presently available recording/reproduction methods, the Off-axis method and the Co-axis method, results in an improvement in the signal quality. The linear minimum mean square error (LMMSE) method is first tested to examine its effectiveness in optimizing the coefficients of the FIR filter. Subsequently, the real-coded genetic algorithm (RCGA), which has the capability of searching a wide range of coefficients, is applied and the result obtained is compared with that for the LMMSE method to see if the coefficient evaluation leads to a local solution or the minimum solution.

The filter coefficient was optimized by the LMMSE method and by RCGA; the latter can search a wider range of optimization coefficients. The RCGA was used for evaluating the optimization by the LMMSE method. In comparison with the filter designed using the LMMSE method, the FIR filter constructed using the RCGA showed an improved BER. In other words, the best coefficients are not necessarily obtained by the LMMSE method only.

7851-48, Poster Session

Evaluation method of an influence of wavefront aberration on signal quality in holographic memory

K. Akieda, A. Nakajima, T. Ohori, K. Katakura, M. Yamamoto, Tokyo Univ. of Science (Japan)

One of the problems that affects the practical use of holographic memory is deterioration of the reproduced images due to aberration in the optical system. The medium used in holographic memory systems must be interchangeable, and hence, it is necessary to clarify the influence of aberration in the optical system on the signal quality and perform aberration correction for drive compatibility. In this study, aberration is introduced in the reference light beam during image reproduction, and the deterioration of the reproduced image signal is examined by both simulation and experiment.

First,the influence of wavefront aberrations on the reproduction signal quality of holographic memory was investigated by simulation. The form of the wavefront along the depth direction of a thick-film medium was calculated using a layer division and plane wave expansion

technique. Also, the wavefront from each layer during reproduction was calculated by the plane wave expansion technique. By adding wavefront aberrations to the reference beam during reproduction and studying the effect on the signal-to-noise ratio.

Second,in this study, we also developed an evalution experimental method of an influence of wavefront aberration on signal quality. We have proved that if an arbitrary Zernike polynomial expression is projected onto a liquid crystal, a corresponding wavefront aberration is obtained. By using this aberration control method, the influence of reference wave aberration on signal quality is cleared.

7851-49, Poster Session

Measuring diameter distribution of fibers based on image analysis

M. Ding, W. Song, S. Tao, Beijing Univ. of Technology (China)

Measurement of the fiber diameter distribution plays a very important role in the field of wool domain, textile industry and commodity inspection. An automatic measurement method based on the image analysis and the diffraction power technology is presented. Firstly, an image is captured by the micrography system and several other sampling image are captured by the step system with the camera moving a proper distance in both longitude and latitude direction. And then, it does pre-processing operation to all the images, including modifying the images by vertical square chart, restraining the random noise by wiener filter and median filter, and many other methods. And then, the binary images are obtained. And a session of processes are operated to the binary images so as to restrain the random noise further. A monochromic incoherent laser is obtained by the way of adding narrowband light filter on a incoherent laser. Binary images are loaded into the spatial light modulation one by one. And then, the optical power spectrum of the fibers can be obtained by a camera at the rear focal plane of the lens by the way of fourier transform. Finally, the diameter distribution of the fibers is computed through the different circularity power of the spectrum based on the numerical calculation method that the fiber diameter region is divided equally. As experiments demonstrate, this method not only computes very quickly, but also generates accurate results.

7851-50, Poster Session

Low-noise multiple watermarks technology based on double random phase encoding method

J. Zheng, R. Lu, L. Sun, Univ. of Shanghai for Science and Technology (China)

Based on double phase random phase encoding method, watermarking technology may provide a secure and robust way to protect the copyright of the printing. Although it is easy to hide the encrypted Fourier hologram into a host image and decrypt the watermark through unique key (blind detection way), the watermarking also bring high signal noise into the host printing and debase the printing quality. In order to overcome this limitation, we study a low-noise multiple watermarking technology, by which embedding multiple watermarks into one host printing and decrypt them with corresponding phase keys individually. Theoretical analysis and digital simulation show that with the same total embedding weight factor, multiply watermarking method can improve signal noise ratio (SNR) of the output printing image significantly. The multiply watermark technology provide a robust, stability, reliability copyright protection method with higher quality printing image.

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7852-01, Session 1

Various tunable PCs/quasi-PCs structures fabricated by reconfigurable interference system

H. Dai, X. Sun, D. Luo, Nanyang Technological Univ. (Singapore)

Multibeams interference technology is extensively used to fabricate 2D or 3D photonics structures (PCs), most of the reported approaches are to achieve beamlets by pre-design mask, DOEs or splitting beams directly by bulk optical elements. Some researchers also fabricated the 2D or 3D PCs structures by imaging phase or intensity distribution of multibeam interference display on the spatial light modulator in the record plane. Here we present a reconfigurable multibeam generated system according to a DMD-based reconfigurable interference system. Base on this reconfigurable system, the number of beamlets and the individual incident angle of incident beam can be tuned readily. The interference system is composed by a DMD chip, a concave lens and a convex lens. The DMD's amplitude modulated property enable effective multibeams generation with various parameters such as numbers, radius and shape etc. The concave lens is used to extend the distance between beamlets to achieve larger incident polar angle for smaller pitch PCs structures. Subsequently, the generated beamlets are focused to one point to present interfering by the convex lens placed after the concave lens. The generated patterns are recorded in the polymer dispersed liquid crystal (PDLC) materials, which can be electrically switched. We demonstrated 3, 4 beams interference with different incident polar angle and azimuth angle, respectively. We also fabricated qusicrystals structures in PDLC by five beams interfering.

7852-02, Session 1

Design and fabrication of ultra-slim light guide for LCD backlights

Z. Fang, X. Zhou, L. Chen, Soochow Univ. (China)

With the development of LED technologies, LEDs are used increasingly in medium - size backlights for PDAs and car navigation systems for restrictions on the use of mercury and the continuing industrial trend towards energy - saving technology. For the above mentioned backlights, the thinner light guide plate is necessary to achieve the portable properties of the products. In this paper, we designed a 5 inch light guide plate by arranging special cone dots on the back surface of optical polycarbonate film with thickness 0.38mm. Then an optical model was built and the luminance distribution of the light guide was simulated by using ray tracing method to achieve an efficient and uniform radiation of light from the light guide. Through the simulation result, the best dot arrangement and cone parameters were obtained. The above light guide was fabricated by roll to roll hot embossing process instead of injection molding process which is not able to fabricate 5 inch light guide with thickness less than 0.4mm. The mold for hot embossing is composed of nickel film with thickness about 0.1mm. The dots on the mold were machined on the digital-controlled micro-nano fabrication equipment by laser etching process. The relationship between the depth and profile of dots and laser energy, pulse number etc. were investigated. The hot embossing process parameters were investigated on fabrication the light guide such as pressure, temperature and rolling velocity. Finally, a 5 inch light guide with the average luminance more than 3000 cd/m2 and the uniformity more than 80% was fabricated. This process will contribute to the mass production of ultra slim light guide in the future.

7852-03, Session 1

Design of multilayer light guide films for mobile keypad

X. Zhou, L. Chen, Soochow Univ. (China)

The design of multi-layer light guide films(MLGF) for LED backlight in mobile keypad has been proposed.Based on the MLGF technology, different keys on the mobile keypad can be illuminated seperatly and used for music mode or phone mode.

The distribution and structure parameters of micro-dots for MLGF are discussed to improve light guide uniformity and efficiency.

The MLGFs are lighted by side-view LEDs and can show different colors when lighted by different color LEDs.

The MLGF sample consisted of 2 layers is fabricated by laser etching and nano-imprinting technology.The thickness of each layer is 100um and the dots diameters can range from 40um to 100um.

The optical perfomances are simulated by tracepro. And the brightness is tested by BM_7.

MLGF provides a ultrathin and low-cost solution for multi-function display of mobile keypad and LED lighting.

7852-04, Session 1

Evaluating the uniformity of color space and the performance of color difference formula

Y. Lian, Beijing Institute of Technology (China)

Research on the uniform color space is still an important work for both for the basic research in color science and the practical applications of colorimetry, especially for recent growing request in display technology. Using small color difference data sets (Macadam ellipses data and RIT-DuPont suprathreshold color difference ellipses data), and large color difference data sets (Munsell notation colors at Value 5 and OSA color system uniform scale data), the uniformity of several color spaces which include CIELAB, DIN99d, IPT, and CIECAM02-UCS is evaluated to find discrepancies in perceptual uniformity of several color spaces, and the performance of color difference formulae in these color spaces is investigated. It was proved that the uniformity of value is better than those of chroma and hue. Overall, for all these color spaces, the uniformity in the blue area is inferior to the other area. The uniformity of CIECAM02-UCS is superior to the other color spaces, followed by IPT. The uniformity of CIELAB for the large color difference data sets is better than it for the small color difference data sets. The value of the PF/3 and STRESS shows that no small and particular formula based on the uniform color space excelled at large color difference.

7852-05, Session 1

A novel coupling structure for large size LCD backlight system

Y. Shi, Tsinghua Univ. (China) and Qiaofeng Tan (China)

Side-light type LCD backlight system is commonly used for small size LCDs. In order to thinner the thickness, reduce the weight and save power of the LCD backlight system, the side-light type LCD backlight system, instead of the direct-light type, are more and more used for large size LCDs. To further improve the brightness and illumination uniformity, in this paper a novel coupling structure using the design method of Fresnel zone plate is proposed. The novel coupling structure

redistributes the light from the LED source into uniform strip-distributed light source at a certain distance. Besides, the scattering dots in the bottom of the light guide plate transform the uniform strip-distributed light source into uniform surface light source. The size and density of the screen printed scattering dots are carefully optimized to improve the performances. Simulation results demonstrate that the combination of the novel coupling structure and the scattering dots can help to obtain over 82% illumination uniformity and over 4000 nits brightness for a 15.1-in. LCD backlight.

7852-06, Session 1

The technology of multiuser large display area and auto free-viewing stereoscopic display

T. Zhao, H. Zhang, J. Han, Capital Normal Univ. (China)

Fresnel lens can project image information to given position eye. It is a stereoscopic display method which can output direction, intensity and color information of the light respectively. So it can realize multiuser stereoscopic display which other methods can hardly realize.

Our research uses led point lights. As the lights' effective irradiation angle is small and the stereoscopic display is thick, we created a Fresnel lens array method that combining Fresnel lens array with led point lights array to a unit, it can divide the whole stereoscopic display system into several units. The quantities of the units depend on the size of the led light and the screen.

The visible area of Fresnel lens array stereoscopic display becomes larger as the units become smaller. Therefore through adjusting controllable point lights of different unit to overlap in position needed, the visible area could be realized visible in large scale. We bring in the real time coordinate of multiuser eyes to supply multiuser watching at the same time. The angular field of users' view in horizontal and vertical direction is same as the angle of led illumination. The distance range between users and screen could be parallel to normal 2d display proper visible range.

On the basis of large visible range, we can work out viewing angle of x and y directions from eyes coordinate acquired by eye-tracking. We selected a known object with its information in any angle, then displayed image according to the viewing angle, so the user can see stereoscopic information of the object in the corresponding angle. It realized 360 degree stereoscopic displaying in normal line of the screen.

We simulated the methods above by matlab, and designed the flow chart of the whole system.

7852-08, Session 1

LED

L. Zhang, Beijing Normal Univ. (China)

Satellite sensors

7852-09, Session 1

The influence on spectrum parameters for high power LEDs with current

F. Ren, Henan Polytechnic Univ. (China)

LED is a kind of electroluminescent device. The character of output light has immediately relation with the applied current. In this paper, High-power blue, green, yellow, white LED as the research object, using WGD-8/8A modular multi-grating spectrometer, the spectrums of four LEDs of different color have been measured. And the influence on spectrum parameters for high power LEDs with current has been studied. The results show that: With the current increase, except blue LED's peak wavelength occurs red shift in the case of high current, the other three light-emitting diodes have a blue shift phenomenon.

7852-10, Session 2

LED white lights with high CRI and high luminous efficacy

G. He, L. Zheng, Donghua Univ. (China)

The mathematical model for LED spectra was established at different drive currents. The simulation program of color rendering of white light LED cluster was developed according to the principle of additive color mixture. The program could predict not only the spectral power distribution, chromaticity coordinates, correlated color temperature, color rendering indices, but also drive currents, input power, luminous flux, luminous efficacy of the cluster. The simulation results shown that white phosphor-coated LED could realize high color rendering but low luminous efficacy, that white light LED clusters with white phosphor-coated LED and red LED could realize given color temperature white light with high color rendering index as well as high luminous efficacy, and that white light LED clusters with Neutral-White /Red/Green/Blue LEDs and with Neutral-White /Red//Blue LEDs could realize color temperature tunable white light with high color rendering index and high luminous efficacy.

7852-11, Session 2

A kind of side-emitting LED backlight light guide panel net dot design method

H. Wang, L. Ji, C. Liu, W. Zhang, South China Univ. of Technology (China)

In this paper, the transmission principle of light crossing the light guide panel was analyzed and a calculating method of the net dot distribution was deduced according to the illumination distribution of LED. Using this method, the light guide panel net dot distribution of a small size backlight was calculated. And, in the light of net not distribution regulation, the net dot layout was optimized and simplified associating with area segmentation adjustment method. Optical model was made and ray tracing was done by optical design software, the simulation result indicate that the surface luminance uniformity of the backlight is 87% and the light efficiency is 71%, which is achieved by less LED sources and area segmentations compared with the same size backlight. The net dot of light guide panel sample was made by laser engraving. The luminance uniformity of testing is consistent with that of simulation.

7852-12, Session 2

LED light source and secondary optical design for the efficient energy delivering on optogenetic experiment

C. Ou, Hsiuping Institute of Technology (Taiwan)

Recently, the solid state light source for the optogenetic had been paid much attention. Due to the fact that the channel material (such as ChR1, ChR2) required particular spectrum compositions to produce the most efficient photostimulatings, this article study several types of the LED spectrum and secondary optical design for optogenetic experiment. The matching of the spectrum between the LED, the spectrum of different channel material and the optical components are also discussed. As for the methodology, we study the energy efficiency of the LED

device to the neuron by consider several factors, which include the the photoperiodism, the photo-morphogenesis, light intensity, light photoperiod. More than this, the discussion on the Etendues of the system and the neuron morphologies through the complicated integrations on the shape of the neuron and the lighting devices are also report. Particular optical design is proposed to provide a more efficient energy delivering into the neuron structures. Results suggest that the position or the light intensity of the LED lighting should be adaptive for different stage of the neuron stimulation.

7852-13, Session 2

Design of precision approach path indicator with LEDs as its light sources

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A precision approach path indicator (PAPI) is a lamp installed in the runway of an aerodrome. It emits white light beam above a certain angle and red light beam below. It helps the pilot keep the aircraft on the right glide path. The traditional PAPIs always use halogen lamps as their light sources. However, the lifetime of the halogen lamps is short, averagely 1500 hrs. The maintenance work of changing the lamps is very inconvenient for an airfield. Light emitting diodes are high reliability photoelectronic devices, whose lifetime can reach one hundred thousand hours. In this paper, the design of a PAPI based on LED light sources is introduced. White and red LEDs are used to emit white and red beam separately. According to the standard Annex 14 of the International Civil Aviation Organization (ICAO), the transition width between the white and red light beam should be less than 3 minutes of arc from far away. This requirement is strict and the optical design of the PAPI is critical. The white and red LEDs are separated into two cases. In each case there is a single lens in front of the LED. The LEDs are placed exactly at the focal planes of the lens. The white LED is fixed below the optical axis to project the white light in the upper part, and the red LED is fixed oppositely. Baffles are used to form a sharp separation of the beam. The transition width of the finally realized PAPI is 2.6 minutes of arc. (National Hi-Tech Research and Development Program (863) of China, No. 2006AA03A173)

7852-14, Session 2

Tuning the emission wavelength of InGaN-based light-emitting diodes using strain-accommodative structures

X. Wang, H. Jia, H. Li, C. M. Dong, T. He, L. Dai, H. Chen, Institute of Physics (China)

In this paper, we focused on tuning the emission wavelength of InGaN-based light-emitting diodes using strain-accommodative structures (SAS). Generally, the adjustment of emitting wavelength is realized by controlling the quantum well (QW) thickness and the QW growth temperature, which decides the indium concentration. It needs low growth temperature and large thickness to emit long wavelength photons. However, the material quality, electrical and optical properties will severally degrade with low growth temperature and wide QW. Meanwhile, the growth of long wavelength LEDs based on the InGaN material still faces severe difficulties because of the large (11%) lattice mismatch between InN and GaN and the strong piezoelectric field-induced quantum-confined Stark effect (PQCSE) induced by the high strain due to lattice mismatch. LEDs with proper SAS, compared to the conventional ones, not only increase the emitting wavelength but also reduce the strain in InGaN well. It provides an alternative approach to tune the wavelength.

Strain accommodation was realized by inserting 35nm n-type InxGa1-xN (x=0.04-0.06) (Sample A) or short period super lattices (SPSL) consisted of 15 period of the 0.5-nm-thick InxGa1-xN (x=0.04-0.06) well and the 2-nm-thick GaN barrier (Sample B) between n-GaN and the multi-quantum wells. Sample C without SAS was grown under the same growth conditions. Under 20mA forward current, the peak wavelengths of sample A, B and C were 532nm, 562nm and 513nm. When the current increased from 3mA to 20mA, the peak wavelength shift of sample A, B and C were 4.1nm, 2.8nm and 7.4 nm, respectively. It shows that two types of SAS would efficiently increase the wavelength and weaken the QSCE, and SPSL structure achieves longer wavelength. So we could tune the wavelength of InGaN-based LEDs by strain-accommodative structures.

7852-15, Session 2

High illuminance light-emitting diode headlight for medical applications

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High brightness light emitting diodes have been used to develop high illuminance headlight for medical applications. It provides various advantages such as high illuminance, long life time, reduced infra red light, extended operation time with battery and light weight. A 3 W LED was employed to achieve the high performance medical headlight. The optical design includes two lenses for high energy transmission and high illuminance. The LED headlight shows 50,000 lux with spot diameter of 8 cm at the distance of 30 cm. For comparison purpose, 5 W LED was also used to obtain the high illuminance headlight. However, the large divergence angle and large spot size of the 5 W LED limits the illuminance to 30,000 lux with increased burden on heat dissipation. The thermal images of the heat sinks indicate that the temperature of the headlight using a 3 W LED is below 50 degree C, which is suitable for medical applications.

7852-16, Session 2

Study of key technologies of visible light communications based on white LED

D. En, N. Zhang, J. Feng, N. Wang, X. Wang, Henan Polytechnic Univ. (China)

Since the advent of white LED, remarkable achievements have been achieved in the luminous flux, luminous efficiency and so on, but it has not been used much in the field of wireless communications. White LED light source is used by visible light communication as a communication base station for wireless information transmission. Visible light communication has the advantage of high transmission power, no electromagnetic interference, etc. In this paper, firstly the basic characteristics of white LED have been described; then the key technologies of white LED visible light communication have been introduced; Finally, the development directions of white LED visible light communication technology have been discussed.

7852-17, Session 2

Three-chip LED illumination system for laparoscopy and minimal access surgery applications

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Light-emitting diodes (LEDs) bring great flexibility in color choice and high luminous efficacy design for biomedical illumination. Based on the state-of-the-art LED chips, a three-chip LED illumination system was developed specially for laparoscopy and minimal access surgery. White

light is produced by mixing three specific wavelengths of amber red, true green and blue, and then coupled into a fiber-optic light guide with 2mm diameter. The whole device has a compact size of 145×92×84 mm3 which is more suitable than a conventional xenon lamp source for portable endoscopes. The illuminance and color characteristic of the three-chip model were analyzed, compared to those of traditional light source. A maximum illuminance of 1960 lux was obtained at the distance of 100 mm, with the average current of 450 mA of the LEDs. Additionally, a simulation environment had been set up to find out the performance of the endo-illuminator in the specific circumstance, which was closer distance and crawl space. Experiments showed that illumination from the LED illuminator was more uniform than that of xenon lamps, especially at closer distance, and images taken under LED illumination were much sharper. With the temperature of 31.5 at the end of the fiber bundle, the endo-illuminator is also a cold light source.

7852-18, Session 2

The cinema LED lighting system design based on SCM

D. En, X. Wang, J. Feng, N. Wang, N. Zhang, Henan Polytechnic Univ. (China)

A LED lighting system in the modern theater and the corresponding control program is introduced. Studies show that moderate and mutative brightness in the space would attract audiences' attention on the screen easily. SCM controls LED dynamically by outputting PWM pulse in different duty cycle. That cinema dome lights' intensity can vary with the plot changed, make people get a better view of experience. This article expounds the architecture of hardware system in the schedule and the control flow of the host of the solution. Besides, it introduces the design of software as well. At last, the system which is proved energy-saving, reliable, good visual effect and having using value by means of producing a small-scale model, which reproduce the whole system and achieves the desired result.

7852-19, Session 3

Full color polymer light-emitting diode arrays with photo-patterning process

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Full-color polymer light-emitting diode (PLED) arrays presently are mainly produced by ink-jet printing. Here, we report a new approach for fabricating full-color PLED arrays that takes advantage of the low-cost and high throughput spin-coating and photo-patterning processes. Compared to previous approaches that also employed photo-patterning, our approach does not require wet processing steps, and the spectra of the colors emitted are not sensitive to the photo-patterning time. Because the photo-pattering is a traditional technology which was proved to be successfully used in producing liquid crystal displays and other electrical productions, this method may provide a low-cost and high throughput procedure to manufacture polymeric flat-panel display devices.

7852-20, Session 3

N-type doping in organic electronic devices

L. Xiao, J. Luo, Z. Chen, B. Qu, Q. Gong, Peking Univ. (China)

Considering the electron mobility in organic light emitting device (OLED) is much lower than that of hole mobility, n-type doping was used to improve the performance of organic electronic device. A facile way to fabricate highly efficient OLED with insulator MnO as an electron injecting and transporting material was devised, which eliminates the problem of the oxidation of reactive dopants. The power efficiency (PE) of 1.1 lm/W by inserting 3-nm-thick MnO as the electron injecting layer was obtained, higher than the 0.8 lm/W efficiency for the reference device with 0.5-nm-thick LiF. A thermal co-evaporation layer containing 10% weight of MnO and tris(8-hydroxyquinolato)aluminum as the electron transporting layer showed more efficient electron transport ability, with turn-on voltage of 3.8 V, lower than 7.4 V for the intrinsic Alq3. Meanwhile, the insertion of thin MnO layer between organic photoactive layer and inorganic metal electrode significantly improved performance and stability of organic solar cell compared to device without it. The power conversion efficiency (PCE) of 2.91% by inserting 3-nm-thick MnO was obtained, higher than the 0.91% efficiency for the device without it, and 2.59% for the device with 0.5-nm-thick LiF. Charge transport of rhenium trioxide (ReO3) in organic electronic devices was investigated. The hole injection/transport was blocked and the electron injection/transport was enhanced with doping of ReO3 in organic electronic devices. Thus the charge balance and efficiency of OLED were improved, 2.7 cd/A of current efficiency (CE) at 20 mA/cm2 for the device with ReO3 was higher than 1.5 cd/A for the device without it. In the case of organic photovoltaic cells (OPV), the open-circuit voltage (Voc), 0.58 V, was higher compared to the device without ReO3 (0.44 V) due to the improvement of interface properties. The PCE was increased to 2.27% by the combination of ReO3 (increasing Voc) with poly(3,4-ethylene dioxythiophene):poly(styrene-sulfonate) (PEDOT:PSS) (improve hole transport to increase Jsc) on the modification of the anode, higher than 1.85% for the device without ReO3.

7852-21, Session 3

Growth of SnO2 thin films by MOCVD and the electroluminesence from the SnO2/n+-Si heterojunction

J. Zhao, Tianjin Univ. (China)

Wide-band-gap oxide semiconductors have been emerging as the potential substitute for the nitrides in the light emitting diode (LED) applications. The main advantage of oxides is the abundance of the source materials, which results in the lower cost LEDs. ZnO have attracted extensive attention in the past 10 years due to its wide band gap (3.4eV) and large exciton binding energy (60meV). However, the p-type bottleneck has hindered the progress of practical ZnO based LEDs. SnO2 is also a direct wide band gap (3.6eV) semiconductor, and in particular, SnO2 exhibit much larger exciton binding energy (120 meV) than ZnO. Furthermore, the SnO monoxide has been proved as a intrinsic p-type semiconductor, which indicates that the p-type issue be easily resolved as compared with ZnO. Therefore, SnO2 may be a more promising candidate than ZnO for the LED applications. In this paper, we deposited SnO2 thin film by metal organic chemical vapor (MOCVD) and fabricated SnO2/n+-Si heterojunction LED. A clear red electroluminescence was achieved at room temperature from the device with a positive voltage applied at Si side.

SnO2 thin film was deposited on Si (100) substrate at 450OC by a homemade MOCVD system using tetraethyltin and pure oxygen as the precusors. The XRD of the as-grown SnO2 film shows a typical polycrystalline structure with pure tetragonal rutile phase. Hall-effect measurement on undoped SnO2 film exhibits n-type conduction, with the resistivity of 0.5 ohm.cm, the electron concentration of 8x1017cm-3, and the Hall mobility of 15 cm2V-1s-1. n-SnO2/n+-Si heterojunction isotope diode was further fabricated by depositing Au contact on the top of SnO2 and the backside of Si. A clear red electroluminescence can be observed by naked eyes at room temperature when a positive voltage of ~5V was applied on the Si side. The EL spectrum shows a broad emission peak centered at ~700nm. It is worth mentioned that the n-SnO2/p+-Si diode shows much weaker EL intensity than the n-SnO2/n+-Si device, which is well consistent with our previous studies on the n-ZnO/n+-Si LEDs.

7852-22, Session 3

An electron transporting blue emitter for OLED

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After the premier commercialization of OLED in 1997, OLED has been considered as the candidate for the next generation of flat panel display. In comparison to liquid crystal display (LCD) and plasma display panel (PDP), OLED exhibits promising merits for display, e.g., flexible, printable, micro-buildable and multiple designable. Although many efforts have been made on electroluminescent (EL) materials and devices, obtaining highly efficient and pure blue light is still a great challenge. In order to improve the emission efficiency and purity of the blue emitter, a new electron transporting blue light emitter (structure shown below), was designed and synthesized. It has two peaks (389 and 405 nm) in the fluorescence spectra and the corresponding fluorescence quantum yield is 0.99 in CH2Cl2 which shows the potential to be a highly efficient deep blue emitter in device. A blue OLED was obtained with the configuration of ITO/PEDOT/PVK:CBP:1-L/LiF/Al. PVK, CBP are polyvinycarbazole, 4,4'-bis(9-carbazolyl)-biphenyl and used as hole transporting layer, electron blocking layer respectively. 1-L is used as both electron transporting layer and emitting layer. They were all deposited by spin coating. The device exhibits a turn-on voltage of 9V, a maximum brightness of 12cd/m2 at 800mA/cm2 (15V). The device gives a deep blue emission located at 420 nm with the Commission Internationale de l'Eclairage (CIE) coordinates of (0.17, 0.10). We also use 1-L as electron transporting material in the device of ITO/PPV/1-L/LiF/Al, the highest current density is 3000mA/cm2 when the operating voltage is 6V. It is proved the current in the device was enhanced indeed by using the new material.

7852-23, Session 3

Polymer flat panel displays made by all-printing process

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Red, green, and blue passive-matrix (PM) polymer flat panel displays (FPDs) with resolution of 96×64 were fabricated by printing not only the emissive layer but also the cathode. The material used as the cathode is conducting Ag-paste synthesized in our lab. The final panels with a driver can show nice pictures. Current efficiencies of 0.62, 4.38 and 0.93 cd/A, and CIE color coordinates of (0.63, 0.37), (0.39, 0.57) and (0.18, 0.16), for red, green, and blue displays, respectively, have been realized. The technique presented in this research affords the first all-printable polymer FPDs that can be fabricated by printing techniques without need of thermal deposition. This result opens a process way with roll-to-roll technique for making polymer flat panel displays.

7852-24, Session 3

The escaped and trapped emission in organic light-emitting devices

Z. Wu, S. Liang, B. Jiao, X. Hou, Xi'an Jiaotong Univ. (China)

The optical loss is a crucial problem for the high efficiency organic light emitting diodes(OLEDs). Although Ray Optics Model predicts only about 20% light can escape and 80% of the generated light is wasted as wave-guiding modes or self-absorption. Various structures were designed to decouple the wasted light, however, the efficiency enhancement was only achieved from 22% to 56%, which is quite lower than the theoretical predictions. How much wasted light on earth can be decoupled in OLEDs is unclear.

In our work, the escaped and trapped emission of organic light-emitting diodes was investigated by both the integrating sphere measurement and numerical simulation. We found that the maximum external coupling ratio, surface emission to the surface and edge emission, is 71%, which is larger than the predictions of previous theoretical models, such as the combined classical and quantum mechanical microcavity model(CCQMM), the "half-space" dipole model, and ray optics model. In order to explain our experimental results, we extended the half-space dipole model, in which the dipole radiation pattern is taken into account. The calculated escaped and trapped emission of devices agreed well with the experiments, which show how much the emitted light in device can be decoupled, and was also expected to be an instruction to design new structure for improving the out-coupling efficiency.

7852-25, Session 3

Solution processable highly efficient OLEDs based on triphenylamine-benzimidazole derivatives

Z. Ge, Ningbo Institute of Technology (China)

A series of novel star-shaped bipolar host materials based on triphenylamine-benzimidazole derivatives (TIBN, Me-TIBN, DM-TIBN) were designed and synthesized. The energy levels of HOMO and LUMO as well as the singlet-triplet energy gap ΔE (T1-S0) calculated by DFT qualitatively agree well with the experimental values. The most stable dihedral angles at the biphenyl linkages in TIBN derivatives increased from 35° (TIBN) to 50° (Me-TIBN) and 89° (DM-TIBN), which leads to a decrease in conjugation between the electron-donating and -accepting moieties accompanied by the significant separation between the spatial distributions of HOMO and LUMO. The EL devices were fabricated with the structure of ITO/PEDOT/TIBN +6mol% Ir(ppy)3/TPBI/Cs:BCP/Al. The spin-coated OLEDs exhibited excellent performance compared with the vacuum deposited OLEDs, in which the devices derived from DM-TIBN showed the maximum luminance of 47,500 cd m-2 and the current efficiency of 27.3 cd A-1.

7852-26, Session 3

AES

Y. Hou, B. Zhang, B. Hu, F. Teng, X. Liu, Z. Lou, Beijing Jiaotong Univ. (China)

In this work, the amplified spontaneous emission (ASE) in the waveguide based on Poly [2-methoxy-5-(2'-ethylhexyloxy)-1, 4-phenylenevinylene] (MEH-PPV) and electric-field modulation of the ASE were investigated. The results show that the ASE can be quenched by the application of electric-field due the dissociation of excitons, which can be used to modulate the gain of ASE. The factors to influence ASE of polymer waveguides were analysed too. Meanwhile the feasibility to realize electrically pumped waveguide laser was probed.

7852-27, Poster Session

First principles caculations of electronic and optical properties of Zn1-x(TM)xO (TM=Mg,Cd)

P. Chen, H. Sun, South China Normal Univ. (China)

The paper present study of the electronic and optical properties of Zn1-x(TM)x (TM=Mg,Cd),through density function theory (DFT) based

on first-principles method. The calculation indicate that the band gap of Zn1-xCdxO narrows as result of the increasing concentrations of Cd. The paper shows that the Zn 4s and Cd 5s electron states broadens to low energy states and that the O2p electron states broadens to high energy states with increasing Cd-doping concentrations. The paper advances a possible theoretical mechanism of Cd-doped regulating Bands gap. Optical property of Zn1-x(TM)x (TM=Mg,Cd) is presented in the paper.

7852-28, Poster Session

Study on high-power LED heat dissipation based on printed circuit board (PCB)

Y. Wang, Tianjin Polytechnic Univ. (China)

The paper designed a simple model of high-power LED lamp, and tested the thermal resistance of four types of PCB under different working current, and the changes of LED junction temperature. Compared to the analysis of experimental results, the obtained value of PCB is not lower LED junction temperature, but in the dependence of heat sink on it. As a result, select PCB reasonable and match the appropriate heat sink, we can be able to reduce the size and weight of LED lighting, as soon as save production costs.

7852-29, Poster Session

Fault diagnosis in LED illuminating circuits based on cloud model

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A cloud model realizes the conversion between the qualitative concept and quantitative value. It can extract the fault feature using the set of sampling data in LED illuminating circuits and convert into a digital characteristic value of the fault status, accordingly achieve a qualitative assessment when LED illuminating circuits are diagnosed. Based on the fault diagnosis method using wavelet neural networks in LED illuminating circuits, with the outstanding characteristics of cloud model about the conversion between the qualitative concept and quantitative value and the time-frequency location characteristics of wavelet transform, a new method for LED illuminating circuits fault diagnosis is proposed in this paper. The selection process about the circuit fault feature based on wavelet transform is described, in which an LED illuminating circuit fault diagnosis cloud model is established. This wavelet transform and neural network based on the cloud model and traditional BP network are used respectively in the fault diagnosis of an example circuit. The simulation results indicate that the method proposed in this paper under the guidance of knowledge in the qualitative diagnosis can be adaptive range, better to avoid the convergence of local best optimization and the premature convergence caused by excessive sampling data.

7852-30, Poster Session

Monocular 3D display unit using soft actuator for parallax image shift

Y. Kodama, K. Sakamoto, Konan Univ. (Japan)

The human vision system has visual functions for viewing 3-D images with a correct depth. These functions are called accommodation, vergence and binocular stereopsis. Accommodation is a useful function for perceiving a depth by the monocular vision system. Binocular stereopsis is one of the most important processes for the human 3-D perception. The binocular vision system has many functions.

Accommodation is a useful function for perceiving a depth by the monocular vision system. And humans have the function called the simultaneous perception. Using this function, humans perceive dichoptically presented images simultaneously and in the correct position. So the 3-D HMD system can display a spatial image with merit that lightness of real and virtual images is not lacking, when humans watch a real 3-D image with the left eye and a virtual 3-D image with the right eye, for example.

The authors have developed a see-through 3-D HMD system. This display has no demerit that lightness of real and virtual images is lacking for a spatial viewing. To realize natural 3D viewing, we have developed the monocular vision system, which can directly project stereoscopic image on a retina, and a 3D image generation system, which can make 3D computer graphics in accordance with accommodation. Assume that an actual object is in the real world. When you perceive this object, a part of the projected image on a retina might be a blur by the lens of an eye. It is a physiological response called as accommodation. In case of virtual 3D image viewing, you can watch a correct 3D image as the actual object is in there if the projected retina image has appropriate blur in compliance with focus adjustment of your eye. Then you might perceive virtual images with same accommodation as you watch real objects. Thus a monocular 3D vision system can provide correct 3D viewing with accommodation, vergence and binocular stereopsis and without a tired feeling at long time watching when the retina image is directly projected and external stimulation induces the focus adjustment by changing the thickness of an eye lens.

To perceive multiple parallax images with just one eye, the image shifting optics consists of a parallel plane acrylic plate, whose inclination causes the image to shift. This image shift is generated by an inclined acrylic plate. To incline the plate, former vision unit used a motor. Therefore its weight is heavy so that observers wear it as glasses. To improve this problem, the authors developed new image shift mechanism for monocular 3D vision. This new image shifting optics consists of an acrylic plate and a soft actuator. This soft actuator is made of the film or wire-like material. The soft actuator can incline the acrylic plate when this actuator is bent (or contracts) by controlling the applied voltage. The soft actuator is thin and light. So the authors could develop the light-weight monocular display unit for 3D viewing with a correct and natural depth using this actuator.

7852-31, Poster Session

Invisible code display for robots' eye communication using polarization control by LCD panel

T. Furukawa, K. Sakamoto, Konan Univ. (Japan)

"The eyes are eloquent as the tongue." This proverb means that one can say more with a look than with ten thousand words. In many cases, we perceive one's true intention from his or her facial expressions and gestures. This is a nonverbal communication. The nonverbal communications are usually understood as the process of communication through sending and receiving wordless messages. The eye contact is a basic and expected form of nonverbal communication as the famous quote by: "the eyes are the window of the heart, and the heart is the house for the soul." This eye contact is a meeting of the eyes between two individuals. The authors hit upon an idea that fundamental transmission can make the best use of the eye communication. In this paper, the authors propose a communication method using an invisible code which is drawn on the eyes of the robot. We have developed the special graphics display for showing expression of robot's eyes and confirmed that our proposed technique enables the mobile robots to transmit and receive information data in order to establish a cooperation environment among robots.

To display visual information and to embed invisible additional information, the display panel needs to hide code symbols so as not to interfere with screen viewing. So we utilize a polarized symbol image

to overlap additional information on the visual screen. The polarized light wave has a useful characteristic to generate hidden images. You know you cannot perceive digits of a calculator if a polarizer is removed from an LCD, i.e., it is impossible for human's eyes to distinguish characteristics of polarization. In our interaction display system using LCDs, we utilize characteristics of polarization. Our proposed display system consists of a conventional LCD, an additional liquid crystal (LC) layer and some optical elements.

LC layers can rotate the direction of the polarization axis according to the applied voltage. The LC layer sandwiched between both polarizers displays visual information. This structure functions as an LCD. Then this LCD emits the polarized light due to the existence of a surface polarizer. Moreover, the overlaid additional LC layer changes the direction of polarization from LCD outputs. This LC layer generates invisible symbol patterns. The final LC layer passes through the output of an LCD or changes/rotations the direction of polarized light waves. This difference of rotation direction makes a binary symbol image. As humans cannot perceive differences of polarization, they directly watch only visual images on the viewscreen without perceiving symbol patterns.

At the detection, the polarized symbol pattern images are observable through the polarizer because this optical filter blocks the wave or not. This enables a camera to detect the invisible code on the display panel. So the display panels show visual images and invisible symbols simultaneously. Human's eyes can get only visual information and a code reader finds an only binary symbol pattern.

The authors have also researched an adaptive user interface for the handicapped. Using this invisible code, the display system provides all users with visual information and assistance like an audio guide if the user needs a support.

7852-32, Poster Session

A design of LED adaptive dimming lighting system based on incremental PID controller

X. He, Z. Xiao, S. He, Guilin Univ. of Electronic Technology (China)

Abstract: As a new generation energy-saving green lighting source, LED is applied widely in various lighting fields. The requirement of its lighting technology is subsequently higher and higher, especially in the automatic on-line detecting system. In this paper, a closed loop feedback LED adaptive dimming lighting system based on incremental PID controller is designed. It consists of MEGA16 chip as a MCU (Micro-controller Unit), the ambient light sensor BH1750 chip with I2C (Inter-Integrated Circuit), and constant-current driving circuit. At the beginning, a given value of light intensity required for the on-line detecting environment need to be saved to the register of MCU. The optical intensity, detected by BH1750 chip in real time, is converted to digital signal by AD converter of the BH1750 chip, and then transmitted to MEGA16 chip through I2C serial bus. Since the variation law of light intensity in the on-line detecting environment is usually unknown, incremental PID (Proportional-Integral-Differential) algorithm is applied in this system. Control variable obtained by the incremental PID determines duty cycle of PWM (Pulse-Width Modulation). Consequently, LED's forward current is adjusted by PWM, and the luminous intensity of the detection environment is stabilized by self-adaption. Both hardware and software of this system are accomplished. And the coefficients of incremental PID are obtained respectively after experiments. Compared with the traditional LED dimming system, it has advantages of anti-interference, simple construction, fast response, and high stability by the use of incremental PID algorithm and BH1750 chip with I2C serial bus. Therefore, it is very suitable for the adaptive on-line detecting applications.

7852-33, Poster Session

Investigation of optimization of layer thickness in bilayer organic light emitting diodes with ohmic contacts

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In this paper, the characteristics of bilayer organic light emitting diodes (OLEDs) with ohmic contacts, especially the optimization of layer thickness, are investigated based on a simple analytic model by numerical study. In the model, both anode and cathode are assumed to be ohmic electrodes, J is assumed to be a monopolar current, and all incoming carriers recombine on an interface, i.e., =JR /J=1, where J and JR are device and recombination current densities.

Current-voltage (J-V) characteristics on different ratios of hole to electron carrier mobilities and the dependences of recombination current on the thicknesses ratio of the two layers are examined. The effects of characteristic electric fields related to material characters of hole transporting layer (HTL) and electron transporting layer (ETL) on devices are also analysed.

The analytic models include equations as below: the drift-diffusion equations of the current densities of holes and electrons in OLEDs, the Poisson equation, the Poole-Frenkel dependence.

The conclusions are shown in the end. (1)There exists an optimal thickness ratio of HTL to ETL for a given thickness of the total organic layer, by which the device reaches a maximal recombination current density. (2) The optimal thickness ratio depends on the ratio of hole to electron carrier mobilities and characteristic electric fields related to material characters of HTL and ETL. (3) For the devices of hole carrier mobility more than electron carrier mobility, i.e., most of bilayer OLEDs, the optimal thickness ratio of HTL to ETL is much more than one.

7852-34, Poster Session

FDTD investigation of light extraction effect of LED by randomly distributed square posts

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In this paper, square posts are randomly generated on the surface of OLED structure for enhancement of light emission. Simulation results shows that random-square-post layer not only largely increase the emission power but also evidently widens the far-field angle distribution. Analysis indicate that change of post filling factor can have pronounced effect on adjusting the orientation of far-field view angle, which is desired in application of LED. Moreover, the influence of refractive index of square post on the radiation power is also inverstigated. Simulation shows that materials with relatively higher refractive index will be more beneficial for the LED light extraction.

7852-35, Poster Session

Electronic structure and spectroscopic property of a novel iridium (III) complex with an ancillary ligand 2-(4-trifluoromethyl -2-hydroxylphenyl)benzothiazole

L. Lei, Taiyuan Univ. of Technology (China)

Iridium (III) complexes with 2-phenylpyridine (ppy) have been demonstrated as a promising phosphorescence dopant in emitting layer of organic light emitting diodes (OLEDs). In most iridium (III) complexes, there exist the strong spin-orbit coupling between π-orbitals of cyclometalated ligand and 5d orbital of the centric iridium. In this

paper, using Gussian 03 Program we will study a novel iridium (III) complex (ppy)2Ir(4-TfmBTZ) with ppy as cyclometalated ligands and 2-(4-trifluoromethyl-2-hydroxylphenyl)benzothiazole (4-TfmBTZ) as ancillary ligand. The results showed that the spin-orbit coupling occurs between not only ppy and iridium atom but also 4-TfmBTZ and iridium atom in this complex. The geometries, electronic structures of ground and the lowest-lying triplet excited state and spectroscopic properties of this iridium(III) complex were carried out by functional theory (DFT) and time-dependent density functional theory (TD-DFT).The highest occupied molecular orbital is dominantly localized on Ir atom and 4-TfmBTZ ligand while the lowest unoccupied molecular orbital largely resides on 4-TfmBTZ ligand. The triplet lowest-lying transition is attributed to Ir-to-4-TfmBTZ charge-transfer (3MLCT) transition while the sub-low-lying transitions are assigned to 3MLCT transition of Ir(ppy)2. The nature of the lowest unoccupied orbital changes from ppy-localized to 4-TfmBTZ-localized and it revealed that phosphorescent color of this new Ir(III) complex can be tuned by introducing suitable ancillary ligand.

7852-36, Poster Session

Vibronic coupling parameters and luminescent properties of Eu2+ doped complex alkaline earth thioaluminates

D. Zhang, W. Xue, Z. Yu, T. Zhang, Y. Jiang, J. Leng, X. Kong, Beijing Institute of Technology (China)

Europium doped alkaline earth thioaluminate (MIIAl2S4:Eu, MII=Mg, Ca, Sr, and Ba) has been proved as the most efficient blue- and green-emitting inorganic electroluminescent material. The characteristic emission peaks of these materials are 499nm, 512nm, 494nm and 472nm (474 nm), with CIE coordinates of (x=0.155, y=0.27), (x=0.158, y=0.65), (x=0.116, y=0.374) and (x=0.129, y=0.122), respectively. Recently, complex alkaline earth thioaluminate doped by Eu (MIIxMII1-xAl2S4:Eu) is researched to obtain better blue and green electroluminescent phosphor of high efficiency. In this paper, the crystal structures of MIIAl2S4 host materials are summarized separately. The crystal structure, space group and unit cell parameters of MIIAl2S4 are also declared and compared. In addition, the MIIS-rich and Al2S3-rich thioaluminates are mentioned in this text and the crystal structure and parameters are illustrated. The luminescent properties of different MIIxMII1-xAl2S4:Eu are researched. Photoluminescence spectra of MIIxMII1-xAl2S4:Eu phosphors are fitted and emission peak corresponds to the 5d 4f transition of excited Eu2+ are achieved. Vibronic coupling parameters of these phosphor materials can be calculated by the formula. With the calculation of characteristic energy and unitless factors, performances of MIIxMII1-xAl2S4:Eu phosphor materials are evaluated. According to the result of assessment, it can be concluded that Mg and Sr thioaluminates is suitable for using as parts of complex thioaluminate phosphors because they can shift the emission peaks since the Mg and Al in the periodic table directly next to each other. In addition, alkaline earth thioaluminates are materials with wide band gap which are similar as alkaline earth sulfides and may be of great potential in the area of optical storage material.

7852-37, Poster Session

The effect of different color temperature lighting sources on road lighting: from mesopic light levels angle

X. Li, J. S. Zhong, China Jiliang Univ. (China)

The theory of mesopic vision provides an important theory foundation for the choice of road lighting sources. The international luminance recommendation for road lighting is between 0.3 and 1.2cd/m2, which is under the mesopic light levels. Recent studies shows that there are no international standards for the mesopic region, however the conventional photometry relying on the photopic luminous efficiency function (V) is not a completely satisfactory at that low light levels. Thus, we want to propose a method to build a relationship between photopic illumination and mesopic illumination.

Furthermore, we propose the equation,Emes=B*Ep, to deduce from the Ep (photopic illumination) to Emes(mesopic equivalent illumination), where B is instant for modified coefficient. The coefficient B can be calculated based upon the modified MOVE-model and the important parameter(X)which describes the proportion of photopic luminous efficacy at any luminance. And the coefficient B can used easily to calculate the mesopic equivalent illumination by using the measuring results of photopic illumination for different color temperature lighting sources under mesopic light levels. Using the equation, we analyze the variation of coefficient B with background lighting level of the different color temperature lighting sources under mesopic vision levels. By calculating the mesopic equivalent illumination of the different sources, our results showing that the higher color temperature LED sources have better visual effects. Moreover, the results provide the basis for further studies on the illuminometer, which might be suitable for mesopic vision.

7852-38, Poster Session

white light LED based on YAG:Ce3+ phosphor and quantum dots

L. Ke, C. Shen, China Jiliang Univ. (China)

With the help of opto-mechanical simulation software-LightTools and SolidWorks, white LED combining by GaN(460nm) chip with blends of YAG:Ce3+ phosphor and CdSe/CdS quantum dots was modeled. Excitation spectrum of YAG:Ce3+ was composed of two bands peaking at 335nm and 460nm. Emission band of YAG: Ce3+ peaking at 532nm corresponds to the 5d 4f transition of Ce3+. The CdSe/CdS quantum dots has the emission peak wavelength of 615nm under the excitation of 460nm. Modeling results showed that the introduction of the QDs can improve the color rendering index of white LED. White LED with color rendering index of 85, CIE chromaticity coordinates of (0.3039, 0.2971), and color temperature Tc of 5678K was obtained as the ratio of YAG:Ce3+ and CdSe/ZnS quantum dots was 1:1.

7852-39, Poster Session

The investigation of the light outcoupling in the blue top-emitting OLED

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A classic electromagnetic theory is used in this paper to investigate the light outcoupling in the blue top-emitting organic light-emitting devices (TEOLED).With this method, the coupling effect of light induced by all kinds of interface and the position of excitons is considered to explain the optical characteristics of the blue TEOLED. Spectra of the devices with different top-electrode and with an outcoupling layer were simulated. The results demonstrate that in the device with a bilayer cathode composed of Sm and Ag, with the increased thickness of Ag, the resonant wavelength induced by the light outcoupling would shift to the long wavelength and the intensity of out light would decrease. On the other hand, if the thickness of Ag is fixed, the change of Sm would not influence obviously the resonant position but change the intensity of light. According to the theory of interference, we also find that in our TEOLED, multi-beam interference is much stronger than wide-angle interference, so the position of excitons that mainly influences the wide-angle interference is relatively not important. In order to decrease

the multi-beam interference, a light outcoupling layer is introduced into the device. Through the simulation, a most suitable thickness of the outcoupling layer is determined. On the basic of above theoretical analysis, some crucial details about the light-emitting in the TEOLED are found and explained. A good agreement is observed between the measurement and the simulation data.

7852-40, Poster Session

Theoretical study the conductivity of Y doped in ZnO

L. Chen, Z. Xiong, Jiangxi Science and Technology Normal Univ. (China)

Based on the first principles calculations, using density functional theory within the generalized gradient approximation we perform a study on Y doped in ZnO, where the total density of states (TDOS), the partial density of states (PDOS) and band structure and conductivity of the systems are included. The calculated results show that with the increase of concentration of Y, the lattice parameter is expanded. Moreover, from the PDOS, we can see that the valence band maximum is determined by the O-p states and the conduction minimum is depended on the Y-d and Zn-s states. Simultaneously, it is found that as the increase of concentration of Y, the band gap of dopant system is broadening. It is because the valence band is more than the conduction band, which are moves towards into lower energy. We also found that the Y-s state plays an important role in red-shifted. In addition, we calculated the number of the electrons which go into the conduction band. We found that as the increase of concentration with Y, the number of the electrons is decreasing. The conductivity of the system is enhanced with the increase of Y concentration. Therefore, it can conclude that the low concentration of Y doping ZnO demonstrates the better conductivity. Our theoretical results are in good agreement with the experiment results.

7852-41, Poster Session

A large size RGB LED BLU LCD display and its imaging management

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A 32” LCD display with direct type RGB LED backlight unit is developed. The grid-noise artifacts in LC control signal are removed using an optimized local dimming algorithm with consideration of the backlight distribution for the identical intensity of LED blocks. The display color gamut space is expanded using suppositional color expansion method, and a color gamut transformation matrix is obtained for transferring the CCFL BLU LCD display gamut system to our RGB LED BLU LCD display gamut system. As a result, the 32” RGB LED LCD display has a static contrast ratio of over 20000:1 and an average of 30% power reduction, and the color has been accurately reproduced in RGB LED BLU LCD display with more richness and more saturation.

7852-42, Poster Session

Synthesis and luminescent properties assessment of Eu-doping barium thioaluminates material

D. Zhang, Z. Yu, W. Xue, T. Zhang, Y. Jiang, J. Leng, X. Kong, Beijing Institute of Technology (China)

Europium-doped barium thioaluminate (BaAl2S4:Eu) is the most efficient blue phosphor for inorganic electroluminescence currently. In order to obtain phosphor material of high luminance and efficiency, many researchers and experts have been investigating on this material and several synthesis methods have been invented. In this work, different synthesis processes of BaAl2S4:Eu material and four main fabrication methods of BaAl2S4:Eu thin film are reviewed and investigated including two sources pulse electron beam evaporation, four sources pulse electron beam evaporation, two targets sputtering and single target sputtering. Crystal structures of BaS-Al2S3 system are summarized and analyzed. BaS-rich and Al2S3-rich thioaluminates are in comparison. In addition, configuration coordinate model and vibronic coupling parameters are introduced as the base of assessment procedures of BaAl2S4:Eu phosphor. PL spectra of BaAl2S4:Eu are collected and vibronic parameters of BaAl2S4:Eu material and thin film are calculated respectively by the formula with photoluminescence(PL) spectra. Finally, the luminescent properties of BaAl2S4:Eu thin film and powder material are evaluated and compared by the assessment procedures in the framework of configuration coordinates model.

7852-43, Poster Session

High brightness green light-emitting diode based on silole-containing polyfluorenes

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A novle conjugated Silole-containing Polyfluorene was successfully synthesized by the palladium-catalyzed Suzuki coupling reaction based on silole and fluorene for pursuit of high-performance polymer light emitting diodes. Optoelectronic properties including UV absorption, electrochemistry, PL, and EL of the copolymers were examined. Spin-cast thin films exhibit intense green fluorescence. We will report the electroluminescent properties of the polymer.

7852-44, Poster Session

Investigation of hole injection characteristics in NPB/AlQ heterojunction devices

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The effect of ozone and O2 plasma treatment of ITO on the charge-carrier injection in ITO/ N, N’-bis-(1-napthyl)-N, N’-diphenyl-1, 1’biphenyl-4, 4’- diamine (NPB)/ tris(8-quinolinolato)-aluminum (AlQ)/Al organic heterojunction devices have been studied through the analysis of current-voltage characteristics. For comparison, three kinds of device with the structures of ITO/NPB/AlQ/Al, ITO(O2 plasma treatment)/NPB/AlQ/Al and ITO(O3 treatment)/NPB/AlQ/Al have been fabricated. In order to determine the electric field distribution in both NPB and AlQ layers, we varied the thickness of NPB layer (assuming the values of 20, 40, 60, and 80 nm), and fixed the thickness of AlQ (60 nm). A sliding shutter was used to achieve a systematic change of the NPB layer thickness. Devices with different NPB layer thicknesses were fabricated simultaneously under the same conditions. From the experiments, it is demonstrated that the average electric field inside AlQ layer is larger than the average field in the NPB layer. The investigation demonstrated that the hole injection into NPB from anode is Fowler-Nordheim (FN) tunneling and the electron injection into AlQ from cathode is Richardson-Schottky (RS) thermonic emission.

7852-45, Poster Session

Power saving back light module with optics and light pipe

Y. Fang, J. Yu, C. Huang, B. Hsueh, S. Wang, National Kaohsiung First Univ. of Science and Technology (Taiwan)

LED play the role at such the kind of modern display light source thanks to its power consumption and the most important, outstanding colour gamut. Modern displays are required to be much thinner and thinner with best colour gamut. We have manipulated the pattern distribution of the micro features to obtain the required optical characteristics. A light guide plate (LGP) of 3.5 inch dimension using an LED light source is used as an example for the study of integrated LGPs. This research designs a piece of light guide film (LGF) at the back of LGP. It may induct the exterior light, and enables the backlight module to achieve the energy conservation. In addition, the special-designed light pipe and optics will induce external light, which will contribute 5 to 10% power savings.

7852-46, Poster Session

Thermal analysis of packaging materials for high-power white light LED

L. Ke, China Jiliang Univ. (China)

With the increasing of LED's power, the capability of the heat elimination and acknowledgement the temperature rise rule influenced the life period and other performances of LED significantly. In this paper, packaging materials, structure and temperature distribution of high-power white light LED were studied by finite element using SolidWorks and Analysis softwares. Kinds of white light LEDs were simulated by different heat sink matieral and thermally conductive adhesive. As the power of white light LED increased, temperature-difference of high-power white light LED enlarged. The temperature-difference of 3W white light LED was 18 K. In this paper, Temperature fields of different heat sink materials were compared such as Cu, Ag, Al and AlSiC. Results showed that the lowest temperature-difference of high-power white LED was 15.06K as using Al heat sink. Temperature fields of LEDs were obtained as using nano-silver(238w/m K) and alloy of Sn/Au(58w/m K), and alloy of Sn/Pb(51w/m K) as the thermally conductive adhesive. Lowest temperature-difference of high-power white LED was 3.61K as using nano-silver as thermally conductive adhesive . Considering the thermal stresses analysis simultaneous, the high power white LED packaged with the Al -heat sink and nano-silver -thermally conductive adhesive showed the optimum effect of the heat elimination.

7852-47, Poster Session

The ferroelectric liquid analysis 0f LCoS

L. Hao, B. Lin, Zhejiang Univ. (China)

Liquid crystal on silicon(LCoS) is a new display patten, which applies the reflectantance to display image. LCoS has many advantages, and the main is reducing the size of the projection. In order to utilize the LCoS, this paper advances a new pattern liquid material which is ferroelectric liquid crystal. It has the characteristics, such as time Division-style full-color display, high resolution, the responds time of rise and fall time is Symmetry, low voltage and high respond. If it is used in the microdisplay, we can attain large area visual display, high open rate and high responding time. The alignment of ferroelectric liquid crystal is very complicated, so we use photo-alignment, rubbing or hibrid-alignment to determine the direction of liquid. Once the liquid layer has fabricated, we take the Berrman's 4*4 matrix to stimulated the photoelectric effect, and the stimulated result is very approximately the experiment. In addition, we use space parameter method to analysis the liquid layer, and we make sure the detailed optical thickness and pretilted angle. The fabrication of LCoS is very difficult, for one reason, it determines the character of the film on the ITO glass, for the other, the technology must combined the IC and LC technology, and it is not so sophisticated now. however, the potentiality of LCoS is very large and maybe instead of traditional display one day.

7852-48, Poster Session

Effect of BCP layer on electroluminescent performances in blue top-emitting organic light-emitting devices

J. Xie, S. Chen, Q. Fan, Y. Yang, W. Huang, Nanjing Univ. of Posts and Telecommunications (China)

The organic compound, 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP) is used as a light outcoupling layer in top-emitting organic light-emitting devices with iridium (III) bis[(4,6-difluorophenyl)-pyridinato-N,C2'] picolinate (FIrpic) emission layer. It is different from the conventional TEOLED that use ITO as a thickness adjustment layer to make the cavity length matchable with the resonant wavelength of the blue light. The total thickness (105 nm) of organic materials sandwiched between the cathode and the anode in this TEOLED is almost same with a conventional bottom-emitting OLED (BEOLED). The influence of the BCP outcoupling layer on EL intensity, luminous efficiency, and EL spectra (Fig. 1) was explored by combining experimental data with microcavity and transfer matrix theories The experimental data was basically consistent with theoretical results. As a result, the high performances such as high brightness, large luminous efficiency, and saturated chromaticity are obtained in the blue TEOLED, which are comparative to those in the bottom emissive OLEDs.

7852-49, Poster Session

Free-form lens design for LED indoor illumination

K. Huang, MingDao Univ. (Taiwan); J. Chen, T. Wang, L. Huang, National Changhua Univ. of Education (Taiwan)

This paper presents a free-form lens design for indoor illumination. This lens consists of a TIR (total internal reflection) surface on the sidewall, a refractive surface on the front side, and a concave surface on the rear side. The TIR surface is decorated with a free-form profile that light rays emitted from the LED with a larger spread angle to the axis will experience a total internal refection and output from the front refractive surface. While the central part of the front refractive surface has a convex surface that makes light rays closing to the optical axis more evenly distributed. The purpose of the rear concave surface is to let light rays emitted from the LED enter the lens straightforwardly. With this lens light rays from a Lambertian-type LED light source can be redistributed so that a uniform illumination can be achieved. The optical simulation results show that the measured optical efficiency is 75% while the uniformity is 80% on a target plane of 6-m diameter and at 2.5-m away.

7852-50, Poster Session

Research at the interface between Cs2CO3 and electron transport materials in OLEDs

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An effective cathode structure for efficient electron injection is critical to the performances of organic light-emitting devices (OLEDs). Since 2004, cesium carbonate (Cs2CO3) has been widely used as electron injection material (EIM), and the results indicate that Cs2CO3 facilitates electron

injection when it contacts with a wide range of metal electrodes, such as Al and Ag. However, little work focuses on the choice of electron transport materials (ETM) to match Cs2CO3 EIM.

In this communication, we found that the electron injection was quite sensitive to the choice of electron transport materials when using Cs2CO3 as electron injection material. OLEDs performed obvious different current characteristics when changing ETM to contact with Cs2CO3 EIM. The detail mechanism of this phenomenon would be discussed here.

7852-51, Poster Session

Study on improvement of OLEDs properties with anti-reflection coatings

C. Liu, D. Wang, I. zhao, W. Jiang, Z. Qin, C. Wang, Jilin Normal Univ. (China)

An anti-reflection(AR) coating system was inserted between the anode (ITO) and the glass substrate in the red light organic electroluminescent devices(OLED) for the structure being K9/ITO/NPB (60nm) / DCJTB (0.3nm) / AlQ (60nm) / LiF (0.3nm) / Al.The AR film system structure is K9 / TiO2/Al2O3 / 2-ITO, and TiO2 and Al2O3 coating optical thickness are also quarterwave length. The results show that the maximum transmittance rate of AR coating is by 95%(610nm), it increased by 8% compared with only using ITO as AR coating. The maximum brightness of the device increased by 30%, the largest efficiency of the devices increased 1.15 times, while reducing the threshold voltage of the devices.The processing is simple and high efficient, and can change AR coating structure according to the OLED device emission wavelength, therefore, can be widely applied to the OLED devices.

7852-52, Poster Session

Study on improvement of OLEDs properties with the AlN insulating layer

C. Liu, J. Wang, C. Wang, L. Zhao, W. Jiang, Jilin Normal Univ. (China)

The thin aluminum nitride(AlN) using as an insulating layer was inserted between the anode (ITO) and the NPB organic film in the organic light-emitting devices(OLED) for the structure being K9/ITO/ AlN / NPB/Alq3/LiF/Al.The effect of the different thickness AlN film on the device performance was investigated. After optimization, improvement of OLEDs properties is biggest when the AlN film thickness is 0.4 nm.Such a structure with AlN layer facilitates the increase of current density and decrease of threshold voltage, resulting in an improved luminance and luminous efficiency. The best results have been obtained on devices with an improvement of 38 % on luminance. This phenomenon is mainly because of the insulating capability of the aluminium nitride coating and the passivating role of AlN film to the ITO surface. The processing is simple and high efficient, can be widely applied to the OLED devices.

7852-53, Poster Session

Effect of chip junction temperature on the performance parameters and life time of high-power LED

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In recent years, with the successful development of high-power and high-brightness LED chips and the continuous improvement of luminous efficiency, more and more high-power LED lamps begin to enter lighting field. At present, the input power of the commercial and high-power LED is generally 1W, the chip area is 1mm×1mm, and the heat flux reached 100 W/cm2. So high heat flux will make the chip junction temperature rise, and further cause the problem of failure rate increasing, light extraction efficiency decreasing and life time shortening. On the other hand, the chip junction temperature rising will cause red shift of its emission spectrum, thus color temperature quality will decline. Therefore, heat dissipation of high-power LED is the key technology to be solved. In this paper, the effects of the chip junction temperature on performance parameters and life time of high-power LED are discussed. The causes of the chip junction temperature rising are analyzed, and some methods to decrease chip junction temperature are given.

7852-54, Poster Session

Synthesis of Eu3+ doped silicate phosphor by sol-combustion method

X. Li, G. Li, L. Jin, G. Jia, Z. Yang, G. Fu, Hebei Univ. (China)

Eu3+doped Y2SiO5 phosphor was prepared by the sol-combustion method using citric acid as complexing agent in this experiment. The X-ray diffraction (XRD) pattern, excitation and emission spectra were used to investigate the crystal structure and luminescent properties of the phosphor. XRD pattern shows that pure Y2SiO5:Eu3+ phosphor was obtained. The excitation spectrum was composed of a broad band from 200-350 nm and a series of narrow bands from 350-500 nm, in which the excitation peaks at 395nm and 470 nm were stronger. The emission spectrum shows the most intense emission peak is located at 613 nm, which corresponds to the 5D0 7F2 transition of Eu3+. The results show that this phosphor could be excited by UV or blue light and emit red light. The luminescent intensity depends on the concentration of Eu3+ and it reached the maximum when the molar concentration of Eu3+ was 4 mol%. In this study, we found that the emission intensity reached maximum when the ratio of citric acid and Y3+ was 1.5:1. The results indicate that Y2SiO5:Eu3+ is a potential red-emitting candidate phosphor for white light-emitting diodes.

7852-55, Poster Session

Study on the luminescent properties of Tb3+ doped pyrosilicate phosphor

G. Li, X. Li, L. Jin, G. Jia, Z. Yang, G. Fu, Hebei Univ. (China)

The Y2Si2O7:Tb3+ phosphor was synthesized by high temperature solid state method. The crystal structure and luminescent properties of phosphors were studied by XRD pattern, excitation and emission spectra in this paper. XRD pattern showed that the sample was single phase Y2Si2O7 crystal and the crystal lattice constants a 0.806nm, b 0.934 nm, and c 0.692 nm. The excitation spectrum is composed of a broad band centered 300nm and three narrow bands corresponding to 4f-4f transition of Tb3+ centered 376 nm, 400nm and 420nm, respectively. The emission peaks of phosphor were located at 487nm, 545nm, 584nm and 623nm, which were corresponding to 5D4-7F6, 5D4-7F5, 5D4-7F4 and 5D4-7F3, respectively. The influences of sintering temperature, sintering time and Tb3+ concentration on the luminescent intensity of Y2Si2O7:Tb3+ phosphor was studied. The results indicated that this phosphor could act as a candidate green phosphor for UV-excited white LED.

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7853-01, Session 1

Overview of plasmonic sensors and their design methods

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Recently, surface plasmon resonance (SPR) based optical sensor technology has made the remarkable progress associated with chemical and biological sensing applications, but research in this area is still attracting great attention. Previously, numerous SPR based sensor configuration and their data processing methods with signal amplitude or phase have been proposed. In terms of sensor structure design, Krestchmann configuration with flat metal layers of reflection-types sensor system have been developed as the most basic structure in the early days and reached commercialization. Then, owing to recent advances in nanofabrication methodologies, plasmonic nano-structures composed of nanoparticles, nanorods, nanoholes, and others have been applied to sensor configuration in order to achieve high performance. Also, researchers have actively developed new types of plasmonic sensors based on extraordinary optical transmission (EOT) through nanoholes and nanoapertures and proposed several sensors with metamaterial. In their sensors, with precisely controlled structural parameters, can be improved is the sensing performance such as detection limits, sensitivity, and dynamic range, relative to the commercial systems.

In this aspect, we will review recent advances in the SPR based optical sensor systems and introduce their design method for enhancement of sensing performance. In addition, the effect of structural parameters of SPR sensors with transmission or reflection-type configuration will be discussed. This analysis could help for realization of SPR sensor systems and development of sensor with improving sensing capability.

7853-02, Session 1

Mid-infrared surface plasmon excitation on highly doped silicon and conducting ceramic materials

J. Lai, Huazhong Univ. of Science and Technology (China)

Mid-infrared surface plasmonic resonance (SPR) phenomena has aroused a little attention recently due to its potential application in chemical and biomedical sensors. Unlike metal materials, highly doped silicon and conducting compounds, such as metallic oxide and ceramic, when have carrier concentrations on the order of 1019 1021 cm-3, have plasma frequencies at near infrared and visible frequencies based on Drude model calculations and may shift the surface plasmon polaritons (SPPs) wavelength to mid-infrared by changing the ambient dielectric properties. In this work, reflectance and transmittance measurements of high doped silicon and conducting ceramic materials TiN as a function of infrared wavelength were conducted and the real and imaginary parts of the dielectric function ( ) and thus the dispersion relation of SP of doped silicon and TiN are determinated. Microstructured thin films with the above materials were fabricated and infrared absorption properties were investigated. The excitation of SPPs on these materials has versatile and sensitive chemical sensing and infrared detector applications.

7853-03, Session 1

CCD fiber Bragg grating sensor demodulation system based on FPGA

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A CCD fiber Bragg grating sensor demodulation system based on FPGA is proposed. The system is divided into three units: spectral imaging unit, signal detection unit and signal acquisition and processing unit.

The spectral imaging unit uses reflective imaging system, which is few aberration, small size, simple structure and low cost. In the signal detection unit, the information of spectrum are accessed by CCD detector, the measurement of spectral line is converted into the measurement of the pixel position of spot, it can simultaneously measure multi point, so the system's reusability, stability and reliability can be improved. In the signal acquisition and processing unit, the drive circuit and signal acquisition and processing circuit are designed by programmable logic device FPGA, the A/D conversion and data storage are controlled by FPGA, fully use of FPGA programmable features and high real-time features, simplified system design, reduced the design cycle, improved the system's real-time monitoring capabilities and demodulation speed.

7853-04, Session 1

Dynamical analysis of evanescent field loss based fiber laser sensing

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Optical fiber sensors (OFS) play an important role in modern intellectualized sensing system. A novel optical fiber sensor based on single mode fiber laser is proposed in this paper. The main elements of the novel fiber laser sensor (FLS) is based in the fact that the output power of fiber laser is influenced by the loss which caused by the absorption loss of analyte in evanescent field of the fiber. The action of the fiber laser sensor is theoretical investigated using three-level system rate equations and propagation equation. By resolving the rate equation, many detail information of the fiber laser are obtained. The function which contacted the output power of the fiber laser and the absorption loss of analyte is build upon the complex refraction index of the analyte and the loss of the resonant cavity of the fiber laser in the rate equation though evanescent field. The imaginary part of matter's complex refraction shows the absorption ability of the matter. We supposed the absorption of the matter in the evanescent field abide by Beer-Lambert law. And the photonic tunneling effect is considered. The relative sensitivity of the fiber laser sensor is given finally.

7853-06, Session 2

High performance FBG interrogation technology with scan fiber laser

Y. Yang, Y. Ma, M. Yang, BeiHang Univ. (China)

The development of fiber-optic sensors based on in-fiber Bragg gratings (FBG) has been of interest because of wavelength-encoded nature and advantage in strain and temperature sensing. To satisfy the demand of real-time measure and monitoring, simultaneous interrogation of multiple wavelengths with fast and high-precision is highly desired. Scan fiber laser has high scan speed and power. So, the FBG interrogation technology with scan fiber laser can achieve high

performance combining with high speed signal process circuit base on FPGA technology.

In this paper, a ring cavity scan fiber laser was demonstrated and the characteristic, include scan speed, spectrum gain flatness, line width and output power was analyzed and the configuration parameters was optimized. A scan fiber laser module was made and test, the 200Hz scan frequency, ~0.02nm line width, more than 40nm scan range and more than 1 mW output power were obtained and the output polarization characteristic was measured. A 12 channels, 20 FBGs per channel FBG interrogator was designed and made with this laser module and the high speed signal process circuit base on FPGA was demonstrated. The different interrogation arithmetic were studied and compared and prove that the centroid method have advantage on interrogation speed and accurate. In this system, the polarization affect was investigated and modified with polarization scrambler. The FBG interrogator was test and 5pm measure accurate with 200Hz scan frequency were obtained.

7853-07, Session 2

Porous silicon based resonant grating filters for biochemical sensing applications

X. Lv, J. Mo, Xinjiang Univ. (China) and Xi'an Jiaotong Univ. (China); Z. Jia, Xinjiang Univ. (China)

Since Sailor at al. first reported porous silicon (PSi) as a biosensor platform, PSi has attracted a great deal of attention and research for biochemical sensing applications. Especially in recent years, various novel PSi-based photonic devices have been exploited for the detection of chemical and biological species, including grating waveguide, resonant microcavities, and diffraction gratings. Liscidini, Weiss and colleagues have fabricated PSi diffraction grating biosensor, having sensitivities much higher than traditional sensors by calculating the diffraction efficiency although the detection signal of m= -3 diffraction order they monitored is very weak. Wei at al. have realized a polymer grating-coupled waveguide biosensor by measuring the reflectance spectra; however, polymer grating had lower sensitivity compared to PSi grating due to the large surface of PSi. Herein, we design and investigate a novel PSi based resonant grating filters as an optical sensor platform and the parameters of the PSi based resonant grating filters are: the PSi grating height of h 0.53μm, period of 0.807μm, the height of PSi buffer layer D 1.09μm and the refractive index of PSi grating and buffer layer are all about 1.55; The spectrum is characterized form a 1550 nm laser at an incident angle of 25.36°. A narrow bandwidth in the reflectance spectrum is shown of this PSi grating filters and this resonance dip shift obviously after little infiltration. This novel PSi grating filters opens the door for design all-silicon sensor array for sensing of various chemical and biological species and can also be good applied in narrow bandpass filter.

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7853-08, Session 2

Some methods for signal-to-noise ratio improvement on the measurement of temperature using a BOTDR sensor

J. Hu, Shanghai Institute of Optics and Fine Mechanics (China)

The Signal-to-noise ratio(SNR) enhancement using polarization scrambler, narrowband grating and data processing in Brillouin Optical Time Domain Reflectometer(BOTDR) is studied theoretically and experimentally . These techniques can provide the SNR enhancement about 10 dB and in our experiment it is confirmed. This makes it possible to perform a better detection threshold and result.

7853-09, Session 2

Demodulation features of different types of signals for fiber-optic sensors

Y. Zhang, X. Sun, J. Cao, C. Zhang, Harbin Engineering Univ. (China)

Firstly, the detection abilities of PGC scheme dealing with the single frequency signals are investigated, based on which, the frequency domain of the signals are analyzed. And the influences caused by carrier to the system upper limit dynamic range and detection performance are studied, and so is the choice of optimal carrier frequency. The idiosyncrasy of input signal and cut-off frequency of the low pass filter are deduced and the principles how to choose the filter's optimal cut-off frequencies are determined.

Secondly, based on the Bessel function theroretics, the mathematical model has been established to analyze the performance of interferometric fiber-optic sensor under the PGC demodulation scheme and with the action of wideband signals. Simulation result show that the dynamic upper limit of interferometric fiber-optic sensor when it operates with the wideband signals must be smaller than that it operates the single frequency. The simulation results are almost correspondent to the data from the experiment in the lake which can prove the correctness of the analysis.

The researchful conclusions of this desertation are of great importance to series of problems as examples as design, developmemt, testing, calibration and application situation of fiber-optic sensors.

7853-10, Session 2

Parameter selection and design considerations with MPOF evanescent wave sensor in the THz wavelength range

H. Xia, J. Yao, Tianjin Univ. (China)

Microstuctured Polymer optical fibres (MPOFs) are much more lighter, more flexible and lower transmission loss in the terahertz (THz) wavelength range than micro-structured silica optical fibers.

THz plays an important function in gas detecting and substance identify. Thus, the MPOF characteristics and THz characteristics were combined in this paper, the MPOFs sensing were studied and explored for finding a superior sensor. Using finite element method to simulate total internal reflection-type transmission characteristics of THz-MPOF evanescent wave, analyze the influence change of THz-MPOF structural parameters on the evanescent wave. At last the design considerations were given. In many cases, the impact of modest holes shape will not have a major impact on a fiber's optical performance. However in sensing case, hollow or air-core fiber, holes shape can present a major problem. Holes shape changes would seem to be closely related to the sensing, especially in 0.1THz-3THz range.

7853-11, Session 2

A near infrared Stokes polarimeter for fiber applications

B. Wang, A. Leadbetter, Hinds Instruments, Inc. (United States)

We describe in this paper a near infrared (NIR) Stokes poalrimeter. This instrument measures the Stokes parameters of a light beam that exits an optical fiber. The key components of this polarimeter include a NIR light source, two photoelastic modulators (PEMs) that operate at different resonant frequencies, a calcite analyzer and a Ge-photodiode detector. The two PEMs in the instrument are oriented at 0o and 45o, respectively, and the analyzer is oreinted at 22.5o. The electronic

signal from the detector is processed using two different demodulation methods. The normalized Stokes parameters are calculated and displayed on a Poincare sphere. We also discuss selected applications of this instrument in the paper.

7853-12, Session 3

Fiber optics in structural health monitoring

J. M. López-Higuera, Univ. de Cantabria (Spain)

The structural health monitoring (SHM) have assumed a significant role in assessing the structures safety and integrity. SHM can be understood as the integration of sensing intelligence and possibly also actuation devices to allow the structure loading and damaging conditions to be recorded, analyzed, localized and predicted in a way that non-destructive testing becomes an integral part of the structure. SHM sensing requirements are very well suited for fiber optic sensing technology. So in this talk after a very brief introduction of the basic SHM concepts, the main fiber optic technologies for this application will be reviewed, several case study and the main current technical challenges will be addressed and, finally, the conclusions summarized.

7853-13, Session 3

An estimation method for feedback level factor C of a self-mixing interferometry system

Y. Fan, Y. Yu, J. Xi, J. F. Chicharo, Univ. of Wollongong (Australia); H. Ye, Zhengzhou Univ. (China)

Self-mixing interferometry (SMI) is a new emerging sensing technology which can be used for displacement, velocity and vibration measurements. In a SMI system, the feedback level factor C is an important parameter since it not only determines the operation regime of a SMI system, but also strongly affects the final sensing and measurement accuracy. Most existing SMI applications use an approximate C value to measure metrological quantities. However, C value is variable during sensing and measurement process. It is very important to develop a fast estimation method of C value for a practical SMI application. This work builds a SMI based displacement sensing system. The displacement waveform is reconstructed using a SMI signal incorporating an estimated C value. An inaccurate C value results in some ripples on the displacement waveform. We studied the characteristics of the reconstructed displacement waveform. The waveforms can be classified into two types. Applying a derivative operation firstly and then following a high-pass filtering, a pulse train is obtained. In a particular section of the pulse train, the direction of pulses determines which type the waveform is. The mean of pulses indicate the deviation between the estimated and the true C. A bisection searching algorithm can be employed for fast estimation of C value by observing the deviation. The proposed method is verified by both simulation and experimental data.

7853-15, Session 3

Design of multi-spot sensor array detector for toxic gas based on spectral analysis

H. Liao, P. Tian, Chongqing Univ. (China)

Sarin, soman and phosgene do great harm to the human health even only 0.01 mg sarin can be lethal and patients can not get accurate treatment if doctors can not identify the types of gases. According to the requirement of single-component toxic gases recognition and trace concentration measurement, a novel array gas-sensitive sensor is developed which chooses metallic porphyrin as sensitive material. On this basis, the multi-spot sensor array detector which is based on the absorption spectrum measurement and multi-spot measurement is designed. This paper focuses on the structural design of the system and the establishment of the spectral analysis method. The model of after-spectrophotometric structure is adopted by the detector. It is made up of five sub-systems which are Optical measurement system, Toxic gas specimen handling system, Machinery transmission and localization system, Embedded hardware control system and Spectrum data processing system. The entire hardware platform is designed based on S3C44B0 & μC/OS-II embedded system. This article puts forward the recognition model which combines the Principal Component Analysis (PCA) with BP Artificial Neural Networks (BPANN) and the algorithm for trace concentration measurement which is based on visible light absorption spectrum analysis. Furthermore, the experiments of type recognition using the PCA & BPANN combined model, the calibration and the trace concentration measurement based on the calculative algorithm are separately carried on. The experimental results show that the correct rate of prediction for 50 unknown samples is 98%, and the maximum relative measuring errors are 3%.

7853-16, Session 3

Optical humidity sensors based on the coupling loss between a doubly cladding fiber and a single mode fiber

X. Zhang, L. Lu, K. Zhen, L. Chen, Z. Ye, South China Univ. of Technology (China)

We report of a doubly cladding fiber optic relative humidity (RH) sensor which was formed on a section in the middle of a single mode fiber. The sensors with different external cladding medium were fabricated. They were tested with a constant climate chamber and an optical power meter. We observed that the sensors were having a very fast response to the relative humidity, and were fully reversible, repeatable with a large dynamic range. We present an analysis of the distribution of transverse-fields of the lowest mode in the doubly cladding fiber when the refractive index of the external cladding medium changes. We found that the changes in the output of optical powers of the sensors were induced by the coupling losses between the doubly cladding fiber and the single mode fibers.

7853-17, Session 3

Demodulation technique based on diffraction optical element for fiber Bragg grating sensing system

Z. Feng, L. Zhang, Changcheng Institute of Metrology and Measurement (China)

A demodulation technique based on diffraction optical elements for fiber bragg grating sensing system is proposed. Compared with the Fabry-Perot inteferometric method, this demodulation technique has no moving parts and has the potential for high speed application. A two optical grating structure is developed to embody the principle. The structure mainly consists of incident part, collimator, diffraction part, imaging lens and photoelectrical detector. Optical and mechanical design are detailed to guaranteed the required performance for the demodulation device. The peak search algorithm is optimized to locate the reflected wavelength center with high accuracy and high speed. The calibration procedure is carried out to relate the pixel position to wavelength. The temperature and vibration experiment are used to testify the device's capability in harsh enviroment. Experiment shows that the 1 picometer resolution and 2kHz speed is obtained in the design.

7853-144, Session 3

Single wavelength interrogated refractive index sensors based on leaky mode couplings

L. Xue, H. Liang, L. Yang, Univ. of Science and Technology of China (China)

A novel long-period fiber grating (LPG) refractive index sensor is presented for the measurements of ambient refractive indices which are higher than that of the fiber cladding. As the measurement parameter, the transmission power of the core mode is interrogated at a single wavelength where the core mode and a leaky mode are phase-matched. Firstly, the couplings of the core mode to leaky modes in the novel structure are analyzed by using complex coupled-mode theory, and then classified into three cases analogous to those in the damped oscillations. The power evolutions of the core mode in the couplings are thus intuitively understood. Based on these, for the first time, we demonstrate, with optimized design parameters the transmission power of the core mode is rather sensitive to the change of a higher ambient refractive index at resonant wavelengths. Then we focus on two optimization objectives. One is to enlarge the operational range while keeping given sensitivity, the other is to enhance the sensitivity within a given operational range. Finally, we demonstrate the operational range of the LPG refractive index sensor can be from 1.46 to 1.7 with a sensitivity of ~10-4, while for a given operational range from 1.455 to 1.465, the sensitivity can be ~10-6, if assuming the dynamic range of the power is less than 30dB and the measurement resolution is 0.01dB for both cases.

7853-18, Session 4

Sensitivity of microstructure optical fiber to strain and pressure

W. Jin, The Hong Kong Polytechnic Univ. (Hong Kong, China)

The phase sensitivity of the fundamental mode of air-silica microstructured optical fibers (hollow-core photonic bandgap fibers and index-guiding photonic crystal fibers) to strain and pressure are investigated. A theoretical model is build to study the effect of axial strain and static (acoustic) pressure on the fiber length and the effective refractive index, and hence the overall phase change of the fundamental mode. Numerical simulation shows that the phase sensitivity to pressure of a hollow-core photonic bandgap fiber depends strongly on the thickness of the outer solid-silica layer and the air-filling ratio of the microstructured inner-cladding, and the normalized sensitivity to acoustic pressure can be 35 dB higher than that of the conventional single mode fiber. The contribution of effective index variation to the overall phase sensitivity to pressure is relatively independent of the thickness of the outer silica layer and is around ~ -15%. The calculated normalized phase-sensitivities of the commercial HC-1550-02 fiber to strain and acoustic pressure are respectively 1 -1 and -331.4 dB re μPa-1 without considering the effective index variation, and 0.9797 -1 and -333.1 dB re μPa-1 when index variation is taken into account. The normalized phase-sensitivity of the commercial NL-3.3 fiber to strain is 1 -1 without considering effective index variation and 0.7773 -1 when the effect of index variation is included. The experimental results match well with the calculated results.

7853-19, Session 4

Study on self-loading F-P fiber sensor micro-machined with 157-nm excimer laser

K. Gu, M. Yang, Wuhan Univ. of Technology (China)

A self-loading Farby-Perot (F-P) fiber sensor is proposed by etching micro-structures on fiber with 157nm excimer laser. Two kinds of structures, i.e. etching on side-face and top-face of single-mode fiber (SMF) and photon crystal fiber (PCF) have been developed. It is concluded that structure micro-machining on PCF is easier than that on SMF, since only a third of power is required when compared to etching process on SMF. Sensing experiments have been conducted concerning their response to stress and temperature, and correlation of the proposed self-loading F-P interference fringe shift with stress and temperature has been investigated. Experimental results show that interference fringe shifts of PCF and SMF F-P sensors are 1.6nm and 2.2nm when there exist 80um elongation along fiber axis, which correspond to stress sensitivity of 0.00141nm/μ and 0.0015nm/μ respectively. Temperature sensing experiments show that interference fringe shifts of PCF and SMF F-P sensors are 0.0535nm/ and 0.0580nm/ in temperature rang of 30 ~100 . The proposed self-loading F-P fiber sensor is very promising as miniature and sensitive sensing component with pure fiber materials, which can find applications in harsh environments such as high temperature, EMI condition.

7853-20, Session 4

Low cost cell phone based digital light meter

S. Sumriddetchkajorn, A. Somboonkaew, National Electronics and Computer Technology Ctr. (Thailand)

The amount of light is an important issue in several scenarios ranging from scenic design, light pollution study, illumination engineering, and agriculture. It is typically determined by using a portable digital light (or lux) meter. By realizing that the proliferation of cell phones is currently tremendous, this paper proposes for the first time a low-cost cell phone based digital light meter. Our innovative idea comes from the fact that the digital camera built into the cell phone is functioned as a two-dimensional light sensitive device and the captured image can be made diffuse. In this way, the diffused image is correlated to the corresponding light level by the built-in microprocessor of the cell phone and our specific algorithm embedded. Our experiment using a typical cell phone embedded with a digital camera and our JAVA program will be discussed.

7853-21, Session 4

Chitosan-diaphragm based optical-fiber hydrophone for in vivo ultrasound measurements

L. H. Chen, C. Chan, Nanyang Technological Univ. (Singapore)

The purpose of this work is the development of a high sensitivity and biocompatibility Fiber-Optic hydrophone for in-vivo ultrasound measurements. The proposed extrinsic Fabry-Perot interferometry (EFPI) hydrophone inherits best attributes of both needle-type and membrane-type hydrophone. The proposed hydrophone is equipped with a natural polymer type of sensing membrane - Chitosan. This natural polymer has acoustic impedance close to that of human tissues, thus, the maximum energy is transferred through the membrane interface to the sensor. Furthermore, it provides a matched-load condition due to its relatively permeable property, which reduces the reflection effects at the boundaries. Since chitosan is a natural polysaccharide, therefore it considered as biocompatible and biodegradable material that can

be safe in performing the in-vivo measurement. The configuration of the sensor is based on the fiber-optic Fabry-Perot interferometry which offers good spatial resolution in the tens of MHz range as the sensing aperture of the single mode fiber is very small around only 6μm in diameter, so the spatial averaging effects are reduced and lead to robust response. The significant applications of the proposed sensor are in vivo micro-imaging, in-vivo lithotripsy measurement or event the laboratory characterization of medical ultrasound sources. In this paper, the performance of the sensor had been characterized by comparison with a PVDF needle hydrophone and proven to exhibit performance comparable with conventional needle-type hydrophone or other reported fiber optic hydrophone in term of sensitivity, frequency response and directivity but yet, proposed EFPI hydrophone is proven to be safety guaranteed for in-vivo ultrasonic characterization.

7853-22, Session 5

Recent progress of linkage methodology between single mode fiber and index guided microstructured fiber

L. Yuan, Harbin Engineering Univ. (China)

Specialty optical fibers, such as multi-core fiber, linear-array-core fiber and annularly core capillary fiber, have been introduced and developed with unusual guiding structures and novel applications. The one of technical challenges to develop the refractive index guided microstructured specialty fibers is how to realize the low loss link between the traditional fiber and specialty optical fiber. In order to insert the microstructured fiber based devices into the standard single mode fiber system, several linkage approaches have been developed and demonstrated. In this paper, we have presented our recently research progress related with this issue. The method for linking between standard single mode fiber and refractive index guided microstructured (RIGM) fibers is proposed based on a process of splicing and tapering at the fusion point of the fibers. In the process of drawing at the fusion point, the mode fields coupling functions and conditions of standard fiber and RIGM fiber were given. And the relationship between coupling output optical power and the tapered length was obtained by mode field superposition theoretical model. Therefore, it can be used to optimal the length of the tapered zone and control the coupling process. This approach is useful in link and inserts the RIGM fiber based devices into standard single mode fiber systems and also could be used for further application of RIGM fibers in sensing applications.

7853-23, Session 5

Modal wavefront sensor employing stratified computer-generated holographic elements

C. Liu, National Univ. of Defense Technology (China)

Since the birth of modern Adaptive Optics (AO) in 1953 wavefront sensors have played an important role in the design of AO systems. Zonal and Modal wavefront sensing technologies are two main approaches to measure the unknown wavefront.. Although the existing zonal wavefront sensor (e.g. Shack-Hartmann wavefront sensor1), in conjunction with high performance hardware and optimized algorithms, can meet the real-time detection requirements, there is still a number of cases in which it is needed to detect the aberration fast enough with an ultrafast wavefront sensor. As a general rule, if low order aberrations dominate it is best to use modal wavefront sensing2. In modal wavefront sensors the wavefront is described by decomposition into a set of orthogonal polynomials (e.g. Zernike polynomials3). We implement a modal wavefront sensor using stratified computer-generated holographic elements (SCGHEs)4-7. The SCGHE is the hybridization of TCGH and volumetric hologram. It consists of two or more layers of TCGH, which are interleaved with optically homogenous buffer layers (here, we set free space separation). These layers are parallel and so close together that the Fresnel approximation is not valid to describe the propagation of light between the layers. Each layer is coded with a Zernike aberration mode. If the SCGHE is illuminated by an aberrated light beam, the diffraction pattern arises at a certain distance behind the element in the diffraction plane, where the Fresnel or Fraunhofer approximation is valid.

We investigate four situations in which the TCGH is designed as 1) continuous amplitude, 2)continuous phase, 3)binary amplitude, 4) binary phase. We set the number of layers to be 2 or 4, each layer coding Zernike aberration mode,,, . The numerical results indicate that, with proper thickness of buffer layers, the approaches in situations 1), 2), 3) are feasible to characterize the existence of specific Zernike aberration mode in the illumination light beam, in the condition that this Zernike aberration mode has been coded into one of the TCGH layers in SCGHE. The disadvantage in the above-mentioned situations is that they are generally photometrically very inefficient, which result from the appearance of high energy level zero diffraction orders. The last approach in situation 4) shows the absence of zero diffraction order, but the diffraction pattern is unpredictable

7853-24, Session 5

Innovation on advanced adaptive optoelectronic sensor system

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Integrated theory and mathematical simulation is achieved. Base on global optimization algorithm, equipment system, which concerns some crucial components, such as, core optics system, multi mode wave front sensor and so on, key method on optoelectronic measurement and preponderant configuration for adaptive sensor system advantage configuration and global design is established and analyzed deeply. Applied method of detecting-control-rendering in real time to compensate dynamic wavefront error, the system achieve automatic to correct interfere and keep ability approach to diffractive limit. The problem of system image blur or resolving power decline caused by atmosphere onflow, correlative difference in temperature,

7853-25, Session 5

A multichannel SPR biosensor with a fixed detection system

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Surface plasmon resonance (SPR) sensors with spectral interrogation provide a high refractive index resolution, a large dynamic range, a fixed optical detection module and have been applied for the detection of several biomolecules. Attempts to increase number of sensing spots were not possible without a mechanical scanning technique or increasing numbers of spectrometers resulting in a bulky and a high-cost instrument. In this work, we propose a new spectral detection unit that uses only one spectrometer to measure the SPR spectrum from multiple sensing spots rapidly and serially without any mechanical movement. This spectral detection unit is designed based on a spatial light modulator (SLM) configuring as a programmable optical aperture for the spectrometer. The SLM is operated such that it allows the reflected light from the selected sensing spot transmitted to the input optics of the spectrometer and blocks the light from the other regions. For real-time monitoring of the size and position of the programmable optical aperture, a camera is placed at the position which both the SLM and the sample can be observed simultaneously. To demonstrate this concept, a 5-ch SPR sensor was built based on the proposed multichannel detection unit and evaluate the device performance using a refractive index test. The average device refractive index resolution

was 3.07 10-6 refractive index unit (RIU) which can be further improved using a SLM with a higher and more uniform on-off contrast ratio. We found that the device can be operated continuously for several hours with minimal heat and does not required fixed dimension of the sensing spots.

7853-26, Session 5

Heterodyne demodulation scheme for fiber optic hydrophone array systems

N. Zhang, National Univ. of Defense Technology (China)

Large dynamic range and highly multiplexing is the modern requirement of the fiber optic hydrophone (FOH) array. Of all the techniques that involved in the developing process of interferometric FOH, signal demodulation is a fatal one, which greatly decides the dynamic range of the detection, as well as the architecture of light-pass. In this paper, we present a signal demodulation scheme based on heterodyne technique, which can help FOH system achieve large dynamic range and large scale multiplexing. Optical system based on the heterodyne demodulation is given. The reference signal in the demodulation procedure is obtained from the optical heterodyne output, which not only simplify the RF electronics, but also eliminate the effects of frequency shifting vibration generated by two acoustic-optic modulators (AOM). This method is quiet different from other reported heterodyne techniques. The digital algorithm is realized, and the maximum signal processing capability is analyzed in detail. Experiments are carried out to validate the demodulation scheme. The detected signals are injected through a piezoelectric cylinder. Experimental results show that a signal with a frequency of 4kHz and amplitude of 15rad could be demodulated without distortion when the heterodyne frequency is 200kHz. The same signal is demodulated using PGC method with a modulating frequency of 100kHz, which is near the upper limit of this parameter, and the result shows distortion. Contrasting the two demodulation method verifies that the system we have designed works well and more suitable for the detection of large signal. Besides, this architecture of system offering the advantage of easy to be time-division multiplexed. Together with wavelength-division multiplexing, it demonstrates the potential for the fiber-optic hydrophone to head for large-scale arrays with high dynamic range.

7853-27, Session 6

Low-cost interrogator for fiber optic interferometers and fiber Bragg grating sensors

J. Gong, Virginia Polytechnic Institute and State Univ. (United States); Z. Li, Wuhan Univ. of Technology (China); A. Wang, Virginia Polytechnic Institute and State Univ. (United States)

We report a low-cost interrogator for fiber-optic interferometric and Bragg grating sensors. The interrogator is based on a compact optical path scanner which is made by splicing a hollow fiber to a single mode fiber and by sealing a segment of air and a segment of thermally expanded liquid inside the hollow fiber. The facets between the fiber-air interface and the air-liquid interface reflect the light from the single mode fiber back, and the optical path difference between the two facets can be controlled by changing the temperature of the liquid. When the compact optical path scanner is place inside a white light interferometer together with a sensing fiber-optic Fabry-Perot interferometer, the optical path difference of the sensing interferometer can be decoded as the optical path difference of the scanner when the interference signal gets maximum. The decoding accuracy of such an interferometer interrogation system was measured to be 14 nm over a range of 40 um. The compact optical path scanner can also be used to form a wavelength meter, which can be applied to decode the Bragg wavelength of a fiber Bragg grating sensor. A decoding accuracy of 3.5 pm was obtained.

7853-28, Session 6

A better quencher in molecular beacons: small gold nanoparicles

J. Xue, Y. Gu, China Pharmaceutical Univ. (China)

Molecular beacons (MBs) was extensively employed in areas such as genetic screening, biosensor development, biochip construction, the detection of single-nucleotide polymorphism (SNP) and messenger-RNA (mRNA) monitoring in living cells. However, the high fluorescence background generated by incomplete quenching of the MBs, greatly decreased the signal to background ratio, and thus, the sensitivity of the assay. With the rapid development of nanotechnology and nanoscience, nanomaterials had been introduced to enhance the sensitivities of bioassays. Particularly, gold nanoparticles (Au-NPs) had attracted considerable interest because of their unique optical characteristics. In this paper, quenching efficiencies of three sizes of gold nanoparticle (3nm, 5nm and 13nm) in a molecular beacon were studied, a small gold nanoparicle with diameter ≈5nm was found out as a better quencher to fluorescein.

7853-29, Session 6

Measurement of tropospheric SO2 by airborne MAXDOAS in Pearl River delta region

J. Xu, P. Xie, Anhui Institute of Optics and Fine Mechanics (China)

The tropospheric SO2 in Pearl River delta region was measured by Airborne Multi Axis Differential Optical Absorption Spectroscopy (AMAX-DOAS) during 10th -15th December, 2008. The SO2 slant columns were derived with DOAS method in the spectral range 310~ 325nm and the vertical columns were retrieved. High values were observed near power plant regions with the vertical column density of 7×1016molec./cm2. Combining with the meteorological data, SO2 flux from the power plant was estimated. Over the City of Zhuhai, the observed SO2 vertical column density was 2.16×1016molec./cm2, which is in good agreement with ground-based MAX-DOAS of 2.4×1016molec./cm2 on the assumption of a well mixed boundary layer of 1000 m and the same aerosol input parameters for radiative transfer model .

7853-30, Session 6

Fabry-Pérot interference enhanced surface plasmon resonance sensor

M. Sung, C. Chiu, D. Huang, National Taiwan Univ. (Taiwan)

A Fabry-Pérot interference enhanced surface plasmon resonance (SPR) sensor was designed and analyzed numerically. It is conceivable to combine the advantages of the high angular sensitivity S of an angular-interrogated SPR sensor and the narrow angular interference features of the Fabry-Pérot interferometer to enhance the intrinsic sensitivity. In our design, a micro-fluidic channel with two parallel interfaces acting as a Fabry-Pérot resonant cavity formed on the metal film of an SPR sensor was employed for sensing the refractive index of the fluid filled in the channel. For optimizing the excitation of the surface plasmons, the thickness of the metal film was also investigated. Owing to the excitation and propagation of surface plasmons at the fluid-metal interface as well as the Fabry-Pérot interference, deep and exceedingly narrow angular dips on the refection curve around the resonant angle of

the SPR sensor can be obtained. The shift of the narrow reflection dips was very sensitive to the refractive index change of the fluid. Meanwhile, the (Full-Width at Half-Maximum) angular dip width FWHM was very narrow (< 0.01°) and can be adjusted by changing the thickness of the resonant cavity. The corresponding intrinsic sensitivity IS= S / FWHM higher than 10^5 RIU-1 around the resonant angle at the wavelength of the input optical signal can be achieved. Compare to the previous work, such a design not only has a good performance of angular sensitivity, but also achieves an extremely high intrinsic sensitivity around the resonant angle at the wavelength of the input optical signal.

7853-05, Poster Session

Comparison of three temperature control systems applications for a special homemade shortwave infrared spatial remote sensor

Z. Xu, J. Wei, J. Li, Q. Zhou, Shanghai Institute of Technical Physics (China)

A image spectrometer of a spatial remote sensing satellite requires shortwave band ranging from 2.1μm to 3μm which is one of the most important bands in remote sensing. We designed an infrared sub-system of the image spectrometer using a homemade 640×1 InGaAs shortwave infrared sensor working on FPA system which requires high uniformity and low level of dark current. The working temperature should be -20±0.2 Degree Celsius. This paper compared three kinds of methods to control the temperature. First one using a temperature control chip Max1978 from MAXIM company, Second one using AND8830 from ANALOG company, Last one is designed based on FPGA device APA300. Experiment shows that MAX1978 has driving mosfet inside its chip which makes the stability is not appropriate for this homemade shortwave sensor. And for the ADN8830 the supply power is limited to 5V, which also limits the driving power of the chip, experiments show that ADN8830 works very well when control the temperature to -15 Degree Celsius, but the result is not acceptable when sensor demand -20 Degree Celsius. The FPGA design have covered all the disadvantages above, but its electronical circle takes much more board resources than MAX1978 and ADN8830. At last we choose the FPGA design for the homemade shortwave infrared spatial remote sensor.

7853-14, Poster Session

Optical devices by the use of liquid photonic crystal fiber (LPCF)

Z. Peng, C. Chan, Y. Zhang, L. H. Chen, Nanyang Technological Univ. (Singapore)

In photonic crystal fiber (PCF) design, one main effort is devoted to achieve special dispersion profile such as controlling the positions of zero dispersion wavelength (ZDW), realizing ultra-flattened dispersion curves and obtaining special dispersion slope. In this paper, a liquid photonic crystal fiber (LPCF) is proposed for dispersion design without modifying the structure of PCF. A series of refractive index liquids (RILs) from 1.30 to 1.42 with an interval of 0.02 are filled into the air-holes of a section of solid core PCF and LPCF is formed. This LPCF is still operating under the principle of index guiding, but dispersion profile changes with the values of RILs filled in. Taking LMA10 from Crystal Fibre A/S as an example, the dispersion properties of this LPCF are fully analyzed by using the beam propagation method. Both material dispersion and waveguide dispersion are considered in the simulation. It is shown that the dispersion value at 1550nm and zero dispersion wavelengrh (ZDW) can be altered to any value in a certain range by filling appropriate RILs without changing the geometric structure of PCF. This property is useful in sensing,dipersion design and nonlinear optics application.

7853-42, Poster Session

The application of HgCdTe detector for measuring methane

C. Chen, H. Yu, L. Lei, L. Li, Y. Wang, Jilin Univ. (China)

Generally, mineral gases include a variety of flammable and explosive gases with the main component of methane (CH4).It is a serious problem that how to detect the concentration of methane in coal mine. Explosive gases as well as their decomposition products have strong absorption feature peaks in the mid-infrared (MIR) fingerprint region between =7 and 13 μm. Since the HgCdTe detectors can convert incident infrared energy into an electrical signal, we can use this characteristic to detect the residual intensity of light which is absorbed by methane. HgCdTe detectors are particularly suited for using in the =7-13 μm spectral region and providing an economical method of obtaining high performance in a rugged and compact package. In this paper, we present double optical path based on quantum cascade lasers (QCLs) operating at wavelengths around =7.6μm and HgCdTe detector for detecting the concentration of methane. The processing of HgCdTe detector output signal includes pre-amplifier module, filtering module, main-amplifier module, peak value detection module, Analog to Digital Converter (ADC) module, Digital Signal Processing (DSP) module and Liquid Crystal Display(LCD) display module. DSP module can calculate the concentration of methane through Lambert-Beer's law and display the concentration of methane on LCD. The sensitivity limit (standard deviation) under field conditions is 1 ppm (20 ppb under laboratory conditions) for a measuring time of 0.6 s. These results represent a significant advance in the use of HgCdTe detector for methane measuring system.

7853-43, Poster Session

The analysis and system design for MCG measurement based on optically pumped cesium magnetometer

Y. E. Zhang, Harbin Engineering Univ. (China)

At present, with the sensitivity of continuous improving, laser optical pumping magnetometer can measure from the earth magnetic field to the bio-magnetic field range. In the bio-magnetic field, cardiac magnetic measurement is also paid more and more attention. In this paper, we discuss cesium optically pumped magnetometer theoretical analysis and system design and the magnetic field gradient measuring principle as well as the transition process of the particles. On this basis, we build the optically pumped magnetometer with first-order gradient structure for the cardiac magnetic measurements and execute to filter through the wavelet transform. Based on optical pumping magnetometer measuring cardiac magnetic will be a positive meaning to explore in the application of life sciences, clinical medicine and other fields.

7853-44, Poster Session

Theoretical and experimental study on chromatic confocal position sensor

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In the past decade, the chromatic confocal technique becomes attractive because of its capabilities for superior resolution, rejection of scattered light and depth discrimination. This method drew special interest in applications such as imaging biological samples, semiconductor fabrication process, in which high definition in both transverse and longitudinal dimensions is required. Particularly, mecro-

electro-mechanical systems (MEMS) fabrication process involves the construction of high aspect ratio trenches on the micrometer or sub-micrometer scale; a typical example is a trench etched 5 microns wide by 100 microns deep. As we know, the chromatic confocal technology is the only one of effective manner for measuring depth of this high aspect ratio trenches without contact at present. In this technique, the depth of each trench is measured by finding color wavelength corresponding to maximum intensity in the detected spectra. The depth-wavelength codification method will largely increase depth measuring efficiency because it doesn't need mechanical scanning. In this paper, we study the chromatic confocal technique application in position measurement theoretically and experimentally. Firstly, a set of refractive lenses are designed and a position measurement device is established for this purpose. The design of lenses is based on ray tracing principle and function of these lenses is to eliminate spherical aberration and designate a desired constant chromatic aberration. Then, calibration of wavelength-depth relationship has been performed. The calibration results accords with the theoretical design results well. Third, influence of the detector pinhole size on axial resolution of the measurement system is analyzed. It is clear from numerical simulation that the full width of half maximum (FWHM) of spectral distribution on the detector will increase with enlargement of pinhole size, which makes axial resolution decrease. The experiment results also disclose identical tendency. Finally, we measure some position values according to the calibration results and compare them with the practical values. The results infer that the position measurement system can realize rapid position measurement with higher precision.

7853-45, Poster Session

Use of water-soluble PbS quantum dots as fluorescent probe in sensing copper(II)

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In this paper, we report a new facile method for the synthesis of water-soluble PbS quantom dots (QDs), using dihydrolipoic acid (DHLA) as a stabilizer. The prepared QDs were characterized by optical techniques and high-resolution transmission electron microscopy (TEM). Next, these water-soluble luminescent PbS QDs were further used to detect copper(II). The obtained experimental results show that the fluorescence of the PbS QDs could be markedly quenched by Cu(II) whereas approximate concentrations of other physiologically relevant cations, such as Zn(II), Ca(II), Mg(II), Mn(II), Na(I) and K(I) etc., almost did not interfere with the fluorescence quenching progress of copper ions. Based on this, a simple and rapid method for Cu(II) determination was developed. Under optimal conditions, the response was linearly proportional to the copper(II) concentration in the range of 1 to 11.5×10-8 M, with a correlation coefficient of 0.995. Hence, aqueous DHLA-stabilized PbS QDs may be a promising fluorescent probe in sensing copper(II) selectively.

7853-46, Poster Session

Study on intensity-modulated surface plasmon resonance array sensor based on polarization control

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Intensity-modulated surface plasmon resonance (SPR) array sensor based on polarization control was introduced and the influences of incident angle, gold firm thickness, polarizer angle, wavelength and data processing on its sensitivity and measuring range were analyzed. A proper parameter selection was brought forward with 700nm wavelength, incident angle 72 °, gold film thickness 40nm and polarizer rotation 50 deg relative to vertical direction to achieve the common-used measurement range of SPR sensor 1.33-1.37 and significant sensitivity improvement comparing to intensity modulation SPR sensors using TM wave only. It was concluded that with high sensitivity, intensity-modulated SPR array sensor based on polarization control can adjust measurement range easily according to the measurement range start point user set by simple rotation of wave plate and polarizer without any other changes. Avoiding angle or wavelength scanning and wave front phase detection, it not only simplifies optical and mechanical structure, but also improves system stability and reduces noise attendant and cost. This scheme can be widely applied to the high-throughput detection of bimolecular interaction analysis, environment monitoring, food safety, pharmaceutical analysis, biomedical engineering and other fields.

7853-47, Poster Session

Enhancement of evanescent waves in four-layer waveguides by means of an anisotropic metamaterials layer with negative permittivity and permeability

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Up to now, almost all of the metamaterials being realized are actually anisotropic in nature and easier to implement in practical applications.

In this paper, we investigate the enhancement of evanescent waves in waveguides, which are fabricated by adding an anisotropic metamaterials layer with negative permittivity and permeability into conventional three-layer waveguides. It is found that such a four-layer planar waveguides can enhance the amplitude of the evanescent waves for both TE and TM modes under some conditions. We mainly focus on the discussion of the TE waves. The characteristic equations have been derived. We have presented the transverse profile for each layer. To get more insights into the properties of the enhancement, we use an approach which was referred to as group index method to examine the enhancement factor. And it is found that the enhancement factor increases exponentially with the thickness of the metamaterial, but there exists a maximum value when complete surface polaritons are established at the boundary between the metamaterial and the cladding. Furthermore, energy flux fractions in the cladding are also discussed in detail as function of the width of the cladding. Finally, we try to use the Finite Difference Time Domain (FDTD) method to confirm our numerical results.

The enhancement effect may have many promising applications such as the waveguide chemical and biological sensors. By means of the enhancement effect, we may improve the sensitivity, signal-to-noise ratio of interest, or overcome the dilemma of the designing those evanescent-wave-based sensors and so on.

7853-48, Poster Session

Theoretical and experimental research on sensing characteristics of Panda fiber loop mirror

L. Zhou, L. Wang, S. Hu, K. Tong, N. Liu, Beijing Univ. of Technology (China)

The birefringence of Panda-type high birefringence fiber with a relative beat lengths was analyzed theoretically and experimentally respectively, and the characteristics of temperature-sensing for a Panda-type high-birefringence fiber loop mirror were studied in both theoretical and experimental. Based on fiber loop mirror system, the birefringence average value of 6.05 × 10-4 of Panda fiber with different sizes was tested while the corresponding beat-length's value of 2.56mm. According to the geometric parameters measured by optical microscope, the birefringence and beat-length of Panda fiber

were simulated in correspond to the dates provided by manufacturers. Further more, the temperature-sensing characteristics of sensing head for the Panda-type high-birefringence fiber loop mirror was researched. The experimental results show that its temperature sensitivity is up 1.41nm / which is coincided with the theoretical results.

7853-49, Poster Session

Design of a temperature control system using incremental PID algorithm for a special homemade shortwave infrared spatial remote sensor based on FPGA

Z. Xu, Q. Zhou, J. Li, J. Wei, Shanghai Institute of Technical Physics (China)

Shortwave infrared remote sensing plays an important role in land, sea, vegetation remote sensing application which is widely using in satellite remote sensing monitoring. A image spectrometer of a spatial remote sensing satellite requires shortwave band ranging from 2.1μm to 3μm which is one of the most important bands in remote sensing. This paper designed an infrared sub-system of the image spectrometer using a homemade 640×1 InGaAs shortwave infrared sensor working on FPA system which requires high uniformity and low level of dark current. The working temperature should be -20±0.2 Degree Celsius. As the sensor generates heat when working, we have to control the temperature. This design adopts Incremental PID algorithm to generate PWM output signal to drive TEC current in order to control the temperature of the homemade shortwave infrared sensor. There are three modules compose of the driving system. They are RS232 module, PID module and AD control module. RS232 module communicates with control platform to set wanted temperature and transfer actual temperature of the sensor back to control platform. AD control module generates the control signal for the AD convert device. PID module generates the PWM output signal with Incremental PID algorithm to control the TEC device adjust the temperature of the sensor. All of the three modules are coded by VHDL and succeed working on FPGA device APA600. The intelligent temperature control system succeeds in controlling the temperature.

7853-50, Poster Session

The ultra-weak feedback effect of DBR/DFB fiber laser and its sensing applications

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We investigate an ultra-weak feedback effect of Single longitude mode DFB/DBR fiber lasers. The ultra-weak-feedback is introduced by the fiber Rayleigh scattering and the scattering of the fiber splicing point. A theoretical model based on the steady-state rate equations is given to describe this ultra-weak feedback effects. The relationships between the feedback level and the laser output power is also given. The corresponding experiments are designed and their results agree with the theoretical analysis well. The modulation of the laser ultra-weak feedback causes the intensity modulation of the fiber lasers, which is reduce the laser stability in one side and is suitable to realize a simple vibration measurement in the other side. The ultra-weak feedback effect based vibration sensing scheme and results are demonstrated by using a simple system composed by a 980nm-pump, a WDM, a photo detector system, and a PZT cylinder. The vibration measurement with frequency range from 1 kHz to 10 kHz are demonstrated and compared with a referenced PZT vibrameter. A packaging method for the proposed vibrameter is applied and its sensitivity is improved by over 20dB. The optimized design of the sensing scheme is discussed based on our theoretical analysis at last. The sensing scheme is simple, low price and easy to multiplexing.

7853-51, Poster Session

Single-multi-single mode FBG and its multi-parameters sensing application

S. Peng, A. Zhang, J. Zhang, W. Sun, L. Yuan, Harbin Engineering Univ. (China)

We demonstrate a novel optical fiber device with the capability of multi-parameters sensing, the device is realized by writing Bragg gratings in multimode fiber of single-multi-single mode(SMS)fiber structure based on a phase mask and a UV laser. Here the core diameter of multimode fiber is 105um. A corresponding compound coupled mode theory is given to describe the novel device. The theoretical spectral characteristics agree well with experimental results. The device is different from the multimode fiber Bragg grating because of the mode-selection capability of the SMS fiber structure. A few dips in the transmission spectra of the device, which are introduced by the Bragg grating and SMS structure itself, are found based on a broadband source ASE and an optical spectral analyzer. The different sensitivities of these dips are found for temperature and strain, which is used to realize strain and temperature sensing simultaneous. We still demonstrate to use the device to realize the refractive index sensing with temperature compensation. The HF corrosion technique is used to reduce the cladding of the multi-mode fiber in order to realize refractive index sensing. The experimental results show that the temperature-compensation can be realized. The optimized parameters of the multi-mode fiber and the Bragg grating are given for different sensing applications according to our theoretical mode. The simple optical fiber device is expected to have broad applications in sensing area.

7853-52, Poster Session

Properties of defect mode in 1D ternary photonic crystal

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we study the properties of defect mode in one-dimensional ternary photonic crystal with one defect layer using transfer matrix method(TMM). First.in the transmission spectrum.of the ternary periodic structures, more band gaps have been found in the long wavelength range as compared to that of a binary structure with similar size. In one of the gaps that is owned by both the ternary and binary periodic structures, more defect modes can be obtained by changing the defect layer location in the ternary photonic crystal as the ternary periodic structures can provide more controlling parameters relative to those of the binary one. Next we show that the defect modes in this ternary periodic structure are very sensitive for sensing very small refractive index changes or very small thickness modulation of the defect layer medium. Although different defect modes in the same gap may have different sensing ability, almost all of them are much more sensitive by comparing with that in binary photonic crystal. This result is also better than that provided by other researchers, in which a transmission peak shifts by 0.35nm for each refractive index change of 0.001. This property may be very useful in designing refractometric sensing elements. Finally we find that the transmission properties of the ternary periodic structures with a negative-refractive-index defect layer are completely different from that with a positive-refractive-index defect layer. This conclusion may help us in designing the different device.

7853-53, Poster Session

Studies on technics and experiments of fused-tapered fiber grating coupler

J. Nuan, H. Y. Yang, X. Zhang, Y. Hu, National Univ. of Defense Technology (China)

As the key point of all optical-network, optical add-drop multiplexer(OADM) can add or drop optical signal of single special wavelength. Fiber grating coupler(FGC) which combines the multiport and wavelength selectivity has the advantage of fiber coupler and fiber grating. It composed of all-fiber so its potential excellent character makes it be more suitable for OADM compared of other electric-multiplexer. With the mature manufacturing technology of fiber grating and fiber coupler, based on the requirement about optical add-drop technique of hi-speed DWDM fiber communication and fiber sensor array investigations have been carried out on FGC. This paper mainly studies the technics of fused-tapered integrative FGC, which starts with the trial-manufacture of fused-tapered FGC. The technical procedure of FGC is finally determined through the analysis of the possible influencing factors in detail and technics improvement. The fused-tapered FGC is successfully produced and a novel testing method is built to experimental study especially for the relative position of fiber grating and taper region of FC. It is systemically investigated that FGC used as OADM through optical add multiplexing(OAM) and optical drop multiplexing(ODM) experiments. Some technical experiences have been obtained such as packaging taper region with V-glass-groove before writing grating rarely affect the character of grating, the different relative position of phase mask and two-cores in coupling region also has no effect on writing grating. The testing results express that the structural shape of taper region is important for the fabrication of high-quality FGC. As the direct influence factors, the length and position of grating must be proper designed to make sure the grating is in the II section of coupling region. These researches have important applied value on fiber communication and all-optical network, which has offered techinics foundation in making integrative FGC.

7853-54, Poster Session

A C2H5OH gas sensor based on long-period fiber grating coated with TiO2 nano-film

A. Zhang, S. Peng, J. Zhang, Y. Chen, W. Sun, L. Yuan, Harbin Engineering Univ. (China)

Long period fiber grating (LPFG) is sensitive to the changes of its surrounding refractive index and it can be used as a biochemical sensor by coating a specified film. Here we present a C2H5OH gas sensor based on a LPFG coated with the TiO2 nano-film. The LPFG is written in single mode optical fiber by using the point and point method based on a CO2 laser. A new liquid phase deposition technique, instead of normal sol-gel deposition method, is used to coat the TiO2 nano-film on the LPFG. The nano-film based on the new deposition technique is more stable and the film's thickness can be controlled easily from 40nm to 300nm by controlling the TiO2 concentration in the liquid and the deposition time. The elementary experimental results, based on a broadband source ASE and an optical spectral analyzer, show that the wavelength of the LPFG loss peak is shifted by ~1nm for the case of the TiO2 nano-film of ~50nm in thickness when the concentration of surrounding C2H5OH gas is increased to 2000ppm. The sensing scheme is realized in room temperature which overcomes the high temperature requirement of the TiO2 film based carbon nano-tube gas sensor. And the sensitivity can be improved by annealing the TiO2 film and optimizing the thin film thickness and the fiber grating parameters further. At last, the optimal design parameters of the LPFG film sensor are obtained based on a four-layered numerical model and the corresponding experiments is going on.

7853-55, Poster Session

Perimeter security alarm system based on fiber Bragg grating

C. Zhang, L. Wang, Wuhan Univ. of Technology (China)

With the development of the society and economy, the better comfort people eager to confront, the more safety requirements they need. Perimeter security alarm system is widely regarded as the first line of defense. Design with a kind of high-powered Fiber Bragg grating (FBG) vibration sensor based on the theory of the string vibration, apply neural network adaptive dynamic programming algorithm to the perimeter security alarm system make the detection intelligently. Intelligent signal processing unit discriminates between real attacks and natural background vibrations by analyzing the vibration signal's frequency, energy, amplitude and duration. Firstly apply FBG sensing technology to perimeter security system. Compare with traditional perimeter security alarm systems, such as infrared perimeter security system and electric fence system, the system is non-power supply structure and it will not be interfered from electric, electromagnetism. Using optical fiber enables long distance monitoring and the maximum detection range will be 20km. It is able to detect the location of event within short period of time (high-speed response, less than 3 second).The system can find the fiber cable break sites and alarm automatically if the cable were be cut. And the system can prevent effectively the false alarm from small animals, birds, strong wind, scattering things, snowfalls and vibration of sensor line itself. It can also be integrated into other security systems. This system can be used in variety fields such as military bases, nuclear sites, airports, warehouses, prisons, residence community etc. It will be a new force of perimeter security technology.

7853-56, Poster Session

Research of HgCdTe detector in methane sensing

J. Li, C. Chen, L. Li, H. Yu, Y. Wang, Jilin Univ. (China)

The mid-infrared (mid-IR) spectral fingerprint regions from 3-5um and from 8-11um are significant importance for molecular detection and identification. In order to detect the methane in coal mine, we design a system for methane monitoring using mid-IR laser and photodetector. The system is characterized by performance sensitive, fast convenient and affordable. In this paper, we especially discuss photovoltaic type HgCdTe detector, cooler, operational preamplifier, and analyze how to improve the circuit design to reduce the noise and achieve a long detectable distance and high signal to noise ratio.

The PVI-2TE-10.6 photodetector is multiple heterojunction photovoltaic IR detector. This HgCdTe detector normalized detectivity D star (D*) is, Time constant ( ) is 3ns. High performance and stability were achieved by using band gap engineered HgCdTe semiconductor, optimized doping and improved surface processing. We use OPA129 as the core of ultra-low bias current monolithic operational amplifier circuit. The sigma-delta-AD7714 is chosen as this system high precision analog to digital (A/D) converter. The device accepts low level signals directly from operational preamplifier circuit and obtains a serial digital word output. It employs a sigma-delta conversion technique to realize up to 24 bits of no missing codes performance, which can achieve the demand of high precision. In our system, S3C2410A is chosen to build an embedded control system.

Through the above design, we achieve the methane sensing system with the measuring range between 0 and 5%Vol, and 0.01% resolution. The maximum error of the whole system is less than ±0.1%.

7853-57, Poster Session

Design of the driving system for visible near-infrared spatial programmable push-broom remote CCD sensing

Z. Xu, J. Wei, Q. Zhou, J. Li, Shanghai Institute of Technical Physics (China)

An image spectrometer of a spatial remote programmable push-broom sensing satellite requires visible near infrared band ranging from 0.4μm to 1.04μm which is one of the most important bands in remote sensing. This paper introduces a method of design the driving system for 1024×1024 VNIR CCD sensor for programmable push-broom remote sensing. There are seven module in the driving system, all the modules is coded by VHDL, and this driving system have five mainly functions: drive the sensor as the demand of timing schedule, control the AD convert device working in appropriate mode, get the parameter via RS232 from control platform, process the data input from the AD device, output the processed data to PCI card to transfer to user end. All the modules above succeed working on FPGA device APA600. This paper also introduced several important keys when designing the driving system including module synchronization, FSM optimization and Top-down design.

7853-58, Poster Session

A sensing system based on temperature-tunable micro-resonator

J. Wang, Beijing Univ. of Technology (China); B. Wang, CangZhou Normal Univ. (China)

Owing to the high quality factor (Q factor) and small mode volume, optical microresonators such as microspheres and microtoroids that support whispering-gallery modes (WGMs), have been found many applications in photonics and nonlinear optics including ultra-low threshold lasers, laser frequency locking and stabilization, high-resolution spectroscopy in various fields. In addition, the concept of a whispering gallery mode-based biosensor for protein detection has also been reported. The application of microsphere in sensing or detection field, such as the biological senor and chemical sensor, gas detection, heavy-metal detection and small-molecule detection are widely demonstrated.

Thermal properties and spectroscopic properties of the glass micro-sphere were presented in this paper. The Er3+ emission spectra of a kind of Erbium-doped glass microsphere were measured and discussed under 532 nm excitation in a series of temperatures. The change in the temperature of the microsphere leads to a change in both the size and the index of refraction of the sphere, which results in the resonance shift of the peaks of whispering gallery modes in emission spectra. By monitoring the shift, the temperature of the environment surrounding the sphere can be determined, which allows us to calibrate the sensing function of the shift proportional to temperature. Based on the thermal effects, we propose a novel optical temperature sensor using micrometer-sized sphere.

7853-59, Poster Session

Research on fiber Bragg grating heart sound sensing and wavelength demodulation method

C. Zhang, Tianjin Polytechnic Univ. (China)

Heart sound includes a lot of physiological and pathological information of heart and blood vessel. Heart sound detecting is an important method to gain the heart status, and has important significance to early diagnoses of cardiopathy. In order to improve sensitivity and reduce noise, a heart sound measurement method based on fiber Bragg grating was researched. By the vibration principle of plane round diaphragm, a heart sound sensor structure of fiber Bragg grating was designed and a heart sound sensing mathematical model was established. A formula of heart sound sensitivity was deduced and the theoretical sensitivity of the designed sensor is 612.55pm/MPa. Based on matching grating method, the experiment system was built, by which the excursion of reflected wavelength of the sensing grating was detected and the information of heart sound was obtained. Experiments show that the designed sensor can detect the heart sound and the reflected wavelength variety range is about 70pm. When the sampling frequency is 1KHz, the extracted heart sound waveform by using the db4 wavelet has the same characteristics with a standard heart sound sensor.

7853-60, Poster Session

Optical components surface micro-strain measurement using fiber Bragg grating sensors

Z. Wang, Nanjing Univ. of Science and Technology (China)

Fiber Bragg Grating Sensors (FBGS) are gaining increasing attention in the field of micro-stress analysis, showing high accuracy and sensitivity. In this paper, FBGS which wavelength variations can be converted to strains, are used to measure the micro-strain variation of a plane mirror where the forces acting upon. Both the self-gravity and extrusion forces are applied to the surface of the optical elements, generating inevitable deformation and decreasing the test accuracy of the whole optical system. First, a micro-strain model is built using finite element analysis to obtain the qualitative value of the micro-strain variation. Next, a series experiments are performed to validate the model is effective. A detailed analysis of the micro-strain variation is acquired from the phase generated carrier homodyne demodulation and then the three-step phase-shifting algorithm based on an unbalanced Mach-Zehnder interferometer system. The experimental results match well with the theory. Both the modeling and measurement results indicate that the sensitivity of this method in measuring the micro-strain can be reached as small as .

7853-61, Poster Session

The research of PSD locate method in micro-laser welding fields

Q. Zhang, Changchun Univ. of Science and Technology (China)

In the field of micro laser welding, besides the special requirement in the parameter of lasers, the locating in welding points accurately is very important. The article adopt position sensitive detector (PSD) as hard core, combine optic system, electric circuits and PC and software processing, confirm the location of welding points. The signal detection circuits adopt the special integrate circuit H-2476 to process weak signal. It is an integrated circuit for high-speed,high-sensitivity optical range finding, which has stronger noiseproof feature, combine digital filter arithmetic, carry out repair the any non-ideal factors, increasing the measure precision. The amplifier adopt programmable amplifier LTC6915. The system adapt two dimension stepping motor drive the workbench, computer and corresponding software processing, make sure the location of spot weld. according to different workpieces to design the clamps. The system on-line detect PSD ‘s output signal in the moving processing. At the workbench moves in the X direction, the filaments offset is detected dynamic. Analyze the X axes moving sampling signal direction could be estimate the Y axes moving direction, and regulate the Y axes moving values. The workbench driver adopt A3979, it is a stepping motor driver with insert transducer and operate easily. It adapts the requirement of location in micro laser welding fields,

real-time control to adjust by computer. It can be content up 20 μm's laser micro welding requirement on the whole. Using laser powder cladding technology achieve inter-penetration welding of high quality and reliability.

7853-62, Poster Session

The modeling of the whole human body and the simulations of the waveguide intra-body communication by using the finite-element method

Y. Chu, Y. Song, K. Zhang, B. Kang, Q. Hao, Beijing Institute of Technology (China)

Intra-body communication (IBC) is a technology using the human body as a transmission medium for the electrical signals. Due to its unique characters, IBC technology is believed as a novel and promising technology for the personal area network (PAN), computer network access, implant biomedical monitoring, etc. On the other hand, the modeling and simulation of the IBC play an important role in the investigation of the waveguide IBC. However, little research has been done to develop the finite-element model of the whole human body. As a result, the IBC simulation with the different signal transmission paths has not been achieved.

In this paper, the modeling of the whole human body and the simulations of the waveguide intra-body communication by using the finite-element method have been proposed. Firstly, we proposed a method to develop the finite-element model of the whole human body and a whole human body model used for the IBC simulation has been developed. According to the geometry of the Chinese male adult, the whole human body is abstract to the head, neck, torso, arm and leg. Meanwhile, the corresponding electromagnetic parameters were also discussed. Finally, the simulations of the waveguide intra-body communication with the different signal transmission paths have been achieved by using the developed finite-element model.

In our investigation, the potential distributions of the human body in the waveguide IBC with different signal transmission paths were analyzed by using the proposed model. Meanwhile, the signal attenuations corresponding to the signal frequency form 100kHz to 5MHz in the waveguide IBC were also discussed. The simulation results indicate that the proposed method and the model offer the significant advantages in the theoretical analysis and the application system design of the waveguide intra-body communication.

7853-63, Poster Session

Research on Cd-iEDTA-BSA immunosensor based on surface plasmon resonance

Y. Li, J. Zhong, Y. Zhang, Y. Tang, Jinan Univ. (China)

Heavy metal pollution emerges as the industry develops, which threads human health severely. Cd is a kind of supervirulent heavy metal and needs inspection for food safety. This thesis studies on the immunosensor technology based on surface plasmon resonance(SPR), successfully detects Cd and introduces the principle of SPR immunosensor detection system. Cd-iEDTA-BSA(complete antigen of Cd) immunosensor has been immobilized by hybridization product or Cd-iEDTA-BSA antibody. There are clearly 3*3 arrays on the sensor chip. Applying two SPR detection methods of imaging and scanning can detect the immunoreaction. The picture captured by SPR imaging system can directly determine the happening of the surface plasmon resonance on the sample arrays and the immunoreaction by the resonance angle. Besides, the content of Cd out of limits can be tested by finding the material which matches the one on the probe of sensor chip in the sample. After the immunoreaction the molecular weight of antigen-antibody compound which forms on the surface of the chip increases, so does the refractive index as well as resonance angle. The resonance system can detect the resonance angle and the refractive index of each position on the sensor chip precisely, and draws the resonance curves. The arrays' resonance curves reflecting the immunocreation have a clearly displacement which indicates the increasement of the resonance angle as well as the refractive index. The sensitivity of the scanning surface plasmon resonance detection system is higher than the imaging one, which is more convenient and consumes shorter time.

7853-64, Poster Session

Theoretical simulation of bending sensitivity of fibre Bragg gratings in special fiber

H. He, Beijing Univ. of Technology (China); L. Wang, Beijing Institute of Technology (China)

The axial strain of bending four-core fiber Bragg gratings (4CF-FBG), bending side-polished optical fiber grating(D-FBG) and bending side-polished four-core fiber Bragg gratings (D-4CF-FBG) is analyzed with mechanics of materials. Bending sensitivity characteristic of Bragg wavelength's shift is obtained. D-4CF-FBG's bending sensitivity is higher than 4CF-FBG and D-FBG, and the variantion of the D-4CF-FBG's bending sensitivity with respect to thickness of side-polished is several to ten times higher than D-FBG. The result was helpful for the design of high sensitivity fiber Bragg grating bending device or sensor system.

7853-65, Poster Session

Multimode-interference-based fiber Bragg grating acceleration measurment

L. Li, China Jiliang Univ. (China)

A novel edge filter demodulation of fiber Bragg grating (FBG) accelerometer using the multimode interference in the multimode fiber core section sandwiched between two single-mode fibers is experimented and demonstrated. An FBG is glued onto the top surface of a cantilever beam. A mass is fixed on the free end of the beam, the mass can transfer the vertical acceleration to the deflection of the beam. The center Bragg wavelengh of the FBG will shift with the acceleration. The multimode interference (MMI) in the multimode fiber core section is sandwiched between two single-mode fibers. MMI is designed as the filter component of edge linear filtering demodulation system for the FBG accelerometer. The experimental results show that the output power detected by the photodetector and the acceleration is linear in the measurable range. The achieved sensitivity and resolution are 4.25 pW/ g and 0.05 g, respectively. The advantages of this system are an all-fiber design, quasi-static and dynamic operation; it is possible to carry out a broader linear range according to the the interference fringes of the MMI and high-speed demodulation. With the low cost of the MMI and the system itself, the cost of demodulating the system based on industrialized FBG accelerometer is greatly reduced and the reliability of this system is further enhanced; moreover, it offers a robust, passive, and simple alternative to other systems which can demodulate relative parameters including strain, displacement, etc.

7853-66, Poster Session

Photonic crystal fiber sensors based on surface enhancement Raman scattering

Z. Di, Tianjin Univ. (China) and Hebei Polytechnic Univ. (China); J. Yao, Tianjin Univ. (China)

The combination of surface enhanced Raman scattering and photonic crystal fiber, which is so called PCF sensor based on SERS, has become a striking focus for the attractive advantages of high sensitivity, anti-interference, simple geometry, flectional light path and little influence for analyte. It offers the advantages of molecular specificity of Raman scattering, huge enhanced factor of SERS and flexibility of optical fibers. The performance of a optical fiber SERS sensor is determined by the two key factors of the excitation optical intensity and the number of particles involved in SERS activity. To improve the performance, fibers with different configures [7-12], such as flat, angled, or tapered tip, D-shaped were tested as SERS platform. However, these con- figures have not overcome the main limitation of two key factors above. While air-hole arrays of photonic crystal fiber (PCF) provide very large internal surface area for SERS action, so PCF is introduced to make the SERS platform to increase more larger active area of SERS. This review discusses the development of novel sensors and presents the state of art for PCF sensor based on SERS, mainly including theory, geometries, applications and trends. Despite recent developments indicate a great promise, some hurdles remain to be overcome.

7853-67, Poster Session

A compact micromachined interferometric accelerometer based on diffraction grating

S. Zhao, Q. Zhou, C. Hou, J. Bai, G. Yang, Zhejiang Univ. (China)

In this paper, a MOEMS accelerometer with diffraction-grating-based optical interference detection is presented. The acceleration sensor consists of a silicon-glass-silicon sandwich structure. The upper layer is a silicon layer with a laser dioxide and two pin detectors fixed on, the middle layer is an optical diffraction grating on glass substrate, and the bottom layer is a proof mass and cantilevers fabricated on silicon substrate. The proof mass and cantilevers were fabricated with two masks process on one silicon-on-insulator (SOI) wafer. The grating and the up surface of proof mass, which acts as a reflective mirror, form a phase sensitive diffractive grating, and illuminating the grating with coherent light generates a series of diffracted optical beams. The intensity of the diffracted beams is sensitive to the displacement between the grating and the proof mass, and the intensity alteration could be detected by differential circuit to get the change of displacement caused by vibratory accelerations. Experiments demonstrated that this accelerometer has good performance of sensitivity, which is about micro-g-scale, and the design, simulation, fabrication, preliminary results are presented.

7853-68, Poster Session

Modeling and simulation of RIM-FOS with single mode illumination fiber and spherical reflector

D. Hua, X. Yuan, Soochow Univ. (China)

A new mathematic model and some simulations are presented for an improved reflective intensity modulated fiber optic displacement sensor (RIM-FOS). In the model, a single mode fiber (SMF) is used as illumination fiber (IF) and a multi mode fiber (MMF) as receiving fiber (RF). The illumination light exiting IF is not uniform, but Gaussian intensity profile. With the spherical reflector coaxial to IF, the ABCD matrix is used to analyze the propagation of light through the spherical mirror. An exact expression of reflected light coupled into RF is derived. Sensor parameters such as the gap between the fiber pairs, the core diameter of RF and the curvature radius of the reflecting mirror, which have great influence on intensity modulation property, are analyzed theoretically with the new mathematic model based on MATLAB. The results show that the sensitivity of the intensity modulation will not simply decrease or increase with the curvature radius of concave reflector increasing when the gap between the fiber pairs, the core diameter of IF and RF fibers are certain. For non coaxial case, approximating through non sequential state of Zemax software with a Gaussian source, multi cylinder volumes, a standard mirror and a detector is innovatively done. The relationship of the reflecting distance and coupling efficiency under different obliquities or off-axis distance are studied conveniently. The characteristic curves and data are given out by several figures and tables.

7853-69, Poster Session

Design and realization of optical scattering signal receiving system

Z. Feng, H. Jia, National Univ. of Defense Technology (China)

The multipath fading and noises unavoidably depress the performance of optical scattering communication (such as Ultraviolet Communication between 200nm and 280nm) in the atmosphere. A data receiving system is designed using two detectors and other ordinary instruments in this paper, which is suitable for optical scattering signal transmitting at a long distance. The signals receiving and processing consist of three steps based on 1.5 dimension spectrum and cross-correlation method: firstly, the signals are received synchronously by two detectors in terms of spacial diversity, and collected by high speed data collection card afterwards; Then the two signals' 1.5 dimension spectrums, which are the third-order spectrum diagonal slices, are calculated in order to decrease the gauss noise; Finally, the cross-correlation is used to the 1.5 dimension spectrums. The cross-correlation could improve the noise-signal ratio (SNR) remarkably as the multipath fading and noises of the two signals are mutually independent. Experiments were carried out to verify the performance of the receiving system. The experimental results show that the designed system can demodulate the optical scattering signals accurately in a very short period of time even if the SNR of received signals is as low as -25dB. When the SNR of received signals could be as low as -20dB, this system can acquire an improvement of 18 dB signal noise rate; meanwhile, the bit error rate (BER) is only 0.65%, and the time of processing is less than collecting. It proves to be effective and adequate in the secure optical scattering communication at a long distance.

7853-70, Poster Session

Fiber optic temperature sensor based on the spectrum analysis detection using a PSD

Y. Zhao, S. Liu, X. Zuo, Y. Cao, Northeastern Univ. (China)

As temperature detection is widely required in industrial production and the optical fiber sensor has such characters as simple structure, small size, all-fiber-based, remote measurement and easy to use, we propose a method for the temperature measurement based on the semiconductor temperature-absorption principle. An optical spectro-grating is used to analyze the sensor signals, and a position-sensitive-device is used to record the measurement results. The measurement principle of the sensor system can be described as follows. When a broad-band light source is input, the absorption edge of the semiconductor material will shift with the varied temperature, resulting in the loss of some light with certain light wavelengths if the broad-band light passes through the semiconductor material. An optical spectro-grating is used to split the remained light into different blazed angles due to the wavelengths. A position-sensitive-device is used to record the edge of the light spot, which is varied versus the measured temperature. Sensor structure and measurement principle are introduced. The feasibility is explained theoretically and results shows that temperature measurement resolution of 0.05 can be obtained.

7853-71, Poster Session

Enhancing the sensitivity of interferometer by the way of slow light

Y. Zhao, H. Huang, Q. Wang, Z. Qi, Northeastern Univ. (China)

Recent years, the technology of slow light generations and applications are becoming hot topics, including data buffering in optical communications and optical signal delay. In this paper, we propose the application of slow light in the field of optical sensor and illustrate several principles and structures to enhance the sensitivity of interferometers based on slow light. According to the experiment results, the sensitivity of the interferometers enhance 600 times at most; however, the sensitivity can enhance 107 times in theory; moreover, the volume of the interferometer can be reduced. The miniaturization and precision devices must be applied and researched deeply in the field of sensor and measurement technology.

7853-72, Poster Session

Bidirectional filter with a fiber Bragg grating achieving single mode oscillation for gyro application

F. Rao, S. Chen, L. Fu, Beijing Institute of Technology (China)

We demonstrate a structure of bidirectional filter that can sustain two counter-propagating single-longitudinal-mode oscillations in fiber ring resonator, which can be adapt for fiber ring laser gyro application. It is know that a traditional He-Ne gas ring laser system can sustain two counter-propagating oscillations due to its inhomogenously broadened atomic characteristic. However, for a laser system using homogenously broadened gain material such as solid-state media, it is difficult to overcome mode competition and establish stable oscillation in both directions, especially for rotation sensing. Here we report this structure of filter and its operation in fiber ring resonator, which decrease the intensity of mode competition and support bidirectional oscillation.

A fiber Bragg grating of 0.1 nm bandwidth is used as wavelength-select element and a polarization control system is include to minimize mode coupling in resonator. Inside the filter, orthogonal polarizations are kept between two counter-propagating waves. A polarization beam splitter guides the two waves after they are reflected by fiber bragg grating. Filter part has been tested for about 3 dB attenuation and 35 dB back-reflection losses. When filter is inserted in fiber ring resonator, bidirectional single mode lasers with different frequencies are generated. The result of experiment confirms that this proposed configuration is effective and has possible significance as a narrow-band filter, which can be adjusted to achieve stable bidirectional oscillation with low mode coupling for gyro application.

7853-73, Poster Session

Reduction of drifts in an optical passive ring resonator gyro based on a hollow core photonic-bandgap fiber loop

W. Jin, The Hong Kong Polytechnic Univ. (China); X. Zhang, Y. Peng, Harbin Engineering Univ. (China)

Fiber optical gyros based on the Sagnac effect have been widely studied as a rotation rate sensor due to their important applications in automobile navigation systems, oil platform stabilization, well logging, and inertial navigation of commercial airliners. The optical passive ring-resonator gyro (OPRG) utilizing a high finesse fiber ring resonator has potentially a high performance with a shorter fiber length than the interferometer-type fiber gyro. It is necessary for the OPRG to use a higher coherence source to get a high finesse resonance, while the fiber gyro requires a low coherence source to reduce the parasitic noise. So OPRG accuracy is generally limited by a small number of deleterious effects that arise from the undesirable properties of the loop fiber, namely: Kerr effect, Faraday effect, and Shupe effect, and Rayleigh backscattering.

The recent advent of hollow core photonic-bandgap fibers (HCPBFs) with relatively low loss offers a radically new means for further reducing these deleterious effects, as well as reducing the complexity, size, and cost of existing fiber optical gyros. The reason is that in an air-core fiber, the optical mode is mostly confined to the air core, whereas in a conventional fiber, it travels entirely through silica. Since these effects are considerably weaker in air than in silica, they are expected to be greatly reduced in a HCPBF. The researchers from Stanford University have reported related results of interferometer gyroscope based on a HCPBF loop, and found that the performance of the gyroscope is improved. But, until now, there is no report about the performance of the OPRGs based on a HCPBF loop.

In this paper, we numerically simulated and analyzed the rotation rate drift induced by Faraday effect, Shupe effect and Rayleigh backscattering in the OPRG based on a HCPBF loop. According the theoretical modulation results, it is interestingly noted that the rotation rate drift induced by these deleterious effects can be largely reduced by only replacing the conventional single mode fiber loop with a HCPBF loop. The theoretical results show that the rotation rate drifts that induced by Faraday effect can be reduced by nearly 2 orders of magnitude, rotation rate drifts that induced by Shupe effect can be reduced by about 1 order of magnitude, and rotation rate drifts that induced by Rayleigh scattering can be reduced by a factor of about 30 in the OPRG with a HCPBF loop than that with a conventional single mode silica fiber. So the performance of OPRG can be promoted enormously by only using a HCPBF loop to replace the conventional single mode silica fiber loop.

7853-74, Poster Session

Virtual Moiré fringe for nanometer detection system based on CMOS microscopic imaging

J. Xu, W. Ye, Zhejiang Univ. of Technology (China); X. Ni, X. Cao, Zhejiang Univ. (China)

Moiré fringe is a traditional subdivision technique in precision displacement measurement. In general, use photodiode as a four-segment sensor. In this paper, we'll introduce a new system for grating subdivision of moiré fringe. The system consists of light source, condenser lens, grating, microscope tube, and CMOS image sensors. Different ways with the traditional image acquisition, there is an angle between grating stripe and the optical axis of the microscope system. Therefore, the stripe image which output by the CMOS image sensor becomes oblique. With different method of our previous study, a virtual moiré will form by the oblique stripes superimposed with the CMOS image array, which using digital image processing. The same as traditional method, the movement direction of the virtual moiré fringe is vertical with the direction movement of grating in this system. The virtual moiré fringe will move a space with grating period, the magnification has a relationship with the angle . Compare with early study, the largest increase for this system is the average effect of grating measurement system will be fully utilized by virtual moiré formed by CMOS image array. For the subdivision technique use the CMOS image array, system resolution will be large increased too. In this paper, the details of system components will be introduced, the magnification relationship of grating period and tilt angle will be discussed. It can be concluded that virtual moiré subdivision system performs better resolution and precision from experiment results.

7853-75, Poster Session

SAW properties of rotating LiNbO3 and LGS substrates

S. Lu, S. Chen, Beijing Institute of Technology (China)

SAW (surface acoustic wave) gyroscope has many prominent advantages But there is no workable product in the market nowadays. The most important reason is the difficult to extract the weak rotation information. Inspired by the background, a new method of extracting signal of the SAW gyroscope effect by use of Bragg diffraction of light by acoustic wave is proposed. According to this method, the rotation velocity information in acoustic medium is coupled to a beam of light, and then by measuring the optical intensity or frequency variation of this beam light using different mean, the rotation information can be got relatively easily. In order to extract the rotation information effectively, the applicable substrates and sensitive cut in the gyroscope should be resolved firstly. In this paper, the work is to choose the applicable material, direction of propagation, and sensitive cut using in SAW gyroscope with light-readout. At first, the propagation characteristics over a piezoelectric half-space are studied, and the LiNbO3 and La3Ga5SiO14 (LGS) substrates are investigated. The dependences of surface acoustic wave (SAW) phase velocity, temperature coefficient of frequency (TCF), power flow angle (PFA) and electro-mechanical coupling coefficient on the cutting axis and the propagation direction are analyzed and discussed. Next, the propagation characteristics of piezoelectric substrates rotating at a constant angular are analyzed, including Coriolis and centrifugal force. Some quantitative analyses of SAW gyroscope effect in X-cut, Y-cut, Z-cut and any Euler angle LiNbO3 and LGS substrates are given in this paper respectively. At last, the applicable material, direction of propagation, and sensitive cut using in SAW gyroscope with light-readout are recommended.

7853-76, Poster Session

Study on optically powered Hall current transducer

Y. Wang, Y. Zhang, J. Zhao, Yanshan Univ. (China)

Abstract: A hybrid fiber optically-powered current transducer with the Hall element is presented in this paper. The sensor probe is the zero-flux current transducer which is based on Hall effect. The main current can be insulated from the measurement circuit by use of Hall current transducer. Due to the broad bandwidth characteristics and the high linearity between the Hall voltage and measured magnetic flux density and the high sensitivity of the Hall current transducer, any changes in the excitation current can be accurately detected without distortion. The three-dimensional model of the Hall current transducer is set up by use of ANSYS software in this paper. The magnetic flux density in the opening air-gap is calculated by nonlinear magnetic analysis method of the three-dimensional finite element. Experimental data shows that the calculation method and results are reliable. At the same time, high power laser power supply is adopted to drive the electronic devices in high potential side, and the reliable insulation between the high potential and low potential is achieved by optical fibers. So the accuracy of this measurement system can be ensured.

7853-77, Poster Session

Study on digital correlation demodulation technology of micro quartz tuning fork gyroscope

Z. Zhang, L. Feng, Y. Sun, Beijing Institute of Technology (China)

Micro quartz tuning fork gyroscope is a kind of micromechanical vibrating gyroscope, which has great value both in military and civil uses. In this article the main factors which affect the performance of micro quartz tuning fork mainly from the characteristics of the structure of micro quartz tuning fork gyroscope are analyzed, and a reference for designation of the signal detection circuit of micro quartz tuning fork gyroscope is provided. Besides, according to the shortcomings of current micro quartz tuning fork gyroscope analog demodulation circuit, and in the operation of quartz gyroscope the reference signal should be in the resonance state with steady amplitude and the reference signal should be in-phase and has the same frequency with the driving signal. A signal demodulation scheme for micro quartz tuning fork gyroscope based on digital correlation demodulation technology is proposed. The ideal of this scheme is that the frequency and the amplitude of the driving signal, and the phase of the reference signal could be adjusted according to the auto frequency selecting property of quartz, so the driving tuning fork oscillation is generated and the in-phase condition of the correlation demodulation is satisfied. The scheme is a combination of hardware and software. The quartz gyroscope signal processing platform is designed on the foundation of DEC6713 DSP development board successfully. The adaptive algorithm including the reference signal frequency tacking, the amplitude automatic gain controlling, the reference signal phase locking, and complex correlation demodulation are devised, and the algorithm is programmed. It is proved that the digital signal process scheme is feasible by means of experimentation.

7853-78, Poster Session

Distance measurement device based on infrared light intensity modulation and fuzzy control theory

C. Shen, M. Wu, X. Chen, J. Xu, Zhejiang Univ. of Technology (China)

Most of the traditional distance measurement using electromagnetic waves or electromagnetic pulse time of flight to obtain distance information. It has been widely used in various fields . High accuracy and high resolution can get by these method. Ranging in many occasions does not need high accuracy and resolution. For example, reversing radar, blind obstacle avoidance, etc. This paper presents a new distance measuring device that based on infrared light intensity modulation. Moreover, the device combine with the fuzzy control theory, so called fuzzy location device based on infrared light intensity modulation. The device includes the infrared modulation transmission unit, collimating unit, infrared receiver unit, background light sensor unit and data processing unit. If alarm distance is n m, data processing unit set infrared light intensity of infrared modulation transmission unit and the light intensity threshold of infrared receiver unit by look-up table with fuzzy control theory. It is according to the current background light intensity. Once the receiving light intensity exceeds the threshold, the system alerts. The paper expounds the working principle, fuzzy control theory on the domain and fuzzy universe, the experimental results of the device and analysis in detail. It shows that the device is small, low cost and suitable for a large number of used when it dose not need high accuracy and resolution measurement.

7853-79, Poster Session

A new design for simultaneous temperature and strain measurement with spontaneous Raman and Brillouin scattering

F. Chen, Shanghai Institute of Optics and Fine Mechanics (China)

We design a new system for simultaneous distributed measurement of temperature and strain based on both spontaneous Raman and Brillouin backscattered signals. The Raman signal can determine the

temperature. Although the Brillouin frequency shift is dependent on both the temperature and the strain of the fiber, once the temperature is determine from the Raman signal, the strain can then be computed from the frequency measurement of the Brillouin signal.

7853-80, Poster Session

Temperature sensor based on in low-birefringence photonic crystal fiber sagnac interferometer

H. Gong, China Jiliang Univ. (China); C. Chan, L. H. Chen, Nanyang Technological Univ. (Singapore); Y. Jin, X. Dong, China Jiliang Univ. (China)

Optical fiber Sagnac interferometers have been developed for many sensing applications, such as strain, temperature, liquid level and curvature. All of them used polarization maintaining fiber (PMF) or high birefringence (Hi-Bi) fiber to introduce optical path difference, in order to cause interference effect between the two counterpropagating waves in the Sagnac loop. In this paper, a low-birefringence photonic crystal fiber (PCF) based Sagnac loop employing as a temperature sensor is proposed firstly. The Sagnac loop includes a 3dB single-mode fiber (SMF) coupler and a 40cm long PCF (NL-1550-NEG-1). The birefringence value is calculated to be 5.8×10-5, which is about one or two orders less than that of PM-PCF or high-birefringence fiber. A section of about 140mm PCF was used as sensing element, and was placed in a temperature-controlled oven. The temperature is increased from 25oC to 85oC with a step of 5oC. The output spectra of the Sagnac loop under different temperatures are measured and analyzed. Due to the low birefringence of this PCF, only one dip appears in the spectrum when an amplified spontaneous emission (ASE) light source is used. The sensitivity of the temperature measurement of -0.123nm/oC is achieved in the range of 25oC-85oC, and the temperature resolution limited by the 20pm wavelength resolution of the OSA is about 0.16oC. In addition, the proposed Sagnac interferometer can be used as a thermally tunable optical band-stop filter for C and L band. The proposed Sagnac interferometer has the advantages of simple structure, easy fabrication, good stability and high sensitivity, so it is useful in many sensing applications.

7853-81, Poster Session

Noise analysis of laser Doppler system which adopting the phase generated carrier demodulation method

L. Zhu, Anhui Univ. (China)

Laser Doppler vibration measuring system has been widely used in many fields., in order to eliminate the phase fading, phase generated carrier (PGC) homodyne demodulation technology has been applied usually, and dual-optical-channel balancing detection technology has been used to suppress the intensity noise of the light source. However, theoretical analysis reveals that the intensity noise of the light source cannot be eliminate totally due to the modulation, which is still the main noise in the system. In this paper, we consider the influence of the intensity noise of the light source and the shot noise of the detectors. By numerical simulating, we analyze the origin of the noise, especially the influence of remnant intensity noise to signal-to-noise ratio of the system, and find the optimal parameters of the system. In the end, we verify the result of numerical simulating by experiments.

7853-82, Poster Session

Algorithm study of phase diverse wave-front sensing

F. Li, C. Rao, Institute of Optics and Electronics (China)

Phase diverse wave-front sensing (PDWFS) is a methodology for estimating wave-front aberrations by solving an unconstrained optimization problem from multiple images whose pupil phases differ from one another with a known manner. Due to the large number of pixels, the problem has a large number of unknowns, and an efficient numerical technique is required. In this paper, the characteristic of PDWFS is analyzed, and various algorithms that can be used for PDWFS are studied with respect to accuracy and computing time. When wave-front distribution is expressed by Zernike polynomials, the unknowns are their coefficients. The steepest descent method, conjugate gradient method and quasi-Newton method are used to solve this optimization problem. Form the results we can see that each of the above three methods can achieve a high accuracy, but considerable computing time is consumed. Analysis shows that most of the computing time is consumed in computing gradients of the objective function. So, a more efficient method that solves the gradients is required. When wave-front distribution is described by N×N discretized sampling points, the unknowns are the sampling points, and so the number of unknowns is large. General optimization algorithms need to calculate a Hessian matrix or generate a Hessian approximation so that the computations are burdensome. More than 1 hour will be consumed when one uses quasi-Newton method. In this paper, the steepest descent method and the limited memory quasi-Newton method are studied. The gradients of the objective function are written into a matrix, and in this way the computing speed is improved greatly.

7853-83, Poster Session

Deflection measurement using long-period grating sensor fabricated on side-hole single-mode fiber by CO2 laser

J. C. Kang, China Jiliang Univ. (China)

Flexural character of long-period grating must be considered in fiber communication and sensor application fields. Different LPG fabricated in different fiber with different method has different flexural character. In this paper, a LPG fabricated by CO2 laser in side-hole single-mode fiber (SHLPG) for deflection measurement was demonstrated according with flexural character. The detailed SHLPG fabrication and its deflection principle were analyzed. In experiment, firstly SHLPG sensor was fixed on cantilever, with different strength on the end of the cantilever, resonance wavelength of SHLPG shifted with the change of strength. Because of orientation dependence about flexural character, experimental measuring about different orientation was also carried out to compare deflection sensitivity. Because of the side-hole in the fiber, above hole direction and its opposite has the opposite resonance wavelength shift. then SHLPG and uniform LPG were fixed paralleling on the side of the cantilever to compare deflection sensitivity about each other. Schematic diagram of the experimental was shown as fig.1. resonance wavelength shift of SHLPG has approximately linearly blue shift with the strength increasing in hole direction. the loss peak decreased linearly approximately with the cantilever curing. The experimental results indicated that SHLPG has higher deflection sensitivity in one direction than uniform LPG and lower deflection sensitivity in other direction than uniform LPG, which can be used in curve measurement sensor fields for high sensitivity and fiber communication fields for low sensitivity. Excellent agreement between the experimental results and theoretical analyses was shown in the paper.

7853-84, Poster Session

Application of demodulation technology for fiber Bragg grating in power system

Y. Li, H. He, G. Yao, North China Electric Power Univ. (China)

Temperature monitoring of the electric power equipment is an important guarantee of the safety and stability of the electric power. This paper introduces the working principle of fiber Bragg grating sensor, designs and realizes a wavelength demodulation system of fiber Bragg grating based on F-P filter. EP1C12Q240C8 chip, produced by Altera Company, is adopted as core processor, and Quartus II is used to write software. A sawtooth wave circuit is formed through 16-bit high-speed D/A convert chip DAC712, and sawtooth voltage is generated to drive F-P filter working in the state of scanning; high-speed 16-bit low-power data converter ADS1601 is adopted to design a data acquisition circuit and gather the output signals of photoelectric detector; High-density Ethernet controller RTL8019AS, produced by REALTEK Company, is adopted to design Ethernet interface, which will transmit the collected signals to PC. Processes the real-time of the data by LabVIEW compiling software program in PC, and the demodulation of fiber Bragg grating wavelength is realized. This system can reach a measurement accuracy of ±0.3 . Through analyzing the sensing scheme of fiber Bragg grating, adopting sensing technology of fiber Bragg grating is put forward to realize the grid-line temperature monitoring system, so as to enhance the security operational capability of the electric power equipment. Demodulation system of fiber Bragg grating has a vast application prospect in power system with the advantages of high measuring precision and good real time etc.

7853-85, Poster Session

Analysis of relationship between far-field images and piston phase errors of synthetic-aperture telescopes for the polychromatic target wave

Z. Liu, S. Wang, C. Rao, Institute of Optics and Electronics (China)

The technology of detecting and correcting piston phase errors is one of the key technologies for synthetic-aperture telescopes to achieve the high resolution. In this paper, a variety of technologies of detecting piston phase errors was briefly introduced and analyzed. And, the relationship between the complex amplitude function of synthetic-aperture systems and different phase aberrations, especially the piston phase error, was deduced. Afterwards, the point spread function (PSF) of two-aperture systems under various phase aberrations was theoretically analyzed in detail, which, led to a description of the relationship between intensity of far-field images and piston phase errors. On the basis of some calculations and simulations, patterns of PSFs' distribution under a variety of piston phase errors were analyzed for the cases of monochromatic and polychromatic target wave, which, led to the regularity of distributions of the peaks of PSF intensity under different piston phase errors, and its fitting function. In addition, the shifting pattern of relevant positions of these peaks was concluded from corresponding simulations, which was followed by its comparison with the regularity of distributions of the peaks of PSF intensity under various piston phase errors. This comparison and its corresponding analysis are believed to provide important theoretical supports for our next step research of innovative methods of detecting piston phase error for synthetic-aperture telescopes systems.

7853-86, Poster Session

Brillouin optical time-domain reflectometry based on Hadamard sequence probe pulse

Y. Lu, L. Hao, C. Li, X. Zhang, Nanjing Univ. (China)

As an optical fiber sensing technology based on detecting spontaneous Brillouin scattering, Brillouin Optical Time-Domain Reflectometry (BOTDR) is attracting significant attention due to its immense potential applications in temperature or strain monitoring. To enhance the signal to noise ratio (SNR) of BOTDR system, a new BOTDR based on Hadamard sequence probe pulse is proposed. In the new BOTDR system, the sequences of probe pulses are generated from the Hadamard matrix. We can obtain N orthogonal probe sequences by constructing an N-dimensional Hadamard matrix and taking each row vector of the matrix as one probe sequence. By detecting the N traces of spontaneous Brillouin scattering of the N Hadamard sequence probe pulse, and by using inverse Hadamard transform, the measured Brillouin frequency shift and power along the sensing optical fiber can be achieved. The BOTDR system is based on detecting spontaneous Brillouin scattering spectrum with frequency scanning method, which is different from the method that using the Landau-Placzek ratio scheme. When compared with the conventional BOTDR system with a single probe pulse, the gain of SNR of the new system with a sequence length N is (N+1)/2N**0.5, without reducing the spatial resolution. It is also found that the same sensing range can be achieved in the proposed system by using lower pulse peak power, when it is compared with the conventional BOTDR system. It has been verified that this system can be used to obtain the distribution of the Brillouin frequency shift of a 37km fiber with sequence pulses with peak power of -13dBm.

7853-87, Poster Session

Optical sensor based on fractal cantor multilayer structures made of porous silicon

J. Mo, Xinjiang Univ. (China) and Xi'an Jiaotong Univ. (China); X. Lv, Z. Jia, Xinjiang Univ. (China)

Porous silicon (PSi) has been demonstrated to be a sensitive sensing platform because of its unique porous structure and the high surface area. Zhong Yin Xiao at al. studied a new photonic crystal structure, which is composed of fractal Cantor multilayer with a defect embedded in its middle, and the new structure has wider stopband and shows a super narrow band in the middle of wider stopband. It can be served as a super narrow bandpass filter and the pass band obtained can be less than 0.6nm. So, this inspiration made us investigate and design novel Cantor multilayer PSi optical sensors. Sensing model of PSi sensor is set up by applying the Bruggeman effective medium approximation theory and method of transfer matrix. The layers thicknesses are dH= 0/4nH and dL= 0/4nL, respectively. The novel fractal Cantor multilayer structures with a defect embedded in its middle is more sensitive than the common periodic structure one (such as Bragg), for providing a higher filling capability of biological solution with respect to the common periodic one. The phenomenon can be ascribed to the capillary infiltration of liquid into the pores, which makes it possible to detect changes in the refractive index of the biological solution, due to the lower number of interfaces. This novel PSi structures opens the door for design all-silicon sensor array for sensing of various chemical and biological species.

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7853-88, Poster Session

Based on the study of fiber grating level tiltmeter

D. En, N. Wang, N. Zhang, J. Feng, X. Wang, Henan Polytechnic Univ. (China)

Fiber Bragg Grating sensor is a kind of widely used new sensors. This paper presents a level based on fiber Bragg grating tilt sensor, with the variation of the tilt angle is converted to optical conversion of the change in deformation mechanism to achieve the measured level of relative horizontal angle measurement, sensor-related design theory is given, and to design sensor sensing structure. The sensor adopts fiber grating method to eliminate reference to temperature and metal bellows packaging method to improve the sensitive strain, and through experiments proved the feasibility of this design.

7853-89, Poster Session

Optical fiber temperature measurement technique based on fluorescence mechanism

X. Bo, Yanshan Univ. (China)

Temperature is one of the most important measured parameters in the measure of scientific and industrial control, as the range of temperature measurement applications expanding, the temperature monitoring of innovation, research and development has been carried out continuously.The measurement environment for the accurate measurement of temperature result in many problem, such as measured target can be extremely harmful, it could be movable, or closing to the measured target is very difficult, and even the probe can not contact to the target, or the presence of electromagnetic noise interference.A kind of fluorescence optic-fiber temperature sensor is studied in this paper. It used sapphire fiber thermal probe, making use of the method that FFT transformation to carry on a processing to the fluorescence signal. With a high melting point, over 2000 ,high transmissions in the wave of band of 0.3~0.4μm and favorable mechanical and chemical inert,sapphire fiber is very attractive for high temperature optical fiber sensor and near infrared energy delivery.The measured fluorescence life time can be obtained by calculating tangent value of first non-zero phase angle. Among the detection range from 0 to 450 ,the thermometer has an average temperature resolution of 0.4 . The experimental results show that this temperature measuring system can effectively decrease the influence of instability of light source and intensity varlation in measuring channel on measurement results. The systerm has the advantage of high accuracy, very high temperature resolution, good dynamic response and immunity to the electro-magnetic interference. So it may be used in microwave treatment and thermal monitoring of Medium Voltage Substations.

7853-90, Poster Session

Application research of DTS system on dam

J. Wang, C. Hu, H. Xu, J. C. Kang, Z. Zhang, Y. Jin, H. Gong, China Jiliang Univ. (China)

Distributed optical fiber temperature sensor (DTS) system is a real-time, on-line and continuous optical fiber temperature measurement system. It is a high-tech instrument for real-time measurement of spatial temperature field. It has become a new detection method in the field of public safety and industrial process monitoring. This instrument has many advantages that traditional instruments do not have. Sensing fiber is not charged, anti-RF and anti-EMI. So DTS system can operate safely in dangerous conditions. So it is an “inherently safe” sensor system. The system can locate precisely of any point along sensing optical fiber. So the DTS system is also optical radar for temperature measurement.

Recently, many research projects of TDS system are carried out in China. Some of them focused on improving performance of the system. And the others focused on using the system in variety engineering projects, such as tunnels, oil pipelines, dam, oil wells, subway, coal mine, power cable and so on.

In this paper, application research of DTS system in leakage of dam is studied. Problems and solutions of using DTS system in application are introduecd. Two typical engineering applications in the Three Gorges Dam and Xin’anjiang hydropower station are studied. During construction of the Three Gorges Dam, In order to prevent cracks of the Dam, temperature of concrete is measured by DTS system real-timely. In application of Xin’anjiang hydropower station, sensing fiber of the DTS system is heated. Position of leakage can be determined by measuring temperature of the fiber. Test results are listed and discussed.

7853-91, Poster Session

Laser stealth technique of optical system

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Optical system could be discovered easily by active laser reconnaissance due to its cat-eye effect, so a kind of protective technique is cried for. In this paper, the unsymmetrical covering technique is advanced to realize the optical system’s laser stealth. A theoretical model of the technique was established. The laser stealth effect was analyzed and the results indicate that covering an area of optical system’s lens could blind the echo in both the covered area and its centrosymmetric area. Therefore, optical system laser stealth could be achieved by covering half of the lens. However, the optical system could still work well in this situation. An experiment was designed to validate the theoretical analysis results. The experimental results are shown to be in good agreement with the theoretical predictions. A conclusion is got that using unsymmetrical covering technique to achieve optical system’s laser stealth is effective.

7853-92, Poster Session

Investigation of the fluorescent efficiency improvement of a novel designed fiber probe for zinc detection

Z. Pan, M. Li, Wuhan Univ. of Technology (China)

A lot of applications of fiber optic sensor for bioluminescence have been widely reported. A key component in fiber optic fluorescent sensing system is sensor probe, whose efficiency will determine the overall sensor performance, and haven’t been thoroughly understood in previous studies. Questions about how the probe structural parameters such as length, diameters and N.A. of its fiber components affect the collecting efficiency of the fluorescence signals. In this paper, we present a pinpoint fiber-glass probe aiming at efficient fluorescence collection. According to the geometric optics approach, we model a sensor probe based on the same principle of coupling ratio analysis between a light source and a fiber, and demonstrate the quantitative relations of the fluorescent collecting efficiency and the structural parameters of the probe by simulation and experiment.

Our theoretical analysis comes up with a optimal probe geometry which has the highest fluorescent efficiency of the designed fiber optic sensor probe, and reveal detailed relations that the efficiency is direct proportion to the core diameter, NA of receiving fiber, and is in inverse proportion to the length, section radius of sensing probe, where the ratio of the core diameter to sectional area of the probe is the key factors for fluorescent efficiency. Demonstrated experimental results based on fluorescent pigment FITC, we measure the UV power, emitting

and collecting fluorescent light power with a home-made probe and detecting system. The experimental results match very well with the simulation conclusions, and discussed for the optimization of probe in the measurement of trace element Zinc.

7853-93, Poster Session

Research on the laser interferometer vibration measurement system based on orthogonal signal

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The interferometric vibration sensor with quadrature detection can generate in-phase and quadrature-phase (I/Q) signals by optical configuration. The influence of the DC component existing in the interferometric I/Q signals is discussed in this paper. The I/Q signals were processed by time derivation and arctangent algorithm to demodulated the analog signals. Theoretical analysis and experimental results prove that this method can be used to eliminate the DC component in the signal, meanwhile, the micro-vibration signals can be measured accurately.

7853-94, Poster Session

Highly birefringent index-guided photonic crystal fiber with two air holes core

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Photonic crystal fibers (PCFs) have attracted more and more interests during the past decade. Owing to the flexibilities on PCF design, several appealing features, such as high nonlinearity, flat dispersion, large negative dispersion, and large effective mode area, etc., have been demonstrated with PCFs. In addition, high modal birefringence can be achieved with specially designed PCFs to realize polarization maintaining fibers (PMF) or single polarization fibers. There can be various applications of high-birefringent PCFs in the field of optical communications (e.g. polarization-sensitive optical modulators) and fiber-optic sensing (e.g. fiber gyroscopes). So far, various high birefringent PCFs with the modal birefringence on the order of have been reported, and birefringence as high as 0.0076 has been experimentally demonstrated in PCF.

In present paper, a novel ultrahigh birefringent index-guided triangular photonic crystal fiber with two elliptical air holes in the core is introduced which guides light by total internal reflection (TIR) when the air holes are smaller than the air holes in cladding. The birefringence and propagation loss of PCFs are investigated using full-vector finite-element method. The impacts of the geometry parameters and positions of the elliptical air holes on the properties of birefringence and leakage loss are discussed. Introduction of two air holes provides us more flexibility and possibilities than traditional index-guided PCF to obtain surprising performances. The suggested structure possesses a large birefringence to separate the two polarization modes. Our suggested structures show that the birefringence can be as high as 10-2 at 1.55μm wavelength, which is higher than those obtained from conventional step-index fiber and traditional PCF.

7853-95, Poster Session

Design of a novel vibration sensor based on Mach-Zehnder interferometer

S. Zhao, B. Yu, L. Pan, D. Jin, X. Wu, Anhui Univ. (China)

Because of a series of advantages such as high sensitivity, non-contact measurement, interferometric vibration sensors have attracted interest from a lot of researchers in vibration sensing field. In this paper, a novel Mach-Zehnder interferomtric vibration sensor which utilizes quadrature detection technology is proposed. In our system, non-polarized light source and 1/4 wave plate is used to obtain two in-phase and quadrature-phase (I/Q) signals. Compared with previous methods, this sensor system has a simple optical configuration and more reliable stability. Theoretical analysis indicates that this sensor can measure the vibration displacement accurately.

7853-96, Poster Session

The performance study of stimulated Brillouin scattering distributed fiber optic sensing based on modified steady-state analysis

X. Qian, K. Wang, Beijing Univ. of Posts and Telecommunications (China)

We present a perfomance study of stimulated Brillouin scattering distributed fiber-optic sensing with modified steady-state-coupled equations.The modified model can give the analytical solutions of transmitted power in long distance fiber and handle with nonlocal effects occured in SBS distributed sensing system. Moreover, the model introduces a new noise factor B that is generated by spontaneous Brillouin scattering, initiated by thermal fluctuations in the medium. In SBS distributed sensing system, this coefficient B which fluctuates with brillouin frequency shift and fiber length will bring in errors that are often neglected in the past. Based on this consideration,we propose a comprehensive theoretical study on the performance of SBS distributed sensing system which uses two independent data processing methods named harmonic reconstruction algorithm and classical aproach respectively. The more precise system SNR results and comparison with former results will be given at last. To our knowlege,it is the first time that modified steady-state model is applicated to the performance analysis of SBS distributed sensing system.

7853-97, Poster Session

Optical fiber sensors for the concentration of acetic acid based on fiber side polishing technique

J. Tang, Z. Chen, R. Fan, J. Yu, J. Zhang, Jinan Univ. (China)

Two kinds of optical fiber sensors that are fabricated by fiber side polishing technique are proposed and demonstrated experimentally in order to measure the concentration of acetic acid. One of them is a side polished fiber Bragg grating sensor, whose cladding in the region of fiber Bragg grating is side polished. Because its reflective Bragg wavelength shifts when polished region is overlaid with different concentrations of acetic acid respectively, the concentration of acetic acid could be measured; The other kind is a side polished single mode fiber sensor, whose part of cladding is side polished. The concentration of acetic acid could be measured by the transmitted optical power when polished region is overlaid with acetic acid. Both of the sensors with different polished depths are fabricated in the experiments to measure acetic acid with concentration from 0% to 100%. The total shift of reflective Bragg wavelength of side polished fiber Bragg grating sensor with a residual thichness of 0μm between polished surface and fiber core is 0.15nm when the concentration of acetic acid overlaid on the polished region changes from 0% to 100%. Its resolution is about 6.67%. The total variation of transmitted optical power in the side polished single mode fiber sensor with a residual thichness of 0.5μm is 1.829dB when the concentration of acetic acid changes from 0% to 100%. The resolution of sensor is 0.55%.

7853-98, Poster Session

Interferometric vibration detection on laser backscattering of speckles pattern

Y. Zhang, S. Zhen, Anhui Univ. (China)

The detection of micro-vibration is widely used in many fields. In this paper we present a new method to improve the vibration detection optical system. The novel method based on speckles pattern which scattered on the surface of the target by a spot of laser beam, we select several speckles patterns at random to observe their self interference by measuring the change of relative phase shift. We devote the speckles pattern process into our own Laser Doppler vibration detection system, presume upon to get more sensitivity and veracity.

7853-99, Poster Session

Temperature-independent bending sensor based on a superimposed fiber Bragg grating

Y. Liu, X. Dong, J. C. Kang, C. Zhao, China Jiliang Univ. (China)

There is a continuous growth of study interest of tilted fiber Bragg gratings (TFBG) for various sensing applications ranging from surrounding refractive index, bending, modern biological analysis, and others. Both a core mode (Bragg) resonance and several cladding-mode resonances appear simultaneously in transmission of a TFBG. While the Bragg resonance is only sensitive to axial strain and temperature, the cladding mode resonances are sensitive to the external perturbations (strain, temperature, bending, refractive index, etc.)Hence, a single TFBG can provide temperature-independent sensing by a comparison between the shifts of the Bragg resonance and the selected cladding-mode resonances. However, due to the separation between the Bragg resonance and the cladding-mode resonances, this kind of demodulation needs a large range of spectrum monitoring which substantially limits its applications. In this paper, a novel configuration in which a TFBG is written overlapping with a uniform FBG is proposed and demonstrated. The uniform FBG working in reflection mode plays as a bandpass filter and the cladding mode resonances only located in corresponding spectral range can be demodulated. It restricts the modulation and demodulation in a narrow spectral range. Bending of a TFBG affects its optical losses due to cladding-mode couplings, therefore different bending results in variation in the reflection amplitude of this configuration. Thus, the sensor makes bending measurement much easier by detecting the reflected optical power.

7853-100, Poster Session

Polymer-coated hybrid fiber grating for relative humidity sensing

T. Li, X. Dong, C. Zhao, Y. Liu, China Jiliang Univ. (China)

The monitoring of the relative humidity is of great importance in many applications. In recent years, many people research in the relative humidity sensing. A relative humidity (RH) sensor based on hybrid fiber grating coated with a moisture sensitive polymer is proposed in this paper. The hybrid fiber grating involves a fiber Bragg grating (FBG) and a tilted FBG (TFBG), which are inscribed at the same place. Such a perfect structure would be extremely useful to opportunely combine uniform FBGs and TFBGs in a single in-fiber structure to obtain parametric simultaneous measurements keeping the advantages of FBGs interrogation. The moisture sensitive polymer can vary when absorbing and desorbing the moisture. The hybrid fiber grating coated with polymer film as humidity sensing will lead to the wavelength shift when the surrounding air of the relative humidity changes. So the sensing principle is based on the effort induced in the grating through the swelling of polymer coating. The experimental results show the fast response speed can not be achieved by traditional sensors, at the same time this facility has high testing accuracy and good stability, so the polymer-coated hybrid fiber grating is a very good relative humidity sensing.

7853-101, Poster Session

A temperature-insensitive load sensor with a single fiber Bragg grating

L. Hu, X. Dong, C. Zhao, S. Jin, China Jiliang Univ. (China)

In the recent two decades, fiber Bragg gratings (FBGs) have attracted lots of research interests in the area of optical sensors as well as communications. A variety of FBG sensors have been designed to monitor parameters, such as temperature, tilt angle, strain, pressure, force, torsion, load, etc. Compared with other types of sensors, FBGs have many advantages including immunity to radio frequency interference (RFI) and electromagnetic interference (EMI), electrically passive operation, high sensitivity, compact size, multiplexing and self-referencing capabilities. In this work, a simple novel load sensor has been demonstrated by embedding a uniform FBG along the axis of a tapered cylindrical polymer block. Due to the load-induced nonuniform strain field applied along the length of the FBG, the bandwidth of its reflection spectra varies linearly with the applied load. By measuring the reflected optical power of the chirped FBG illuminated by a flattened broadband light source with an optical power meter, complex wavelength interrogation system is avoided and temperature-insensitive measurement of load is realized. Preliminary experimental results show a well agreement with the theoretical analysis and indicate that a high accuracy and high resolution can be achieved. Since the FBG is well protected by embedding in the tapered elastic polymer, the sensor is expected to have an excellent reliability.

7853-102, Poster Session

Spectra extraction for wavelength-modulation spectroscopy of intra-cavity absorption gas sensor

W. Han, Y. Wang, K. Liu, D. Jia, T. Liu, Tianjin Univ. (China)

Low-frequency wavelength modulation is introduced to increase sensitivity of intra-cavity absorption gas sensor (ICAGS) system. ICAGS system including erbium-doped fiber amplifier (EDFA), pump laser, tunable fiber Fabry-Perot (F-P) optical filter and gas cell is set up. Using virtual instrument technique, modulation function is generated by Labview software and outputted through the AO ports of data acquisition card to tune the driving voltage of optical filter. The AI ports collect the laser power signals in a synchronous mode. Harmonic spectra can be computed by adopting the method of the Discrete Fourier Transform (DFT). According to the characteristics of different order harmonic, even harmonics and odd harmonics are analyzed respectively. Here, second harmonic is used to determine the spectral intensity, and third harmonic is mainly used to locate the position of spectral lines. With optimum 10Hz frequency modulation, acetylene absorption experiments were carried out. The pump current of EDFA is 80mA and the acetylene concentration in the gas cell is 10000 ppm. After spectra extraction, in the 1526nm to 1537nm wavelength range, 17 absorption lines of acetylene were achieved. The results indicated that the error of wavelength position is less than 0.1nm and the minimum detection limit of acetylene is about 120×10-6. It is possible to realize the recognition of measured gas type and multi-component gas detection for ICAGS system.

7853-103, Poster Session

Temperature spatial distribution of pulsed laser-induced plasma in air

C. Xin, The Academy of Equipment Command & Technology (China)

The characteristics of laser-induced plasma temperature are highness, varying rapidly and distributing non-homogeneously, which lead to the difficulties of plasma diagnosis. Currently, the main technique for temperature measuring of laser-induced plasma is using emission intensity ratio from the plasma spectrum with a spectrometer or an OMA (Optical multi-channel analyzer). However, it is impossible to acquire the spatial distribution of plasma temperature but the temperature on several dispersive spots through the method mentioned above. In order to acquire the planar distribution of the temperature field of laser-induced plasma exactly, we established a new temperature measuring system based on narrowband filters and high-speed camera. On the assumption that the plasma is local thermodynamic equilibrium (LTE) and optical thin, the plasma temperature can be calculated by measuring the relative intensity of two spectral lines, NII399.50nm and NII500.515nm. While the pulse energy of TEA CO2 laser was 35J, the planar distribution of temperature field was measured by the new measuring system. The two major contributions are as follow: first, a new measuring system was established, with which the planar distribution of the plasma temperature field could be acquired expediently with a spatial resolution of 137μm; second, the characteristics of temperature distribution were achieved and analyzed in detail. The result showed that the temperature distributes symmetrically in vertical. In horizon, the temperature in the side facing the laser was as high as 30000K while it was 15000K in the other side. The research in this paper could provide important experimental elements and numerical evidence to the laser plasma diagnosis, interaction of laser and materials, and the process of energy deposition in laser propulsion.

7853-104, Poster Session

Discrimination of strain and temperature using a long-period fiber grating inscribed in high-birefringence photonic crystal fiber combined with a fiber loop mirror

C. Li, F. Xu, X. Shi, M. Shi, D. Tao, D. Ren, B. Yu, Anhui Univ. (China)

In this letter, Our work presents a simplified improvement for discrimination of strain and temperature. The sensing head is composed by a long-period fiber grating inscribed in high-birefringence photonic crystal fiber and a Sagnac loop mirror based on the remaining high-birefringence fiber for simultaneous measurement of temperature and strain. The sensitivities of each resonant dip for strain and temperature are different in magnitude and sign when a change of temperature and/or strain is realized.

7853-105, Poster Session

Strongly evanescent field coupling between nanofibers for sensing transverse optical force

J. Yu, Z. Chen, J. Zhang, Y. Zhong, X. Yi, Sr., J. Tang, F. Huang, Jinan Univ. (China)

Using full-vector finite element method, transverse optical forces induced by strongly evanescent coupling between two identical micro/nanofibers is theoretically investigated. It shows that anti-symmetry and symmetry modes can induce attractive and repulsive force, respectively. When light power of the symmetry mode at 980nm wavelength is 10mW and the gap between the micro/nanofibers with 400nm diameter nears 380nm, the repulsive force reaches maximum (2.04 pN/um), which results in 105nm displacement at the center of 100um-long suspended nanofiber. Based on pump-probe scheme, a novel potential method for optical force sensing is proposed. Using Euler-Bernoulli beam equation and coupled mode theory for waveguides, the deformation impact on the splitting ratio of coupling nanofibers is also modeled. It is found that, through the deformation effect, the above repulsive force (2.04 pN/um) can change the splitting ratio of coupling nanofibers from 0.70 to 16.47 when coupling length of nanofibers is fixed at 100um and the gap is 380nm. It shows that measuring the splitting ratio of the strongly coupling nanofibers can potentially provide a high sensitive method for measuring the optical force.

7853-106, Poster Session

Analysis and simulation of fiber Bragg grating sensing networks using CDMA

D. Li, J. Qi, Shandong Univ. (China)

In order to increase the multiplying density of Fiber Bragg Grating (FBG) sensors, a novel FBG sensing network based on measuring point CDMA encoding technology has been developed. Furthermore, the necessary condition of measuring point CDMA code has been discussed and the measuring performances of this system have been analyzed. Simulation experiment indicates that in a spectral range of 25.5nm, this type of sensing network can arrange 41 FBG sensors and the measuring range of every sensor reaches 10 nm.

7853-107, Poster Session

Thermal independent solution concentration sensing with tilted fiber Bragg grating

D. Hu, J. Qi, Shandong Univ. (China)

The temperature and solution concentration sensing characteristics of tilted fiber Bragg grating (TFBG) is investigated by means of theoretical analysis and experiments in this paper. It shows that the core and cladding modes exhibit nearly but not exactly the same thermal sensitivity with good linearity throughout the investigated temperature range in the experiments. The dual-sensitivity problem of TFBG to temperature and solution concentration is solved by calibrating every cladding mode wavelength with the core mode wavelength which is not sensitive to the solution concentration respectively to cancel out the temperature effect, and this method makes thermal independent solution concentration measurement possible. It indicates that the cladding modes wavelengths linearly shift to the long wavelength direction with the increasing sucrose aqueous solution concentration, the demonstrated sensitivity is up to 5.3 pm/(g/40mL).

7853-108, Poster Session

The optimization design of parameters for a wavy vibrating diaphragm of fiber optic microphone

P. Li, B. Yu, S. Zhao, L. Li, X. Wu, Anhui Univ. (China)

Fiber-optic microphone has many advantages, such as simple structure, high sensitivity and anti-electromagnetic interference. In recent years, vibrating diaphragm of the fiber-optic microphone is becoming a hot research because vibrating diaphragm has a great influence on its

performance. We use the ANSYS software to do static mechanical analysis in this paper for a new patch of wavy vibrating diaphragm and simulate the frequency response curve of the vibrating diaphragm, and also analysis the relationship between parameters and sensitivity such as the vibration diaphragm thickness, diameter, and elastic modulus .This could provide a useful reference probe for designing Fiber-optic microphone.

7853-109, Poster Session

Temperature and stress response characteristic study on Ag-coated fiber Bragg grating

X. Shi, F. Xu, C. Li, D. Ren, M. Shi, D. Tao, J. Dai, Anhui Univ. (China)

Fiber Bragg grating (FBG) is an important optical passive device and widely used in optical fiber communication system. The application of normal organic polymer coating FBG used in some area is limited because of its easy annealing and aging at high temperature. Employing chemical methods, we obtain different thickness of uniform and compact surface silver layer by controlling etching conditions and reaction time. The temperature and stress experiment result show that the temperature response of FBG surface silvered is up to 300 . The sensitivity of temperature and stress increase effectively and keeping good linear response characteristic in the meanwhile. It is proved that FBG with metal silver coating effectively improved the characteristic in its high temperature application area.

7853-110, Poster Session

A new phase generated carrier demodulation method based on fixed phase delay

Q. Shi, L. Wang, M. Zhang, Q. Tian, Y. Liao, Tsinghua Univ. (China)

This article proposes a new PGC demodulation method based on Fixed Phase Delay (FPD-PGC) by 3×2 directional coupler, using second-harmonic of two interferometric signals to demodulate. Previous research has confirmed that system performance using Orthogonal Demodulation Type PGC (ODT-PGC) method is determined by many parameters, such as signal phase delay, FM depth, laser intensity modulation. The demodulation principle of the new method is described in detail and its performances have been studied. Theoretical analysis and experimental results show that the new method combines main advantages of directional coupler method and ODT-PGC method, and eliminates, to a great extent, the impacts of FM depth, signal phase delay, intensity modulation. Signal-to-total-Harmonic Ratio (SHR) of new method increases more than 30dB compare with ODT-PGC method under the condition of intensity modulation coefficient is 0.4. Besides that, Signal to Noise Ratio (SNR) also improves significantly.

7853-111, Poster Session

A novel multi-path combination matching Michelson interferometer for straindeformation sensing

H. Jiang, L. Yuan, Harbin Engineering Univ. (China)

Based on low-coherence white light interferometric technology, a novel multi-path combination matching Michelson interferometer system has been proposed and demonstrated. The multi-path combination Michelson interferometer is configured by a series 2×2 fiber optic coupler connected each other. One end of the coupler array is connected with SLD light source in one port, the other port is linked with a photodiode detector. The other end of the 3dB fiber coupler array is with a coated reflective mirror in one port, the other port is terminated with a fiber collimator, and a reflective scanning mirror mounted on a translation stage and perpendicular to the fiber collimator. The scanning mirror is moving back and forth to match each optical path of the combination Michelson interferometer. In this multi-path combination Michelson interferometer, each fiber arm could be used as strain or deformation sensor. By using optical path tracking and recording technique, the quasi-distributed strain of each fiber arm can be calculated. The sensing system can be used to measure distribution strain or temperature. It has the potential in the applications of large scale smart structures health monitoring.

7853-112, Poster Session

Study of reflection-type fiber optic biosensor based on multimode interference

D. Zheng, E. Li, L. Qun, C. Tang, C. Wang, Tianjin Univ. (China)

A reflection-type fiber-optic biosensor based on multimode interference (MMI) is reported in this paper. It is fabricated by connecting a segment of coreless silica fiber (CSF) with a reflective film to a single mode fiber (SMF). This structure has been demonstrated to be a simple and effective way to realize multimode interference in optical fiber. And by utilizing the interference of the higher order modes excited in the CSF, the fiber sensor can measure the refractive index of the surrounding solution. The reflection-type fiber-optic sensor based on multimode interference is studied by numerical simulation and experimentation. The results show that the wavelength of the interference trough on the output spectrum goes with the increase of surrounding solution's refractive index, and when the refractive index is less than 1.4 there is an approximately linear relationship between the wavelength of interference trough and the refractive index. When the refractive index is higher than 1.4, the sensitivity significantly improves. The minimum resolution can reach to 10-6.

Based on the research work of the refractive index sensing, the application in biological sensing of the fiber-optic sensor based on MMI is studied. By modifying the goat anti-rabbit IgG antibodies onto the fiber sensor probe, a reflection-type fiber-optic biosensor based on MMI can be constructed. Experimental results show that the output spectrum of this fiber-optic biosensor can reflect the modification process and the immune responses between sheep anti-rabbit IgG and rabbit IgG.

7853-113, Poster Session

Studies of third-order optical nonlinearities of poly[2,1,3-benzoselenadiazole-(2,5-didodecyloxy-1,4phenylene)ethynylene] embedded in porous silicon

M. Xiang, Z. Jia, Xinjiang Univ. (China)

In the last years there has been a great interest in the in the nonlinear optical of nanometer-sized semiconductor crystals. Porous silicon (PS) generated great interest in view of its possible application in optoelectronics.It is well known that strong quantum confinement effect in porous silicon and its characteristic features show great enhanced optical nonlinearity. Porous silicon is constituted by a nanocrystalline skeleton like sponge that remains after a partial electrochemical dissolution of silicon . In order to enhance nonlinear properties even more, pores can be filled up with other more nonlinear materials. Considering polymers have been come under critical study regarding their potential as NLO materials. We inject A new type π-conjugated poly[2,1,3-benzoselenadiazole-(2,5-didodecyloxy-1,4-phenylene) ethynylene](PPE) into porous silicon, presenting reflection Z-scan

method of third order nonlinear susceptibility and experimental result concerning the third order nonlinear behaviors of PPE embedded in porous silicon. The picoseconds measurement show a significant increase of nonlinear refractive index not only with respect to the standard optical materials but also to the bulk conjugates polymers. Embedding of PPE in nanopores enhances considerably their already large nonlinear refraction index and lowers their overall absorption due to a negative nonlinear absorption. The experimental results exhibit that the sample possesses relatively large third-order NLO properties at 532 nm. The reason can be explained as follows, the π-electron conjugation bond would be expected to have a significant effect on the ground and excited state dipole moments and electronic transition energies of the molecule and, consequently, could affect the third-order nonlinear optical property of the molecule. The large magnitude of the third-order nonlinear coefficients of the sample shows that it is a promising candidate for further material development and possible photonic device applications.

7853-114, Poster Session

Dynamic pressure sensor by using of π-shifted single-mode fiber Sagnac interferometer

J. Gan, Shanghai Institute of Optics and Fine Mechanics (China)

A dynamic pressure sensor based on the π-shifted single-mode fiber Sagnac interferometer (SMF-SI) is proposed. Compared with the conventional SMF-SI, the π-shifted SMF-SI is independent of the orientation of birefringence associated with the optical device within the loop. The response of the SMF-SI, especially orientation-free characteristics of this proposed sensor is analyzed by using the Jones matrix. This configuration eliminates the uncertainty orientation of birefringence in fiber loop and exhibits an excellent repeatability and high sensitivity, which makes the following demodulation of measurand possible. Some sensing applications, which would benefit from this configuration, have been proposed and discussed. A pressure sensor, which benefits from this configuration, has been implemented successfully. the static pressure response agrees very well with the theoretical analysis and shows the great potential for the practical application. The dynamic pressure response of the π-shifted SMF-SI is tested, and the results show that different waveform of the dynamic pressure signals could be detected and identified, also the amplitude and frequency of the dynamic pressure signal can also be demodulated exactly. Up to 2kHz bandwidth of the frequency response has been demonstrated successfully. Higher frequency response can also be achieved if the frequency response of the driver circuit for PZT increases.

7853-115, Poster Session

Research of fiber Bragg grating strain sensors by optical sensor technique

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In this paper, we propose a simple interrogation scheme for fiber Bragg grating (FBG) dynamic strain sensor based on optical interference. The whole device is simply consists of a DFB laser with an integrated photodiode, so it's small-sized, low-cost, and easy to collimate. A small percentage of the injected lightwave resonantly reflected off the grating structure reenters the laser cavity and modifies the emission properties of the laser, resulting in the formation of characteristic sawtooth fringes which contain the embedded strain information. The strain response is relatively linear in relation to the wavelength shift of FBG under strain, which is proportional to the number of interference signal fringes. We have studied the fundamental principles and simulate them. To analyze the interference signal, we use fringe-counting technique, which limit the resolution to about 10 μstrains corresponding to a half-fringe. Further, reference strain values are measured by a reference sensor using another technique to compare with the experimental results thus obtained using the proposed technique. We have also demonstrated the feasibility by experiment, which shows a good agreement with the theoretical analysis. Up to this day, the combination of the FBG sensor and optical interference technique has been rarely reported, and we believe it well attract remarkable interest in the later years.

7853-116, Poster Session

Measurement of ammonia by a portable UV-DOAS gas sensor based on multi-pass cell

J. Wang, P. Xie, Anhui Institute of Optics and Fine Mechanics (China)

Ammonia, the third most important abundant nitrogen compound, is a primary alkaline gas in the atmosphere. It has strong absorption bands in the deep ultraviolet (DUV) spectral range and so can be reliably detected by the differential optical absorption spectroscopy (DOAS) technique. A portable UV-DOAS gas sensor based on multi-pass cell has been designed to detected trace gases, especially for ammonia, in the DUV spectral range, with good performance using a broad-band Deuterium source and high-sensitivity spectrometer. With the optical path as long as 20m, such a sensor could detected NH3 concentrations as low as 100ppb according to the result of in-situ measurement. Fast response time and low measurement error of this portable gas sensor could be competent for emergency monitoring.

7853-117, Poster Session

Analysis of a low-finesse extrinsic Fabry-Perot interferometric optical fiber sensor

Z. Yang, M. Zhang, Y. Liao, Q. Tian, Tsinghua Univ. (China); Q. Li, Y. Zhang, Z. Zhuang, Chinese Academy of Engineering Physics (China)

Theoretical and experimental aspects of the extrinsic Fabry-Perot(FP) interferometric(EFPI) optical fiber sensor are studied. The FP cavity in an EFPI sensor is usually formed between the endface of a lead-in fiber and a reflector placed at a distance usually less than a few hundred micrometers to the lead-in fiber endface. The reflections at the lead-in fiber endface and at the reflector are coupled back to the lead-in fiber and interfere to form certain interferometric fringe patterns. For a low-finesse EFPI sensor, the change of cavity length will influence the visibility of the interference fringes reflected back into the fiber. The fringe visibility of a low-finesse cavity illuminated by a single-mode optical fiber has been analyzed by modeling of the output of the fiber as a point source or, more accurately, as a Gaussian beam. These analyses show that the aperturing effect of the fiber reduces the effective reflection coefficient of the second surface of the cavity and is the dominant mechanism for degrading fringe visibility. In this paper, an analysis on the fringe visibility of EFPI sensors based on the power distribution is presented. Both lasers and broadband light sources have been used for the interrogation of the EFPI sensor heads, but broadband light sources which make the sensor immune to source fluctuations, cable and connector losses, and loss of system power have attracted more attention recently. The effect on the fringe visibility of the cavity length and the source bandwidth is explored. The analysis may provide useful guidance for sensor design.

7853-118, Poster Session

Design and experimental study on an LS-FTF self-adaptive infrared gas concentration detection system

W. Ye, C. Zheng, X. Yu, Z. Song, Y. Wang, Jilin Univ. (China)

Considering that the noises resulting from low modulation frequency are serious and cannot be totally eliminated by the classic filters, a novel infrared (IR) gas concentration detection system based on the least square fast transverse filtering (LS-FTF) self-adaptive modern filter structure is proposed. The principle, procedure and simulation on the LS-FTF algorithm are described. The system schematic and key techniques are discussed. The procedures for the ARM7 processor including the LS-FTF and main program are demonstrated. Comparisons between the experimental results of the detection system using the LS-FTF algorithm and those of the system without using this algorithm are performed. By using the LS-FTF algorithm, the noises and interferences can be effectively eliminated. Thorough experiments performed for the fabricated device show that the maximum detection error is decreased from 14.3 % to 5.4%, the minimum detection level is about 100 ppm, and the detection sensitivity is 100 ppm. The measured maximum response time is less than 12 s, and also the detection stability increases as the variation range of the relative error becomes much smaller.

7853-119, Poster Session

Tapered optcial fiber fabricated by high-frequency pulsed carbon dioxide laser

M. Li, F. Pang, H. Guo, Y. Liu, N. Chen, Z. Chen, T. Wang, Shanghai Univ. (China)

Fiber-optic refractive index sensor is of one the most important technologies in bio- and chemical sensing system. Monitoring the variation of optical fiber evanescent wave is a primary method to realize refractive index sensor. In this paper, a novel method was proposed to fabricate tapered optical fiber which has strong evanescent wave field in the tapered region. We used a high-frequency pulsed CO2 laser as a heating source. Compared with conventional continuous CO2, the high-frequency CO2 laser can sustain a long-term high temperature with a relatively low power output. Our system relies on a scanning mirror, which can scan the laser beam across the taper region. The optimal heating and stretching parameters are determined through a series experiments. An effective laser scanning pattern consisting of ten scanning lines with different intervals and directions is designed to obtain a relatively uniform temperature field. Based on our laser-induced tapering system, the CO2 laser beam was continuously scanned across a length of fiber rod which was being pulled synchronously. Symmetrical fiber tapers with taper waist diameters of ~10-20μm, overall lengths of ~10-16mm and transimission losses of ~0.8-3dB at 1550nm were obtained. The taper profile is measured and presents a good fit with the “decaying-exponential” model. The “self-regulating” law is demonstrated during the tapering process, which shows the desired taper waist diameter as a function of the laser power. A refractive index sensing experiment using those fiber tapers is also reported to show the tapered fiber’s excellent sensing ability due to the existense of a strong evanescent field in the tapered region.

7853-120, Poster Session

Investigation of strain sensors based on fiber Bragg grating used for steelwork

T. Wang, D. He, Z. Wang, Y. Quan, Y. Wang, Beijing Jiaotong Univ. (China)

In the past few years, fiber Bragg grating (FBG) sensors have attracted a lot of interest and there were number of studies on the use of FBG sensors to detect the strain of steelworks. This paper describes the strain sensors based on FBG with different package used for steelwork.

At first, the model of tested steelwork is founded by the way of finite element, and strain distribution of the steelwork can be predicted through Finite element analysis (FEA).

Three different strain sensors to include bare FBG, FBG sensor packaged with steel sheet and resistance strain gauges are set on the same specified locations of steel specimen decided by FEA, and load is added on the steelwork by rally machine. Strain values of the steel specimen can be caught by three kinds of sensors when load is stabilized. Then the load added on the steelwork is changed from 0KN to full range and back to 0KN, meanwhile the values of strain are recorded respectively.

Result of experiment shows that strain values caught by two kinds of FBG sensor and resistance strain gauges are coinciding, and they are all close to the theoretical values which are provided by FEA. Linearity between values of strain caught by FBG sensors and load is high. Sensitivity of FBG sensor packaged with steel sheet is 1.2pm/μ which is close to the bare FBG.

The experimental observations show that FBG sensors with different packages can be set on diverse steelworks conveniently, and can monitor strain of the steelwork well.

7853-121, Poster Session

Analysis on measured signal retrieval approaches in pyramid wavefront sensor

J. Wang, W. Jiang, Institute of Optics and Electronics (China)

Pyramid wavefront sensor (PWFS) is derived from Foucault knife test theory, and it holds a distinct characteristic of simultaneously measuring two signals in x and y directions. Compared with traditional Shack-hartmann wavefront sensor (HSWFS), due to no requirement to split light for subaperture PWFS can detect the object with more faint magnitude. For how to choose the denominator of measured signal, presently, there are three processing approaches as follows. (1) According to wave optics theory the intensity of input wave is regarded as the denominator to calculate the measured signals in the case of uniform optical intensity. (2) The average of energy in whole CCD image plane is employed to describe the denominator. (3) The averaging energy of four pupils in CCD image plane is employed to describe the denominator.

Numerical simulation and experiment demonstrate that all existing approaches are not optimal scheme. When the first approach is chosen, unstable closed-loop result may be obtained in the presence of intensity scintillation. Additionally, the noise in the CCD detector will affect the measured signals. For the second approach, the immunity to noise is also not better. Due to energy loss involving in optical transmission process the summation energy in CCD image plane does not represent the total energy, and we can obtained an appropriate proportion. For the last approach, the averaging energy of four pupil images reduces gradually as the residual phase decreases. The Strehl ratio increases in the beginning of closed-loop correction and then falls down to a stable value.

Finally, in the paper, a new approach is employed to describe the denominator is presented and investigated, in which the averaging energy of four pupil images in each pixel. The simulated results demonstrate that this scheme holds good noise-immunity ability and high closed-loop correction speed, and it can achieve stable and high-accuracy correction result. Related experiments are carried out to verify the reliability of new approach.

7853-122, Poster Session

Experiment validation of Correlating Shack-Hartmann wave-front sensor for a point source object

L. Chen, C. Rao, Institute of Optics and Electronics (China)

To complement the phase aberration, adaptive optics(AO) system is used in most astronomical telescopes. The key step in the AO system is to estimate the location of the subimages formed by the Shack-Hartmann wave-front sensor. Normally the centriods(Center of gravity) of the point source spots are estimated to determine the local wave-front slopes. However the center-of-gravity (COG) algorithm, suffers from several weaknesses. At first, there are many situations when a standard point source is not available, such as situations with strong atmosphere disturbance and dim light situations .Secondly, COG suffers from a significant propagation of CCD read out noise. Instead of the traditional COG algorithm, we use the correlation algorithm to estimate the subimages spots' relative bias from a reference spot. This paper presents the main characteristics of this method and its comparison with the COG algorithm, analysis shows this correlation approach has better linear and robust performance and is suitable to conquer the problems list before. Moreover both simulation and experimental data from a point source based indoors experiment is carried out to verify the expected conclusions. The result shows that the correlation method can be efficiently used to detect the wave-front aberration for point source based AO systems.

7853-123, Poster Session

A effective method for suppression the polarization-noises in a fiber optic Michelson interferometer

L. Xue, Institute of Semiconductors (China)

An effective method to suppress the polarization noises in a Michelson interferometer with controlling the temperature of Faraday rotator mirror (FRM) is proposed. The polarization noises decline 1 magnitude in the case of operation wavelength shift. The experimental results are in good agreement with those of theory.

7853-124, Poster Session

Experimental research of the fibers micro-vibration sensor

D. Jin, G. Wang, B. Gao, B. Yu, Anhui Univ. (China)

n this work, a fibers micro-vibration sensor made use of two single mode fibers(SMF) as the sensing probe designed for micro-vibration detecting was described, the micro-vibration sensor sensing property was measured by the change of light intensity and gets the attained signal through photoelectric conversion and optical processing circuit. By comparing the measured signal and original signal, we can conclude that the fibers senor has high sensitivity and an enhanced immunity to electromagnetic interference, it also has the advantages of small size, simple construction, so this new fibers sensor has potential application foreground to real-time and accurate measure micro-vibration.

7853-125, Poster Session

Research on the characteristics of hydrogel coated long period gratings

X. Yu, M. Zhang, Y. Liao, Tsinghua Univ. (China)

A long period grating (LPG) is a photo-induced periodic modulation of the refractive index of the core of a single mode optical fiber. The resonant wavelength and amplitude of the attenuation bands of an LPG are sensitive to the refractive index of external surrounding, so LPG can be used in many applications such as chemical sensing, biochemical sensing and environment monitoring. In recent years a large amount of research has focused on film-coated LPGs to enhance the sensor's sensitivity to ambient refractive index changes. In this paper, the characteristics of the LPG with thin film coating are analyzed theoretically by using the optical couple-mode theory and cylindrical four-layer waveguide model. The influence of film factor, including the refractive index, thickness, and the refractive index of the surrounding medium on the sensitivity of LPFG is analyzed detailed. By choosing properly the thickness and refractive index of the thin-film overlay, the sensitivity of the LPFG can be improved significantly. In order to verify the theoretical analysis and enhance the sensitivity of LPG to humidity, hydrogel is chosen as coating material. The characteristics on the hydrogel coated long period grating are investigated experimentally. The transmission spectral response of hydrogel coated LPG to relative humidity is measured. It shows that the resonant wavelength and the amplitude of attenuation bands are high sensitive when relative humidity is above 50%RH.

7853-126, Poster Session

Fiber optic micro-displacement sensor using a tilted fiber Bragg grating and a PSD as the signal detection device

Y. Zhao, Q. Wang, H. Wang, Northeastern Univ. (China)

Micro-displacement is measured by the fiber Bragg grating (FBG) sensor based on a cantilever structure. The micro-displacement is generated by the piezoelectric transformer (PZT), which is placed under the free end of the cantilever. The FBG is attached at the center of the lower surface of the cantilever. When the PZT is expanded with the applied voltage, deflection at the free end of the cantilever will occur, resulting in the strain variation on the lower surface of the cantilever. This strain will act on the FBG sensor, whose reflected wavelength will shift. A tilted fiber Bragg grating (TFBG) is used to change the FBG's shifted wavelength to varied radiation angle from the TFBG, and a position sensitive device (PSD) is used to record the light spot position variation, which is corresponding to the varied radiation angle. Sensor structure and measurement principle are introduced. The feasibility is explained theoretically and results show that displacement measurement resolution of 62nm can be obtained.

7853-127, Poster Session

Magnetic fluid filled hollow-core photonic crystal fiber F-P sensor

T. Hu, Harbin Institute of Technology (China); Y. Zhao, Q. Wang, Northeastern Univ. (China); Z. Lv, Harbin Institute of Technology (China)

As a new optical transmission medium, photonic crystal fiber (PCF) has many unique features because of its micro-structure, which provides a chance to solve many difficult problems and has become a research focus in communicating and sensing technologies. Since magnetic fluid appeared, it has been applied in various fields, and has become

a novel functional material. Especially its controllable refractive index feature makes it become a new optical material. In this paper, based on the magnetic fluid controllable refractive index feature, magnetic fluid is used as the sensitive medium, resulting in a new type of fiber F-P sensor. The magnetic fluid filled hollow core PCF(HC-PCF) fiber F-P sensor is proposed, in which the core of HC-PCF will be filled with magnetic fluid, working as the cavity of the fiber F-P sensor. By applying a variable external magnetic field, the refractive index of magnetic fluid will be changed, so does the output spectrum of the sensor. Through the demodulation method, the applied magnetic field can be derived from the sensor output spectrum. Method to improve the contrast of interference fringes is also studied. Theoretical simulations of the mode distribution of HC-PCF after filling the magnetic fluid has been carried out, and the sensor production process is introduced. Given the parameters of the magnetic fluid, relationship between the applied magnetic field and optical path difference of sensor output spectra is simulated. The effects on the sensor output spectrum with different F-P cavity length are also studied, and the sensor multiplexing capability is discussed as well.

7853-128, Poster Session

Experimental research on the effect of Young's modulus on optical fiber microbend strain sensor

R. Tao, M. Li, Wuhan Univ. of Technology (China)

Based on the experienced model of fiber optic microbend sensor, we studied and experimentally compared several fiber microbend grippers made of materials with various Young's modules.

By investigation of the theoretical model of fiber microbend sensor, we found that Young's modulus (E) of fiber optic microbend grippers have affected the sensor's performance by adding an extra deformation to the fiber microbend amplitude. Calculating the derivative of the basic function of microbend with respect to F then E, we get an expression of sensor's output signal as a function of E shown that the output of the microbend sensors decrease with the Young's modulus of the grippers increase, and the changes are nonlinear.

To verify the accuracy of the theoretical derivation, we designed and made four optical fiber microbend grippers of different materials, including stainless steel, Polyvinyl Chloride (PVC), polypropylene (PPR) and bamboo, and the same geometric parameters of grippers that consist mechanical period of 3.75mm which derived for optimal sensitivity from the well-known microbend interval equation, and carried out the comparable experiments under the same initial testing conditions, which adjusted to be almost the same during the manufacture and installation process of the fiber microbend gripper.

We set up the testing system with a LED, a 62.5/125μm multimode fiber, a mode scrambler and a PIN photo-receiver. The experimental data showed that the outputs of the microbend sensors and our theoretically simulated curves made rather good matches than the linear curve fit to the external force (F) applied. The conclusion might be useful for future reference of microbend strain sensors design.

7853-129, Poster Session

Analysis of preparation of Chinese traditional medicine based on the fiber fingerprint drop trace

Z. Zhang, J. Wang, W. Sun, Y. Qi, Harbin Engineering Univ. (China)

The purpose of the fiber micro-drop analyzing technique is to measure the characteristics of liquids using optical methods. The fiber fingerprint drop trace (FFDT) is a curve of light intensity vs. time. This curve indicates the forming, growing and dripping processes of the liquid drops. A pair of fibers was used to monitor the dripping process. The FFDTs are acquired and analyzed by a computer. Different liquid samples of many kinds of preparation of Chinese traditional medicines were tested by using the fiber micro-drop sensor in the experiments. The FFDTs of preparation of Chinese traditional medicines with different concentrations were analyzed in different ways. Considering the characters of the FFDTs, a novel method is proposed to measure the different preparation of Chinese traditional medicines and its concentration based on the corresponding relationship of FFDTs and the physical and chemical parameters of the liquids.

7853-130, Poster Session

Effect of hydroxyl group upon optical fiber sensors used in permanent downhole

T. Hu, Harbin Institute of Technology (China); Y. Zhao, Northeastern Univ. (China); Z. Lv, Harbin Institute of Technology (China)

Fibers in the optical fiber sensors would react with water and hydrogen in permanent downhole measurement under the high temperature and pressure. This reaction would change the absorption loss of the fibers, which would affect the reliability of the measurement system. To analyse this problem, the course of hydroxyl penetrating through fibers was investigated. The source of penetrating hydroxyl was discussed. The penetration changes the chemical bond combination inner the fibers, which causes the increase of the absorption loss and the reduction of useful life of the fibers. The results show that at the wavelength of 1.38μm, when the content of the hydroxyl group is about 0.0001, the absorption loss can reach 33dB/km. The analyses also point out that carbon-coated fiber could increase the static fatigue resistance parameter, thus increasing the useful life of the fibers exponentially.

7853-131, Poster Session

Investigation of highly sensitive atomic magnetometer

A. Yang, Zhejiang Univ. (China)

Highly sensitive magnetometers capable of measuring magnetic fields below 1 pT are important for many applications such as geophysical surveying, space science, non-destructive testing, medical diagnoses and gravitational wave detection etc.

The atom magnetometer is based on the measurement of electron Larmor spin precession of optically pumped atoms, have reached and even surpassed the sensitivity of SQUIDs, but have much lower sensitivity in the more compact designs required for magnetic imaging applications.

We report a simple and highly sensitive all-optical atomic magnetometer that uses the advanced technique of single laser beam detection based on the interaction between laser beam and rubidium atoms in magnetic field. This interaction is dependent on the magnetic field surrounding the Rb atom cell, therefore the magnetic field information can be obtained by measuring the changes of the laser power transmitted through the Rb atom cell. A sensitivity of 0.5pT/Hz1/2 has been achieved by analyzing the magnetic noise spectrum, which exceeds that of most traditional magnetometers. This kind of atomic magnetometer is very compact, has low-power consumption, and has a high theoretical sensitivity limit, which make it suitable for many applications.

We also analyzed some important factors that may affect the sensitivity of the magnetometer, such as the temperature of the Rb cell, laser intensity, detuning, polarization, diameter, and the ways to improve the sensitivity of the atomic magnetometer. It is shown that higher sensitivity can be obtained by using laser with larger diameter, higher polarization, smaller detuning, choosing an optimum temperature and laser intensity.

7853-132, Poster Session

A microstructured optical fiber based surface plasmon resonance sensor

P. Bing, Tianjin Univ. (China)

Recently, Microstructured-optical-fiber (MOF) based surface-plasmon-resonance (SPR) sensor has attracted considerable research and development interest, because of their distinct advantages, such as easy to realize the phase matching between the core-guided mode and the plasmonic mode, without packing problem, high sensitivity, small sensor volume and so on. In this paper, we propose a new MOF based on SPR sensor in which plasmons on the inner surface of the metallized channels containing analyte can be excited by a fundamental mode of microstructured fiber. The sensor was theoretically investigated via finite element method and the resonance wavelength and SPR amplitude were calculated. Numerical results show this kind of sensor has a higher spectral resolution when the analyte index is changing. Also, a narrower resonance spectral width is appear which can improve the sensing performance in terms of signal to noise ratio (SNR).The improvements in spectral width and SNR can both contribute to a better detection limit for this refractive index sensor.

7853-134, Poster Session

Study of PVDF thin film optical fiber humidity sensor

X. B. Li, M. Yang, J. Dai, H. Liu, D. Yin, Wuhan Univ. of Technology (China)

A novel optical fiber humidity sensor using polyvinylidene fluoride (PVDF) as sensitive material was proposed in this paper. Three-layer coating was deposited on the end-face of a optical fiber, which forms an extrinsic Fabry-Perot (F-P) interference cavity. Ag layer deposited by DC magnetron sputtering was used as mirror layer of the Fabry-Perot interference structure. PVDF layer was realized with Czochralski method as F-P cavity. Simulation was performed using the transfer matrix method to analysis the relevant parameters on sensor performance. Experimental result shows the interference fringe shifts to longer wavelength when relative humidity increases. The fringe shifted 2.4nm with a good linearity response when relative humidity increases from 11% to 97%. The linearity of interference fringe shift to relative humidity was 0.9503, the response time was less than 1min.

7853-135, Poster Session

A strain sensor based on cladding mode resonance of optical double-cladding fiber

J. Zhang, F. Pang, H. Guo, Z. Chen, T. Wang, Shanghai Univ. (China)

A strain sensor based on cladding mode resonance of optical double-cladding fiber (DCF) was proposed and experimentally demonstrated. The sensing head was fabricated by splicing a section of double-cladding special optic fiber into single mode fiber (SMF). The proposed DCF is comprised of three parts: core, inner cladding, and outer cladding. The core and the outer cladding are with the same refractive index which is a little higher than that of the inner cladding, since they are made of pure silica and fluorine-doped silica respectively. Attributed to the thin thickness of the inner cladding, the core mode can leak to the outer cladding and propagates as cladding mode which presented a strong resonant spectrum at the phase-matching wavelength. When the DCF sensor is pulled, the strain applied to the fiber decreases the refractive index due to the photoelastic effect. According to the coupled mode theory, the phase-matching wavelength will shift to a shorter wavelength. By detecting the resonant spectrum variation, the stain sensor can be realized. As shown by the experimental results, the strain sensitivity is achieved -2.76 pm/μ over 1020 μ measurement range with good repeatability. With the simple configuration and attractive performance, the specialty DCF fiber strain sensor can be explored for wide sensing applications.

7853-136, Poster Session

A fiber laser accelerometer based on the double flexural strips structure

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In recent years, fiber laser accelerometer has been attracted more and more attention due to high resolution, high signal-to-noise ratio (SNR) and a compact all-fiber design. By appropriately designing of the “transducer” head, the laser sensor can sense vibration signal. This paper reports a unique fiber distributed feedback (DFB) laser accelerometer based on double flexural strips structure.

In this paper, a single-longitudinal-mode DBF fiber laser is used as the accelerometer head which is fabricated based on the theory of equivalent phase shift. A short laser cavity is constituted with two FBG and an equivalent π phase-shift. The threshold value and slope efficiency are about 5mW and 0.21%, respectively.

The double flexural strips structure consists of a mass block, a double semi-circular flexible film and a base. The fiber laser is fixed in the two holes that locate at the centre point of each semi-circular elastic film. When applying vertical vibration stimulus, the inertia force of the mass block will pull or compress the flexible films, which will lead to the drift of the wavelength of the laser beam. By measuring the change of the lasing wavelength, we can obtain the value of the acceleration by employing a 3×3 coupler unbalanced interferometer demodulator.

In this experiment system, the vibration is excited by a Vibration Exciter (Type 4808). Test results show that the laser accelerator has high sensitivity of 1591 rad/g at 400Hz and the corresponding SNR ratio is 43 dB. It is an excellent candidate for high precision and micro vibrations detection.

7853-137, Poster Session

Precision improving solutions based on ARMA model and modified self-adapted Kalman filter for MEMS Gyro

X. Jiang, Y. Zong, Academy of Armored Force Engineering (China)

MEMS gyro is used in inertial measuring fields more and more widely, but random drift is considered as an important error restricting the precision of it. Establishing the proper models closed to real sign of movement and random drift, and designing a kind of effective filter is available to enhance the precision of the MEMS gyro. The dynamic model of angle movement is studied, the ARMA model describing random drift was established based on time series analysis method, and a modified self-adapted Kalman filter was designed in the sign processing. Finally, the random drift is distinguished and analyzed clearly by Allan variance. It is included that the above method can effectively eliminate the random drift and improve the precision of MEMS gyro.

7853-138, Poster Session

A method to measure the fast and slow component of scintillation in plastic scintillating fiber

F. Shi, Institute of High Energy Physics (China)

The fast and slow components of scintillation in plastic scintillating fiber were measured, since the characters of the slow component fluorescence in plastic scintillating fiber (BCF10) are not published by the manufacturer. A method of this measurement is proposed using the newly developed silicon photomultipliers as the photo-sensor to readout the light signals of scintillating fiber activated by the 90Sr ray. The Ratio of the light yield between the prompt and the long-lived fluorescence is measured to be 2.5:1 and time delay is 125ps for the slow component of scintillation in BCF10 scintillating fiber.

7853-139, Poster Session

The design and application of algae automatic online monitoring system based on fluorescent sensing technology

G. Yin, Anhui Institute of Optics and Fine Mechanics (China)

Algae monitoring and early-warning turn into one of the important tasks in the water environment protection. Chlorophyll-a fluorescence spectroscopy is of high sensitivity, better ability to differentiate, and easy to realize in situ monitoring, so it has attracted great attention. However, study of algae automatic online monitoring system is rarely mentioned in literatures.

The paper designs the algae automatic online monitoring system based on fluorescent sensing technology and emphatically introduces the system principle, design and application. Through continuously and automatically system performance testing for more than 1000 hours in Caohu, the results show that stability, accuracy and real-time performance of the system completely meet the demands of algae online monitoring.

7853-140, Poster Session

High stability and radiation-resistance broadband fiber-optic source

X. Suo, Y. Yang, M. Yang, BeiHang Univ. (China)

With high output power and good spectrum stability, Erbium-doped Super-fluorescent Fiber Sources (ED-SFS) are has been widely used in fiber-optic sensor and fiber communication system. Especially, SFS has been regarded as the best broadband source for high performance fiber optic gyroscope. Recently, the fiber-optic sensor and communication system for space application were developed and reliability and radiation-resistance were necessary in this application field.

In this paper, the characteristic of backward double pass configuration SFS was simulated and analyzed. Two type of output spectrum profile, flat and gauss shape were realized with gain flatten filter and edge filter respectively. To satisfy the field application demand, the output optical power and mean wavelength stability were theoretically analyzed and simulated, the optimized configuration parameters were obtained. For high performance fiber optic gyroscope application, a vary parameters control technology was taken and the less than 0.5 ppm/deg mean wavelength stability was achieved within -45deg - +70deg. To developing radiation-resistance broadband source, the erbium-doped fiber radiation characteristic was studied with radiation experiment with different dose and dose rate and shied method. The erbium-doped fiber recovery effect was analyzed and studied experimentally too. Based the experimental data, the SFS configuration parameters and pump laser diode power were optimized and the radiation-resistance SFS was producted. Experimental test shows that this source can stand against more than 50Krad(Si) radiation dose (Si) and the gauss shape spectrum output have better radiation-resistance capability than flat spectrum source.

7853-141, Poster Session

Wavelet transform de-noising technology for distributed optical fiber sensor

Y. Wang, Y. Yang, M. Yang, BeiHang Univ. (China)

The temperature or/and strain measurement accuracy, resolution and response of distributed optical fiber sensors with Rayleigh, Raman and Brillouin scattering are mainly limited by their weak signals with low signal-noise ratio. The signal-noise ratio can be improved with conventional BOXCAR integrator. However, to get high signal-noise ratio, the integral time must be long. This will affect system response seriously, especially in fire alarm application. To improve the signal-noise ratio and response characteristic simultaneity, the wavelet transform de-noise technology was introduce to distributed optical fiber sensor system. The back-scattering signal characteristic was analyzed in this paper and the mother wavelet, the maximum decomposition scale and the processing of threshold were optimized in order to get better signal-noise ratio and minimize the impact to signal response. A Raman scattering distributed optical fiber sensing experimental system was set and the signal process arithmetic was realized. Experimental test indicate that wavelet de-noising method can notably improve signal-noise ratio and guarantee the spatial resolution simultaneously. The comparative tests suggest that the temperature resolution was improved by more than 50% and the measurement accuracy and the measuring period were improved greatly.

7853-142, Poster Session

The co-measurement of pressure and surrounding refractive index based on LPGs

J. Zhu, Y. Jiang, W. Xue, Beijing Institute of Technology (China)

A novel optical fiber sensor for simultaneous measurement of pressure and surrounding refractive index (RI) based on long period gratings (LPGs) is proposed and demonstrated. This device composed by a metal girder and consists of two LPGs (LPG1 and LPG2) with different wavelengths. These two LPGs were written on a single mode fiber (SMF) and stick on the girder symmetrically in order to get the same curvature when the girder was bent. LPG1 was covered by glue with the RI of about 1.4, therefore, is insensitive on surrounding RI.

Surrounding RI induces changes to the propagation constants of the cladding modes, thus changing the group refractive indices as well as the effective refractive indices. However, with LPG1 shielded from the environment by glue, the RI sensitivity of two LPGs is different. Once the axial force acts on the girder at the same time, a micro-bending is created on the LPGs which induce the wavelengths shift. Since the resonance peeks of these two LPGs change differently, the simultaneous measurement has been done.

The experimental results show that the device has a good performance in measurement. This sensor has a potential application in a simultaneous differential pressure and refractive index control system and is expected to use in liquid concentration or specific gravity measurement system.

7853-145, Poster Session

Corresponding characteristics of the alignment parameters in large segmented-mirror telescope system

M. Hui, Beijing Institute of Technology (China); J. Deng, Shanghai Jiao Tong Univ. (China); Y. Fei, Y. Zhao, Beijing Institute of Technology (China)

We describe a method for measuring and aligning phase parameters with Zernike polynomials in large segmented-mirror telescope system. Numerical model is developed to establish the dependence of tip-tilt phase parameters on the polynomial coefficients C1 and C2 and know the real displacement direction though the measurement and calculation of Zernike polynomials. Its performance is analytically examined in detail and some experimental results demonstrating its effectiveness are also given. This method extremely simplified the segment phase adjustment process to a certainty. The measurement result proved that the tilt is 15 and the tip is 7 (=633nm), showing that the precision is about to nanometer level.

7853-31, Session 7

A novel fiber optic film temperature sensor taking advantage of thermal optical effect as well as temperature-dependent absorption of semiconductor

M. Li, Wuhan Univ. of Technology (China); Y. Li, Wuhan Photon Science and Technology Inc. (China)

Abstract: After several decades, the development and application of absorptive fiber semiconductor temperature sensor has been slowed down for the difficulty to satisfy the critical requirement of the special wavelength and broadband lightsource. On the other hand, temperature-dependent refractive index, i.e. thermal-optic effect the semiconductor materials seems gain little attention beyond the semiconductor processing industry. With a much larger temperature-dependent refractive index than the common optical materials, such as glass and quartz, many semiconductor are also very popular coating materials and convenient to form a thin layer on fiber. Taking advantage of the interaction of large temperature-dependent refractive index and temperature-dependant absorption coefficient of semiconductor, we manage to build a very small, sensitive, simple and low cost fiber temperature probe operating at communication wavelength. We develop a sensor model for an optical fiber-germanium (Ge) film type temperature sensor based on the modified optical film theory which involves temperature-dependent absorption below infrared transparent window of Ge as second major cause for reflectivity change beside thermal optical effect. Investigation of the feasibility and sensitivity of the fiber-film probe has been carried out theoretically and experimentally within the temperature regime of -20-120°C, which is the most used temperature range for industry monitoring. A sensitivity of reflectivity change about 0.001/°C has been demonstrated by the experimental results of the novel designed sensor. Further discussion on the potential of sensitivity and further application are presented.

7853-32, Session 7

Multiplexed FMCW interferometric polarization-maintaining fiber strain sensor

G. Zheng, Beijing Institute of Technology (China)

Optical frequency-modulated continuous-wave (FMCW) interference can provide a higher accuracy and a longer dynamic range, because it generates a dynamic signal and thus to calibrate the fractional phase, determine the phase shift direction and count the number of the full periods is easy. Multiplexed fiber-optic sensors are useful since a single sensor can obtain the information of several targets. Fiber-optic strain sensors have many important applications in civil construction and aviation industry, and have been intensively investigated during the last two decades.

This paper introduces a practical multiplexed FMCW interferometric fiber-optic strain sensor, which mainly consists of a frequency-modulated laser, a polarization-beam splitter, an X-type polarization-maintaining fiber coupler, a photodetector, and two different lengths of polarization-maintaining fiber which are connected to the fiber coupler for sensing strain. The principal axes of the sensing fibers are rotated by 45 degree with respected to the coupler, so that the linearly-polarized laser beam can propagate in the two modes. The strain of the sensing fiber changes the optical path differences between its two modes, and shifts the phase of the beat signal. Because the lengths of the two sensing fibers are different, the frequencies of the two beat signals are not the same. Hence, these signals can be separated by using two electronic band-pass filters. The advantages of this sensor include higher accuracy (0.3-micro strain), long gauge length, long leading fibers, and immunity from the environmental influence. It is suitable to remotely measure the multidimensional strain of the large constructions.

7853-33, Session 7

The new-conceptual fiber optic gyroscope

G. Zheng, Beijing Institute of Technology (China)

The new-conceptual fiber-optic gyroscope is introduced. The gyroscope employs the two newly-emerged advanced technologies: the optical frequency-modulated continuous-wave (FMCW) interference and the differential fiber-optic gyroscope, and therefore, can overcome the problems in the traditional fiber-optic gyroscopes, such as temperature drift and poor long-term stability. The FMCW interference, which was originally investigated in radar technology, has been successfully used to construct various fiber-optic interferometers and sensors. The advantages of this technology include easy calibration and counting fringes, absolute measurement and simple signal processing. The interest in the application of the FMCW technique to rotation sensing has been growing for a long period. The problem in the FMCW fiber-optic gyroscope is that the gyroscope must be an unbalanced interferometer, and the initial optical path difference in the interferometer introduces an unexpected non-reciprocal phase drift if the environmental conditions are unstable. This paper reports a differential fiber-optic FMCW gyroscope. The advantages of the differential fiber-optic FMCW Sagnac interferometer include: (1) Due to the nature of the differential structure, the unexpected non-reciprocal phase drift is automatically removed, and the calibration fact of the interferometer is automatically doubled. (2) Benefited from the FMCW technology, this interferometer has no zero-sensitivity point, no bulky frequency or phase modulation component, but have a higher resolution and a larger dynamic range.

7853-34, Session 7

Traffic monitoring and weight detection using fiber optic microbend sensor

N. Naorin, North South Univ. (Bangladesh)

In this work we are proposing a method for monitoring vehicle traffic and vehicle weight measurement in highway. Our proposed method includes calibration of a fiber optic microbend sensor that is placed on any specific lane of highways. The light transmission loss of the fiber due to different weight specimens is measured in laboratory and graphically plotted. A software program has been written for this project where this microbend sensor can be used for real time vehicle weight

measurement in highways. In the simulation part randomly generated vehicles cross a specific fiber optic microbend sensor. Individual vehicle weight, crossing time, time spent on the sensor for each crossing vehicle can be monitored. The program simulates for a specific time and after that it concludes the nature of the traffic pattern. The simulation shows graphical representation of individual vehicle information that has been previously monitored along with the result of the traffic pattern such as heavy congestion, light congestion, congestion free road.

7853-35, Session 7

Batching interface detection system based on LED array

Y. Qian, J. Zhang, J. Li, Z. Chen, Jinan Univ. (China)

In order to accurately and timely detect and separate the batching interfaces of two liquid oils in a petroleum transmission pipeline, a novel batching interface detection(BID) system based on near-infrared spectroscopy (NIRS) is established in lab. The system is modularized into four parts which are LED light source module, optical detection module, A/D conversion module and serial communication module respectively. During the system design, optical signals are transmitted through optical fibers to meet the explosion-proof requirements. The light source in the system is an LED array which consists of 32 NIR LEDs with different central wavelength from 1000nm to 1700nm. During the design of LED light source, instead of adjusting the LED's light intensity into the same way, dual optical detection method is applied, which not only simplifies the adjustment process of LED light source but minimizes the influences on the detection system due to the stability of light source. A single microcontroller MSC1211 integrated with 24-bit ADC is selected as the core of the system, which can realize A/D conversion and help to collect the spectral datum and control the light source. The system has been used to classify the gasoline samples in lab environment. 60 gasoline samples have been bought from gas stations and classified for two sorts 93# and 97#. The result shows that only two samples are labeled wrong. It can be concluded that the system will be satisfactory if the calibration model is optimized. Because of having few parts apart the system can be highly integrated, which is very important in practical applications.

7853-36, Session 7

Signal analytical processing based on wavelet transform for tunable diode laser absorption spectroscopy

F. Dong, Anhui Institute of Optics and Fine Mechanics (China)

Gas analysis based on tunable diode laser absorption spectroscopy (TDLAS) provides features of high sensitivity, fast response and high selectivity. When target gas concentration is below a few parts-per-billion spectrometers become more and more sensitive towards noise, interference, drift effects and background changes associated with low level signals. It is purpose of this paper to address some of the problems which are encountered at these low levels and to describe a signal processing strategy for gas monitoring with wavelet transform. Different parameters of wavelet are studied and an improved wavelet-based signal enhancement process is proposed based on the feature of TDLAS second-harmonic signal. The algorithm uses bior 3.9 wavelet basis function and multi-resolution decomposition. In this paper we take gas detection of H2S as an illustration, The results show a plausible improvement in performance of TDLAS system and enhancement of detection limit from 10 ppm to hundreds of ppb level under various noise conditions.

7853-37, Session 8

Strength of silica optical fibre subjected to chemical environment

I. V. Severin, Polytechnical Univ. of Bucharest (Romania) and Univ. de Rennes 1 (France); R. El Abdi, M. Poulain, Univ. de Rennes 1 (France)

Along with telecommunications, special optical fibres have been developed for use in smart structures and sensors. Reliability issues may be critical in practice, and accordingly, this study aims to investigate the behaviour of standard commercial epoxy-acrylate polymer coated fibres subjected to aggressive and sometimes unusual chemical reagents, either in the liquid or in the vapour phase. This includes acethylene, ammoniac and dimethyl sulfoxide (DMSO). Multimode optical fibre were exposed to gaseous NH3 and C2H2 for different durations ranging between 5 and 180 hours after being previously evacuated. Fibres were immersed in dimethyl sulfoxide between 40 minutes and 18 hours, and also in deionised water for comparison. Tensile test results were processed using Weibull statistics. It was observed that these chemicals lead to a more severe degradation of fibre strength than a mere exposition to liquid water, with a maximum effect for DMSO. Surprisingly, by comparison to the reference fibre, fibre strength decreases after vacuum treatment and re-exposition to atmospheric moisture. Chemical mechanisms involved in strength reduction are discussed.

7853-38, Session 8

Online monitoring of industrial flue gases using tunable diode laser with a core-control module

Z. Zhang, Anhui Institute of Optics and Fine Mechanics (China)

Increased demands on air quality have created incentives for new methods to monitor gas pollution in production process. In this paper we will present an online gas analyzer based on tunable diode laser absorption spectroscopy (TDLAS) technique. Signal measurements with a sensitive device inevitably suffer from the predictable or unpredictable sources such as intensity fluctuations and the laser output wavelength dithers. In order to eliminate or at least reduce the measurement uncertainty and gain high reliability, a close-circle core-control module with functions of digital signal generator, digital lock-in-amplifier, data acquisition and data processing has been developed to substitute the independent signal generator board, analog lock-in-amplifier and data acquisition card in our previous system. Utilizing the digital core-control module and the advanced digital signal processing techniques the performance of the TDLAS system has demonstrated great improvement in long term field tests.

7853-39, Session 8

Online monitoring of anti-slide piles by using fiber Bragg grating soil pressure sensor

M. Cao, Yunnan Electric Power Test & Research Institute (China); C. Li, Kunming Univ. of Science and Technology (China); D. Wang, Yunnan Electric Power Test & Research Institute (China); Y. Zhang, T. Liu, J. Jiang, Tianjin Univ. (China); J. Li, Yunnan Electric Power Test & Research Institute (China); Y. Chen, X. Xu, Kunming Univ. of Science and Technology (China)

The transformer substation of 220 kV Yan Jing is located on the fracture zone. Since the transformer substation was built on Dec. 27th, 2005, the foundations have subsided, the protecting walls have cracked, and

the faults between the protecting walls and the anti-slide piers have occurred because the shear stress of slope soil is bigger than the shear strength. By using the liquid transmission, a fiber Bragg grating soil pressure sensor is developed. Under the action of pressure, the first diaphragm presents bending moment. Then, the second diaphragm presents the bending moment, which causes the strain of pressure-sensitized grating mounted on the other side of second diaphragm. However, the temperature-compensated is achieved by the differential operation between the pressure-sensitized and the temperature-compensated gratings. In the North East corner, the ten soil pressure sensors are separately fixed on the front slope and the back slope of the 5 upper anti-slide piers. In the South West corner, the other ten soil pressure sensors are separately embedded in the front slopes between the front slope of the 10 lower anti-slide piers and concrete. By using the repeatability of the mechanical transducer and the reliability of wavelength modulation, the grating soil pressure sensor converts the shearing force of anti-slide piers into the shift of Bragg grating. The short term surveys indicate that the maximum pressure variation is 35 kPa in 24 hour. The long term measurements indicate that the distribution of pressures is unequal because the pressure variations of different piers are various.

7853-40, Session 8

Monitoring of tunnel second lining by using fiber Bragg grating strain sensor

C. Li, Kunming Univ. of Science and Technology (China); M. Cao, D. Wang, Yunnan Electric Power Test & Research Institute (China); H. Liu, Z. Zhang, Yunnan Aerospace Engineering Geophysics and Measurement Co., Ltd. (China); Y. Zhang, T. Liu, Tianjin Univ. (China); J. Xu, Kunming Univ. of Science and Technology (China)

The Dong Yang tunnel is situated in the landform region of tectonic erosion, low mountains and hills area, where the wall rock are the all weathered mudstone with rock joints and bedding fissures. In the procession of tunnel, the vault crown of early support-protect engineer of K147+535~K147+575 subsided with the maximum settlement of 1 m, and invaded the second lining section. In the procession of replacing vault, the roof fall occur in the range of K147+564 K147+570. A differential fiber Bragg grating strain sensor is developed for monitoring the surface strain of tunnel structure. Under the stress of structure, the displacement of a gauge rod is translated into the deflection of the cantilever beam, on which the fiber Bragg gratings suffer the strain and shift their Bragg wavelengths. The ten monitoring sections are selected to install the grating strain sensors from K147+540 to K147+610. Especially, the second lining is enhanced by the steel plate from K147+592 to K147+598. In the monitoring section, there are 7 sensors fixed on the vault crown, the right and left vault shoulders, the right and left vault middles, and the right and left vault feet. By using the repeatability of the mechanical transducer and the reliability of wavelength modulation, the grating sensor converts the strain of second lining into the shift of Bragg wavelength of the strain-sensitized gratings. The survey results indicate that the abnormal expand strain occurs on the monitoring section of K147+560, but both abnormal expand and strain occur on the section of K147+590.

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7854-01, Session 1

Micro- and microscopic nonlinearities competing in the THz emission from a femtosecond laser focus

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The atomic gas at the focal spot of a femtosecond laser, is a source of radiation at THz frequency. The emitted THz power increases manifold if a bicolor scheme is used where a fundamental optical wave is mixed with its second harmonics satellite at doubled frequency. The characteristics of emitted THz wave are influenced by several parameters of the radiations at pump frequencies such as, relative time delays between pulses, orientation of polarization vectors and intensities of pulses. The formation of a plasma channel in the process of optical breakdown has the significance in the analysis of the process generation of THz radiation. We should differentiate two formation regimes of the medium: ionization-free and multiphoton ionization of gas. The imaginary time method is used to describe the multiphoton ionization of atoms of gases under the bicolor femtosecond laser irradiation. The obtained formulas are applied for the qualitative explanation of experiments in the generation of THz radiation from an optical breakdown in a focus spot of a femtosecond laser in gas. We also discuss a new mechanism of the THz radiation generation in an atomic gas caused by the response of the atom itself to the presence of the bicolor femtosecond laser field. In the model and in the experiments we suppose that the laser field strength is lower than the atom ionization. In spite of this, the efficient generation of the THz radiation takes place. However in the presence of the multiphoton ionization this mechanism may also be observed.

7854-02, Session 1

Physics-based processing for terahertz reflection spectroscopy and imaging

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The spectra obtained from terahertz (THz) transmission measurements of pure explosives have unique structure that can readily be used for detection and classification. However, for many practical applications the opacity of targets limits measurements to reflection geometries where the spectral signature can be distorted by scattering from rough interfaces, layering effects, and wave interaction with granular inclusions. Furthermore, object facets or surfaces are not generally aligned normal to the THz beam, so the received signal is diffuse scattering, which can be appreciably lower in signal strength than specular returns. Many of the challenges in reflection spectroscopy can be addressed with advanced signal processing approaches based upon the coherent and incoherent combination of multiple returns, and particularly with the formation of images. Imaging strategies such as synthetic aperture processing improve resolution by combining multiple measurements with a phase relation (or time delay) obtained from a model of object position and propagation environment. In physics-based processing, this model is extended to include the scattering structure expected for an assumed target or material. Additionally, the data can be used to assess the coherence of the returns and adaptively adjust the imaging weights. This paper presents theoretical and experimental imaging results from physics-based processing of THz time domain pulses with application to sensing of explosive devices. The ability identify materials is quantified for canonical sensing geometries as a function of sensor topology and accuracy of the a-priori scattering model.

7854-03, Session 1

The research of THz wave propagation in the atmosphere

H. Xia, J. Yao, Tianjin Univ. (China)

THz wavelengths frequency vary from 0.1THz-10THz, the study on propagation feature of THz wave in atmosphere is very important, such as space communication, gas detecting and substance identify. THz wave propagation core problem is to establish THz wave propagation models, then establish database and expression.

In this paper, the characterization of THz propagation features in the atmosphere are studied, the fundamental principle of THz propagation, the propagation models, the radiative equation expressions, and weighted expression are developed while analyzing the THz propagation in atmosphere. The expressions are computed with the parameters of general meteorological phenomena. It is shown that the THz propagation models that can be used in engineering design as the experimental data are verified with the theoretical calculation

7854-04, Session 1

THz-infra-UV transmission spectra of BGO:Ca/Pb crystals

N. Li, B. Hou, Beijing Univ. of Technology (China)

The THz-Infra-UV transmission spectra of Bi4Ge3O12 (BGO) and BGO:Ca, BGO:Pb crystals have been measured at the room temperature. The crystal samples were cut along the (001) plane and twin polished. The thickness is Lz=1.969nm, Lz(Ca)=0.730 mm, Lz(Pb)=0.425mm.

The ultraviolet-visible-infrared spectra of transmission T( ) of three samples have been measured by ShiMaDZu Corporation's spectrum analyzer at the room temperature, and the wave length is from 200nm (or 6.216eV) to 2000nm (or 5000cm-1). Mid-infrared transmission T(1/) spectra of three samples have been measured by BRUKER Corporation's VERTEX 80/80v FT-IR ShiMaDZu spectrum analyzer at the room temperature, and the wave number 1/ is from 4000cm-1 (or 2500nm)to 50cm-1(or 1.5THz). A measured data gap of the spectrum is from 2000nm to 2500nm, or is from 5000cm-1 to 4000cm-1, although it is very small.

The forbidden gap Eg of electronic energy bands are about 3.66eV (339nm). There exist the wide phonon absorption bands for three crystals in the range of THz~mid-infrared in the region from 1.98THz (or 66 cm-1) to 47.3Thz (or wave number 1577cm-1). But BGO:Pb crystal have two transmission peaks at 40.77THz (or 1359 cm-1) and 2.37THz (or 79 cm-1) respectively, BGO:Ca crystal has a transmission peak at 2.43THz (or 81 cm-1). The breadth of phonon absorption band has been discussed.

7854-134, Session 1

Science, technology, and application of THz wave air-plasma photonics

X. Zhang, Rensselaer Polytechnic Institute (United States)

No abstract available

7854-05, Session 2

New scheme to generate low-frequency terahertz waves using an optical external intensity modulator and cascaded optical interleavers

Z. Zheng, Y. Li, L. Chen, J. Yu, S. Wen, Hunan Univ. (China)

We propose a novel technique to generate low-frequency (0.1-0.2THz) Terahertz waves using an optical external intensity modulator and cascaded optical interleavers. We have generated two sidebands with a frequency spacing of 0.112 THz by this kind of scheme. Terahertz waves can be generated by beating the two second-order optical sidebands when they are detected by a high-speed optical detector. After 20km SMF-28 transmission, we observe that the two second-order optical sidebands are still stable. Our results demonstrate that this novel scheme can offer one alternative solution to generate Terahertz waves for long distance transmision.

7854-06, Session 2

Fast large area nondestructive testing using all-electronic 3D terahertz/millimeter wave imaging

T. Loeffler, A. Keil, H. Quast, SynView GmbH (Germany)

As is well known, Terahertz and millimeter waves penetrate most dielectric or non-conducting materials. Hence, THz imaging allows numerous non-destructive testing applications. One example is the 3D imaging of composites and foams. However, in the past THz imaging was not mature enough to fulfill the numerous industrial and commercial needs. The main limitation was a limited dynamic range leading to a too long image acquisition time of up to several hours. As has been shown before, contrary to the often used opto-electronic methods, the use of all-electronic emitters and detectors lead to fast, reliable, and cost-effective Terahertz / millimeter wave imaging systems, which are capable to acquire full 3D images in minutes instead of hours.

But for many industrial applications, the imaging speed needs to go down to seconds, even in case of larger objects, i.e. larger scan areas. The here presented all-electronic technology allows several options to further decrease its already high imaging speed. At first, optimized mechanical scanning in combination with a receiver array allows to image an area of approximately 16 cm by 32 cm with a refresh rate of 10 Hertz. A second option is to combine several measurement heads to a synthetic aperture with or without mechanical scanning.

In our contribution we will give an overview on the used all-electronic 3D Terahertz imaging technology, its applications and limitations, and show recent results on the progress to fast imaging of large objects.

7854-07, Session 2

2D THz and GHz signature for identification of explosive on reflected THz signal

V. A. Trofimov, S. A. Varentsova, Lomonosov Moscow State Univ. (Russian Federation); J. Chen, Portland State Univ. (United States)

The method for substance identification in THz and GHz frequency range, which permits to obtain the unique 2D signature of the substance, is used for treatment of experimentally measured signals, reflected from ordinary materials and selected explosives. The method of identification is based on the analysis of THz and GHz spectrum dynamics (spectrogram) of medium response and has the ability not only to detect the presence of the substance in the sample but to identify it by its “spectral-time fingerprint”, which is unique for each investigated substance.

Under certain condition a relaxation time for excited energy levels of molecules can be determined from the spectrogram as well. This fact gives us new opportunity for substances identification.

We showed that THz and GHz spectrograms of THz pulses, reflected from the hidden explosives, widely differ from spectrograms of simulant themselves despite of little difference in their THz spectra.

7854-08, Session 2

Terahertz spectroscopy properties of the selected engine oils

S. Zhu, K. Zhao, T. Lu, S. Zhao, Q. Zhou, China Univ. of Petroleum (China); Y. Shi, Capital Normal Univ. (China); H. Zhao, R. Bao, Q. Miao, C. Zhang, China Univ. of Petroleum (China)

Engine oils, most of which are extracted from petroleum, consist of complex mixtures of hydrocarbons of molecular weights in the range of 250-1000. Variable amounts of different additives are put into them to inhibit oxidation, improve the viscosity index, decrease the fluidity point and avoid foaming or settling of solid particles among others. In recent years, much attention has been paid to the THz spectroscopic studies of petroleum products. In this paper, the optical properties and spectroscopies of selected kinds of engine oil consisting of shell HELIX 10W-40, Mobilube GX80W-90, GEELY ENGINE OIL SG10W-30, SMA engine oil SG 5W-30, SMA engine oil SG 10W-30, SMA engine oil SG 75W-90 have been studied by the terahertz time-domain spectroscopy (THz-TDS) in the spectral range of 0.6-2.5 THz. Engine oil with different viscosities in the terahertz spectrum has certain regularity, and the specific kinds of engine oil can be identified according to their different spectral features in the terahertz range. The THz-TDS technology has potentially significant impact on the engine oil analysis.

7854-09, Session 2

Direct detection behavior of a superconducting hot electron bolometer measured by Fourier transform spectrometer

W. Miao, K. Zhou, W. Zhang, Z. Lin, Q. Yao, Purple Mountain Observatory (China); Y. Delorme, R. Lefevre, Observatoire de Paris (France); S. Shi, Purple Mountain Observatory (China)

Superconducting hot electron bolometer mixers are currently the most sensitive devices for coherent detection in the THz frequency range. Some projects such as TREND and HIFI have utilized superconducting HEB mixers as detectors on the ground and in space. One of the key factors that may affect the performance of superconducting HEB mixers

is the coupling of the RF radiation. At THz frequencies the investigation of the RF coupling of the HEB mixers is usually based on Broadband Fourier Transform Spectrometer (FTS). In this paper, we present the measurements of the direct detection behaviors of a superconducting hot electron bolometer integrated with a log spiral antenna by using Broadband Fourier Transform Spectrometer (FTS). We first measure the current responsibility and the output power responsibility of the superconducting HEB mixer at different bias voltage. The measured results are in good agreement with the calculations. Then the direct response of the superconducting HEB mixer was measured based on the current responsibility and output power responsibility of the HEB mixer. Two Fourier Transform Spectrometer measurements give nearly identical results. Furthermore, the influence of the beamsplitter of the Fourier Transform Spectrometer on the response is also examined.

7854-10, Session 2

Terahertz spectrum of acesulfame-K

H. Wang, G. Zhao, L. Liu, B. Wei, Capital Normal Univ. (China)

The food security is a public hygiene problem. It not only relates to a personal health, but also influences economic and social development. Therefore, the international community pays more and more attention to the problem of food security. There are many additives used in the food. The sweetener is one of the most important additives of food. The use of sweetener has characters of great capacity and widely area. Some sweetener has been used in medicine. However, most of sweetener is not natural composition. It may arouse a multiform toxicity while it is used inappropriately. To better use of sweetener and prevent its abuse, the discrimination and detection of sweetener is significant important.

Terahertz time-domain spectroscopy (THz-TDS) is a new coherent spectral technique. In this paper, the spectral characteristics of Acesulfame-K in the range of 0.2-2.6THz has been measured with THz-TDS. We obtained its transmission spectrum, refractive index spectrum and absorption spectrum at room temperature in the nitrogen atmosphere. The results show that Acesulfame-K has the abnormal dispersions at 0.40THz, 0.66THz, 0.94THz, 1.79THz and 2.30THz. The vibration absorption spectrum of single molecule of Acesulfame-K is simulated based on the Density Functional Theory (DFT). It is found that Acesulfame-K has the obvious absorbance in THz region. This result shows that THz-TDS has a potential application in the field of food security.

7854-11, Session 3

Terahertz research activities at Seoul National University

G. Park, Seoul National Univ. (Korea, Republic of)

The terahertz research activities at Seoul National University will be reviewed. High power tearhertz electronics has been investigated for terahertz wave generation using high current electron beams using microfabrication techniques. Interaction of terahertz wave with water and biological systems is being investigated using various instruments of terahertz electronics and terahertz photonics. The details will be reviewed.

7854-12, Session 3

Terahertz photon production from cold atoms inside an optical cavity

C. Zhang, Capital Normal Univ. (China)

The Dicke model was proposed by Dicke in 1954 to describe a single mode of photon coupled to an assembly of N atoms with the same strength. It was found that there is a quantum phase transition from a normal phase at weak coupling to a super-radiant phase at strong coupling at the thermodynamic limit N = ∞. Here, we solve the model at N 1 and also discuss its possible experimental implementations inside a cavity. By studying the Dicke model by 1=N expansion, we identify an emergent quantum phase diffusion mode inside the super-radiant phase and also work out many remarkable experimental consequences of this mode such as its low frequency, photon number squeezing properties and photon statistics. The energy of the phase diffusion mode can be continuously tuned into many frequency ranges from Micro-wave to Terahertz (THz) to Infra-red. The photons from the super-radiant phase are in a number squeezed state with much enhanced signal/noise ratio which may have wide applications in quantum information processing. The photon statistics is strong sub-Poissonian. The effects of dissipations due to leaking photons out of the cavity are also discussed. The connections with the recent experiments of the strong coupling of a BEC of N 105 87Rb atoms to the photons inside an ultrahigh-finess optical cavity are carefully analyzed. Several experimental schemes todetect the phase diffusion mode are proposed.

7854-13, Session 3

An efficient optically pumped terahertz laser without metal mesh mirrors

L. Miao, D. Zuo, Y. Lu, Z. Cheng, Huazhong Univ. of Science and Technology (China)

The photon conversion efficiency of a simply designed optically pumped pulsed terahertz laser (OPPTL) is studied experimentally. The terahertz laser cavity is just composed of a 2 m long quartz glass tube, an antireflection-coated Ge crystal window and a SiO2 crystal window. The Ge crystal acts as the high-reflectivity mirror of terahertz radiation and the input coupler of pump laser instead of complicated metal meshes. The Ge crystal is as thin as near 3 mm thick, whose exact thickness is designed according to etalon effects to maximize terahertz reflectivity. The crystal quartz acts as the output coupler of terahertz radiation. NH3 gas is filled in the cavity as the active medium and pumped by the 10P(32) line of a TEA CO2 laser. As high as 25.9 mJ terahertz radiation at the wavelength of 151.5 μm is extracted from 1.76 J pump energy. The corresponding photon conversion efficiency of this terahertz laser reaches 41.5%. A 5 mm thick GaAs crystal with high resistance is also chosen to be the input coupler to compare with the carefully designed thin Ge crystal. The experimental results shows that the efficiency of the Ge window is 53.7% higher than that of the GaAs window. The reason of this result is that the reflectivity of the Ge crystal for 151.5 μm wavelength is much higher than that of the GaAs crystal, which is demonstrated experimentally and theoretically in this paper.

7854-14, Session 3

A new portable device of testing materical's hemisphere emissivity

J. Wu, Xi'an Institute of Applied Optics (China)

A new portable device for measuring hemispherical emissivity of matericals such as grass was shown. The principle of testing was present, which elimated the spurious emission interference. Some testing experiments were done, the result was given, which proved its accuracy and reliability.

7854-15, Session 3

Review and analysis of terahertz frequency electromagnetic shielding

Y. Zhu, Xidian Univ. (China)

A number of research groups worldwide have reported the theoretical and experimental behaviour of shielding capabilities in Thz range. A comprehensive survey of published paper for the shielding effectiveness within the Thz region has been undertaken. Then the Thz pulse penetration through small apertures is discussed for general aperture shapes.

7854-16, Session 4

An analytical investigation of excitonic absorption in terahertz-field-driven quantum wells

T. Zhang, Xi'an Institute of Optics and Precision Mechanics (China)

An analytical solution of the optical susceptibility of quantum wells driven by a terahertz (THz) field is achieved based on the density-matrix formalism. A simple three-level model is adopted for the quantum well structures, with the levels coupled by a near-infrared (NIR) and a THz field. The equation of motion for the optical polarization is derived from Liouville's equation for the density matrix. Using Floquet's theorem, and under the rotating-wave approximation with respect to the NIR probe field, analytical expression for the optical susceptibility of the driven quantum wells is obtained. Different features rising induced by the driving THz field in the absorption spectrum of the NIR probe are discussed for the THz field near resonance and out of resonance of the intra-excitonic transition. This analytical investigation of the susceptibility of the THz-field-driven quantum wells is much useful for clearly identifying the physical principles obscured in the full numerical calculations.

7854-17, Session 4

Superconducting integrated THz receivers: development and applications

V. P. Koshelets, A. B. Ermakov, L. V. Filippenko, N. V. Kinev, O. S. Kiselev, M. Y. Torgashin, Institute of Radio Engineering and Electronics (Russian Federation); A. A. J. de Lange, G. de Lange, SRON Nationaal Instituut voor Ruimteonderzoek (Netherlands); S. I. Pripolzin, V. L. Vaks, Institute for Physics of Microstructures (Russian Federation)

A Superconducting Integrated Receiver (SIR) comprises on one chip all elements needed for heterodyne detection: a low-noise SIS mixer with quasioptical antenna, an Flux-Flow Oscillator (FFO) acting as a Local Oscillator (LO) and a second SIS harmonic mixer (HM) for the FFO phase locking. Light weight and low power consumption combined with nearly quantum limited sensitivity and a wide tuning range of the FFO make SIR a perfect candidate for many practical applications. In particular, the SIR developed for novel balloon borne instrument TELIS (TErahertz and submillimeter LImb Sounder) covers frequency range 480 -630 GHz. As a result of recent receiver's optimization the DSB noise temperature was measured as low as 120 K for the SIR with intermediate frequency band 4 - 8 GHz. An intrinsic spectral resolution of the SIR well below 1 MHz has been confirmed by CW signal measurements in the laboratory.

The capability of the SIR for high resolution atmospheric spectroscopy has been successfully proven with first scientific balloon flights from Kiruna, North Sweden. To ensure remote operation of the SIR several software procedures for automatic control have been developed. Diurnal cycles of ClO and BrO has been observed with BrO line level of only about 0.5 K. All these results are promising for future data reduction. Possibility to use the SIRs for analysis of the breathed out air at medical survey has been demonstrated.

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7854-18, Session 4

Influence of the parameters of the SRR to the resonant frequencies in terahertz band

L. Li, D. Zhao, Q. Zhou, Y. Shi, C. Zhang, Capital Normal Univ. (China)

When the incident THz's wave vector perpendicular to the surface plane of the split-ring resonator (SRR) and the polarization parallel to the boundary with a gap, a SRR have two resonant peaks, the positions of which have strong correlation with the parameters of the SRR. Through the simulation of SRRs with different periods, width of the metal, length of the gap, and length of the boundary, the positions of the two peaks can be moved. The influence of these parameters of the SRR to resonant frequencies can be received through the analysis of the date, and the resonant frequencies even can be controlled. This work will provide a reference for the design of the similar samples.

7854-19, Session 4

High transmittance and wide pass-band filter based on a three-layer structure of metal-dielectric-metal hole arrays

L. Rao, D. Yang, L. Zhang, T. Li, X. Liu, Zhejiang Univ. (China)

The terahertz transmissions of sub-wavelength metal hole arrays have been found to exhibit high transmittance at some frequencies and a great many of researches have been done to investigate the physics and explore the potential applications like sensing, imaging, filtering and amplifying. The hole's shape, lattice period, metal's type, array film's thickness and the dielectric layer attached on the metal array can all influence the terahertz transmission properties. In this paper, square lattices of air holes were fabricated on a three-layer structure of metal-dielectric-metal using micromachining technology. The metal-dielectric-metal structure is based on RT/duroid 5870 produced by Rogers corporation. The square period is 400 μm and the radius of circular hole is 100 μm. The thickness of the structure is about 787 μm with metal thickness of 35.6 μm and dielectric layer thickness of 711.2 μm. The loss and dispersion of the dielectric layer with the dielectric constant of 2.33 are low at high frequencies. Terahertz transmission properties through the sample were measured by the state-of-the-art THz-TDS system. Experimental results show that there is a high transmittance centered at 1 THz with a wide pass-band exceeding 100 GHz. Transmission spectra calculated by FDTD method were given for comparisons and showed good agreements with the experimental results. Through analysis, the extraordinary transmission phenomena are caused by both the localized resonance and the excitation of surface waves existing on the metal arrays. This kinds of metal hole arrays can be the potential candidate of filters in the terahertz free space device systems.

7854-20, Session 5

New IR detectors with small pixel pitch and high operating temperature

P. Tribolet, M. Vuillermet, SOFRADIR (France)

More and more systems are requested to be more compact keeping constant system performances. One of the best approach is to reduce the pixel pitch of the IR detector while new technology improvements are carried out to improve the detector performance.

The last developments at SOFRADIR / France for cooled IR detectors are following these trends. As a matter of fact, HgCdTe (Mercury Cadmium Telluride / MCT) staring arrays for infrared detection do show constant improvements regarding their compactness, by reducing the pixel pitch, and regarding performances.

Among the new detectors, the family of 15 µm pixel pitch detectors is offering a mid-TV format (384 x 288), a TV format (640 x 512) and a HD-TV format (1280 x 1024). The latest development concerning the mid-TV format is performed according to very challenging specifications regarding compactness and low power consumption. Thanks to recent improvements, the MCT technology allows to operate detectors at higher temperature (HOT detectors), in order to save power consumption at system level. In parallel, the 15µm pitch permits to reach challenging density and spatial resolution. This Focal Plane Arrays (FPA) is proposed in different tactical dewars, corresponding to various systems solutions.

7854-21, Session 5

High frequency coaxial pulse tube cryocoolers for cooling infrared focal plane arrays

H. Dang, Shanghai Institute of Technical Physics (China)

This paper reviews recent advances in high frequency coaxial pulse tube cryocoolers (PTCs) in Shanghai Institute of Technical Physics, Chinese Academy of Sciences (SITP/CAS). The attractive merits of the PTCs such as the reliable cold fingers with further lower vibration output and EMI level and potential longer lifetime makes them more attractive candidates than their Stirling rivals for cooling infrared focal plane arrays. The coaxial arrangement is adopted to acquire a compact system, and also minimize the change in adapting to the geometry specifications of the existing Dewar systems, which are often tailored to the geometry characteristics of the Stirling cryocooler because of the long practical application history. All PTCs use the inertance tubes composed of different inner diameters and lengths as the only phase-shifting mechanism to realize high reliability. To date, PTCs cover from 30 K to 200 K and the cooling power levels from hundreds of milliwatts to 10's Watts. Tests suggest that they have the potential to provide effective cooling for HgCdTe-based infrared focal plane arrays from near visible down to very long wave infrared region. The paper presents a brief overview of the data package, and also discusses the efforts to realize space qualified PTC technologies.

7854-22, Session 5

The image denoising method for MEMS based uncooled infrared imaging system

H. Zhu, Y. Zhao, Beijing Institute of Technology (China)

The uncooled infrared imaging based on MEMS has more and more broad space for development in recent years. An uncooled thermal detector array was designed and set up using bi-material micro-cantilever structures, which can bend with the temperature change. The effective image points of objects' infrared images which are readout by an optical method from this thermal detector array are discrete. For this reason, the output image should be filtered based on the gray mean value of square window, firstly. Then, each point of image can be decided to assign zero or restore the initial gray, according to the threshold of gray-scale value summation of the filtered image's single direction template. Comprehensive two directions' data that is in horizontal and vertical, the final result is achieved. The experimental results demonstrate, this algorithm can remove noise well without losing the details of objects' effective image points.

7854-24, Session 5

Adaptive vibration control system of mechanical cryocooler

B. Yang, Y. Wu, Shanghai Institute of Technical Physics (China)

Vibration disturbances generated by mechanical cryocooler, representing in a series of harmonics, are critical issue in practical application. A control system including electronic circuit and mechanical actuator has been developed to attenuate the vibration. The control algorithm executes as a series of adaptive narrowband notch filters to reduce corresponding harmonics. Unlike existing other methods, our algorithm does not require actuator transfer function, thus ensure it more adaptive under a variety of operating and environmental parameters. Using this algorithm, all the vibration harmonics of Cryocooler were attenuated by a factor of more than 36 dB, i.e., the residual vibration force was reduced from 3.44Nrms to 0.05Nrms over the 300 Hz control bandwidth, the converging time is only less than 20 seconds, and the power consumption of mechanical actuator is less than half a watt. The control system has achieved the general vibration requirement of Infrared detection and superconductor filter application. Furthermore, this control method can also be used in vibration suppression of compressor, and the cold tip of Pulse tube cryocooler.

7854-25, Session 6

Ultra-high spectral resolution infrared spectrometer for trace gases detection

Z. Dai, Shanghai Institute of Technical Physics (China)

An infrared spectrometer with high spectral resolution is developed for the purpose of atmospheric trace gases measurement from future low-earth orbit satellites. The spectrometer is based on Fourier transform technique. Infrared radiation goes into the instrument from a 2-axis pointing mirror. A telescope collects the infrared radiation and transfers it to the interferometer. Two cube-corners act as the moving mirror to generate optical path difference (OPD). A laser metrology reference interferometer is built in the instrument to get the OPD information. Two infrared detectors are used. One is for long-wave band detection and the other for mid-wave detection. When the cube-corners move, the scene radiance is modulated to generate interferograms. Infrared detectors transform the optical signals into electric signals. Infrared spectra of the scene are obtained by Fourier transform calculations of the interferograms. The unapodized spectral resolution is 0.02cm-1 over the spectral coverage from 2.5 to 13 microns. Clear absorption features of CO, CO2, as well as CH4 trace gas samples are observed with this instrument in the laboratory. Concentrations of the trace gases can be derived from the absorption features. The ultra-high spectral resolution infrared spectrometry will be an effective method to investigate the atmospheric trace gases.

7854-27, Session 6

Sub short noise 3D laser radar based on second-order coherence

X. Zhang, H. Yan, Q. Zhou, Zhejiang Univ. (China)

The array area three dimensional(3D) active imaging laser radar is a kind of remote sensing system which benefits high detection speed and no machanism scanners. This type of laser radars employ area optical modulation devices such as micro-channels plate (MCP) image intensifiers to modulates the photons flying time into intensity which can be detected by a charge coupled device(CCD). The distance measuement precision of this kind of laser radars is determinated by the short noise of the photons numbers. As well known the short noise obeys the Possion distribution which means the signal to noise ratio(SNR) increases with the evolution of the photon number. This peroperty limits the perforemance of this kind of laser radar for 10 times distance measurement precision improvement needs 100 times power increasement. In this paper, a method based on second-ord coherence is presented to compensate the short noise. A semipermeable half mirror and an additional CCD is introduced in the 3D active imaging laser radar system. We employs the photon number state as the basis vectors and the creation operator destruction operator to discribe the detection process. The analysis result shows the photon bunching effect improves the SNR of the distance masurement with the same photon numbers. For the good corherence property and suitable statics property, the pseudo-thermal light is proposed to replace the laser which is the light source of the array area 3D active imaging laser radar. An experiment system is introduced which has results verified the effect of the therectical analysis. The next work and protential applications are also discussed in this paper.

7854-28, Session 6

Elimination of reflection induced artifacts in flash thermography

L. Feng, P. Zou, N. Tao, Capital Normal Univ. (China)

Flash thermography non-destructive evaluation features fast, non-contact and suitable for composite inspection. High energy flash is applied to heat the surface of the sample and the temperature of surface is recorded after the flash. The flash tube and frame are still warm and may be reflected by sample's low emission surface. If the reflection is recorded then it will appear as artifact. Several methods were used to eliminate the artifact. Subtraction could reduce the artifacts, but duo to the variation of the reflection intensity, this method does not always take effect. For the flash tube and frame have fixed appearance their spatial spectrum have fixed distribution which make it is not difficult to eliminate the artifacts in spatial spectral domain. Different samples were inspected and the results show that spatial filtering is effective in most cases.

7854-29, Session 6

Statistical analysis on the scatter properties of Gauss random rough surfaces

J. Shu, Z. Li, Nanjing Univ. of Science and Technology (China)

The expressions for the intensity distribution of the scatter field, which are available to any state of polarized incident light, is derived, utilzing Kirchhoff approximation on the basis of the the electromagnetic theory. The intensity distributions of the scatter field from a series of gold surfaces are calculated by means of Monte-Carlo method. These surfaces have different roughness, but the same correlation length. The height distribution of these surfaces is Gaussian. With the increase of the rms height, the attenuation of coherent scattering, the boardening of diffuse scattering intensity distribution and its moving to the normal direction are observed. By analysis of statistics, it is obtained that the statistical distribution of the local slope varing with the rms height and reflecting coefficient of these local slope are the main reason for these phenomenon.

7854-26, Poster Session

Analysis of bit error ratio introduced by ellipse gauss beam drift and power calculate in space optical communication

W. Zhan, H. Li, Z. Wang, H. Jiang, Changchun Univ. of Science and Technology (China)

The bit error ratio (BER) and power are very hard to calculate in space optical communication. Lots of factors have influence on them so as to need a compromise to consider the complex factors. By analysis the influence on the BER such as that of beam drift, beam divergence angle, communication distance, link loss, detector sensitivity etc. the paper proposes the view that ellipse Gaussian beam can inhibit beam drift by the random shock and relative motion of the optical platform and reduce the BER, and further proposes the method of calculating the transmit power by the BER. Experiment shows that it is secure to use the calculation methods of the BER and power. Innovation: 1. The semiconductor laser usually sends out ellipse Gaussian beam. The common practice is to compress and reshape ellipse Gaussian beam into park-type beam. The paper proposes that through theoretical analysis, ellipse Gaussian beam in space optical communication can reduce bit error ratio in a proper range and restrain the vibration of platform.2. The power calculating is very difficult in space optical communication. The paper propose that it is more secure and reliable to adopt this method that reverse radiating power of the semiconductor laser to calculate power in the combination of such factors as air channel analysis, optical system loss, according to bit error ration of communication and signal-to-noise of detector.3. The combination of theoretical researched and engineering practices promote to apply the results of researches and analysis to key research projects of space optical communication and to verify the rationality and precision of the point of view and methods proposed in the paper.

7854-41, Poster Session

Optical properties of CuS nanoparticles at terahertz frequencies

Y. Yang, Minzu Univ. of China (China)

Covellite copper sulfide (CuS) has attracted increasing attention in recent years due to its applications as a cathode material in lithium rechargeable batteries and its high conductivity. Spectroscopy study of CuS nanomaterials is necessary to characterize their optical properties over a broad frequency range and to further explore their potential applications in broad areas. However, to our knowledge, the investigation of low-frequency spectrum in CuS NPs did not reach the broad terahertz spectral region.

In this article, the low-frequency optical properties of CuS nanoparticles are measured by the terahertz time-domain spectroscopy and are extracted by applying Bruggeman effective medium theory. The measured refractive index, power absorption, and dielectric function are well fitted by the Lorentz model of dielectric response. In addition, the extrapolation of the measured data indicates that the absorption is dominated by the lattice vibration localized at 4.7 0.3 THz, which leads to an excellent agreement with the FTIR measurement. A Drude-Smith model provides an excellent fit to the observed conductivity in our work, revealing a localized behavior with high electron backscatter in the nano-structured materials. The scattering time is characterized by an average value of 64.3 fs, which is dependent on the size of NPs.

Our investigation suggests that THz-TDS technique is a powerful method for detecting the optical properties in semiconductor nanostructures, and it could help us to reveal the material properties in the terahertz range and to find out the promising physical effect for special application.

7854-42, Poster Session

The THz time domain spectra of SrB4O7 crystal

Y. Wang, Changchun Univ. of Science and Technology (China); B. Hou, Beijing Univ. of Technology (China); H. Wang, G. Zhao, Capital Normal Univ. (China); Y. Shi, Graduate Univ. of the Chinese Academy of Sciences (China)

SrB4O7 (SBO) is a promising nonlinear optical crystal. It has the orthorhombic structure with group classified as Pnm2. The sample for the experiment was cut along the (001) plane and twin polishing with 1.632mm thickness. It exhibits a wider transparency range from UV to far-IR. And its absorption edge lies at 160nm. The forbidden band gap is about 7.76eV. The THz spectra of SBO crystal had been studied from 0.1 to 2.5THz. The THz time domain spectrum of SBO shows the strong resonance characters. In THz experiment, the vertical incident electromagnetic waves radiate the polished side twice along (001) orientation. The crystal turned 90 degrees relative to the first in the vertical direction. There are different optical properties in two directions. We gained the curves of the refractive index and absorption coefficient dependence of frequency in the region of 0.1-2.5THz. The absorption curves shows opposite parabola character. One is upward opening and the largest absorption coefficient is 10cm-1. The other is down opening and the less absorption coefficient is 1cm-1. The refractive index n is stable linear with frequency and it is 3 from 0.4THz to 2.5THz. But the refractive index of two directions shows the opposite tendency from 0.1 to 0.4THz. The reason of the difference is that polarized beam radiates the orthorhombic crystal. The properties of the sample show that it is possible to apply it to laser field.

7854-43, Poster Session

The optical and electrical properties of W-doping VOx thin film

H. Li, X. He, Hefei Univ. of Technology (China)

The transition temperature of VO2 is most important for the technological applications. For the application as thermochromic coating, it should be reduced to be in human comfort range. Doping was proposed to modify the transition temperature. It was reported previously that doping by different elements such as W, Mo, and F, could decrease the transition temperature. Tungsten, with an effect of ≈–23 °C /at.%, was the most promising dopant amongst them.

In our work, the thin films of W-doping VOx, were synthesized onto glass substrates using reactive DC magnetic co-sputtering deposition technique. The optimum synthetic process was obtained, that is, the gas pressure was 2.0Pa, the ratio of O2/Ar was 1.0:15, the sputtering power of vanadium target was 120W, while the sputtering power of tungsten target was 45W, their sputtering times were all 30minutes. Then the W-doping VOx films were annealed through nitrogen atmosphere at 450°C for 2 hours. The structures of films were characterized by x-ray diffraction. The effects of W dopant on the semiconductor -to-metal phase transition of bare VOx were investigated by measuring the temperature dependence of their electrical resistance and their infrared transmittance spectrum. Remarkably strong effects of W doping were observed on VOx films both the optical and electrical properties. The IR transmittance was decreased from 67.46% to 44.86%, while the transition temperature could be improved from 68°C to 48°C through W-doping . In addition to, at corresponding transition temperature, the temperature coefficients of resistance were changed from -1.48 %/ °C into -1.71 %/ °C for W-doped VOx film.

7854-44, Poster Session

Propagation of THz wave in random coal aggregates

H. Li, Z. Wu, Xidian Univ. (China)

Terahertz(THz) fields is a generic term for waves with a spectrum between 0.1 and 10 THz(the corresponding wavelengths extending from 3mm up to 30). Some unique physical phenomena with characteristic features are producing in this range of frequencies. This spectrum has become the interest of many scholars. A generalized multi-particle Mie-Solution(GMM) is provided by Xu, and it is an extension of Lorenz-Mie theory to the multi-sphere case, generally applicable to an arbitrary aggregate of spherical particles. The Monte Carlo(MC) method is designed to handle multiple scattering under some assumptions. In the multiple scattering computations, a good agreement has been shown from the comparison between MC and the four-flux model.

In this paper, multiple scattering properties of coal aggregates by GMM and MC are described. Using the GMM, the extinction efficiency Qext, scattering efficiency Qsca, the albedo W0 and the asymmetric factor g of a single aggregate consisting of 16 spheres are obtained,

Qextv=.53901E+01,Qabsv=.21135E+01,Qscav=.32769E+01,W0=0.607948,g=.29490E+00.

As the THz wave with incident on the coal aggregates, the distributions of scattering intensity and the effects of refractive indexes on it are given. With the data, the MC method is used to analyze the multiple scattering of an opaque slab consisting of some coal aggregates. The Reflectance and transmissivity of a coal slab as a function of optical thickness are shown.

7854-45, Poster Session

Optical properties study on liquid crystals in the terahertz range

H. Sun, Beijing Union Univ. (China) and Beijing institute of Technology (China); Q. Zhou, C. Zhang, Capital Normal Univ. (China)

Terahertz radiation, which occupies a large portion of the electromagnetic wave, is in the range between the far-infrared and microwave region. Because of its unique nature, terahertz radiation has wide application prospects in physics, chemistry, biomedicine, communications, radar and security checks, etc. Liquid crystal, which is a kind of macromolecule soft material with special properties in physical, chemical and optical, has been widely used in thin planar displays. Recently, much attention has been paid to non-display studies of liquid crystals, covering the fields of biology, chemistry, physics, material and engineering. In this paper, the transmission spectra of several liquid crystals such as RDP-92975 are measured by THz time-domain spectroscopy technique and free-space electro-optic sampling method. The absorption coefficient and refractive index of liquid crystals in the THz range are calculated. Furthermore, the optical parameters are compared and analyzed, expecting to fill the spectrum gap of liquid crystals in the THz range and provide the experimental and theoretical foundation for the application of liquid crystals.

7854-46, Poster Session

Characterization of terahertz emission from a laser-induced air plasma with a dc biased field

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Terahertz (THz) can be generated from a laser-induced air plasma. However, there is a drawback of this technique is that the conversion efficiency between infrared pulse and THz pulse is relatively low, which is about 10-9. If an external electric field effect on the air plasma, the terahertz intensity can be enhanced by several orders of magnitude. In our experiment, 100fs laser beam was focused by a lens and creating a 7 mm-length approximately air plasma. The air plasma was sandwiched by two parallel copperplate electrodes, which separated by a 7 mm gap, and the size of each electrode was 10×10mm2. If define the direction of plasma propagation as the axis X, and the polarization of pump pulse will be in X-Y plane. The external electric field was along the axis Y and axis Z, respectively, i.e. the dc biased was parallel and perpendicular to the polarization of THz, respectively. The voltage applied to the electrodes can be varied from 0 to 6kV. When the external electric field varied from 0 to 8.6kV/cm, and the changing of direction of dc electric field in ±Y axis and ± Z axis, respectively. We found that the total THz amplitude increase linearly with the voltage increase and the spectrum shift to low frequency with external electric field in all four conditions. The total polarization of the THz pulse changed from the elliptically polarization without dc bias to near-circular polarization with certain external electric field. Surprisingly, when we used the experimental data obtained with external electric field subtracted the data obtained without external electric field, we found that all the THz polarization in different voltage conditions unchanged, and they are all elliptical polarization. We consider that the reason for this phenomenon is the air plasma and dc bias is independent sometimes, i.e. they are two different THz source. The total intensity of THz is the sum of them. In addition, with the influence of the strong external electric field, the air plasma will be change into dipole, so the low-frequency shifts occurred. Finally, the residual elliptically polarization are result form dc biased field distribution.

7854-47, Poster Session

Polarization-controlled THz spectroscopic imaging for nondestructive inspection

L. Zhang, Capital Normal Univ. (China); H. Zhong, Peking Univ. (China); C. Deng, F. Yu, C. Zhang, Capital Normal Univ. (China); Y. Zhao, Beijing Institute of Technology (China)

Terahertz (THz) time-domain spectroscopy has been used to measure the time-dependent electric field of a terahertz pulse directly. After the application of the technique to imaging, some of materials have been visualized by the terahertz imaging technique. Some techniques have been developed recently to enable polarization characterization in THz imaging system, such as rotating the (001) axis of the (110)-oriented electro-optic sensor, using a modified electro-optic sampling setup with (111)-oriented electro-optic crystal, or employing birefringent material as polarization analyzer [10-13]. In this letter, we developed a THz polarization-controlled imaging modality. The polarization of the emitted THz wave is controlled to be horizontal and vertical through changing the relative phase of the fundamental and the second-harmonic waves in the two-color laser-induced air plasma THz generation configuration. The anisotropy of the industrial sprayed-on-foam-insulation (SOFI) is characterized by measuring its azimuthal angle dependent THz polarization response. The experimental results indicate that the vertically polarized incident THz wave is more sensitive to the polarization variation induced by the anisotropy of the detected sample than the horizontal polarization of the incident wave. This work demonstrated that this THz polarization controlled imaging system can be used for highly sensitive industrial inspection and biological related characterization.

7854-48, Poster Session

Radiation calibration and error analysis for an IR opto-electric system

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To perform radation calibration on a large-aperture IR opto-electric system, a radiation calibration system based on an extended area blackbody and a spectral calibration system based on an IR monochromatic collimator were established. The IR monochroic collimator was composed of a cavity blackbody, a converging lens, a monochromator and a collimator, which used to spectrally calibrate the IR opto-electric system to determine its normalized relative spectral resoponse function. A large extended area blackbody, which covered the input pupil and the field of view of the IR opto-electric system, was used to perform radiation calibration on it to determine its radiance responsivity. Error sources of radiation calibration were analyzed, and the uncertainty of the radiance responsivity was dependent on the stability of the IR system output value, the uncertainty of the radiation emitted from the extended area blackbody, the uncertainty of the spectral calibration for the IR system, and stability of the background radiation. The analysis and calculation results showed that the uncertainty of the radiance responsivity of the IR opto-electric was smaller 10%. Finally, some measures which help in reducing the error of radiation calibration of the IR opto-electric system were proposed.

7854-49, Poster Session

The experiment research on optical mirror's thermal deformation

S. Dai, S. Chang, K. Zhang, Z. Jiang, National Univ. of Defense Technology (China)

The optical system used in aerospace must work under a very difficult aerospace condition. The temperature between the sides which one is facing the sun and the other one is opposite the sun can reach about 200 . These temperature grids can bring thermal deformation to the optical components and then influence the whole system's image or detect results. To measure the deformation, we first establish a simulation environment, in this environment, we use a infrared light whose beam directly incident on one side of an optical mirror, and the thermal imager is used to measure the temperature distribution on the surface of the mirror and the Zygo GPI laser interferometer is used to measure the surface deformation. Finally we put all the deformation data into optical design software to analysis the aberrations of a typical Newton image system. These aberration data can be used to improve the thermal design of aerospace optical system. And the results are useful for the practical applications of the optical mirror in the aerospace environment.

7854-50, Poster Session

Reflect mode terahertz time domain spectroscopy for seal liquid detecting

Z. Zhang, Capital Normal Univ. (China)

We built a reflect mode terahertz time domain spectroscopy system for seal liquid detecting. It used air plasma THz emitter for getting a high THz power to 5mW and used ZnTe EO sample for getting high

sensitivity difference detection. Experiment demonstrates this system can detect the liquid in the seal container. We measured the reflection data on the second interface between the bottle and the inside liquid. It has a relation with the refraction coefficients of the liquid in the THz region by Fresnel formula. The liquid can be indentified by comparing the curves of reflection and a database of known liquid refraction coefficient. In this paper, water and alcohol were detected and indentified. In additional, the data processing and an analyzing for getting the reflection data on the second interface is discussed.

7854-51, Poster Session

Investigation of honeycomb structure using pulse infrared thermography method

H. Li, China Aero-Polytechnology Establishment (China)

To reduce weight and improve strength in the aerospace industry, composite structure has gained popularity as a replacement for conventional materials and structures, such as adhesive bonding and honeycomb structure. Honeycomb structures composed by a honeycomb core between two facesheets are very common on aerospace parts. However, the adhesive bonding process is more susceptible to quality variations during manufacturing than traditional joining methods. With the large increase in the use of composite materials and honeycomb structures, the need for high speed, large area inspection for fracture critical, sub-surface defects in aircraft, missiles and marine composites led to broad acceptance of infrared based NDT methods. Infrared thermography is one of several non-destructive testing techniques which can be used for defect detection in aircraft materials. Infrared thermography can be potentially useful, as it is quick, real time, non-contact and can examine over a relatively large area in one inspection procedure. In this paper, two kinds of defects which are of various size, shape and location below the test surface are planted in the honeycomb structure, they are all tested by pulsed thermography, analyze the thermal sequence and intensity graph got by this methods, it shows that pulsed thermography is an effective nondestructive technique for inspecting disbonding defect, can distinguish the location and the dimension of the defect exactly.

7854-52, Poster Session

A detection technology of THz based on surface plasmon resonance

B. Su, Capital Normal Univ. (China) and Institute of Microelectronics, Chinese Academy of Sciences (China)

This paper describes a new detection technology related to the bolometric micromechanical sensors for detecting THz radiation. The micromechanical sensor comprises thermo-sensitive bi-material micro-cantilever beam array with selective absorbers dedicated to THz radiation energy, micro-prism array and optical readout system based on surface plasmon resonance for detecting the bending of the micro-cantilever element. In static mode, incident radiation absorption raises the cantilever temperature and, as a result, it bends proportionally. The cantilever bending changes the thicknesses of the gap between the lower surface of the cantilever and the metallic thin film. It will result in a shift of the SPR angle. Consequently, the surface plasmons excitation efficiency and therewith the measured at a fixed incident angle reflectance of a metallic film will be changed almost proportionally to the cantilever bending. Therefore the incident radiation power can be determined via the metallic film reflectivity change. The paper introduces the bi-material for fabricating the micro-cantilever beam and their optimal thickness for the best deflection through computer simulation. The material of silicon was used to fabricate the micro-prism array, and the technique procedure for manufacturing the micro-prism and the micro-cantilever beam was described in detail. Because of its uncooled performance of the detection technology, the micromechanical sensor will have a low cost and ease of fabrication of large bi-dimensional array with an enhanced signal-to-noise ratio.

7854-53, Poster Session

Application of continuous-wave THz imaging in banknote discrimination

J. Yang, Shenzhen Institute of Advanced Technology (China)

THz wave can penetrate many materials which are opaque to visible or infrared light. The property that transmissions vary with materials or densities makes it suitable to measure the distribution of dielectric coefficient or thickness. When THz light propagates through a banknote of RMB, which is transparent for THz radiation, the transmitted THz radiation carries signals of security features. In this letter, experimental researches on banknote discrimination by continuous-wave THz imaging are demonstrated by using of an optically-pumped THz laser (OPTL, Sifir-50, Coherent) and a pyroelectric camera (PyrocamIII). The OPTL emits radiation at 158.51 μm (1.89THz) with about 70mW average power. The camera contains 124×124 element array of detectors. And real-time THz images of water-mark and security thread are achieved. THz images of genuine notes are clear and stable, while that of forged notes are confused and random. The watermark is generated by varying the paper thickness as the paper is being manufactured, while “watermark” on counterfeited notes is printed, so its THz imaging is indistinct or even no images appear. The security is the same. Results show that the authenticity of the tested banknote can be reliably determined by comparing its THz imaging with that of genuine banknotes. This research is only the first step in demonstrating the feasibility of banknote discrimination by THz imaging, however, THz technology provides a novel method of banknote discrimination.

7854-54, Poster Session

Synthesis arrangement and parity correction of 480×6 linear array infrared detector

Q. Wang, P. Hong, B. Wang, C. Wang, Huazhong Institute of Electro-Optics (China)

A signal processing technique for 480×6 linear array IR FPA is introduced in this paper. According to the configuration and technical specification of the detector, which has multi channels, channels mixing, high speed outputs and separate columns between odd and even, a real time digital processing unit based on the CPLD, FPGA and DSP has been developed to achieve the data synthesis and arrangement function and the parity correction algorithm. A special interface circuit with 4 CPLDs is designed to complete the first synthesis step where the 16 channels of data are combined into 4 channels. The second step is finished in FPGA and ROM address encoder where the 4 channels of data are combined into 1 channel. Then a simulation experiment is introduced to show the logic validation of arrangement function. For output data synchronization, FIFO is adopted to achieve the delay between odd and even channels in the parity correction. When the scanning direction is in odd-before-even order, data of odd channels enters the columns synthesis unit without any processing. Data of even channels shall be processed in the columns synthesis unit after entering the FIFO unit first and experiencing the delay process. In even-before-odd order, data of odd channels experiences the delay process while the even ones not. Thereby the pre-processing before image processing of 480×6 linear array thermal imager is accomplished. To verify the design, output images are shown in 800×480 format.

7854-55, Poster Session

Research of the solar photovoltaic cells output characteristics influenced by infrared wave in the solar spectrum

B. Su, Capital Normal Univ. (China)

The energy of solar radiation on the earth mainly concentrates in 0.29~3μm wavelength range, where infrared wave accounts for 53 percent, visible light accounts for 44% and ultraviolet accounts for 3%. For the photovoltaic cells, different light coming from solar radiation has different energy and different penetration depth. For the short waves, the photovoltaic cells have large absorption coefficient and have small absorption coefficient for the long waves. As for the sunlight in the material of the battery, if the photon energy is greater than the semiconductor forbidden bandwidth, it will inspire electron-hole pairs, and vice versa. When the range of wavelength is 0.5 1.2μm, silicon photovoltaic cells can transform the light energy into electrical energy and heat energy, and only heat energy to the light which wavelength is greater than 1.2μm. From above, the photovoltaic cells will make most of the sunlight change into heat energy, which will influence the characteristics of the photovoltaic cells unless the heat was dissipated in time. In the paper, the thermal battery pasted on the back of the photovoltaic cells is adopted to absorb the heat, so the photovoltaic cells can keep a good state long time. The strategy of energy management is presented in the paper in detail.

7854-56, Poster Session

Design of infrared images high speed transmission technology based on fiber

X. Yang, D. Pan, P. Hong, C. Wang, Huazhong Institute of Electro-Optics (China)

Due to the development of IR FPAs resolution and the transmission speed of the images, the requirement for the high speed IR images transmission becomes a significant part in the whole IR imaging system. The fiber based transmission method is proved to be a promising technique which can replace the traditional methods based on the electrical signals. This paper introduces the design of digital IR images transmission technique based on fiber, according to the characteristics of IR imaging data. This long wire transmission is accomplished utilizing the FPGA which is designed to control the data cushion synthesis process, receive the high speed imaging data and send out the real time VGA images. FPGA provides the reference clock signals to help the encoder convert the 16 bits parallel imaging data into the serial LVDS signals. Then the MAX9376 chip is introduced to convert the LVDS signals into the LVPECL signals, for only the LVPECL signals can be received by the laser diode. The receiving process is just opposite, where the LVPECL signals are finally converted into the parallel data. To verify this design, the VGA controller function is achieved by Verilog HDL programming in FPGA, so that the parallel IR imaging data can be converted into the high resolution images. The experiment images show that the effective resolution of the image in 64Mhz is 1024×800, and the transmission rate reaches 1.125Gb/s which is much higher than the traditional methods and fully satisfies the requirement for the long distance IR imaging data transmission.

7854-57, Poster Session

Twin-channel optical readout technique for microcantilever IR image system

X. Chu, Y. Zhao, L. Dong, Beijing Institute of Technology (China)

Uncooled focal plane array (FPA) IR imaging system based on MOEMS technology are developed rapidly these years.

7854-58, Poster Session

Research on the improved nonuniformity correction algorithm of the cooled infrared FPA

D. Zhan, C. Wang, Z. Zhang, P. Hong, Huazhong Institute of Electro-Optics (China)

Fixed pattern noise (FPN) of the cooled infrared FPAs has a significant impact on the imaging quality. In this paper, the related parameters are tested in lab based on the cooled 320×256 MCT FPAs produced by Sofradir. Then the relation between residual FPN (RFPN) and the factors which may influence RFPN are discussed. Further, this paper analyzes the scene based nonuniformity correction algorithm. This NUC algorithm is based on an improved self-adaptive least mean square (LMS) algorithm. For the traditional LMS algorithm, there are defects in the solution process for the expectation values of the pending pixels. Meanwhile, the uncertainty of initial coefficients may cause a long constringency period. The algorithm introduced in this paper improves the solution method to the expectation values of the pixels. The reciprocal of gray scale grads is smoothed as the coefficients. In this way, the noise can be smoothed, and the internal points in the pixels area will be enhanced. The correction gain and offset obtained in the two-points temperature correction method are taken as the initial values, so that the iterative algorithm for the coefficients can be optimized without increasing the complexity of the LMS algorithm. Moreover, the constringency speed will be faster, and the uniformity error can be controlled at the minimum level. Finally, this NUC algorithm is achieved utilizing a FPGA+DSP circuit system. According to the practical images, the correction speed and images quality of the new algorithm are improved significantly compared to the original one.

7854-59, Poster Session

A novel frequency-tunable metallic grating structure for trapping broadband THz surface plasmons

J. Li, C. Yang, Tsinghua Univ. (China)

Currently, much effort is being devoted into slowing down the velocity of light by means of surface plasmon-assisted metallic structure, based on its capability to spatially confine electromagnetic energy within subwavelength dimension. Especially in THz frequency range, slow surface plasmon polaritons(SPPs) occupy extremely low loss and low dispersion, making it a promising tool in future highly miniaturized integrated optical devices for THz photonics or optoelectronics. Some structures have already been raised to achieve ultraslow or trapped SPPs, which, however, lack frequency tunability. So here we propose a novel frequency-tunable metallic grating for trapping broadband THz SPPs.

First a metallic grating of constant depth is introduced beneath the surface of a metal film, then dielectric material with graded depth is filled in the grooves. With the graded depth, SPP dispersion curves and cutoff frequencies vary at different locations. Since the group velocity of SPPs at the cutoff frequency is extremely low, the guided SPPs at different frequencies can be localized at different spatial positions and form a THz broadband “rainbow”, as verified by finite difference time domain (FDTD) simulation.

More importantly, our design allows us to more freely relocate the trapped waves, i.e. it holds frequency tunability. By temperature-tuning the refractive index of the dielectric material and omitting expansion or contraction of the metal, we can change the dispersion relations thus the cutoff frequencies, so for a specific position, SPPs at a different frequency can be localized there. From our simulation, the cutoff frequency goes through a decrease of ~4GHz when the refractive index increases by 0.1%.

7854-60, Poster Session

Experiment tests of atmospheric turbulence effects on the infrared thermal imagers performance

C. Wang, Z. Zhang, P. Hong, Q. Wang, Huazhong Institute of Electro-Optics (China)

Atmospheric turbulence has a strong impact on the performance of long range IR thermal imaging system. This research indicated the experiment method to analyze and predict the strength of turbulence and range performance of IR thermal imagers. In order to describe the strength of atmospheric turbulence, this project measured the values of structure constant of refractive index fluctuations, Cn2. The experiments were performed with two identical laser scintillometers in moderate climate in Wuhan, China. The instrument collected Cn2 values integrated over the horizontal optical path of 100m. As Cn2 usually varies randomly, a model which is expressed as a function of time, temperature, humidity and wind speed is usually utilized to predict Cn2 values in engineering applications. In this paper, the calculated results were compared to the experiment data which were collected continuously for three months in summer. Then the engineering model is modified to fit the experiment data. Meanwhile, two IR thermal imagers in MWIR and LWIR bands were installed in the same location. These thermal imagers provided the performance of detection range and identification range in the same atmospheric condition. After that, the simulation tool is utilized to calculate the range values based on the imaging system characteristics, atmospheric condition and Cn2 values. This paper analyzed the range values in different groups and proved the validity of the range prediction tool. The range advantage for the MWIR band at low turbulence values was proved in the experiment. Further, the experiment results also proved that the LWIR imager could surpass the performance of MWIR at high turbulence values.

7854-61, Poster Session

Design of a zoom optical system with a front stop

J. Zhang, X. Zhang, X. Feng, Changchun Institute of Optics, Fine Mechanics and Physics (China)

Generally, in the most case, the system stop of a zoom lens is located at the middle part of the optical system, and is usually near the first surface of the rear fixed group, when considering some factors such as aberration balancing, and construction. From the point of view of the actual requirement, a visible zoom optical system whose system stop is located in front and zoom ratio is three was proposed. The design method and result was given, where influences of various aberrations on the optical system were sufficiently considered, and the problem of second order spectrum correction was particularly focused on. The focal length of the optical system is 240mm~720mm, the diameter of the system entrance pupil is 72mm, the MTF value is close to the diffraction limit at the Nyquist frequency of 68lp/mm, and all the MTF values at various focal positions are higher than 0.3.

7854-62, Poster Session

Terahertz wave opto-mechanical scanner for security

C. Deng, Beijing Institute of Technology (China)

This paper describes a new opto-mechanical scanner that is hopeful about future apply for terahertz (THz) imaging in security applications. The target of using this scanner is portal screening of personnel for high-resolution imaging of concealed threat objects. It is not only applied to active THz imaging but also applied to passive THz imaging. THz radiation can penetrate many materials that are opaque to visible and infrared light, such as plastics, cardboard, textiles and so on. Compare to microwave radiation, THz radiation have a shorter wavelength. it has a higher spatial resolution. Compared to X-ray, THz photon energy is only 4.1 milli-electron volt. it is harmless to living organisms. Compared to infrared, THz radiation is less sensitive to thermal background noise. So the Thz imaging technology has a potential to be applicable in security inspection at airports, stations and other public place. Now, the most THz imaging system works at point to point mechanical scan pattern. The speed of this raster scan is too slow to apply to practical field. 2-D THz array detector can be applied to real time imaging. But at present their cost is prohibitively high. Fortunately low cost, high performance, opto-mechanically scanner is able to meet the current requirements. An opto-mechanical scanner should be able to rapidly scan a 2-D image of the scene. It also should have high optical efficiency so that an image system can achieve the required thermal sensitivity with the minimum number of receivers. These ensure that it can easily operate at any wavelength, and be active or passive. The opto-mechanically scanning can meets these requirements and is being developed into a high performance, low-cost prototype system that hopefully will meet the future needs for THz security.

7854-63, Poster Session

The birefringence property of magnesium fluoride crystal in THz frequency region

F. Yu, L. Zhang, Capital Normal Univ. (China); H. Zhong, Peking Univ. (China); C. Deng, Beijing Institute of Technology (China); C. Zhang, Capital Normal Univ. (China)

Because precise control of THz polarization has gradually identified its importance in a number of applications, there is a pressing need to develop THz polarizing devices such as wave plates, polarization analyzers and polarization splitters, etc. In this letter, a 0 -cut magnesium fluoride (MgF2) crystal is investigated in 0.2-2.2 THz frequency region as a future candidate for THz wave plate. A standard THz-TDS system is employed: the predominantly p-polarized terahertz wave is emitted; a piece of 2 mm thick (110)-oriented ZnTe crystal was used as the sensor for electro-optical sampling detection. A polarization sensitive detection method is used. The azimuthal angle dependent transmittance in 0.2-2.2 THz frequency region for magnesium fluoride (MgF2) crystal is measured and the absorption coefficient and refractive index of the e ray and o ray is obtained. Results of the experiment demonstrates that magnesium fluoride (MgF2) crystal bears not only extremely large birefringence property, but also good transparency for THz emission, which means it is a candidate for THz polarization device. The capability of magnesium fluoride (MgF2) crystal as a THz wave plate is investigated. The agreement between experimental data and theoretical curve shows that its optical properties are sufficient for construction of wave plate operating in 0.2-2.2 THz frequency region. In addition, the difference between refractive index for the o ray and e ray is larger than crystalline quartz, which suggests that a thin magnesium fluoride crystal can be made into terahertz wave plate that is available for multi-frequency points.

7854-64, Poster Session

Fast realize infrared images simulation by inversing the scene of the visible light images

F. Bai, T. Bai, Beijing Institute of Technology (China)

The infrared imaging simulation technology as a very effective and economical means as well as its great significance plays an important role in modern precision-guided weapons research and development.

This paper is different from other traditional methods, which start from building the objects' thermal model to realize infrared images simulation. This paper obtains simulated infrared images of one target scene directly from its visible light scene. We get our research results just from find the mapping relationship from visible images and infrared images of the same targets at the same condition and environment. If I get enough mapping relationship, I can get a simulated infrared image required from a given visible image for just several seconds. Thereby realize fast infrared images simulation. In this paper, first it has introduced the basic theory of infrared image simulation, and analyzed the surface features of infrared radiation of typical ground targets and backgrounds. Then, introduce how to find the mapping relationship of the same goal from its visible light images and infrared images obtained under the same conditions, show the simulated images of the same condition under this mapping relationship and compare them with the real infrared images taken by thermal imaging system. Finally, we extended the mapping relationship to 3-5μm, 8-14μm, different weather conditions (sunny, cloudy), different imaging distance (close shot, long shot). It has been show that based on the experimental results this method can effectively improve the infrared simulation condition, which made the operation easy and practical.

7854-65, Poster Session

Identification of ores and gems using THz polarization

Z. Yu, Y. Zhang, X. Wang, Y. Cui, Capital Normal Univ. (China)

Terahertz (THz) spectroscopy and imaging technology has been proposed to have a lot of potential applications. In this presentation, the polarization information of various ores and gems in the THz frequency region has been investigated. The images of the samples for different polarization are captured by using a balanced polarization imaging system. The system is based on the THz quasi-near-field real-time imaging system presented by Xinke Wang et al. This setup systemically integrates the THz balanced EO sampling technique and the dynamic subtraction technique, which can effectively improve the signal to noise ratio in the time domain and the spectrum measurement accuracy of the imaging system. The imaging speed is dramatically reduced to several minutes by using two high speed CCDs which are used to detect two orthogonal polarization components of probe beam. The subtraction of two corresponding images presents the balanced image of the sample. By rotating the half wave plate inserted in the probe beam 45 degree, another polarization component of the THZ radiation which is orthogonal to the present one can be measured. The spectra of the samples on each pixel can be extracted from a series of images, thus the refractive indices, absorption coefficients, and polarization rotation coefficient can be drawn. The above information can be used to identify different ores and distinguish real gems, which may be of great importance in jewelry appraisal.

7854-66, Poster Session

Terahertz time-domain spectroscopy of Cd1-xZnxTe single crystal

R. Wang, Shanghai Institute of Technical Physics (China)

Cd1-xZnxTe single crystals were grown by Vertical Bridgman method. The optic and dielectric properties of Cd1-xZnxTe (x = 0.04) single crystals in 0.2–2.5 THz frequency range have been investigated by using transmission-type THz time-domain spectroscopy. Two absorption modes at 1.6 THz and at 2.1 THz were observed, which are attributed to the quasi-local mode of ZnTe in CdTe and to the CdTe 2TA phonon process, respectively. The complex refractive index and dielectric function were extracted from the measured transmittance and phase shift in 0.2–2.5 THz range.

7854-67, Poster Session

Fast calculation of object infrared spectral scattering based on CUDA

L. Li, W. Niu, Z. Wu, Xidian Univ. (China)

Infrared scattering spectral calculation is an important method of researching Aerial object scattering characteristic of sky and earth background IR irradiation. For non-Lambertian surface object, spectral scattering of each surface element is the function of incident directions and scattering directions, so the calculation about spectral scattering of background irradiation from the hemispheric space for each surface element is required. Commonly a object consists of too many surface elements, which results in enormous calculation and requires significant CPU time in the traditional computing platforms. Here, computational unified device architecture (CUDA) is used for paralleling the spectral scattering calculation from non-Lambertian object of sky and earth background irradiation. The bidirectional reflectance distribution function (BRDF) of five parameter model is used in object surface element scattering calculation. The calculation process is partitioned into many threads running in GPU kernel and each thread computes a visible surface element infrared spectral scattering intensity in a specific incident direction, then sum the calculation results of all threads through reduction to obtain the surface element scattering intensity. All visible surface elements' intensity are weighted and averaged to obtain the object surface scattering intensity. The flowchart of parallel algorithm is shown here. Finally, the comparison of results of the CPU calculation and CUDA parallel calculation of a cylinder shows that the CUDA parallel calculation speed improves more than two hundred times in meeting the accuracy, with a high engineering value.

7854-68, Poster Session

Calibrating a near-infrared hyperspectral imaging system

W. Wang, J. Paliwal, Univ. of Manitoba (Canada)

Near-infrared hyperspectral imaging technique gains much research popularity in recent years. A properly calibrated hyperspectral imaging system is crucial to successful extraction of meaningful data from sample of interest. In this article, we would like to focus on some of the inherent problems associated with a liquid crystal tunable filter (LCTF) based hyperspectral imaging system. Chromatic aberrations and non-uniformity pixel responses are discussed and solutions are proposed to minimize their impact on the image quality. We will talk about procedures to bring images acquired at different wavelengths back to focus. We also would like to discuss methods to compensate for the camera defects such as dead or hot pixels. In conclusion, the paper would like to illustrate the effects of aforementioned correction procedures on the hyperspectral images acquired on our system.

7854-69, Poster Session

The properties of vanadium oxide thin films before and after annealing in N2/H2 atmosphere for different hours

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Having excellent heat sensing performance, vanadium oxide films have been extensively applied in uncooled IR detectors. However, due to its complex structures and variety of valences, it is very difficult to produce films suited for the utilization. So, it makes great sense to find

out the relationship between macro and micro properties. In this paper, annealing experiments were performed at 450 for different hours on vanadium oxide films fabricated by RF magnetron sputtering. Changes in the electrical, structural properties and chemical composition were studied. From R-T measurement and calculation, it was found that both R and TCR (Temperature Coefficient of Resistance) of the films increased after annealing. AFM analysis revealed that both particle size and surface roughness were aggrandized greatly after annealing. XRD analysis showed that the as-sputtered film was almost amorphous while new phases V2O5(0 0 1) and VO2(0 1 1) appeared in the annealed films and the grain sizes varied between 10-40nm. Although the atmosphere is N2/H2, XPS analysis revealed that the annealing process added the ratio of O:V, which could be ascribed to the mixed O2. Through peak fitting, it was determined that large quantity of V in low valence states and even metal states existed in both as-sputtered and annealed films, which could be the crucial cause for the unstable performance of uncooled infrared detectors using these films. Therefore, fabricating parameters should be adjusted during the sputtering process to decrease the content of V in low valence states.

7854-70, Poster Session

The cryogenic readout system with GaAs JFETs for multi-pixel cameras

Y. Hibi, H. Matsuo, National Astronomical Observatory of Japan (Japan); H. Nagata, H. Ikeda, Japan Aerospace Exploration Agency (Japan); M. Fujiwara, National Institute of Information and Communications Technology (Japan)

Our purpose is to realize a multi-pixel sub-millimeter/terahertz camera with the superconductor - insulator - superconductor photon detectors. These detectors must be cooled below 1 K for their best performances. In our previous studies, we showed these detectors are practical.

Since these detectors have high impedance, signal amplifiers of each pixel must be setting aside of them for precise signal readout. Therefore, it is desirable that our new designed readout system work well even in cryogenic temperature.

We selected the n-type GaAs JFETs as cryogenic circuit elements. From our previous studies, the n-type GaAs JFETs have good cryogenic properties even when those power dissipations are low. We have designed several kinds of integration circuits (ICs) and demonstrated their performance at cryogenic temperature. Contents of ICs are following; AC coupled trans-impedance amplifiers (AC coupled CTIAs), voltage distributors for suppressing input offset voltage of AC coupled CTIAs, multiplexers with sample-and holds, and shift registers for controlling multiplex timing. The power dissipation of each circuit is 0.5 to 3 micro watts per channel.

We also have designed and manufactured 32-channel multi-chip-modules with these ICs. These modules can make 32-channel input photo current signals into one or two serial output voltage signal(s). Size of these is 40mm x 30mm x 2mm and estimated total power dissipation is around 400 micro watts. Now, we are preparing to demonstrate these modules.

In this presentation, we report cryogenic test results of these ICs, outline and estimated performances of the multi-chip modules, and application capability of this system.

7854-71, Poster Session

Analysis of holographic diffractive optical element used for fabricating THZ spectrum photonic crystals

Y. Liu, Institute of Armored Force Engineering (China)

In recent years, the field of Terahertz science and technology has entered a completely new phase of unprecedented expansion that is generating every growing levels of broad-based international attention. Terahertz band photonic crystals (PhCs) equipments must be having an extensive application promising.

Holographic lithography method is an easy way to get large area photonic crystals. Using a single diffractive optical element (DOE) to create a three-beam interference pattern is a more stable and robust approach for fabricating 2D PhCs. The central of DOE surrounded by three gratings oriented 120° relative to one another. Under the illumination of single linearly polarized beam with normal incidence, the three first-order diffracted beams of the gratings superimpose and form a 2D interference pattern. The DOC can be fabricated by holographic method.

In this paper, the types of holographic diffraction gratings are sinusoid gratings. As the polarization direction of linearly polarized light can be changed when the light passed from the gratings, in addition, the diffraction efficiencies are different when the incident linearly polarized light and grating vector have different included angles, the contrast ration of interference pattern will be reduced because of different polarization states and light intensity. To solve this problem, rigorous coupled-wave analysis (RCWA) is used to calculate the influence of grating depth and polarization angle on diffraction efficiency. By adjusting three angles between the polarization direction of incident lights and grating vectors and the parameters of grating depths and diffractions, uniform interference pattern can be obtained.

A project about fabricating DOS for THZ band 2D PhCs is proposed in this paper.

7854-72, Poster Session

Infrared thermal wave testing for building envelope

X. Li, S. Zhao, N. Wu, D. Chen, BeiHang Univ. (China)

Buildings are generally covered with ceramic tile or cement. It is easy to form defects such as voids, delaminations and other kinds of damage, since these structures are exposed outside, experienced cold and hot changes for a day or suffered from the wind and rain throughout a year. These defects greatly threaten human life and property security. Therefore detecting and evaluating the damage of the building outer surface are of great significance.

Infrared thermal wave testing is an active approach for a quantitative thermal scanning of the surface of various structures and elements. The cooling-down process of building structures after heating-up with an external radiation source was analyzed to detect defects inside and below the surface. In this paper, ceramic tiles containing voids with different sizes at various depths will be presented. The specimens were tested by pulsed infrared thermal wave testing. The results proved that this method is reliable in detecting the delaminated ceramic tiles on a building. Then real building walls detected by this method to explore the internal defects, and the types of defects were analyzed. Field testing for building outer-wall defects confirmed that not only infrared thermal wave testing is applicable to building envelope but also it is a good method with many advantages such as high speed, non-contact, and effective.

7854-73, Poster Session

Magnetic effects on superconducting tunnel junctions at different temperatures

C. Zhang, Purple Mountain Observatory (China)

With extremely high sensitivity, SIS (superconductor-insulator-superconductor) mixers are playing an increasingly important role in space THz astronomical and atmospheric observations. It is well known that SIS mixers are operated with the application of magnetic field to

suppress the Josephson effect, especially at THz frequencies. To meet the requirements of space applications such as low heat dissipation, high stability and miniaturization, here we compare the magnetic effects of a superconducting coil and a permanent magnet on 0.5 THz Nb and NbN SIS junctions, respectively. The Josephson current and subgap leakage current of the two kinds of SIS junctions are measured with different magnetic fields. Since NbN SIS junctions may work at as high a bath temperature as 10 K, which is of particular interest for space applications, we also investigate the magnetic effects on NbN SIS junctions at different temperatures. Detailed experimental and analytical results will be presented.

7854-74, Poster Session

Satellite thermal infrared remote sensing applications in the earthquake

L. Zhang, Beijing Normal Univ. (China)

Earthquake prediction is a remarkable scientific problems, the international multi-country attached great importance to the development of seismic monitoring technique, different times of earthquake scientists always strive to master the latest technology used in the seismic monitoring. Although different types of current seismic network has been all over the world, while the instruments and equipment has also been great progress, but still can not meet the requirements of earthquake prediction. Network monitoring, but get rid of stereotypes, use of modern seismic monitoring technology to explore new methods and techniques, such as satellite remote sensing technology has become China's earthquake research and earthquake prediction to improve the level of crucial importance. As the satellite remote sensing technology has covered a wide range of informative, real-time monitoring and high accuracy, and has attracted national attention and interest of the earthquake scientists. 80 years since the 20th century, the foreign seismologists have begun to satellite remote sensing technology for seismic activity of the attempt. Chinese seismologists first exploration seismic data using satellite thermal infrared radiation precursory and experimental research in simulation has done pioneering work and made significant progress. Although the use of satellite remote sensing technology to study and resolve the problem the earthquake is just the beginning, but for the existing earthquake monitoring and prediction system, the judge of this technology will help increase the capacity of earthquake region and the weather forecast, no doubt the earthquake for the 21st century monitoring and forecasting work that a new direction. This article describes the satellite thermal infrared remote sensing in earthquake monitoring and research progress in the application and analysis of satellite thermal infrared remote sensing in the thermal infrared surface temperature before and after the earthquake, discussed the formation mechanism of the method. This paper also analyzes the technology in the earthquake prediction problem, propose a future research priorities.

7854-75, Poster Session

Thermal infrared remote sensing to monitor soil moisture

L. Zhang, Beijing Normal Univ. (China)

In recent years, with the successful development of high-power and high-brightness LED chips and the continuous improvement of luminous efficiency, more and more high-power LED lamps begin to enter lighting field. At present, the input power of the commercial and high-power LED is generally 1W, the chip area is 1mm×1mm, and the heat flux reached 100 W/cm2. So high heat flux will make the chip junction temperature rise, and further cause the problem of failure rate increasing, light extraction efficiency decreasing and life time shortening. On the other hand, the chip junction temperature rising will cause red shift of its emission spectrum, thus color temperature quality will decline. Therefore, heat dissipation of high-power LED is the key technology to be solved. In this paper, the effects of the chip junction temperature on performance parameters and life time of high-power LED are discussed. The causes of the chip junction temperature rising are analyzed, and some methods to decrease chip junction temperature are given.

7854-76, Poster Session

Infrared scanning imaging system based on IR fiber bundle

W. Gang, Shanghai Institute of Technical Physics (China)

In infrared scanning imaging system, long linear-array detector is need for large field of view. Instead of using long linear-array detector, we couple a non-conventional IR fiber bundle and a small IRFPA whose format is 320×256 in system to implement 1024×4 format linear array imaging. The input of fiber bundle is long linear-array and output is plane-array. Fibers in IR fiber bundle are one to one mapping. Input terminal of fiber bundle is set at the focal plane of telescopic objective in system, and output terminal is coupled to IRFPA by coupling lens. By calibrating the position of each fiber in IRFPA, together with the mapping relationship between input and output of fiber bundle, a look-up table is established. With the table, we restore the line object image. According to the scanning period of system, we finally get the infrared scanning image. This kind of infrared system is noval and has good promising in future.

7854-77, Poster Session

A novel design of a high performance passive millimeter-wave imager for security

W. Zhu, Y. Zhao, L. Dong, Beijing Institute of Technology (China)

The passive millimeter wave (PMMW) imaging technology has adopted in a wide range of military and civil practical applications, such as remote sensing, blind landing, navigation and security scanning. Because of its good transparency of clothing at millimeter wave band, a millimeter wave radiometer can be used to imaging and distinguish concealed contraband beneath clothing, for example, guns, knives, detonator and so on.

This paper describes a high performance optical mechanical scanning millimeter-wave imager for airport security. This imager is constituted of three mirrors, they are: a concave mirror whose function is to converge the millimeter-wave, a line scanning mirror and a frame scanning mirror. It employs a crank-rocker mechanism to generate a high speed line scanning, which produces a horizontal FOV (field of view) of 24°. Accompany with a frame scanning mirror of ±25° in vertical direction, it brings about a two-dimensional scan of the scene of 2m×1m which is 2 meters away from the system. By this scanning mechanism, we use a single channel of a 94GHz receiver to collect the radiation from the concave mirror which acts as the focusing element. Then the output of the receiver passes to an A/D converter and is displayed on a conventional PC. The new scanning arrangement meets these requirements and is being developed into a high performance, low-cost, compact prototype system that hopefully will meet the present and future needs for millimeter-wave and terahertz imaging.

7854-78, Poster Session

Wavelet denoising of pulsed laser radar signals

X. Cai, L. Wang, S. Yang, J. Liu, Heilongjiang Univ. (China)

Ladar (Laser Radar) is a radar that uses laser in place of the radio-frequency signal used in conventional radar. In contrast to a passive optical imager which only produces two dimensional intensity images, a laser radar system can produce three dimensional images of the scene. The range accuracy and resolution for a pulsed laser radar depend not only on the ladar parameters such as laser pulse width, pulse shape, the receiver's bandwidth and noise generated timing jitter, walk, nonlinearity and drift but also on the target characteristic and the signal processing approach. In this paper, A wavelet filter is designed to denoise the contaminated laser signals. For the given laser signals, the filter based on the combination of correlation and thresholding is proposed. The gain of the filter is compared with the traditional thresholding method. It is shown that the combination of the correlation and thresholding denoising method is more effective for the weak laser radar signal processing compared with the traditional thresholding method.

7854-79, Poster Session

Computational reconstruction of thermal infrared integral image based on modeling sensor physical effects

X. Wang, Xidian Univ. (China)

a thermal infrared integral imaging system is proposed for acquiring and displaying 3D surface infrared emission radiance information of a real target. To intuitively analyze infrared integral image quality, we perform the numerical simulation and reconstruction of thermal integral image based on the modeling of sensor physical effects. Specifically, the 3D object with thermal infrared radiance texture is first focused into infrared elemental images by combining the virtual model of infrared microlens array and the response characteristics of detector array. Further, the displayed thermal elemental images are obtained by simulating main degradation factors including the spatial filtering blur, sampling effects, and spatial-temporal noise involved in practical infrared sensor. Finally, the thermal infrared 3D integral image is reconstructed by plane-plane reconstruction technique method based on the degraded elemental images. Their simulation results are demonstrated and analyzed.

7854-80, Poster Session

Infrared image enhancement based on the edge detection and mathematical morphology

L. Zhang, Y. Zhao, L. Dong, X. Chu, Beijing Institute of Technology (China)

The development of the uncooled infrared imaging technology from military necessity. At present, It is widely applied in industrial, medicine, scientific and technological research and so on. The infrared radiation temperature distribution of the measured object's surface can be observed visually. The collection of infrared images from our laboratory has following characteristics:(1) Strong spatial correlation, Low contrast, Poor visual effect;(2), Without color or shadows because of gray image, and has low resolution;(3) Low definition compare to the visible light image ;(4) Many kinds of noise are brought by the random disturbances of the external environment. Digital image processing are widely applied in many areas, it can now be studied up close and in detail in many research field. It has become one kind of important means of the human visual continuation. Traditional methods for image enhancement cannot capture the geometric information of images and tend to amplify noise. In order to remove noise and improve visual effect. Meanwhile, To overcome the above enhancement issues . The mathematical model of FPA unit was constructed based on matrix transformation theory. According to characteristics of FPA, Image enhancement algorithm which combined with mathematical morphology and edge detection are established. First of all, Image profile is obtained by using the edge detection combine with mathematical morphological operators. And then, through filling the template profile by original image to get the ideal background image, The image noise can be removed on the base of the above method. The experiment show that utilizing the proposed algorithm can enhance image detail and the signal to noise ratio.

7854-81, Poster Session

A novel scheme for simultaneous transmission of 10-Gb/s baseband and 20-GHz microwave signals in radio-over-fiber system

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Radio over fiber (ROF) system is an essential technology for the provision of untethered access to broadband wireless communications. Next-generation access networks are driving the convergence of wired and wireless services to offer end users greater choice, convenience, and a variety of ultrahigh bandwidth services in a cost-efficiency way. Therefore generation and transmission of high-speed baseband and RF signals with a simple and reliable configuration are vital to successful deployment in real networks. A novel ROF scheme to simultaneously modulate and transmit 10-Gb/s baseband and 20-GHz microwave signals on a single wavelength using single-sideband (SSB) modulation technique is proposed and verified by simulation. The proposed scheme is based on a Dual-Parallel Mach-Zehnder Modulator (DPMZM). The scheme can carry the microwave signals on either the upper sideband(USB) or the lower sideband(LSB) only and the baseband signals on the other sideband. Therefore the crosstalk between the signals with dual services is very small. The optical 20-GHz millimeter wave (mm-wave) carrier is generated by means of subcarrier-multiplexing (SCM) technique to carry 155-Mb/s baseband signals while 10-Gb/s baseband signals are imposed on the original optical carrier via SSB modulation. The simulated result of BER and the eye diagram are achieved separately. The eye diagram is clearly opened, the Q factor of it is about 9, and the jitter is very small. The signals with dual services are successfully transmitted over 50-km single-mode fiber.

7854-82, Poster Session

Fiber-based micro-cantilever infrared read-out system

C. Gong, M. Hui, L. Dong, Y. Zhao, Y. Guo, Beijing Institute of Technology (China)

This paper describes a new concept to micro-cantilever infrared read-out system for detecting infrared radiation. This concept is based on fiber panel. It is known that the loss of Light transmission in fiber is quite low, and the anti-interference ability of fiber is strong when transfering light. Taking into account the advantages of optical fiber, we add optical fiber panel into the micro-cantilever read-out system to modulating the reflected light of micro-mirrors and reducing the noise of optical read-out system. We conducted a theoretical analysis and designed an optical fiber-based micro-cantilever infrared read-out system. We believe that the micro-cantilever infrared read-out system based on fiber panel can provide a low cost and high reliability suggestion for infrared imaging system.

7854-83, Poster Session

Measurement of the anti-alias filter response curve slope in Fourier transform spectrometers

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Before sampling the interferogram in Fourier transform spectrometer (FTS), there is an anti-alias analog filter to reduce the aliased noise. When the mirror velocity fluctuates, the frequency of the electrical signals will fluctuate. Since the analog filter has a roll off, the fluctuation in frequency can cause signal amplitude fluctuations that can have the appearance of noise in the interferogram. To reduce the mirror velocity error, the slope of the filter response curve needs to have flat amplitude response in the frequency range we need. We design an analog electrical filter with a sixth-order Butterworth low pass filter and a second-order high pass filter to meet the requirements of the FTS. The slope of the filter is less than 10-4 in the frequency range we need. To test the slope of the filter response, a method based on discrete time Fourier transform (DTFT) is adopted. A sweep signal from the signal generator is used to obtain the amplitude response trend. Fine measurement is then carried out in the frequency range that corresponds to the spectral range of the FTS. A precision signal generator is needed to generate a sinusoidal excitation with high frequency stability and high amplitude stability. The output of the filter is measured when the sinusoidal excitation is used as the filter input at the edge frequency that has the largest slope in the band. Multi-sampling is used to achieve high accuracy. If the slope on these frequencies can meet the requirements, the slope of the filter response in the band will meet the requirements. By using discrete time Fourier transform (DTFT) technique to process the sampling data, the influence of the 50Hz electrical interference and other noise is reduced and the accuracy of the measurement is improved. Studies show the measurement accuracy of the filter slope based on DTFT is much better than that based on direct signal amplitude measurement. Test results indicate the DTFT method meet the requirements for the anti-alias filter testing of the FTS.

7854-84, Poster Session

Study on peak-seeking algorithm for wavelength in Fourier transform infrared spectrometer

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There are 3 kinds of algorithms, the classic algorithm, center of gravity algorithm and the second derivative peak-searching algorithm, who are widely used now have been discussed in the paper. The similarities and differences of them are also analyzed in this paper.

7854-85, Poster Session

High quality continuous-wave THz imaging with 2.53THz OPTL and a pyroelectric detector

P. Bing, Tianjin Univ. (China)

Terahertz wave compared with the traditional light sources have many unique properties, since THz has higher spatial resolution because of its high frequency and doesn't produce damaging effects on biological tissue due to its low energy. THz continuous-wave (THz-CW) imaging technique developed very quickly. However, its imaging quality was poor. In this paper, we put forward the high-quality THz imaging. There are several factors which will affect the imaging quality such as THz power, wavelength, spot size, step of stepper motor, frequency of chopper, responsively of detector and so on. We use the FIRL-100 produced by Edinburgh Instrument as THz source. THz source pumped by CO2 laser can generate 118μm wave whose highest power can reach 150mW, so it can provide higher THz frequency and power than other THz source. The resolution of imaging system is mainly determined by spot size on the surface of sample which can be focused to submillimeter in our system. The smaller step of stepper motor is, the more pixels the unit area has, thus higher resolution imaging can be obtained. What is more, pyroelectric detector used in our experiment not only can work at room temperature but also has high responsivity at low modulation frequency of chopper. Considering above factors, we achieved a high-quality imaging which can identify the object about 0.4mm.

7854-86, Poster Session

The light weight study of the W-style radiant cooler

L. Fu, Shanghai Institute of Technical Physics (China)

The radiant cooler is widely used in long life aircrafts at present, because it has some prominent excellences. With the development of the space infrared detect technology, the radiant cooler should provide lower temperature and more cooling capacity in order to obtain particular observation information. The radiant cooler's size will become bigger even to the meter size. So it is time to solve the difficult problem to design the radiant cooler of light weight with excellent thermal capability and better mechanical capability.

We have performed the light weight study of the W-style radiant cooler, which is constructed in two stages. The radiant cooler mainly consists of housing, earth shield, first stage radiator, second stage patch and support system. The main weight of the radiant cooler is focused on the housing, first stage radiator and earth shield, so we optimized the parts using the finite element method. Finally, we have acquired the optimizing radiant cooler with the 17.3% light weight ratio. At the same time, the thermal capacity is unchanged and the mechanical capacity is enhanced by the vibration test verification. The results are very useful for designing the next generation radiant cooler with lower temperature and more cooling capacity.

7854-87, Poster Session

Contamination effects on radiant cooler

H. Xu, D. Dong, Shanghai Institute of Technical Physics (China)

The radiant cooler is used to cool optics and detectors to reduce signal noise in infrared (IR) telescopes. In spaceborne applications, temperatures as low as about 60 K can be achieved by a suitably designed radiant cooler radiating into space. The low effective sink temperature of deep space provides an ideal environment for the passive radiant cooling of IR detectors and related devices to the temperatures indicated. This approach involves no moving parts, provides inherently long life, and requires no power.

FengYun-3 meteorological satellite's payloads Infrared Atmospheric Sounder (IRAS), Visible and Infrared Radiometer (VIRR) and Medium Resolution Spectral Imager (MERSI) are optical instruments with infrared channels and three passive radiant coolers are used to cool respective IR detectors.

In-orbit radiant cooler could be contaminated by excessive molecular, particulate and outgassing. One of the significant contamination effects on the radiant cooler is that outgassing products form spacecraft materials degrade system performance by changing thermal properties.

The contamination can change the emittance, solar absorptance and scattering of the surface of optical reflector and earth shield. During the spacecraft buildup process, contaminants may accumulate on hardware

surfaces. Particulate or molecular films may increase scatter or adsorb energy at various wavelengths. This could result in the decrease in the ability of a radiant cooler to dissipate heat from the cold patch. The working performance of radiant cooler would be decreased.

7854-88, Poster Session

THz spectroscopy and polarization of jade

X. Guo, W. Xiong, J. Shen, Capital Normal Univ. (China)

Identification using Terahertz Time-Domain Spectroscopy (THz-TDS) technique has been widely applied in the field of illicit drugs and explosive detection. However, this technique can not be used in jade. In this paper, we present various properties of jade at THz field, including the identification and polarization analysis. It provides detailed and integrated studies of jade at THz field. The main works in this paper are summarized as follows:

In the first part, Hotan Jade, Suet white jade and Xiuyan Jade are tested using THz-TDS technique. The characteristic absorption spectra and refractive index are obtained in the range of 0.2 to 2.6 THz. The experimental results show that different samples have different absorption characters and the refractive index in the range of 0.2-2.6THz. The results indicate that it is feasible to apply THz-TDS technique for identification of Jade, which provides a new approach for the nondestructive testing of Jade.

Another part of this paper presents polarization analysis of THz pulse passing through a bulk jade. Owing to birefringence effect, the temporal THz waveform through a thickness enough jade has two peaks, coming from ordinary beam and extraordinary beam, respectively. Studying the absorption spectra and the transmission temporal THz waveform of this bulk jade, we could remove fake absorption features caused by material birefringence and get the real absorption spectra of jade which indicates the information of sample accurately.

7854-89, Poster Session

Carrier relaxations in trap states of GaInNAs and HgCdTe thin films

F. Ma, Shanghai Institute of Technical Physics (China)

Degenerate pump-probe experiments have been performed with GaInNAs and HgCdTe thin films. The differential transmission versus probe delay time shows a negative value for both films, indicating a photoinduced absorption from the trap states. After the negative minimum the differential transmission resumes to zero with long time constants. A rate equation formalism has been employed to model the carrier dynamics. The calculations fit the experimental differential transmission very well. The extracted time constants show that in relaxing to the equilibrium state the carriers in the trap states of GaInNAs decay with a single time constant of 1.2 ns, while those in HgCdTe show two time constants of 0.9 ns and 13 ps, respectively. This implies that there exist two types of deep level traps, fast and slow, in HgCdTe thin films.

7854-90, Poster Session

The study of atmospheric pollution using terahertz wave

H. Cai, D. Wang, J. Shen, Capital Normal Univ. (China)

Terahertz (THz) radiation is a new type of far infrared coherent radiation sources. In recent years, THz time domain spectroscopy (THz-TDS) technique has been proposed and verified to be a non invasive diagnostic tool to identify substances since many of them, such as illicit drugs and explosives, have characteristic absorption spectrum (i.e. fingerprint spectrum). In this paper, Terahertz Time-Domain Spectroscopy is used to study the characteristic of such air pollution gases as mist, dust and harmful gases in THz band.

In our experiments, the THz wave generates from the ionized gas plasmas by four-wave mixing. It is a promising source for terahertz time-domain spectroscopy for its high intensity of THz pulse and wide bandwidth. ZnTe is used to detect the THz radiation by electro-optic sampling. In order to study the characteristic of gases, we designed a gas chamber with two windows. The windows of the chamber are made of Polytetrafluoroethylene (PTFE) which has a low absorption for THz. Then the chamber is flushed with gases. The gas pressure in the chamber can be controlled by a barometer and air pump. Both the temporal wave forms which pass through the gas sample and without it are measured. By using fast Fourier transformation (FFT), the frequency domain spectra of both the reference and the sample can be obtained. Then the absorption spectrum, refraction index and extinction coefficient of the gases are obtained in the range of 0.2 to 2.6 THz. We also investigated the influence of pressure on absorption spectrum by changing the pressure of the gases in a chamber which is specially designed. The experimental results indicate that the absorption peak is become sharper with decreasing the pressure. This work establishes the THz spectra database of pollutants for future identification and study. Our experiments prove that terahertz Time-Domain Spectroscopy technique should be a powerful candidate for environmental protection as an effective means of detecting atmospheric pollutants.

7854-91, Poster Session

Absorption peaks study of -Zn3BPO7 crystal in THz band

H. Ju, Beijing Technology and Business Univ. (China); B. Hou, Beijing Univ. of Technology (China); X. Li, B. Li, Beijing Technology and Business Univ. (China)

Using electro-optic sampling technique and helping with the application of THz time-domain spectroscopy-transmission equipment, the reference THz wave and the sample THz wave has been measured in a range from 0.3 THz to 3.0 THz, and the absorption index has been obtained. Absorption peaks of -Zn3BPO7 crystal sample are found in 1.396 THz, 2.002 THz, 2.476 THz and 2.674 THz. The first important condition of the direct interaction between lattice and light is that they must have the same frequency and wave vector; also lattice vibration mode should be transverse because the light is electromagnetic wave. The absorption peaks are found integer times the optical phonon basically after calculation. The sample shows great resonance absorption. Ten longitudinal optical phonon points are detected from the No. 1 to No. 11. One hundred and fifteen transverse optical phonon points are detected from the No. 14 to No. 135.

7854-92, Poster Session

Terahertz imaging technique and application in large scale integrated circuit failure inspection

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Terahertz ray usually means the electromagnetic whose frequencies lies in between 0.1THz~10THz, the waveband region of the electromagnetic spectrum lies in the gap between microwaves and infrared ray. With the development of laser techniques, quantum trap techniques and compound semiconductor techniques, many new terahertz techniques have been pioneered, motivated in part by the vast range of possible applications for terahertz imaging, sensing, and spectroscopy. There are three prime motivations for this interest: (a) THz radiation can detect concealed weapons because many non-metallic, non-polar materials

are transparent to THz radiation; (b) target compounds such as explosives and illicit drugs have characteristic THz spectra that can be used to identify these compounds and (c) THz radiation poses no health risk for scanning of people because THz photon energy is only millieV. THz imaging technique was introduced, and compared with microwaves imaging and infrared ray imaging, THz imaging can give us not only the density picture but also the phase information within frequency domain. As a result, THz imaging technology has significant scientific value and extensive application foreground in environmental monitoring, medical diagnosis, nondestructive examination and security detection. There are two important considerations that favour THz imaging for industrial applications: (a) spatial resolution and (b) spectroscopic signatures. Terahertz detection inherently has a roughly ten times better spatial resolution compared to millimeter waves systems simply because the electromagnetic wavelength of THz radiation is roughly ten times shorter than millimeter waves radiation. Consequently, images of suspicious objects such as concealed metallic or metal weapons are much sharper and more readily identified when imaged with THz imaging scanners. On the base of these, the application of THz imaging in nondestructive examination, more concretely in large scale circuit failure inspection was illuminated, and the important techniques of this application were introduced, also future prospects were discussed. With the development of correlative technology of THz, we can draw a conclusion that THz imaging technology will have nice application foreground.

7854-93, Poster Session

a design of thz modulator use the photo-carrier surface plasma effect

P. Yang, J. Yao, Z. Di, X. Ding, Tianjin Univ. (China)

A design of light modulator for THz amplitude and phase modulations has been presented in this paper. Simplest versus of the Drude model is adopted, in which the collision damping is independent of the carrier energy. In our experiment, we use THz-TDS as THz source and detector. A laser whose wavelength is 808nm was used to irradiate the intrinsic Si(high-resistance) wafer, so as to let it generate the Photo-carriers, and to influence the conductance . The Photo-carriers will change the absorption coefficient of the THz wave and also influence the dielectric of the sample, hence to control the characteristics of the THz wave in the silicon wafer . The transmission and refract characteristics of the silicon wafer during THz range have been measured when it under the irradiation of the laser . By changing the light intensity, due to the different photon-generated carrier concentration, the single transmission of the THz wave in the silicon wafer sample is changing remarkable . Theoretically, the modulation depth can be more than 80%. The experiment shows that it is feasible to control the transmission of the THz wave in a silicon wafer by using a laser. Base on these theory, we present our design of light modulator for THz, and show the Digital simulation of our design. Also, according to this design theory, Optical/ electronic integrated modulation of THz can be realized, that will be our future work

7854-94, Poster Session

Cherenkov quasi-phase-matched THz-wave radiation based on deference frequency generation

D. Xu, Tianjin Univ. (China)

For DFG in an optical waveguide, Cherenkov-type phase matching is a surface-emitting generation method, where lights of two different frequencies are taken as a guided mode, and a THz wave is taken as a substrate radiation mode. Quasi-phase-matched (QPM) has been used to guided-to-guided interaction in the waveguide, which leads to this interaction being significantly enhanced due to the use of d33, the largest nonlinear coefficient in LiNbO3 crystals. Compared with conventional DFG, the QPM Cherenkov configuration can provide higher conversion efficiencies due to the use of d33, and at the same time, maintain the previous advantages on the wide phase-matching bandwidth and large tolerance of variations in pump wavelength and waveguide parameter.

In this paper, THz radiation with optical difference frequency generation in the form of Cerenkov radiation from a planar waveguide is analyzed in detail by a coupled-mode theory. An approximate solution is given which expresses the DFG efficiency in terms of periodically poled waveguide parameters such as period, a wave guiding layer thickness, and the optical nonlinearities of a wave guiding layer and a substrate. Numerical examples are plotted for a periodically poled lithium-niobate (PPLN) crystal. Finally, the significant effect of a periodic modulation of the sign of an optical nonlinear d constant is discussed.

7854-95, Poster Session

Excitonic optical absorption in quantum wells under intense terahertz waves polarized along the grown direction

Y. Li, Shangluo Univ. (China)

Excitonic optical absorption in quantum wells (QWs) under intense terahertz (THz) waves polarized along the grown-direction is investigated. The characteristics induced by the strong THz field in the optical absorption spectrum near the band gap edge are analyzed by coherent wave approach. The calculated results with and without the presence of the THz fields are presented. It shows that the excitonic absorption peaks are splitted or broaden when the illuminating intense THz wave is near resonance or out of resonance. The presence of an intense THz field results in the formation of replicas in the absorption spectrum. The replica present on both sides of the main excitonic peaks and are not symmetric due to the Coulomb interaction between electrons and holes.

7854-96, Poster Session

Experimental study on the electro-optic effect of crystal in the terahertz range

W. He, D. Yang, M. Dong, Zhejiang Univ. (China)

The electro-optic effect of crystals is common in the light range, based on the principle that by imposing appropriate electric field on electro optic crystals, their refractive indexes would change accordingly. In this paper, the electro-optic effect of the crystals was observed and discussed in the terahertz range, theoretic analysis was implemented on the experiment's feasibility; Three crystals, ZnTe, GaAs and Si were chosen as the experimental group in the research. The main contributions of this paper are that the series of experiments to research the transverse electro-optic effect of three crystals in the terahertz range have been designed and fulfilled, the way to use terahertz TDS system properly to measure the spectrum changes of refractive indexes of crystals under voltage 0-200 V with 10 cm distance in terahertz range is demonstrated, and the scheme for portrait electro-optic effect experiment is designed for research in the next step. According to the measurements, the refractive index of GaAs had obvious changes around 0.0932 in the frequency from 800 GHz to 2 THz, the refractive index of ZnTe has comparatively small changes around 0.015, and the refractive index of Si hardly changes. The results have validated that the refractive indexes of electro-optic crystals ZnTe and GaAs have changed as the intensity of the external electric fields varied appropriately. And that may have potential applications in photoelectric devices in the terahertz range. Both theoretic analysis and experimental results demonstrate the experimental study is reasonable and successful.

7854-97, Poster Session

Thermodynamic character of fiber array visible to infrared image transducer

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A technique of fiber array structure of visible to infrared image transducer was discussed for infrared imaging control and guide. Different form the normal fiber array, the structure here is micro-fabricated on quartz glass, and in front of fiber is covered with visible absorb member. The fiber array structure works in vacuum and cooling chamber. The 3D model of fiber array structure in the theory of secondary radiation for finite element analysis was established. The material parameter, including density, specific heat and thermal conductivity, and the structure size including section size, length of fiber array transducer for temperature and time character were studied. The simulation results show that the thermal conductivity and length of fiber array are key parameters for transducer's property, and the optimized parameters for fiber array structure transducer were given. The fiber array structure of visible to infrared image transducer has the advantage of high spatial and temperature resolution, and low manufactural cost. The optimized parameter for fiber array visible to infrared image transducer can reach the frequency of 100Hz and higher temperature of 150 in case of increasing impulse power which can be used as infrared scene projector in infrared imaging hardware-in-the-loop simulation experiment.

7854-98, Poster Session

Sideband separating mixer for 600-720 GHz

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The ALMA band 9 (600-720 GHz) receiver cartridge based on two single-ended (dual sideband) SIS mixers in orthogonal polarizations has been produced. In the case of spectral line observations in the presence of atmospheric backgound, the integration time to reach a certain desired signal to noise level can be reduced by about a factor of two by rejecting the unused sideband. The goal is to upgrade the current ALMA band 9 cartridge to a full dual-polarisation sideband separating capability, with minimal impact on the overall structure of the cartridge, providing a minimal-cost upgrade path.

A new design of sideband separating mixer was presented on the ISSTT-2010 conference. Here we will demonstrate the first experimental results of the sideband separation performance and noise temperature measurements.

The ALMA requirements are 335K SSB noise temperature over 80% of the band, and 500K over the entire band; the sideband separation should be better than 10dB.

7854-99, Poster Session

Abnormal enhancement of terahertz signal by using a hole

D. Zhao, Y. Shi, Q. Zhou, L. Li, C. Zhang, Capital Normal Univ. (China)

Huygens-Fresnel principle and half-wave method are usually used to explain the diffraction effect as the light passing through a hole. In recent years, the advent of optoelectronic sources and receivers of subpicosencond pulses, the terahertz electromagnetic radiation has aroused much interest in the propagation properties of these pulses. The terahertz time-domain spectroscopy and imaging technologies is an important method to research materials absorption characteristics.

Because the propagation of terahertz pulses is basically due to diffraction, any manipulation changing the spatial distribution of the incident terahertz pulses will lead to changes of the time waveforms and the spectra of the focused pulses. Many have used Fresnel zone plate method to produce the amplitude and phase type devices to realize different diffraction demand, include optical and microwave field and so on. But for terahertz signal, since the terahertz' broadband characteristics, it's difficult to use Fresnel zone plate in the same detection point to focus all frequencies in the experiment. And thus have less people through the Fresnel diffraction theory and Fresnel zone plate method to increase the THz signal strength.

This article from the Fresnel zone theory, introduces the method can enhance the terahertz signal up to 13.87%, by throughing a hole and discusses the reasons of this phenomena. This method is simple and does not require a major adjustment of the original THz-TDS system, so the methods can be widely applied in actual experimental system.

7854-100, Poster Session

Air-core terahertz fiber with high birefringence

J. Li, H. Chen, Z. Hong, China Jiliang Univ. (China)

Terahertz (THz) radiation has attracted increasing interest due to its big potential for the applications such as spectroscopy, imaging, communication and sensing. THz waveguides, which can remotely deliver the THz radiation, have been considered as a big step towards the compact and robust THz systems. However, THz radiation is strongly absorbed in most kinds of materials, which gives a challenge to achieve low-loss THz waveguides. It is well known that propagation of THz wave in dry air is nearly lossless. Therefore, several polymer fibers with a pattern of sub-wavelength air-holes in the core have been proposed and demonstrated effectively to reduce the loss for THz guiding.

In this paper, we propose an efficient air-core THz fiber with high birefringence and low modal absorption loss. The photonic crystal fiber (PCF) has a triangular-lattice with circular subwavelength air-holes in the microstructured cladding and elliptical subwavelength air-holes in the core. In this structure, the effective index of the core is above that of the cladding, that leads to a better confinement of the field and ensures the low loss characteristic for THz guiding. With elliptical air-holes in the core, the proposed THz fiber exhibits high birefringence. The background medium is the polymer material with low absorption in THz region. The proposed design has been simulated based on the finite element method with anisotropic perfectly matched layers (PML) absorbing boundary condition. Numerical simulations show that with a moderate ellipticity of the elliptical air-holes in the core region, the proposed THz fiber can exhibit high birefringence on a level of 10-2 in a 0.2THz to 2.0THz frequency range. And the THz fiber's guiding loss caused by material absorption can be reduced effectively by the addition of more air holes in the core region.

7854-101, Poster Session

Easy robot programming for beginners and kids using augmented reality environments

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The mobile robot has wheels to move itself. 'Go', 'Back', 'Left' and 'Right' commands enables to transfer the robot anywhere you like. The wheels are rotated by motors. In order to move the robot, a motor driver

needs to control the motors. You must actually indicate which motor to work and how much it to rotate. However it is difficult for beginners to program and troublesome for all users to indicate in detail. So these basic commands are automatically translated into the program for the motor driver in our system. Moreover the authors developed the card programming environment using command and instruction marker which enables beginners or kids to enjoy lightheartedly the mobile robot operation.

At a situation of the card programming for our mobile robot control, a camera shots the programming stage where you arrange the instruction cards on. On our card programming environment, you can instruct eight commands on the table at the same time.

To realize the card programming, our developed easy robot programming system needs to recognize markers in the real world and discriminate command and instruction from drawn patterns on the markers. Our command or instruction involves two printed symbol patterns which are a visible symbol and an invisible pattern. The visible symbol shows a function or a role as the man can easily understand. The invisible pattern is used for recognition by the vision system. The human can only perceive visible symbol. The camera only shots the invisible pattern because its lens is covered the infrared passing filter. This invisible pattern of a command card consists of a black square frame filled with some kind of a pattern. We shoot command cards on the table and take picture of it. The computer vision system firstly finds the black square flames from video streams and then recognizes patterns within the interesting regions. On our developed system, the authors make use of a mixed reality software in order to recognize a kind of the marker and measure its position. This software library is called ARToolkit. ARToolkit involves a video capture, a 3D graphics generator, a spatial measuring and an overlay imaging for the creation of augmented reality applications. The card programming stage has eight slots and the center is an origin marker for measuring card positions. A user puts the instruction cards onto these slots by turns of execution. The robot programming system finds the all instruction markers and overlays signs on the markers of the captured video scene as flags in case that the recognition process is correctly finished. You can easily control this robot to move anywhere you like and turn head lights on or off using the command and instruction cards.

7854-102, Poster Session

Iterative restoration algorithms for improving the range accuracy in imaging laser radar

C. Yang, H. Yan, X. Zhang, W. Shangguan, H. Su, Zhejiang Univ. (China)

Scannerless Imaging laser radar has been a focus of research in these years for its fast imaging speed and high resolution. We introduced a three-dimensional imaging laser radar using intensified CCD as the receiver with constant gain and line modulated gain, the distance map of a scene is obtained from two intensity images. According to the transmission characteristics of the imaging system, a model of degeneration of the gray images is established and the range accuracy of imaging laser radar based on this model is analyzed. The results shows that the range accuracy is related with the reflectivity, the actual distance and some other factors for the fast-distance-varying region, while it is mainly concerned with shot noise for the flat area. On the basis of the cause of measurement error and the distribution characteristics of noise, a method which uses iterative restoration algorithms on obtained intensity images is presented, Simulation is carried out and the results show that root mean square error of distance map obtained with this method is decreased by 50%, compared with the distance map obtained by measurement. Finally the restoration results of radar images are demonstrated to verify the effectiveness of this method.

7854-103, Poster Session

The reflectance spectra and electrical properties of nanocrystalline metal thulium

F. Liu, Beijing Univ. of Technology (China)

Nanocrystalline bulk metal Tm samples were prepared by spark plasma sintering (SPS) technique, and the mean sizes of the two samples are 30nm (sample1, sintered at 573K) and 100nm (sample2, sintered at 573K and annealed at 773K) respectively. The reflectance spectra R within 200nm-2500nm wavelength range of the two samples were measured by UV spectrophotometer (UV-VIS -NIR). The minimum of the reflectivity is 2.38% at 240nm for sample 1, and the minimum of the reflectivity is 3.82% at 232nm for the sample 2. The reflectance minima correspond to the plasma oscillations frequency of nanocrystalline bulk metals Tm and the number density n of free electrons can be calculated by the plasma oscillations frequency . The value of free electrons number density n of nanocrystalline bulk metal Tm samples is about 2×10^28/m^3, suggesting there is only 0.6 free electrons in each Tm atom, maybe which is connected with strong electronic correlation effect. The electrical resistivities of the two samples were measured by vibrating sample magnetometer (VSM). Since the samples are of bulk material having transmissivity of zero, their surface absorption spectra can be obtained from the reflection spectra of the samples, and in turn their index of refraction, dielectric function and conductivity, so as to compare them with the actually measured electrical resistivity.

7854-104, Poster Session

A novel method of infrared radiation measurement based on a reference blackbody

C. Yang, J. Zhang, L. Cao, Y. Li, Changchun Institute of Optics, Fine Mechanics and Physics (China)

IR radiation measurement is one of important ways for target signature acquirement and target recognition. When measuring IR radiation signatures of a target using an IR measurement system in the atmosphere, the precision of radiation measurement is mainly dependent on the output stability of the IR system, the calibration precision of the IR system, and the precision of atmospheric transmittance measurement, where the precision of atmospheric transmittance measurement is the most significant contributory factor. A conventional method of atmospheric transmittance measurement is to obtain various atmospheric parameters using atmosphere observation devices, and to calculate the atmospheric transmittance and the air path radiance between the target and the IR system from these parameters by using a atmospheric radiation transport calculation software. The uncertainty of the atmospheric transmittance obtained by the conventional method is about 10%~20%. To improve the precision of target radiation measurement, a novel radiation measurement method based on a reference blackbody was presented, where the blackbody working at high and low temperatures was used to measure the atmospheric transmittance between the target and the IR system. The atmospheric transmittance calculation model, and the target radiation measurement and inversion model were proposed. From analysis on these models, the precision of atmospheric transmittance measurement of the presented method was mainly dependent on the calibration precision of the IR system and the radiance uncertainty of the reference blackbody, and the precision of radiation measurement and inversion was dependent on the output stability of the IR system and the radiance uncertainty of the blackbody. The radiation measurement experiments showed that the precision of atmospheric transmittance measurement of the presented method was higher than that of the conventional method, and the precision of target radiation inversion was significantly improved.

7854-105, Poster Session

A digital processing method for detecting micro-cantilever deflection of micro-cantilever focal plane arrays

C. Gong, M. Hui, L. Dong, Y. Zhao, Beijing Institute of Technology (China)

This paper describes a new digital processing method for detecting micro-cantilever deflection of micro-cantilever focal plane arrays. Nowadays, the research of bi-material microcantilever infrared imaging system is becoming a hot field of infrared imaging. It is known that one of the key technologies of microcantilever infrared imaging system is bi-material microcantilevers deflection measurement. The old method is doing a two-frame subtraction operation after the CCD receives digital data from optical readout module. However, the subtraction method will make the data processing complicated, because the method may make the result data be negative. We must compare the size of the corresponding pixels first to prevent data overflow. In addition, the old method is easy to obtain the background noise for interference. Taking into account the disadvantages of old method we introduce a new method to slove above problems successfully in the paper. We believe that this new digital processing method for detecting micro-cantilever deflection will be widely used.

7854-106, Poster Session

Large focal depth of THz imaging system based on quasi-Bessel beams

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THz imaging technology will be potentially used in structure's defects detection, package inspection, on line product quality control, security screening or other nondestructive testing fields. But due to its long wavelength, it is difficult to obtain high spatial resolution and large focal depth simultaneously for conventional imaging system.

In this paper, diffraction free quasi-Bessel beams are used in THz imaging system to enhance the focal depth with reasonable spatial resolution. PE conical lenses were designed and fabricated to generate quasi Bessel beams. Numeric simulations demonstrated that with suitable parameters of the conical lens, the diffraction free collimated range is from 50mm to 150mm at 300 GHz after the lens, i.e. 100mm of focal depth for the imaging system. Compared with a conventional spherical lens of 100mm focal length, its focal depth is only 21mm.

An THz imaging system based on quasi-Bessel beams was established by using backward wave oscillator(BWO) as THz source. The spatial distribution of the propagating beam after the lens was measured by Pyrocam III, and results are in good agreement with simulations. Furthermore, a transmission imaging system based on quasi-Bessel beams with 2D moving translation stage was established for the inner defect detection built-in artificially in phenolic foam samples. The defect with diameter of 0.4mm was figured out successfully.

7854-107, Poster Session

Carrier dynamics of doped silicon measured by femtosecond pump-terahertz probe spectroscopy

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The carrier dynamics in the n-type silicon (n-Si) as well as in the p-type Silicon (p-Si) have been investigated by using femtosecond pump-terahertz probe technique. The measurements show that the relative change of terahertz transmission of p-Si at low pump power is slightly lower than that of n-Si, due to the lower carrier density induced by the recombination of original holes in the p-type material and the photogenerated electrons. At high pump power, the bigger change of terahertz transmission of p-Si originates from the greater mobility of the carriers compared to n-Si. The obtained results indicate that femtosecond pump-terahertz probe technique is a promising method to investigate the carrier dynamics of semiconductors.

7854-108, Poster Session

Analysis of scattering and polarization characteristics of chiral sphere with large size parameter

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The scattering characteristics of chiral media have attracted much attention due to many associated interesting phenomena in optical and electromagnetic activities and their potential applications in various fields. In this paper, the stable and accurate recursive formulas are proposed to calculate scattering coefficients for a chiral sphere with large size parameter in a plane wave.

Based on the spherical vector wave functions, we research the scattering of a homogeneous chiral sphere to a plane wave. The expressions for the expansion coefficients of scattered fields and internal fields are obtained. The logarithmic derivatives of Ricatti-Bessel functions are introduced in order to avoid the numerical overflow of high-order terms or larger argument spherical Bessel function and problem of the accumulative error in the matrix calculation. Thus, the scattering characteristics of a chiral sphere with larger size parameter can be studied numerically. Moreover, the influence of chiral parameter on the polarization properties is also numerically analyzed.

The chiral sphere can be reduced to an isotropic sphere to confirm the correctness of the results which anastomose Generalized Lorentz-Mie's. The analysis in this paper is useful in the areas of target stealth, radar detection and microwave device fabrication.

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7854-109, Poster Session

A total variation denoising algorithm for hyperspectral data

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Hyperspectral remote sensing, as one of the most advanced techniques of remote sensing science, has been widely applied in many domains. Since noise can undermine the effectiveness of information extracted from hyperspectral imagery, noise reduction is a prerequisite for many classification-based applications of hyperspectral imagery.

Most traditional denoising algorithms focus on only spatial or only spectral domain, and have not efficiently utilized the three dimensional feature of hyperspectral imagery data cube. In this paper, an effective three dimensional total variation denoising algorithm for hyperspectral imagery is introduced. First, a three dimensional objective function of total variation denoising model is derived from the classical two dimensional TV algorithms. For the consideration of the fact that the noise of hyperspectral imagery shows different characteristics in spatial and spectral domain, the objective function is further improved by utilizing two terms (spatial term and spectral term) and separate regularization parameters respectively to adjust the trade-off between

the two terms. Then, the improved objective function is discretized by approximating gradients with local differences, majorized by a quadratic convex function and finally solved by a majorization-minimization based iteration algorithm.

The performance of the new algorithm is experimented on a set of Hyperion imageries acquired in a desert-dominated area in 2007. Experimental results show that, properly choosing the values of parameters, the new approach removes the indention and restores the spectral absorption peaks more effectively while having a similar improvement of signal-to-noise-ratio as minimum noise fraction (MNF) method.

7854-110, Poster Session

THz/sub-THz narrow-gap semiconductor detector

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Direct detection THz/sub-THz bolometer based on electron heating is considered. Warm electrons bolometer theoretical model is developed and experimental results on sensitivity in THz/sub-THz region of narrow-gap bipolar HgCdTe semiconductor sensitive layers, which also are used for ultimate performance long-wave IR detectors, are reported. In the model, an electromagnetic wave propagates in bipolar semiconductor waveguide, heats electrons and holes, and therefore creates their thermodiffusion flow and, as well as, the ectromotive force. The possibility without cooling or moderate cooling (T~100 K for HgCdTe sensitive layers) to get an acceptable for applications values of the noise equivalent power (NEP) in the bolometer proposed is shown. Results of calculations are compared with the experimental ones for n- and p-type narrow-gap Hg1-xCdxTe (x~0.2) with dimensions 50x50 and 10x50 microns. Sensitivity of bolometers was measured at T = 70-300 K and frequencies from f= 37 to f= 1.58 THz. Estimations have shown that NEP in such structures in the range of T~(100-300) K can reach NEP~(10^-11 to 10^-9) W/Hz1/2.

7854-111, Poster Session

16-km horizontal-path experimental demonstration of fine tracking system for satellite-to-ground optical communication

Y. Cao, Chongqing Univ. of Technology (China)

In the satellite-to-ground optical communication, APT(Acquisition, Pointing and Tracking) technology is the key technology that makes the terminals with narrow beam to aim each other accurately, fine tracking is the core technology of APT, the bandwidth and precsion of fine tracking are the most important parameters to determine the communication link. Firstly, the construction and working principle of fine tracking system are introduced and analyzed. Secondly, a novel adaptive fuzzy PID algorithm is introduced, the weights of PID parameters can be adjusted in real time. Thirdly, in a terrestrial free-space 16km optical data link, experiment of fine tracking are demonstrated successfully, efficiency of fiber coupling is enhanced obviously, the tracking precision reaches 4.8μrad at 16km distance, the experimental results show the fine tracking system is robust.

7854-112, Poster Session

Large dynamic range interferogram acquisition scheme for ultrahigh spectrum resolution Fourier transform infrared spectrometer

X. Sun, D. Li, Shanghai Institute of Technical Physics (China)

In order to achieve ultra high spectrum resolution performance such as 0.02cm-1, a large dynamic range and high precision infrared information acquisition technic is implemented in the Fourier Transform Infrared Spectrometer (FTIR) which has very large optic path distance (OPD). The interferogram is digitized using analog to digital converter (ADC) to exert the calculation power of the Fast Fourier Transform (FFT) algorithm. The ratio of the signal intensity at zero optical path (ZPD) to the root-mean-square (rms) noise level is the SNR (signal to noise ratio) which is often called the dynamic range. SNRx = I(0)/NEP (SNRx is the dynamic range related with OPD=x, I(0) is the intensity of the signal at ZPD position, NEP is the Noise Equivalent Power). The dynamic range of this instrument is about 26000:1. So, to sample the infrared interferogram with the digitization noise below the other noise contributors, a space qualified ADC of at least 18 effective number of bits (ENOB) is needed. Therefore the signal obtained can de divided up into a maximum of about 262100 levels.

A dual ADC based information acquisition scheme is designed to reduce the noise contribution of the digitization while copping with the high dynamic range. Principle, calculation, simulation and implementation of the scheme are presented in this paper. Firstly, the signal conditioning requirements for digitization are analyzed and calculated. Gain-ranging amplifiers are used to increase the dynamic range of the interferogram. On each side of the center-burst of the interferogram, the gain is set lower, while on the swing side, the gain factor is set 8 times with 3bits increased to 16-bit ADC ENOB of which is 15 or less, so totally (15+3) 18 effect bits are achieved. Secondly, to decrease the aliasing noise generated by the process of sampling, a Sallen and MFB combined analog active filter structure is used to realize the anti-aliasing function which decreases the gain-bandwidth product (GBP) requirement. Thirdly, experiments are carried out to obtain digitized interferogram based on which spectrum is calculated through FFT algorithm. Experiments indicate the spectrum resolution reaches 0.02cm-2 with the dedicated dual ADC and gain-ranging method.

7854-113, Poster Session

Application of millimeter-wave photonics technology in passive millimeter-wave imaging

Y. Zhang, Y. Jiang, Y. He, H. Wang, BeiHang Univ. (China)

Passive millimeter-wave imaging is attractive due to the ability to obtain images during the day or night; in clear weather or in low-visibility conditions, such as haze, fog, clouds, smoke, or sandstorms. In passive imaging application, high sensitivity detection technology is necessary. In recent years, there has been considerable research in millimeter-wave signal processing using photonic technology for radio-over-fiber systems and phased array antennas. The availability of high-speed optoelectronics components and optical fibers make it possible to use optical fiber links to transport and process millimeter-wave in applications of passive millimeter-wave imaging. The processing of millimeter-wave signals in the optical domain has advantages such as large bandwidth, low loss and immunity to electromagnetic interferences. In this paper, a passive millimeter-wave detection method using optical modulation and photodetection is presented. The millimeter-wave energy collected by the antenna is transferred to the sidebands of the optical carrier by an optical modulator, and then transmitted through optical fiber. Optical filters are subsequently used to suppress the optical carrier and a photodetector is used to

detect the energy of the remaining sideband. Lock-in amplification technology is used in the detection to improve sensitivity. The principle of the detection method and the key technologies are described. The relationship between the responsivity and the component parameters is discussed. The noise characteristic and the sensitivity of this detection method are analyzed. A passive millimeter-wave scanning imaging system using this detection method was implemented. The imaging experiment results using this imaging system are presented in this paper. The experiment results show that this imaging method is effective in passive millimeter-wave imaging.

7854-114, Poster Session

Analysis of terahertz radiation characteristics of tank

R. Liu, Y. Jiang, BeiHang Univ. (China)

The study of radiation characteristics of targets and backgrounds is an important research topic for its benefits in the optimization of a sensor and its observation conditions. Especially in the terahertz region where much interest has aroused for the development of remote sensing, but little work has been done in the field. In this paper, imaging of the tank, formed by passive terahertz sensors was studied, including calculation of the temperature field, analysis of atmospheric absorption effects and the ray-tracing models.

Firstly, the temperature field of the tank was calculated. The armored vehicle was divided into three parts simply: the gun barrel, wheels and the main body. For each part, the physical model was built on principles of heat transfer, which includes radiation, convection and conduction between different parts of the vehicle, and heat exchanges with the environment.

Secondly, the atmospheric absorption effect was simulated, for terahertz radiation is strongly absorbed due to atmospheric water vapor when propagating through the air. The change of radiation characteristics of tank was studied further when the distance of detection increased.

Finally, the atmospheric absorption effect was simulated by a ray-tracing model based on OpenGL in the Visual C++ environment. The various parameters which influenced image definition were analyzed.

In conclusion, terahertz radiation characteristics of the tank in different working situations were simulated by three stages. By comparison, the main factors that affect the identification of the tank in the terahertz band can be found out, providing theory foundation for target recognition and performance evaluation of remote sensing systems.

7854-115, Poster Session

Temperature measurement of contact resistance based on infrared detection

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Abstract: For science and technology, the level of science and technology is determined by the measurement accuracy and efficiency to some extent. Contact resistance can not be ignored in precise measurement. Because the measured object is not directly contacted with infrared measurement device, there is no friction. Infrared measurement has the advantage of high sensitivity, fast response and so on. In this paper, the reasons for the temperature rising of the contact resistance and its harm and the importance of measuring the temperature of the contact resistance in precise measurement are analyzed firstly; then some theories of the infrared detection technology are introduced; finally, an infrared temperature measurement system based on SCM is designed.

7854-116, Poster Session

The observation of terahertz spectra of all-trans beta-carotene molecule

J. Zuo, L. Zhang, F. Yu, Z. Zhang, C. Zhang, Capital Normal Univ. (China)

The carotenoid molecules associated with the proteins perform the important physiological functions of harvesting, transferring and dissipating light energy in the light-harvesting process. Especially, these functions originate from changes in the electronic and molecular configurations of the carotenoid molecules under the influence of intermolecular or intramolecular interactions with the apo-protein. Terahertz spectroscopy is a power tool for the prediction of the configuration or conformation of the carotenoid and non-covalent interactions. All-trans beta-carotene molecule has eleven conjugated double bonds in the polyene chain with all-trans configuration. In this paper, the low-frequency vibrations of all-trans beta carotene molecule were firstly observed. One hand, the vibrational modes of 0-3 THz were obtained by terahertz time-domain spectroscopy (THz-TDS). The absorptivity and dispersion relations of all-trans beta-carotene molecules were also presented in this frequency region. On the other hand, the other vibrational modes in the range of 3-20 THz were obtained through far-infrared Fourier-transform spectrometer. There exhibit a lot of rich and distinct vibrational peaks. The fact that the terahertz spectra of all-trans beta-carotene molecules represent unique fingerprints of the molecular geometries of both beta-ionone and long conjugated double bonds. And the environment of the molecule leads us to the conclusion that THz technique can be used for the recognition of organic molecules and, of great importance, their conformation.

7854-117, Poster Session

Continuous wave terahertz phase imaging

W. Sun, Capital Normal Univ. (China); X. Wang, Harbin Institute of Technology (China); Y. Cui, Y. Zhang, Capital Normal Univ. (China)

Continues wave terahertz imaging can be used widely in the field of security inspection and nondestructive examination because of its simplicity and stability. However, depth information of the inner structure of detected samples may be neglected, because most of continues wave terahertz imaging systems only provide intensity information. Alternatively, phase imaging can supply more information to present the relative optical depth profile of the sample's surface and interior. In addition, the imaging quality of phase imaging is higher than that of intensity imaging in most cases. In this presentation, we proposed an image method with continues wave terahertz interferometry to obtain the sample's phase information. In the experiment, a 0.4THz Gunn diode and a Schottky diode are used as terahertz source and detector respectively. By the raster scanning, a terahertz image is obtained. A reference terahertz beam was added into the exiting continues wave terahertz imaging system to be a Michelson interferometer. A delay line was arranged on the reference beam to provide three fixed phase shifts. With three maps obtained at these three positions, a phase image is obtained by using a phase shift algorithm. Afterwards, this phase image is unwrapped to get its accurate phase profile. By this method, a bulk of foam with three different height steps and three pieces of papers with terrace structure are imaged. The results show that the inner structures of samples can be identified clearly and the relative optical depth profiles of samples can be obtained. Moreover, the longitudinal resolution of this continues wave terahertz imaging system is measured and discussed.

7854-118, Poster Session

Transient surface photoconductivity of GaAs emitter studied by terahertz pump-emission spectroscopy

Y. Shi, Capital Normal Univ. (China)

Carrier dynamics and relaxation processes in semiconductors have attracted much attention due to wide physical interest and potential device applications. Since terahertz signals are very sensitive to carrier density and mobility, pulsed terahertz system is a promising tool for obtaining information concerning the ultrafast carrier dynamics in materials. In the past years, much work has been done by using optical pump-terahertz probe techniques to investigate the photoinduced changes in the material photoconductivity, which contains the information of carrier density and mobility, with a temporal resolution of subpicosecond. However, very few studies, which analyze the transient surface photoconductivity of terahertz emitters, are found in literature. In our previous paper, we demonstrated that the carrier capture process in unbiased semi-insulating (SI) GaAs could be detected by a terahertz pump-generation technique. The measured capture time constant was found to be 20 picoseconds.

In this paper we further simulate the capture process by analyzing the photo-induced change of surface photoconductivity of GaAs based upon the Hertz vector potential. Through theoretical modeling, we find that the terahertz waveforms are correlated with the transient photoconductivity. Experimentally, it is also found that the time-resolved conductivity increases with pump-generation delay time and pump power, fairly consistent with our carrier capture model. Finally, the temperature-dependent measurement is also discussed.

7854-119, Poster Session

Slow light in the dielectric-loaded metallic waveguide for terahertz wave

J. He, X. Li, Z. Hong, W. Wang, China Jiliang Univ. (China)

The left-handed metamaterial (LHM) waveguide composed of LHM layer and normal dielectric medium layers has opposite power flow in LHM layer and normal dielectric layers. When the negative power flow in LHM layer equals to that in normal dielectric layers, the guided supports slow light propagation. velocity. And the guided is able to slow down the light over a broad band if it is slowly tapered. However, the low-loss uniform bulk of LHM is very difficult to realize up to now. And, the loss and the non-adiabatic tapered structure for a realistic waveguide will severely limit the performance of slow-light propagation. Actually, LHMs or periodic structures are unnecessary to realize opposite power flow in different layers of a waveguide. Opposite power flow can be obtained in high-permittivity-dielectric-loaded metallic waveguides in terahertz region. Thus, the modes in the dielectric-loaded metallic waveguide may have similar properties (including slow light) to those in an LHM waveguide. We investigate the dispersion relation for the realizable dielectric-loaded metallic waveguides in terahertz region. Then, the slow light waveguide structures are designed accordingly to achieve the “trapped rainbow” (broadband slow light). We also show that the slow light with low loss can be still realized in a practical waveguide when the loss of GaAs rod is considered. The novel filter based on such slow light structures are also been investigated.

7854-120, Poster Session

Terahertz difference frequency generation in GaSe from a doubly-resonant walk-off compensated KTP OPO

K. Zhong, Tianjin Univ. (China)

Compact, efficient, widely-tunable coherent terahertz (THz) sources provide us convenient facilities in frequency domain spectroscopy and imaging. To satisfy such requirements, Various methods have been exploited based on difference frequency generation (DFG) in nonlinear crystals. The generated THz peak powers have reached a high level and the tuning range is wide. However, most of the reported DFG systems are very bulky and complicated, restricted by the dual-wavelength-laser generating methods. Another defect for the DFG method is the low conversion efficiency, which can be improved by way of longer DFG crystals, higher pump intensity, or using pump lasers with longer wavelengths. Unfortunately, all these methods are limited by the properties of available crystal (serious absorption, low damage threshold, etc) and the development of all-solid-state lasers.

In this paper, the DFG process is theoretically analyzed considering the absorption coefficient, pump intensity and output wavelength. In the experiment, we have achieved a THz DFG system based on a walk-off compensated intracavity pumped dual-wavelength KTP OPO employing two identical KTP crystals. The KTP OPO is doubly resonant and works near the degenerate point at 2.128μm, which doubles the quantum efficiency compared with DFG using pump pulses around 1μm. This THz source is simple and compact, about 10×10×40cm2 in size. Besides lower threshold and better stability, the walk-off compensated KTP OPO greatly improves the pump beam quality and enhances the DFG conversion efficiency. With an 8-mm-long GaSe crystal, the generated THz tuning range is from 0.186THz to 3.7THz with the maximum peak power of 11W at 1.68THz. An average enhancement of 76.7% for the THz energies is realized using the walk-off compensated KTP OPO than a common one. The conversion efficiency can be improved with a longer and better GaSe crystal.

7854-121, Poster Session

Theoretical study on the generation of THz sub-comb via surface-emitted optical rectification of ultra-short pulse in periodically poled lithium niobate

P. Liu, D. Xu, J. Yao, Tianjin Univ. (China)

Narrow-band and multi-cycle teraherzt wave can be generated by optical rectification of sub-picosecond optical pulse colinearly in a PPLN[1]. For tightly focused pump beam, surface-emitted geometry(when the THz-wave is observed in direction perpendicular to the direction of the input pulse propagation) was also proposed[2]. In this paper, we did further research on surface-emitted geometry theoritically and proposed a method for THz sub-comb generation.

The principle of THz sub-comb generation was analyzed both in mathematical model and in physical mechanism. With radiating antenna model, which is different from plane wave approximation by taking into account the diffraction of THz wave, we got the expression of radiated THz electric field both in frequency and time domain. The characteristic of output THz wave is determined by two parameters: the poling period of crystal and the effective duration of input pulse eff. Different from the pervious work[2,3], in which the output is narrow-band THz wave with one center frequency, we got a comb-like THz spectrum by increasing and decreasing eff. Similar to the mode-locked optical comb (a fs-pulse train), the corresponding temprol form is a train of THz pulses with one single cycle. The polarities of every two adjacent pulses are opposite.

As a finite series of THz pulses, the generated THz wave can’t be

used as a frequency comb, so we call it “THz sub-comb”. With a wide free spectrum range, it could be used as the source of THz wireless communication with wavelength division multiplexing.

7854-122, Poster Session

A low-loss and birefringent terahertz waveguide based on polymer elliptical tube

J. Wang, Tianjing Univ. (China) and Nanjing University of Posts and Telecommunications (China); J. Yao, Tianjing Univ. (China)

Terahertz (THz) waveguides that can be used for remote transmission the broadband THz radiation play an important role in THz system and attracted much interest over the past years. However, almost all materials are highly absorbent in the THz region and there is also a large loss from the water vapor in the atmosphere. So design of efficient waveguides is still an arduous work, and a perfect THz waveguide will be a big step toward compact and robust THz systems and their applications in communication, sensing, imaging, and spectroscopy. In this paper, we propose a low-loss and birefringent THz waveguide, a polymer elliptical-tube with a cross section of elliptical ring structure. Compared it with other polymer THz fibers with complex cross sections, it is easy to fabricate and will be one of the most important candidates for THz waveguides. A full-vector finite-element method with perfectly matched layer (PML) boundary conditions is used to analyze the properties of the polymer elliptical-tube. Numerical results show this kind of tube has better loss property as a large part of mode power is trapped in the air core inside the polymer elliptical-tube, and such asymmetrical structure is easy to achieve high birefringence.

7854-123, Poster Session

The guidance mechanism and numerical simulation of THz polymer hollow-core photonic crystal fiber

R. Wang, J. Yao, Tianjin Univ. (China)

With the development of terahertz (THz) technology, an efficient propagation waveguide is essential for the construction of compact THz devices. However, almost all materials are highly absorbent in THz region, which makes the waveguide design an arduous task. Hollow core photonic crystal fiber with a larger air core at the center and a cladding formed by a periodic arrangement of polymer tubes has been demonstrated in this paper. The guidance mechanism is novel, based on anti-resonant reflection from struts of solid material in the cladding. The leakage of guided modes from the air core is confined by a low overlap between the guided modes and cladding modes. Since most electromagnetic field in the fiber is dominated in the air core rather than propagates in the absorbing material, hollow core fibers have obvious advantages in lower absorption and dispersion. The propagation characteristics of the fibers, such as the mode field distribution, the effective area, the loss coefficient and the dispersion property are numerically investigated through the finite element method. The result shows that an effective way to reduce the absorption and dispersion is to increase the fraction of the field propagating in the air core.

7854-124, Poster Session

Study on generation of high-power terahertz wave from surface-emitted THz-wave parametric oscillator with MgO:LiNbO3 crystal

Z. Li, J. Yao, D. Xu, J. Li, K. Zhong, P. Bing, Tianjin Univ. (China)

THz-wave parametric oscillator (TPO) is one of the most efficient methods to generate THz-wave, which has many advantages, such as compactness, narrow linewidth, coherent, wide tunable range, high-power output and room temperature operation. Surface-emitted TPO allows THz-wave to emit out perpendicularly to the surface of MgO:LiNbO3 crystal without any output coupler, so the beam quality of THz-wave is improved. Moreover, the interaction area among three waves lies just under the exit surface of THz-wave, which means that the propagation length of THz-wave in crystal is short and the absorption loss will be low. In our experiment, high-power THz-wave radiation from surface-emitted TPO using MgO:LiNbO3 crystal was obtained. The measured values of THz-wave frequency agree well with the theoretical curve calculated from the noncollinear phase matching condition. The output of THz-wave from 0.8 THz to 2.9 THz has been gained, the maximum THz-wave output was 289.9 nJ/pulse at 1.94 THz when pump power density was 211 MW/cm2, and the energy conversion efficiency was 3.43×10-6. The stability of our THz-wave parametric oscillator was about 7% when pump power density was 211 MW/cm2. During the experiments the radiations of first-order, second-order and third-order Stokes waves were observed. The experimental results agree well with theoretical analysis.

7854-125, Poster Session

Research on thermal characteristic of electronic devices using thermal microscopy

J. Wang, L. Gao, Beijing Institute of Technology (China)

Electronic devices and Micro-Electro-Mechanical System(MEMS) have been widely used in the national economy. Traditional testing methods can not obtain the temperature distribution and not complete the performance test related with heating for electronic devices and MEMS, such as the degree of heating and thermal fatigue life. In recent years, simulation method is used to analyse temperature change in PCB and the second integrated chip design which has played a positive in enhancing the reliability of electronic devices. But, the effective testing means is still shortage in practical use.

Infrared thermal imaging techhology as a new diagnosis of non-contact testing technology can be effectively used for fault diagnosis of electronic devices. While, the thermal microscopes can obtain the temperature distribution detail of the objects and provide effective testing method for work and fault analyse of large scale integrated circuits and MEMS in practical use .

In this paper, temperature rising process of PCB is simulated using ICEPEAK simulation software. Some factors that affect the chip temperature are analyzed, such as heat sink, cooling-off hole and the fan. The chip actual working temperature is tested by the thermal microscopy, and the factors above mention are analyzed in experiments. The relation between actual chip working temperature and simulation temperature is acquaired.

So, this paper is divided into four parts. a brief discussion on the development new testing mothod for electronic devices are given firstly. Secondly, the typical thermal microscopes for testing electronic devices are introduced, some testing examples are given. Then, PCB temperature rise process is simulated by ICEPEAK simulation software, some factors affected heating are analyzed, the relation between simulation and actual work is bulit. Finally, conclusion regarding that thermal microscopes are the development direction for the electronic devices design and reliability testing .

7854-126, Poster Session

The separation for simultaneous transmission of baseband and microwave signals in a radio-over-fiber system

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Radio-on-fiber (RoF) systems with great potential that applying subcarrier-multiplexing (SCM) techniques to realize cost-effective millimeter-wave wireless access networks draw much attention along with the convergence of wired and wireless services as the coming of next-generation access networks. Simultaneous generation and transmission of 10-Gb/s baseband signal and 20-GHz microwave signal with 155-Mb/s on-off-keying(OOK) data on a single wavelength over 50-km-long single-mode fiber(SMF) or dispersion-shifted fiber(DSF) based on a dual-parallel Mach-Zehnder modulator(DPMZM) is investigated in this paper. After simultaneous modulation of the baseband signal and microwave signal at the central office(CO), the hybrid signals after transmission over the fiber link are separated by interleaver or fiber Bragg grating(FBG) at the base station(BS). The parameters of interleaver and FBG are critical in the RF/baseband data signals hybrid transmission because the baseband signal and microwave signal are only tens of GHz spacing and hard to be separated with each other. Therefore the center wavelength spacing and bandwidth of interleaver, also the reflection ratio, center wavelength and bandwidth of FBG are to be considered carefully. Through theoretical analyses and numerical simulation, the proper characteristic parameters are chose to separate the simultaneously transmitted baseband and RF signals to achieve open eyegram and high Q factor. For the domenstrated10-Gb/s baseband and 155-Mb/s RF signal hybrid transmission system, the relations of Q factor with the reflection ratio and bandwidth of fiber Bragg grating are analyzed separately in different transmission fiber links(SMF and DSF).

7854-127, Poster Session

Terahertz semiconductor metamaterials for tunability

J. Han, Tianjin Univ. (China)

Negatively refracting metamaterials have been a subject of recent enormous interest because they possess electromagnetic response characteristics that are not displayed by natural materials. The usefulness of such a device could be extended tremendously if the metamaterial's response characteristics can be dynamically tuned. We suggest three types of tunable metamaterials. The first two types comprise SRRs that are not metallic but are made of semiconductors whose electromagnetic response properties can be tuned by the external magnetic field and temperature. In the third design, we suggest an alternative strategy for thermally tunable metamaterials. In the design, we consider incorporation of the semiconductor into the gap of metallic SRRs, where precise patterning of semiconductors permits frequency tuning of the metamaterial resonance by changing the temperature. It will be shown that broadband blueshift of resonance frequency in our proposed structures can be implemented.

7854-128, Poster Session

Performance of free-space optical communication systems using circle polarization shift keying with spatial diversity receivers

C. Liu, X. Yu, Y. Yao, Harbin Institute of Technology (China)

In Free-space optical (FSO) links, polarization is the most stable characteristic of a laser beam while propagating through the atmosphere. Polarization shift keying (PolSK) modulation scheme has about 3dB better sensitivity than an on-off keying (OOK) modulation. PolSK also has the simplicity in the system construction. It can be an attractive modulation scheme for FSO communication systems to improve the reliability and performance. On the other hand, spatial diversity can mitigate some of the effects of atmospheric turbulence and improve the performance of FSO communication systems. We propose a FSO communication system with circle polarization shift keying (CPolSK) modulation and diversity receivers. The FSO communication system utilizes the spatial diversity receivers to receive the binary signals which are modulated by the two rotation states of circle polarization. In CPolSK scheme, the requirement of polarization coordinates alignment can be not considered and the complexity of system configuration has no significant increasing. A closed-form bit-error rate (BER) expression is derived for such a FSO scheme by considering the Gamma-Gamma atmospheric channel fading model. This closed-form model can predict the BER performance without the need of lengthy simulation runs. The BER performance can be analyzed by the parameters such as atmospheric conditions, link length, communication wavelength, receiver aperture size and the number of spatial diversity receiver. Numerical results demonstrate the influence of the above parameters on the FSO systems and show quantitatively the differences in behavior between various different parameters. These results can be helpful for the practical FSO system in future.

7854-129, Poster Session

Analysis of quantitative differences in large-aperture size for free-space optical communication systems with circle polarization shift keying and on-off keying in atmospheric turbulence channels

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Receiver aperture size is an important parameter in free-space optical (FSO) communication system design. Large-aperture size is one of the effective approaches to attenuate the effect of atmospheric turbulence. Increased aperture size will lead to a heavy configuration in receiver. Circle polarization shift keying (CPolSK) modulation scheme has better sensitivity than an on-off keying (OOK) modulation. It means FSO communication systems with CPolSK can realize a smaller size in receiver aperture, and achieve better performance than the systems with OOK. It is necessary for the system designer to know the differences in receiver aperture size between CPolSK and OOK with a given performance target . We propose a theoretical model to study the quantitative differences in the size of large-aperture size between CPolSK and OOK. We consider Gamma-Gamma atmospheric fading channel. Utilizing the theoretical model, the quantitative differences in the size of large-aperture size can be analyzed with the impacts from atmospheric condition, average signal-to-noise ratio (SNR), link length, and communication wavelength. Numerical results show that FSO systems using CPolSK can use the smaller aperture size than the systems using OOK in order to reduce the receiver size, and the longer communication wavelength can reduce the size even smaller with a better BER performance than the shorter one, while it is not obvious with increasing link length. Meanwhile, increasing average SNR leads

to a reduction of the difference in aperture size. These results can be essential for the designing of such FSO systems in atmospheric channel.

7854-130, Poster Session

Investigation of the mixing mechanisms for a terahertz superconducting hot electron bolometer mixer

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Superconducting hot electron bolometer (HEB) mixer is the most sensitive heterodyne detector in the frequency range between 1 to 6 THz. In our previous work we have measured the noise temperature of the HEB mixers at 0.8 and 1.5 THz to be 500 K and 1700 K respectively even with a relative thick NbTiN film (12 nm) [1]. The size dependence measurement of the noise temperature indicate the two cooling mechanisms (phonon-cooling and diffusion-cooling) exist in the HEB mixer simultaneously. In this paper we will focus on the investigation of the combination of cooling mechanisms in the HEB mixer based on the in-situ and ex-situ process respectively. We will study the effect of superconducting microbridge length and the thickness of NbTiN film on the noise temperature and IF gain bandwidth, and define individual contribution of the diffusion- and phonon-cooling mechanism. In addition, we will present a theoretical model to demonstrate the measurement results and give the critical condition of the two cooling mechanisms.

[1] Ling Jiang, Shoichi Shiba, Tatsuya Shiino, Ken Shimbo, Nami Sakai, Tetsuya Yamakura, Yoshihisa Irimajiri, P. G. Ananthasubramanian, Hiroyuki Maezawa, and Satoshi Yamamoto, “Development of 1.5 THz Waveguide NbTiN Superconducting Hot Electron Bolometer Mixers,” Superconductor Science and Technology, 23 (2010) 045025.

7854-131, Poster Session

Frequency selective surface based on metamaterials

J. H. Shi, Harbin Engineering Univ. (China)

Metamaterials have attracted a tremendous amount of attention in recent years. Achieving resonances with high-quality factors is essential in order to make metamaterials’ performance efficient. Fedotov et al. recently reported that resonators with weak free-space coupling can be achieved in a planar metamaterial by breaking the symmetry of two split resonators.

In this work, we studied frequency selective surfaces based on planar metamaterials using the finite element method. Metamaterials that were used in our research consisted of identical subwavelength metallic inclusions structured in the form of asymmetrically split rings (ASR) or asymmetrically split ring apertures perforated through the metallic cladding designated as positive and negative metamaterials. ASR patterns can be etched from 35μm copper cladding covering IS620 PCB substrate of 1.5mm thickness. Each copper split ring had the radius of 6mm and width of 0.8mm and occupied a square translation cell of 15×15mm. Such periodic structure does not diffract normally incident electromagnetic radiation for frequencies lower than 20 GHz. The rings of positive metamaterials have two equal splits dividing them into pairs of arcs of different length corresponding to 150 and 180 deg, while negative metamaterials resembled a regular two-dimensional array of asymmetrically split ring apertures, complementary to ASR pattern. Each ring aperture was split into pairs of arcs of different lengths (corresponding to 150 and 180 deg) separated by equal gaps. We presented the spectral feature of metamaterials in the forms of asymmetric split rings (ASR) and slit elements and showed the dependence of the quality factor on the structural parameters. The electromagnetic response was also illustrated.

7854-132, Poster Session

A Radio-over-fiber system with 64-QAM photonically generated OFDM signals

J. He, J. Li, D. Yang, Hunan Univ. (China)

Recently the combination of orthogonal frequency division multiplexing (OFDM) and radio-over-fiber (ROF) techniques have become attractive solutions in realizing future broadband wireless networks because OFDM technique has high spectrum efficiency and the tolerance to chromatic dispersion and polarization mode dispersion, which can increase the bandwidth and extend transmission distance over fiber. In the OFDM-ROF system, previous investigation reported that generation of millimeter-wave for carrying OFDM signal by frequency up-conversions, such as the frequency doubling using an optical carrier suppression modulation and frequency quadrupling.

In the paper, we have proposed and simulated a ROF system transmitting 25Gbit/s OFDM signals. In the transmitter, the input random binary digits are modulated by OFDM technology, which is used 64-QAM modulation in each sub carriers of OFDM signals and transformed to the digital signal. Then a Mach-Zehnder modulator (MZM) is used to modulate OFDM signals to the optical carrier generated by laser. The optical signals transmitted in the optical fibers, and are turned back into the microwave through an optical/electrical (O/E) converter in the receiver. Finally the binary digital signals can be obtained through OFDM-demodulation. For the OFDM modulation part, IFFT enables the parallel transmission of the signal. We add training series for channel evaluation, and rotative prefixion is to diminish the interruption between the signals. For the OFDM demodulation part, the signal is synchronized after optical-to-electronic conversion, including package edge detection and best time synchronization. Then the phase shifting of the received signal is corrected by channel estimation.

From the simulation results of proposed OFDM-ROF system, it can be seen that error free performance could be achieved for the generated downstream 25Gbit/s OFDM signals after 40km standard single-mode fiber transmission.

7854-133, Poster Session

Quantitative analysis of Ni, Zr and Ba in soil by combing neuro-genetic approach and laser induced breakdown spectroscopy

Q. Shen, Zhejiang Normal Univ. (China)

We propose a method of combining neuro-genetic approach with laser-induced breakdown spectroscopy (LIBS) to predict the concentrations of Ni, Zr and Ba in soil samples. In this paper, an artificial neural network (ANN) based on gradient descent with momentum and adaptive learning rate back propagation (GDMABP) algorithm is used. A simultaneous optimization strategy based on genetic algorithm (GA) is employed for selecting number of neurons in hidden layer and momentum coefficient in GDMABP ANN to obtain an optimized network. Subsequently, the network is used to predict concentration of Ni, Zr and Ba from the tested LIBS data. The approach of neuro-genetic for LIBS is detailedly described. Resultant experimental results are compared with those obtained from conventional calibration curve method at the end. Overall, the approach of combining neuro-genetic approach with LIBS is capable of predicting elemental concentration.

7854-135, Poster Session

Methods of THz pulse holography

A. A. Gorodetsky, Saint-Petersburg State Univ. of Information Technologies, Mechanics and Optics (Russian Federation); V. G. Bespalov, St. Petersburg State Univ. of Information

Technologies, Mechanics and Optics (Russian Federation)

In this paper, we present description of new methods developed for imaging with terahertz(THz) waves - methods of THz pulse holography. We present two methods - referenceless THz pulse holography and THz pulse holography with reference beam. We present theoretic results of method design, modeling of superbroadband THz pulses diffraction on arbitrary amplitude and phase objects, and numeric reconstruction of the latter followed by setup for THz holography design and experimentally obtained reconstruction of an object by means of referenceless THz pulse holographic object imaging. We propose the next step of currently proposed techniques - THz pulse holographic interferometry as well.

7854-136, Poster Session

Noncontact ultrasonic infrared thermography inspection technique

N. Tao, Capital Normal Univ. (China); Z. Zeng, Chongqing Normal Univ. (China); L. Feng, Capital Normal Univ. (China); D. Chen, BeiHang Univ. (China); Y. Li, Capital Normal Univ. (China)

Traditional ultrasonic infrared thermography is a technology in which acoustic energy is coupled to the object by means of an acoustic transducer in contact with the materials, and cracks or defects within the material are captured by an IR camera with the temperature of the defective area is relatively higher than that of the surrouding area. Sometims, the stress to the interface resulted in the extended crack, especially for the filmy or brickle materials. Accordingly noncontact ultrasonic infrared thermography technique has been presented, with a ultrasonic being used as the energy source without contacting with the object, and with an infrared camera monitoring the surface temperature distribution.. This new technique is described, along with selected applications to defects detection in a variety of materials.

7854-137, Poster Session

Study on the symmetric line-laser rut measurement

H. Song, C. Fang, Chang'an Univ. (China)

The rut results based on the line-laser rut measurement are often subjected to the vehicle bumps, vehicle pitch changes in practice applications. The principle of line-laser rut measurement and the factor are analyzed from the perspective of optical imaging. A new method of symmetrical line-laser rut detection is proposed. This method uses symmetric line-laser imaging system and can effectively reduce the rut test errors caused by the vehicle bumps, vehicle pitch changes. Experimental results show that the symmetric line-laser rut measurement can be used to detect road surface rut.

7854-138, Poster Session

Study on the symmetrical laser displacement sensor for the road surface measurement

H. Song, R. Ma, Chang'an Univ. (China); Y. Zhang, TaiZhou Univ. (China); H. Ding, Chang'an Univ. (China)

The asymmetry imaging spot caused by the CCD saturation and the scattering of uneven road surface usually leads to lower accuracy in the road surface detection. A new method of the symmetric displacement sensor for the road measurement is given. The sensor consists of two symmetrical image systems. The sensor has two CCD's which are arranged reversedly. The centroidal algorithm is adept to calculate the coordinates of the image point of CCD. The finial displacement is given by the average of the coordinates of the image point of two CCD. The experimental results indicate that the symmetrical laser displacement sensor can reduce the asymmetry imaging test error and improve the precision of measurement effectively. It is very suitable for the pavement evenness, rut and texture detection.

7854-139, Poster Session

Preliminary study on quality evaluation of pecans with terahertz time-domain spectroscopy

B. Li, China Agricultural Univ. (China); W. Cao, S. Manthanker, W. Zhang, N. Wang, Oklahoma State Univ. (United States)

This paper reports a preliminary work on a feasibility study of applying terahertz (THz) technology for pecan quality evaluation. A set of native pecan nuts collected in 2009 were used during the experiment. Each pecan nutmeat was manually sliced at a thickness of about 1mm, 2mm, and 3mm and a size of about 2cm (length) 1cm (width). Pecan shell and inner separator were also cut into the same size. The absorption spectra for the nutmeat slices, shell, and inner separator were collected using a THz time-domain spectroscopy (THz-TDS) developed by a group of researchers at Oklahoma State University. The test results show that nutmeat, shell, and inner separator had different absorption characteristics within the bandwidth of 0.2-2.0 THz. To study the capability of insect damage detection of the THz spectroscopy, the absorption spectra of insects (living manduca sexta and dry pecan weevil) were also collected. Due to high water contents in the insects, very obvious spectral characteristics were found. The results from the preliminary study show a potential of THz technology applied for quality detection of bio-products. However, since bio-products mostly have high water content and are handled under an environment with certain levels of water content, practical issues needs to be further investigated to make the THz technology a feasible tool for quality evaluation.

7854-140, Poster Session

Advanced one-dimensional triple wavelet analysis in row for infrared images from un-cooled infrared MEMS system

L. Ding, M. Hui, Y. Fei, L. Dong, Y. Zhao, Beijing Institute of Technology (China)

For the limitation of detecting materials, the images from the novel un-cooled infrared system based on visible light readout are blurry and have low contrast. The images also have more noise and larger holes. Especially after pseudo-color processing, the noise and holes will become much clearer. For the characteristics of images in the un-cooled IR system, the traditional image processing methods for IR images are not suitable for the image in our research. Therefore, an advanced one-dimensional triple wavelet analysis in row for infrared images is presented based on the characteristics of un-cooled infrared system.

In this method, the triple wavelet decomposition is made in each row of image, and detail coefficients and approximation coefficients of each row can be obtained. The detail coefficients in the first time of wavelet decomposition express the whole details of image containing noise and the edge of object. So after low-pass filter, the noise in the image can be suppressed. By the wave reconstruction made between the approximation coefficients in triple wavelet decomposition and the detail coefficients after low-pass filter, each row in images without noise and holes can be gained. In wavelet reconstruction, a weight being proportional with the filtering window is multiplied with detail coefficients. The weight can make sure the gray value of whole picture

and the contrast cannot be lower after low-pass filter. The images from un-cooled infrared system are processed in the computer with the software of MATLAB. The results support that compared with traditional methods the novel method can be more effective to eliminate the noise and fill holes, and better response to the temperature details of objects.

7854-30, Session 7

Large submillimeter and millimeter detector arrays for astronomy: development of NbSi superconducting bolometers

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The accomplishment of the Planck and Herschel space missions in the submillimeter and millimeter range was made possible by a continuous effort on detector development and their validation in ground based or baloon instruments. Limited by the intrinsic fluctuations of the radiation coming from the astronomical sources themselves, the sensitivity improvement can only come from increasing the number of photons collected. The integration time cannot be extended anymore, therefore the development of large arrays of detectors is required. We present here the characterisation and the laboratory performance of a TES array using NbSi alloy sensors on SiN membranes. The manufacturing process allows a good uniformity of the thermometers characteristics across the array. The readout electronics is based on SQUIDs and a SiGe ASIC multiplexer operated below 10 K. The coupling efficiency of the detector with the input radiation by means of antenna is analysed, as well as the frequency response of the device. The system performance achieved so far is adapted for the realisation of a ground based millimeter camera.

7854-31, Session 7

Antenna coupled microwave kinetic inductance arrays for ground based astronomy

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Microwave Kinetic Inductance Detectors (MKID) technology is relatively recent detector technology which offers great potential for achieving large focal plane arrays both in space and ground base applications. Inherent frequency domain multiplexing allows to build such arrays efficiently and at relative low cost due to reduced complexity. Pixel sensitivity, of such arrays, demonstrated recently, is fully adequate both for space and ground base applications.

We report here on design, construction and evaluation of medium size (100-250 pixel) antenna coupled MKID focal plane arrays in frequency range 150-400 GHz intended to be used as demonstrator for several ground based facilities.

These MKID arrays will be made of hybrid NbTiN/Al material or of single thin Al layer.

Array design, dark noise equivalent power (NEP) as well as on sky performance (as available) will be presented. Problems of optical coupling and optimal distribution of resonators across read out frequency band will be discussed. Possible digital read out scheme will be outlined as well.

7854-32, Session 7

New design enhancements for microbolometer PIR security sensors

K. C. Liddiard, Electro-optic Sensor Design (Australia)

The design and development of microbolometer passive infrared (PIR) security sensors at Electro-optic Sensor Design (EOSD) has previously been described at the present and other SPIE forums. The primary object of this patented technology is to provide a higher performance option to current pyroelectric PIR sensors, including longer detection range, detection of developing fire and machinery failure, and imaging capability. A number of other applications have been identified.

The EOSD sensor technology employs a novel mosaic-pixel focal plane detector array (MP-FPA), together with purpose-designed optics and electronic readout to achieve high detective performance in low product cost, short range sensor applications. In previous papers emphasis was placed on FPA design for amorphous silicon (a-Si) microbolometers, and other materials were briefly discussed as options. In this paper new MP-FPA designs will be described for further performance enhancement and application to vanadium oxide (VOx) and other silicon alloys, including amorphous Si:Ge. The designs are intended for high volume production in CMOS/MEMS foundries. The performance of different FPA designs is compared for upgrade PIR security sensors and low cost thermal imagers.

7854-33, Session 7

Calibration of the mid-infrared imaging camera

N. Li, Graduate Univ. of the Chinese Academy of Sciences (China)

We present the pre-launch infrared calibration of the 3~5um infrared focal plane array. Use the extended area blackbody as a standard radiation source, whose temperature range is Amb-500 and wavelength range is 1-99um.The infrared calibration experiment is held in a dark house where ambience is controlled. Set the integration time of infrared camera at 1ms, 2ms, 3ms, 4ms and 5ms, and acquire image of blackbody at different temperature in case of each integration time. Then use linear regression models to fit the radiance response curve of the camera. Consider pixels at different temperature images to be the predictors, and radiance of blackbody at different temperatures as responses. Before curve fitting, we should pick out extreme values called outliers which are defined as individual data points that you exclude from a fit because they are inconsistent with the statistical nature of the bulk of the data, and have a large influence on the fit.

Then we use linear least squares, weighted least squares and robust least squares methods to fit the calibration data. At last, evaluate the goodness of the three fit methods. We also use three methods to evaluate it. They are residual analysis, goodness of fit statistics and confidence & prediction bounds. To be concluded, the weighted least squares and robust least squares give better fitting. However, the weighted least squares method should know the variances of the responses to determine the weight of each point before cure fitting. Conversely, the robust least squares method which uses an iteratively reweighted least-squares algorithm, automatic obtains the best weight of each point. So, the robust least squares method is more suitable for infrared calibration application.

7854-34, Session 7

Polarization modulation terahertz filter based on metallic fractal structures

G. Zhao, B. Wei, L. Liu, Capital Normal Univ. (China)

Terahertz transmission through the metallic mesh structures has attracted increasing interests due to their potential application on terahertz optical devices. Terahertz radiation can excite the surface Plasmon polarization on the metallic structures by the suitable mode match. The frequency selection surface can selectively reflect an electromagnetic wave with the resonance frequency. Terahertz transmission through these metallic mesh structures behave as some of band pass filters that can be used for the modulation of terahertz wave propagation.

In this paper, the terahertz transmission properties of metallic fractal structures are presented by the terahertz time domain spectroscopy and the numerical analysis based on the finite differential time domain simulation. Several metallic fractal structures including the H-shape fractal pattern, the square-hole fractal pattern, and the cross-coupled fractal pattern are studied. The terahertz transmission spectra of these metallic fractal structures are shown at two polarization of terahertz field perpendicularly. The results show that the asymmetric metallic fractal structures such as H-shape fractal structure have an obvious polarization dependent and frequency selective transmission. The symmetric structures have no such polarization dependence. Terahertz transmission through the H-shape metallic fractal structure can be switched between the different pass bands by changing the polarization direction of terahertz field relative to the first-level fractal line. Therefore, a potential application may be to realize a polarization tunable terahertz filter based on this kind of H-shape metallic fractal structure.

7854-35, Session 8

TAD2: the first truly non-intrusive lie detection system deployed in real crime cases

S. Sumriddetchkajorn, A. Somboonkaew, National Electronics and Computer Technology Ctr. (Thailand)

Interrogation is an important step for seeking truth from the suspect. With the limit of the intrusive nature of the current polygraph in mind, we show here a highly-sought-after non-intrusive lie detection system with a friendly user interface called TAD2. The key idea behind our TAD2 is based on the analysis of far-infrared data obtained remotely from the periorbital and nostril areas of the suspect during the interrogation. In this way, measured change in skin temperature around two periorbital areas is converted to a relative blood flow velocity while a respiration pattern is simultaneously determined from the measured change in temperature around the nostril region. In addition, TAD2 is embedded with our automatic baseline assignment that is used for distinguishing the subject's response into normal or abnormal stage. In our TAD2, the officer can choose to perform one of the three standard lie detection tests, namely, Zone Comparison Test, Modified General Question Test, and Relevant & Irrelevant Test. Field test results from suspects in real crime cases will be discussed.

7854-36, Session 8

A design study on terahertz interferometry in Antarctica

H. Matsuo, National Astronomical Observatory of Japan (Japan); S. Shi, Q. Yao, Purple Mountain Observatory (China); Y. Luo, Tohoku Univ. (Japan); T. Matsuo, Jet Propulsion Lab. (United States); I. S. Ohta, Kinki Univ. (Japan)

Antarctica is at the forefront of millimeter, submillilmeter-wave astronomy, where atmospheric transmission is high and stable. High altitude site at 4000 m in Antarctica such as Dome A and Dome F could be most suitable for astronomy at supra-terahertz frequencies. We expect some atmospheric window at 1.5, 1.9, 3.4 and 5.8 THz, where ionized atomic emission lines as well as dust continuum emission can be observed. Terahertz frequency region have been suffered from low angular resolution observations from airplanes, balloons and satellites with small telescopes. Terahertz interferometry form Antarctica high-altitude plateau will change this situation dramatically.

In this presentation I will discuss on a design study of terahertz interferometer in Antarctica. First I will discuss comparison between heterodyne interferometry and direct detector interferometry. Although heterodyne interferometry is matured and its sensitivity can be nearly background limited, frequency bandwidth and pixel counts are limited. Direct detectors, on the other hand, have larger bandwidth and large format array can be used to realize high-efficiency observing system. Multiplying interferometer using Martin-Puplett type double-input Fourier transform spectrometer can be used to subtract atmospheric background fluctuation. Requirements on detector performances such as background limited sensitivities, pixel counts, time response and dynamic ranges will be discussed.

I will also include discussions on photon counting interferometry, which is first experimented by Hanbury Brown and Twiss in 1950's. By implementing fast response FIR detectors to measure photon arrival time, visibility can be measured by the correlation of the photon statistics.

7854-37, Session 8

Dielectric response of (Ca0.5+xSr0.5-x)[(Al0.5Nb0.5)0.5Ti0.5]O3 complex perovskite at terahertz region

M. Hu, Hubei Univ. (China); K. Mu, C. Zhang, Capital Normal Univ. (China); H. Gu, Hubei Univ. (China)

Dielectric ceramics with ultralow loss at Terahertz frequency are widely desired due to their important applications in future Terahertz wave communication. Recently, calcium-based complex perovskite ceramics with Ca(B1B2)O3 (B1=Zn2+,Mg2+,Ca2+,Fe3+,Al3+; B2=Ta5+,Nb5+,Ti4+) formula were found to have ultralow loss at GHz frequency. However, their dielectric behaviors at THz frequency are still lack of investigation. Since the cations and their bonding environment, especially the octahedral tilting structure in Ca(B1B2)O3 complex perovskites were of crucial importance to the dielectric properties, adjusting the A-site cation size would be an effective way to modify the tilting angles, and subsequently improve the dielectric behaviors in above ceramics in THz frequency range. In present paper, complex perovsktite ceramics (Ca0.5+xSr0.5-x)[(Al0.5Nb0.5)0.5Ti0.5]O3 (abbreviated as CSANT) were synthesized by conventional solid-state reaction.

The X-ray diffraction patterns indicated that besides CSANT perovskite

solid solution, small amount of Ca4Ti3O8-based layered perovskite phase was also segregated after x≥-0.1. The BO6 octahedra in CSANT became more antiphase tilted as the increase of x value and a crystal structure transition from Fm3m cubic to Pbnm space group underwent at x=-0.1. The compositional dependence of the dielectric properties of CSANT ceramics were elaberately investigated by using Time-Domain THz transmission spectrum. Results illustrated that the power absorption property in CSANT ceramics were closely related to the Ca/Sr cation ratio at A-Site of perovskite and the tilting transition of BO6 octahedra. The power absorption exhibited a monotonous variation with Ca/Sr cation ratio, which could be explained in line with one-phonon absorption approximation in classical damped oscillator model. When the optimal sintering process was employed to CSANT ceramic, a lowest THz absorption could be obtained in x=0.3 CSANT ceramic, with a mean real part of refraction index being around 1.6, which manifested itself a great potential usage in dielectric resonators and filters in THz frequency range.

7854-38, Session 8

Far-infrared in vivo signature of human skin by terahertz time-domain spectroscopy using waveform rebuilding technology

X. Li, China Jiliang Univ. (China) and Zhejiang University (China); J. He, China Jiliang Univ. (China)

Terahertz time-domain spectroscopy (THz-TDS) has become a very important tool for determining optical material parameters in broadband range between a few tens of gigahertz and several terahertz. The band is regarded containing unique information about the vibration and rotation of molecules which was little understood before and will create chemical and biological sensing modalities that avoid labeling, have high sensitivity and take advantage new signatures. Terahertz spectroscopy has been used successfully to characterize DNA and proteins. Terahertz pulsed imaging has previously been used for imaging of basal cell carcinoma, a form of skin cancer, ex vivo in the laboratory and more recently in vivo.

We present terahertz time-domain spectroscopy characterization of human thumb skin in reflection measurement mode with wave rebuilding technology. As the sensitivity of terahertz radiation to polar molecules of water is very high, biological tissues with high level of hydration show strong absorption at terahertz frequencies. Considering in vivo application at the same time, the reflection measurement mode is preferred. A reflective THz TDS system is built, and THz spectra of human thumb skin are obtained. In the TDS experiment, we let thumb skin contact one side of a highly resistive silicon wafer with 2mm thickness, and THz pulse normally incident on the other side of the wafer. The reflected THz pulse detected with EO sampling includes two parts, one is from air-silicon interface, and the other from silicon-skin interface. We extracted optical material parameter of human thumb skin using waveform rebuilding technology, in which the pulse from silicon-skin interface is taken as a sample signal, and from the air-silicon interface as a reference, since there is obvious Fresnel transform function exists. The reflection spectrum for the thumb skin is successfully calculated by minimizing the difference between the measured sample waveform and a rebuilt one in time domain. This waveform rebuilding technology has potential applications in THz spectroscopy both for simple layer and for complex layer-structures in human skin.

7854-39, Session 8

Study on detection and identification model of passive teraherz imaging system for extended target

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Detection and identification performance prediction is an important part in designing the passive teraherz-band imaging system. This paper presents a novel detection and identification performance model of passive teraherz imaging system for concealed extended target. In the modeling process we take into account factors such as radiation principle of target and background, the characteristics of atmospheric transmission, and imaging detecting system, and human eye perceive. First we research interaction principle of teraherz radiation for object based radiation principle of low temperatures teraherz blackbody. We calculate target and background teraherz radiation power, and analyze specular reflection and lambertian reflection characteristic of target and background. So target-to-background contrast is described in different fields and ranges. Secondly, we research the effect of teraherz beam attenuation in different atmospheric environment, and choose the best teraherz atmospheric absorption frequency. So we can account target radiation power in the surface of imaging system. Thirdly we research passive teraherz imaging detecting theory. And we research the effect of teraherz beam focalizing characteristic, interference, diffraction for imaging system, and present a imaging and detection method for improving THz radiometric resolution. Due to untest target is extended, the two dimensional real-time scanning method is adopted. So we account imaging system modulate transfer function and target detection and identification probability of passive teraherz imaging system in different distance and teraherz frequency. The paper shows experimental results for a target/background as ranges and is useful to design and evaluate the passive teraherz imaging system for concealed object detection and identification.

7854-40, Session 8

Image fusion based on millimeter-wave for concealed weapon detection

W. Zhu, Y. Zhao, L. Dong, Beijing Institute of Technology (China)

Image fusion is the technique that integrates and processes the multi-source images from various sensors intelligently and obtains more accurate, complete and dependable description about the same scene than any of the individual source images. The purpose of image fusion is to utilize the complementary and redundant information in multi-source images. As a result of this processing, the fused image should be more suitable for human visual perception or computer further processing tasks such as object recognition and feature extraction, etc.

This paper describes a novel multi sensor image fusion which is presented for concealed weapon detection (CWD). As is known to all, because of good transparency of the clothing at millimeter wave band, a millimeter wave radiometer can be used to image and distinguish concealed contraband beneath clothing, for example guns, knives, detonator, ere. As a result, we adopt the passive millimeter wave (PMMW) imaging technology for airport security. However, in consideration of the wavelength of the millimeter wave and the single channel mechanical scanning, the millimeter wave image has law optical resolution. Therefore, visible image (VI), which has high resolution, is proposed for the image fusion with the millimeter wave image. Before the image fusion, a novel image pre-processing which specifics to the fusion of millimeter wave imaging and visible image is adopted. And in the process of image fusion, multi resolution analysis (MRA) based on Wavelet Transform (WT) is adopted. In this way, the experiment result showed this method has advantages in concealed weapon detection.

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7855-01, Session 1

PEM-based polarimeters for industrial applications

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The photoelastic modulator (PEM) is a resonant polarization modulator operating on the basis of the photoelastic effect. The PEM affords high modulation purity and efficiency, broad spectral range, high power handling capability, large acceptance angle, large useful aperture and excellent retardation stability. These superior optical properties of the PEM are particularly suited to high sensitivity polarimetric measurements.

A polarimeter is an optical instrument for measuring either the polarization state of a light beam or the polarization properties of a sample in terms of diattenuation, retardation and depolarization. While certain applications require measuring the complete set of polarization properties, most of the industrial applications only need the accurate determination of one or two specific polarization parameters. The PEM-based polarimeters have been used in a variety of industrial applications, including semiconductor, flat panel display, pharmaceutical, and many other industries. In this paper, I will review polarimetric metrology and industrial applications using the PEM technology.

7855-02, Session 1

Computer simulation of photoelasticity

D. Yan, S. Ma, Beijing Institute of Technology (China)

Photoelasticity can provide isochromatics (the contour of maximum shear stress) and isoclinics (the orientation of principal stress) using a specially designed optical setup based on the phenomenon of temporary birefringence of photoelastic materials. For long period of time, photoelasticity is proved to be a powerful tool in visualizing/quantifying stress fields. Analysis of the stress field from isochromatics and isoclinics needs good understanding of the stress distribution, which is often not easy when analyzing a complicated model. At this time, a simulation of the experimental results on a similar model will greatly help understanding the experimental data.

In this paper, a photoelasticity simulation system is constructed. The stress field of a loaded model is firstly calculated using finite element method (FEM), and then the intensity of interferometric fringes (isochromatics and isoclinics) from the photoelastic setup is calculated using the Jones calculus. The whole system is realized with Matlab. Using this system, the isochromatics and isoclinics on a model in any shape could be simulated. The validity of the simulation system can be verified by the comparison of the experimental results and the simulated results.

7855-03, Session 1

Spectroscopic topological Stokes polarimeter

T. Wakayama, Saitama Medical Univ. (Japan); Y. Otani, Utsunomiya Univ. (Japan); T. Yoshizawa, Saitama Medical Univ. (Japan)

Singularity optics has attracted great interests because of unique optical properties of singular beam such as an optical vortex beam and a vectorial vortex beam. Techniques for the generation of the beam have been proposed by a lot of researchers using a sub-wavelength structure, a photo aligned polymer and a spatial modulator. In spite of having great potential to the measurement, proposals of the measurement using a singular beam are not many. Until recent years, our group has generated singular beams with both polarization and phase singularity. We became aware that the singularity beam has possibility to measure polarization properties such as Mueller matrix and Stokes parameters according as our research advanced. This idea has a potential to measure the polarization properties in real-time. Moreover, it can bring polarization information shut in the beam spot. In our study, axisymmetrical quarter wave plates (AQWPs) are fabricated by the alignment of segments of quarter wave film. In addition, the azimuthal angle of the device is changed its own direction. This device works as same as the technique of rotating quarter wave plate. In this paper, we have developed spectroscopic topological Stokes polarimeter. In the experiment, we evaluated birefringence distribution of the AQWPs. When the position of singularity point changed in the beam spot, we measured states of polarization. In this result, we could determine the change of polarization states corresponding to the change of the singularity points.

7855-04, Session 1

Line type polarimeter for spectroscopic Mueller matrix

Y. Otani, Utsunomiya Univ. (Japan); S. Takano, Tokyo Univ. of Agriculture and Technology (Japan)

A line-type polarimeter for spectroscopic Mueller matrix is developed to evaluate the surface profiles of nanostructures. A spectral line imaging camera which is consisted on the grating and prism is employed as a one-dimensional spectrometer. Its one-direction works as a spectral line direction and position of x axis at a two-dimensional CCD camera. The halogen lamp is employed for a white light source. It is fixed on the goniometer stage for changing the incident angle for 0 to 90 degrees of incident angle.The Mueller matrix, which is 4´4 matrix that fully defines the polarization characteristics of an object. It is important to evaluated between polarization properties and the surface profile of the nanostructures is examined. All polarization properties can be shown Mueller matrix which consists of 4x4 elements. We succeeded to decompose the Mueller matrix to polarization properties to depolarizer matrix, a retarder matrix and a diattenuator matrix from full Mueller matrix. From these Mueller matrices, we can obtain the many polarization properties such as diattenuation, total retardance, linear retardance, orientation, optical rotation and degree of depolarization.

7855-05, Session 1

Double-aperture speckle shear interferometry without the influence of in-plane displacement and its derivative

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In industrial metrology, the determination of slope distribution information is of vital importance in the investigation of out-of-plane displacement of thin plates because the slope distribution is related to the stress and strain distributions of theses plates. In speckle

metrology, double-aperture speckle shear interferometry is a powerful tool in the measurement of slope distributions, and has been used extensively to analysis the stress and strain fields of thin plates in the last decades. However, this speckle shear interferometry is intrinsically sensitive to both in-plane displacement component and its derivative. Fringe pattern generated from it contains information of slope, in-plane displacement and its derivative. In order to obtain the pure slope distribution, it is necessary to eliminate the influence of the in-plane component and its derivative. A modified double-aperture speckle shear interferometry using CCD as a digital recording medium that is only sensitive to the derivative of the out-of-plane displacement (slope) distribution is proposed in this paper. A mask with two apertures separated at a certain distance is placed in front of the imaging system, and a glass wedge is placed in front of one aperture so as to introduce a lateral shear. Temporal phase shifting technique has been used for quantitative fringe analysis. A piezoelectric transducer (PZT) device which is attached on the rear of the mirror and driven by a PZT driver is employed to control the phase shifts. The speckle noises in slope distribution fringe patterns can be removed after these fringe patterns pass through low-pass filtering. A theoretical analysis and an experimental demonstration are given. Results from theory and experiment are in good agreement.

7855-06, Session 1

Measurement of the elastic modulus of solid material with objective speckle field

P. Ran, Z. Fan, Kunming Univ. of Science and Technology (China)

There are two recording methods to record the speckle filed of the scattered surface, one is called subjective speckle field which is recorded by the CCD with imaging lens, and the other is objective speckle field that is recorded with CCD without imaging lens. The subjective speckle field can be used to measure the total field in-plane displacement but the sensitive or resolution capability of it is much smaller than that of objective speckle field, however the objective speckle field can only be used to measure the parallel displacement. In this paper, an approach based on the objective speckle filed to measure the elastic modulus of solid material with three points bending method is presented. When the specimen is proper loaded and deforming in its elastic deformation region, the images of objective laser speckle field of the force rod loading are recorded on CCD, the each two images are added and performed fast Fourier transformation(FFT), the parallel straight even separated fringes appear in the FFT frequency spectrum, and according to Fourier transformation theory, the number of the fringes N equals exactly to the displacement of the identical speckle pairs, the displacement of the rod for loading force can be calculated by multiply N with the size of the CCD pixel, and the deflection of the specimen is equal to the displacement of the force loading rod, therefore, the elastic modulus of the specimen is obtained, and the value of the elastic modulus agrees well with the stretch approach in which the tensile strain is measured with strain gauge. The approach presented in this paper has advantage of noncontact and very high resolution, if combined with sub-pixel algorithm the resolution capability can be improved further.

7855-07, Session 1

Determination of the optimal marker positions for optical extensometer considering lens distortion

Z. Zhao, X. Wang, S. Ma, Beijing Institute of Technology (China)

Extensometer is a useful tool for measuring the strain (the relative movement of two points) of a specimen subject to load. Different from the mechanical extensometer, optical extensometer measures strain by capturing the images of two markers and then analyzing the movement of the two markers with specially designed image analysis algorithms. Before using optical extensometer, two markers with good contrast must be firstly fixed on the measured specimen, and then the high quality digital images of the two markers are captured and analyzed.

Besides the requirement on high contrast and low noise, the more important aspects to affect the accuracy of the optical extensometer is the pixel resolution of the digital image. The measurement resolution of the marker location algorithms is often evaluated as pixel, for example 0.05 pixels. Therefore, the higher pixel resolution of digital image will induce a higher strain measurement resolution in optical extensometer. In order to obtain the highest pixel resolution, the imaging system should be adjusted to create a field range just covers the two markers. That means the two markers are at the two edges of the image. However, if considering the distortion of the lens, the edges of the image are with higher distortion than the center. The distortion will obviously affect the accuracy of the marker locating algorithms. Therefore, when applying optical extensometer, a balance should be found between the high pixel resolution and high distortion of the marker image. In order to obtain the best measurement accuracy, the maker positions for optical extensometer should be optimized. An optimization model for choosing best maker position for optical extensometer is constructed on the considering of the pixel resolution and second order lens distortion. A standard rubber specimen is tensioned and the strain is measured using optical extensometer with makers located at different positions. The experiment show that the extensometer using markers located at the position optimized from the model in this paper gives the best measurement results.

7855-08, Session 1

Error analysis of strain measurement induced by operating temperature of uncooled CCD

J. Pang, Q. Ma, S. Ma, Beijing Institute of Technology (China)

Optical extensometer is a non-contact optical system to measure the strain (relative movement of two points) of a deforming object. By using optical extensometer, two markers with good contrast are firstly fixed on the measured object, and then the digital images of the two markers are captured. The position of each marker is registered in high precision using specially designed image processing algorithms, and then the strain is calculated from the difference of the movement of the two markers.

In this paper, the influence of operating temperature of uncooled CCD on the accuracy of strain measurement was investigated. A special board with two circular markers is placed on a stable vibration-free platform. The images of the board are continuously captured by an uncooled CCD, and then the relative movement of the two markers (strain of the board) is calculated from the captured images through image analysis methods. Theoretically, the strain of the unloaded board should be zero. However, the experimental results do not support this. It shows that the measured strain of the board keep grew in the early stage, while kept steady in the late stage. During the images capturing, the temperature of the CCD is recorded using thermo couples. The measured temperature of the CCD shows a similar tendency with the change of strain. The changes of the measured strain have an agreement with that of the CCD's temperature. For different types of the uncooled CCD, the temperature changes is about 5~10 from the beginning of the experiment to the end (about 4 hours), and the error of the measured strain induced by the temperature was about 150~200μ . It is considered that the error is related to the inherent noise of the electronic components of the CCD whose operating mode is sensitive to the temperature changes. When using the optical extensometer, it is suggested to preheat the CCD 1~2 hours before the measurement. Otherwise, the strain induced by the operating temperature should be eliminated from the measurement results.

7855-09, Session 1

Optical system design for crack inspections using magneto-optical imaging

Q. Hu, Quest Integrated, Inc. (United States)

Magneto-optical technique is a hybrid flaw inspection method that combines the high sensitivity of eddy current techniques and fast visualization of optical inspections. The cracks in metallic structures results in eddy current path variation, and thus vertical magnetic field changes that will cause Faraday rotation of the polarized light. An analyzer is used to separate the polarized light between areas with flaws and areas without flaws before it enters a digital camera. The optical system has to have high image contrast, low noise level, and minimum image distortion. This paper discusses the optical system design in magneto-optical imaging for surface and subsurface crack inspections. Both the optical system modeling and design trade-offs are presented. Initial test results are described.

7855-10, Session 2

Development of an inner profile measurement instrument using a ring beam device

T. Yoshizawa, T. Wakayama, Saitama Medical Univ. (Japan)

Inner profile measurement has a lot of request from various fields such as mechanical industry, automobile and aircraft industries, and even in the medical and dental fields. We proposed measurement method of inner diameters of pipes and/or holes using a ring beam device which consists of a conical mirror and a laser diode. This measurement method is based on optical sectioning principle using triangulation. This optically sectioned profile of an inner wall of pipe objects is analyzed to produce the inner diameter or profile. Here, we report recent development and applications of this optical instrument with a simple and compact configuration. As experimental results, we show performance of the instrument and some examples for inspection of mechanical components.

7855-11, Session 2

Automatic, fast, and high-density optical inspection for shell-shaped engineering objects

X. Liu, X. Peng, A. Li, Y. Yin, C. Zhang, D. He, Shenzhen Univ. (China)

Three dimensional (3-D) optical measurement has been widely applied for the automatic inspection of a variety of engineering objects. Challenges of automatic inspection of 3-D engineering objects with a shell-shaped surface may involve in the complexity of topology of the surface that will lead most 3-D vision inspection systems to fail. Furthermore the requirements of automatic, fast, accurate and high-density data acquisition and reconstruction are also big challenges in in-situ inspections. Automatic implies the inspection free from the interaction, and fast, high-density and accurate inspection makes whole-field optical method preferable, for instance, a fringe projection or phase measuring technique. However, it would be very difficult for a fringe projection technique to reconstruct the phase distribution or a range image for a shell-shaped engineering object due to the thin-wall geometric characteristics. In this paper, we propose an approach for the inspection of shell-shaped engineering objects mentioned above. This approach includes the establishment of an in-situ 3-D calibration target in a measurement volume, which consists of a number of benchmark points. The coordinates of those benchmark points are obtained from the photogrammetry technique and they are thereafter employed for the determination of the poses and orientations of multiple sensors, which will be further used to implement the vision inspection task. Each individual sensor at different pose can acquire only a portion of the test object so that the registration and fusion of range data obtained from each individual sensor are needed in order to reconstruct a complete 3-D model that can be comparable with a nominal CAD model. A practical example with the inspection of a quartz crucible is presented to demonstrate the validity of the proposed approach.

7855-12, Session 2

A palm-top camera for 3D profilometry incorporating a MEMS scanner

T. Yoshizawa, T. Wakayama, Saitama Medical Univ. (Japan)

To improve difficulties inherent to the conventional three-dimensional profiling system based on pattern projection method, we have proposed incorporating a recent digital device such as a MEMS scanner into projection optics. Due to this revision, first of all, such a small size system like a palm-top camera was attainable, and low cost measurement system was potentially realized. In this system, we can control the scanner to produce the projection pattern with appropriate periodical structure and sinusoidal intensity distribution. Due to this flexible pattern projection, phase-shifting technique becomes applicable for industrial inspection and measurement in automobile industry and others. The camera is as small as a photographic digital camera in size. I addition, our recent improvement of measuring performance by modulating the projected pattern is to be demonstrated.

7855-13, Session 2

Phase shift based measurements using a pocket LCD projector

Y. Williams, K. Harding, GE Global Research (United States)

Phase shifting based measurements have been well established for use in both interferometry and structured light based measurements. The use of modern LCD, DLP or LCOS based projectors to create and shift projected patterns for use in phase shifting systems has provided new capabilities such as pattern masking, adjustable resolutions and active preprocessing, along with many challenges. Now the latest consumer projection technology has made available low cost, pocket sized projectors, some with built in memory. These small projectors open up the possibility of mini-phase shift systems, as well as the possibility of portable measurement systems. This paper explores some of the possibilities for systems made with pocket size pattern projectors, and what some of the limitations may be that will need to be overcome. Experimental data will be presented that illustrates some of these challenges.

7855-14, Session 2

A hand-held triangulation sensor for small features measurement

G. Abramovich, K. Harding, GE Global Research (United States)

No abstract available

7855-15, Session 2

A simple optical system for measuring small rotation angle of mechanism

W. Li, Institute of Electrical Engineering (China); Q. Ma, Beijing Institute of Technology (China); D. Li, S. Liu, Y. Chen, Institute of Electrical Engineering (China)

Measurement and inspection of the small rotation angle of precision mechanism is of great importance to the evaluation of the stiffness and stability of the mechanism. In this paper, a simple optical system for small rotation angle measurement is constructed. A small laser diode is fixed on the rotation part of the mechanism. The laser beam is received by a semitransparent screen, which is placed at a certain distance from the mechanism. The spot on the screen is captured by a digital CCD camera. The position of the spot could be registered from the image in high precision using the gray centroid algorithm, a special designed image processing algorithm to locate a marker in digital image. When rotation occurs, the movement of the spot could be calculated from the recorded images during rotation. And then the angle can be calculated from the spot movement according to geometrical relationship. Using a high resolution CCD camera and a high magnification optical lens, the movement of the spot could be identified at sub-micron level. Therefore, the resolution of the rotation angle is expected to be 10-6 degree, if the distance between the screen and the laser diode exceeds 1 m.

In order to verify the system and evaluate its accuracy, a deflection test of a low carbon steel cantilever beam is performed. A Basler CCD camera (with resolution of 1624×1236 pixel) and Avenir lens is used to capture the spot images. The experimental results show that the measured deflection is of good agreement with the theoretical value. The maximum relative error was less than 1.5%.

The optical system is then used to measure the stiffness of a folding mechanism on satellite. The application shows the advantages, such as high resolution, low cost and great convenience, of the system.

7855-16, Session 2

Two-dimensional dynamic photoelectric autocollimator based on single linear CCD

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Autocollimator based on the principle of optical autocollimation is a common instrument used to measure the small angle, which is widely used in the domain of aerospace, measuration and scientific research etc. a novel method for the dynamic measurement of the two-dimensional small angle based on a single linear CCD is proposed, which consists of a photoelectric autocollimator, a single linear CCD and a circuit of image acquisition and processing etc. In this system the array of green LED is used as the balance light, the linear CCD is used to trace the position of N shape reticle moving with the mirror rotating, and the high scale integrated chip FPGA is used to realize the high speed data acquisition and processing, which make true the two-dimensional small angle measurement. Experimental results show that the measuring distance is around 1m, the measuring range is ±15', the measuring speed is 2KHz, and the measuring accuracy is no more than 1". This system has the advantages of simple structure, high accuracy and fast measuring speed, which provides an effective technical solution for dynamic two-dimensional angle measurement.

7855-17, Session 2

Absolute phase calculation from one composite RGB fringe pattern image by windowed Fourier transform algorithm

Z. Zhang, Z. Jing, H. Feng, H. Ma, S. Zhang, Hebei Univ. of Technology (China)

One challenging problem in phase-based fringe projection 3D imaging systems is how to obtain absolute phase of discontinuous surface from one snapshot image. Phase-shifting (PS) and Fourier transform (FT) algorithms are mostly applied to calculate phase information. Although PS algorithm can give high precise value, it needs multiple captured fringe pattern images having phase shift in between. While FT profilometry calculates the phase map from one fringe pattern image, it has been applied to such fields as fast acquisition of unstationary objects surface. Because of the internal properties of the discrete FT on a finite image size, leakage effects near edges or discontinuities cause errors in the calculated wrapped phase. Both PS and FT algorithms only obtain wrapped phase map, which needs to be unwrapped. Recently, the optimum three fringe number selection method was proposed to obtain the absolute phase map pixel by pixel from three wrapped phase maps, which maximizes the dynamic range of the shape data1. If three fringe patterns having the optimum fringe numbers are captured at the same time, the absolute phase of discontinuous surfaces can be obtained in a real-time way.

This paper presents an absolute phase calculation method from one composite RGB fringe pattern image by using the windowed Fourier transform (WFT) algorithm2 and the optimum three fringe number selection method. Three fringe patterns having the optimum fringe numbers are coded into the red, green and blue channels of a composite color image. The generated composite RGB fringe patterns are projected from a Digital Light Processing (DLP) projector and the deformed fringe patterns on an object surface captured by a color CCD camera from a different viewpoint. The WFT algorithm limits the processed image to a small area, so it can give much better phase near edges or discontinuities than FT algorithm. Applying the WFT algorithm to the three fringe patterns obtains three wrapped phase maps. An absolute phase map is calculated pixel by pixel from one composite RGB fringe pattern image after applying the optimum three fringe number selection method to the three obtained wrapped phase maps. Therefore, the proposed method can measure 3D shape of objects having discontinuous surfaces from one snapshot image. Experimental results on moving discontinuous objects show that the proposed method reliably obtains the 3D shape information.

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2. K. M. Qian, H. X. Wang, and W. J. Gao, Windowed Fourier transform for fringe pattern analysis: theoretical analyses, Applied Optics 47(29), 5408-5419 (2008).

7855-18, Session 2

High-resolution dynamic three-dimensional profilomety based on a combination of stereovision and color-encoded digital fringe projection

D. Li, J. Tian, Shenzhen Univ. (China)

A high-resolution dynamic three-dimensional (3-D) profilometry based on the combined stereovision and color-encoded digital fringe projection is proposed. In this technique, a sinusoidal fringe pattern is encoded with spatial neighborhood strategy based on De Bruijn sequences. A decoding algorithm for the color pattern is presented. The absolute phase value is retrieved by space method based on locally

intensity variety, and unwrapped by dividing the periods based on the intensity peak and the corresponding color information. Therefore, only a single color image is needed to realize the unique code in pixel resolution, which meets the demand of high-resolution, real-time 3D shape measurement. Significantly, this technique has the ability of pixel-level resolution. It is more suitable for measuring discontinuous objects. Since the phase value at each pixel is used to assist stereo matching, the measurement speed can be increased up to the frame rate of the camera, and the measurement accuracy is also enhanced. With parallel processing technique, a measurement system consisted of one projector and two cameras is developed. Experimental results are presented to show the feasibility of the proposed method.

7855-19, Session 3

Profilometry using optical comb light source and sinusoidal phase modulation technique in Fizeau-type interferometer

S. Choi, H. Miyatsuka, O. Sasaki, T. Suzuki, Niigata Univ. (Japan)

A profilometry based on Fizeau interferometer with a combination of the optical comb light source and the sinusoidal phase modulation (SPM) technique is demonstrated. This profilometry enables precision measurement of surface profile and coherence tomography with a high accuracy of nanometer order and long dynamic range over the optical wavelength.

The white-light interferometry for the step-profile measurement longer than wavelength cannot generally be achieved by the Fizeau interferometer. However, using the optical comb enables the white-light interferometry-like step profile measurement with the Fizeau interferometer. Because of discrete wavenumber components of the optical comb, the interferometric signal has periodical high-order intensity peaks whose interval is a constant value in optical path difference (OPD). By employing a high-order peak in the Fizeau interferometer, highly-stabilized common-path profilometry can be achieved. Moreover, our method is based on not only measuring intensity peak position but mapping the phase by the SPM technique.

The optical comb was generated with a Fabry-Perot etalon and a super luminescence diode with the center wavelength of 840 nm. The bandwidth of the generated optical comb was 20 nm. The wavenumber was swept by controlling the resonance length of the Fabry-Perot etalon. The sweeping range was about 500 micro meters in terms of OPD. Displacements of a mirror were measured by detecting a zero-phase position using the first order peak. The difference between the two positions of the intensity peak and zero-phase was about 80 nm in terms of OPD. The accuracy estimated by 5 repeated experiments was about 13 nm.

7855-20, Session 3

A displacement reconstruction algorithm used for optical feedback self mixing interferometry system under different feedback levels

Y. Fan, Y. Yu, J. Xi, Univ. of Wollongong (Australia); H. Ye, Zhengzhou Univ. (China)

The optical feedback self-mixing interferometry (OFSMI) has been studied extensively in recent years. The signal generated by an OFSMI system can be used for reconstructing displacement. Feedback level is an important parameter which strongly affects the shape of the signal. Some methods have been reported on displacement reconstruction at particular feedback levels. However, in practice, the feedback level can be variable in an OFSMI system. It is necessary to develop an algorithm which can obtain displacement under any feedback levels. In this work, the waveform features observed from an OFSMI system is studied firstly. The core part of the OFSMI system consists of a laser diode (LD), a lens and an external moving target. When the light emitted from the LD hits the external target, a small portion of reflected or backscattered light re-enters the laser cavity and consequently changing the amplitude and frequency of the laser power. This laser power is acquired by a computer which can be used for the extraction of external target's movement information. An algorithm for measuring displacement of the target in the OFSMI system is presented. The measurement error is caused mainly by inaccurate locations for those characteristic points on the waveform of a sensing signal. The paper classifies the waveforms by optical feedback level and gives an identification rule for those characteristic points. The proposed algorithm is verified by simulation signals firstly, then applied on extensive experimental sensing signals. The results show that the displacement of the target can be reconstructed under any feedback level with high accuracy.

7855-21, Session 3

FPGA-based signal processing in an optical feedback self-mixing interferometry system

Z. Li, Y. Yu, J. Xi, J. F. Chicharo, Univ. of Wollongong (Australia); H. Ye, Zhengzhou Univ. (China)

Optical feedback Self-mixing Interferometry (OFSMI) can achieve a high-precision displacement sensing and measurement by using off-line data post-processing. Towarding to practical applications, such existing off-line post-processing are insufficient for numerous reasons, most notably because the existing methods cannot support high-performance real-time measurement demands. Field-programmable gate arrays (FPGAs) are an attractive method to handle both high throughput and adaptability to the real-time digital signal processing. In this work, we build a FPGA based displacement sensing system by using OFSMI technique. The sensing signal from the OFSMI system is feed into a FPGA development system for high speed processing, from which the displacement information can be obtained. The FPGA design includes noise reduction block, signal peak identification block and impulse magnitude tracking block. By investigating the features for both the sensing signal and the noise involved, we decide to use a median filters for removing sparkle like noise while a Bandpass FIR filter for reducing the high frequency noise and the slow time-varying fluctuation. As the magnitude of the sensing signal is time-varing, for adapting such variation, a dynamic updating threshold is specially considered in the design for gurantee the measurement accuracy of the tracking block. Both simulink and hardware tests show that the FPGA design can achieve fast displacement sensing.

7855-22, Session 3

Time-resolved vibrational surface profile measurement of ultrasonic motor using stroboscopic oblique incidence interferometer

Y. Mizutani, T. Iwata, Univ. of Tokushima (Japan); Y. Otani, Utsunomiya Univ. (Japan)

We propose a measurement method of vibrational surface profile for a traveling wave-type ultrasonic motor (USM) using a stroboscopic oblique incidence interferometer. One of a main component of the USM is a stator which consists of several piezoelectric transducers. The transducers are controlled by high-frequently electrical signal in the ultrasonic region. There has been considerable interest in its surface profile for development of a controlling method and new devices for the USM. However it is difficult to observe its surface profile because there are diffused and vibrational surface. To overcome those problems, we

focused on an oblique incidence interferometer with a modulated light source. An obliquely incident light would offer advantage of the diffused surface because of higher reflectance than the vertical-incident type interferometer. Furthermore, for detecting interference at the vibrational surface profile using a CCD camera, a modulated light source is synchronized with an electrical signal of the USM. A proposed system consists of a master oscillator for modulation of the electrical signals of the USM and He-Ne laser, the USM (Shinsei Kogyo, USR30-B3) and the obliquely interferometer. Its interferometer consists of a prism and time-resolved interferograms are detected by a CCD camera. By using our proposed system, we are successful to detect a modulated surface of the stator. In this paper, our experimental setup and some results are shown.

7855-23, Session 3

Quantitatively three-dimensional imaging for microstructures with phase measuring technique

A. Li, X. Peng, Shenzhen Univ. (China)

Quantitatively imaging of three-dimensional (3-D) microstructures are of great concerns and become increasingly important in both academic and industrial circles, such as life science, micro science and technology (MST), microelectronics, industrial inspection, to name just a few. To meet the needs of this scientific and technological development trend, cost-effective 3-D microscopy techniques and instruments are highly required. In this paper, we report a novel 3-D microscope that is able to quantitatively acquire and measure the 3-D range data of microstructures. The presented approach is based on the phase measuring technique, and the instrumentation prototype is built up on a stereo microscopic platform. The working principle of proposed technique is briefly described as follows: the structured illumination and light detector are configured in two channels of stereo microscopic platform, respectively. The detected phase distribution that encodes the topographic information of microstructures is provided by the deformed structured illumination. The phase decoding is accomplished by five-step phase shifting and generalized temporal phase unwrapping techniques. The mapping between the retrieved phase distributions and depth variations of the test microstructure is determined through the calibration of the prototype system configuration. In this way, one is able to quantitatively imaging and measuring the 3-D range data of microstructures. It is worthy to point out that the proposed technique and prototype provide a cost-effective solution for imaging and measuring 3-D microstructures in terms of an inexpensive, robust, and fast fashion of imaging and measurement. Experiment results with various microstructures are also presented to show the effectiveness of the proposed approach and the prototype.

7855-24, Session 3

Theoretical analysis of the frequency splitting caused by intracavity quartz crystal

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The Zeeman dual-frequency laser is important in optical metrology for industrial applications. However, for the longitudinal and transverse Zeeman laser the frequency difference between the right- and left-hand circularly polarized light must be less than 3 MHz and 1 MHz respectively. Hence, the measuring speed of an interferometer equipped with a Zeeman laser is typically less than 700 mm/s. To resolve this problem, frequency splitting technology based on the intracavity birefringent elements has been employed to increase the frequency difference from approximate 40 MHz to several hundreds MHz. Rotatable quartz crystal as a typical birefringent element is employed to adjust the frequency difference of the birefringent dual-frequency laser. The birefringent dual-frequency lasers have been employed to measure displacement, velocity, angle, and so on. However, the mechanism that the frequency difference is adjusted by the intracavity rotatable quartz crystal is not clearly, and no theoretical curve of frequency difference has been matched with the experimental curve. In this paper, the problems are resolved, and the theoretical analysis and the detailed formulae are proposed. In the analysis, beside the birefringence effect the optical activity of quartz crystal is considered. After the Jones matrix of optical activity quartz crystal is deduced, the polarization angles of two lasing eigen-modes are deduced based on the self-reproduction of laser. Then the phase difference and the frequency difference of the two lasing eigen-modes are deduced. Based on the above deduction, the curve continuities of the polarization angle and the frequency difference as a function of the rotation angle of quartz crystal are discussed, and their formulae are revised. Finally, the theoretical curves of polarization angle and frequency difference are calculated based on their revised formulae, which are matched with their experimental curves.

7855-25, Session 3

Optical FMCW interference: a new technology for optical metrology

G. Zheng, Beijing Institute of Technology (China)

Frequency-modulated continuous-wave (FMCW) interference, which was originally investigated in radar, has been recently successfully introduced in optics. Optical FMCW interference naturally generates a dynamic signal, both the phase and frequency of which are relative to the optical path difference between the two interfering optical waves. Hence, optical FMCW interference not only can measure the relative change of optical path difference (or other related parameters) more accurately and easily, but also can measure the absolute value of optical path difference (or other related parameters). The phase measurement gives a resolution thousands of times higher than the frequency measurement. Particularly, since the signal of optical FMCW interference is a dynamic signal, to calibrate the fractional phase, distinguish the phase-shift direction and count the number of full periods is quite easy. Therefore, compared with traditional optical homodyne interference, optical FMCW interference can offer a higher accuracy and a longer measurement range. During the last few years, some important achievements in both the theory and application of optical FMCW interference have been made. Today, optical FMCW interference has become a well-defined new branch of physical optics. The investigation of optical FMCW interference not only extends our knowledge about the nature of light, but also offers a new advanced technology for optical metrology. Optical FMCW interference can be used to upgrade some existing optical instruments and to create the new-conceptual optical instruments. In this paper, I attempt to review the principle and applications of optical FMCW interference in metrology.

7855-26, Session 3

Profile measurement with a spectral interferometer and the multi-wavelength back-propagation method

K. Otsuki, S. Choi, O. Sasaki, T. Suzuki, Niigata Univ. (Japan)

The multi-wavelength back-propagation (MWB) method can determine an optical path different (OPD) from the amplitude and phase distribution of the interference signal for multi-wavelength. In this study, we demonstrate a thickness measurement of a glass film by use of the spectral interferometer and the MWB method. The phase distribution was detected by the sinusoidal phase modulation (SPM) technique. The combination of MWB method and SPM introduced in the spectral interferometry improves phase ambiguity and enables precise measurement of zero-phase position with high accuracy of nm order.

In our experiment, a super luminescent diode (SLD) with the center wavelength of 840 nm and the bandwidth of 40 nm was used as the light source. The interference beams from an object and a reference mirror were incident onto a diffraction grating to get an interferometric spectral image. One dimensional phase distribution of the spectral image was detected by a CCD image sensor. The phase and amplitude distributions of multi-wavelength were measured along the vertical direction of the CCD. The reference mirror was vibrated sinusoidally to detect the phase accurately by the SPM technique. By the back-propagation processing using the detected amplitude and phase, the OPDs of the front and rear reflecting points of a glass film were obtained. The thickness and refractive index of the glass film were100 micro-meter and 1.5, respectively. The thickness profile was successfully measured over the region of 539 micro-meters, and the repeatability of 2 nm was estimated from a standard error among 3 repeatedly-measured profiles.

7855-27, Session 3

Sinusoidal wavelength-scanning common-path interferometer with a beam-scanning system for measurement of film thickness variations

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When a laser beam is incident into a film, two beams are reflected from the front and rear surfaces of the film, respectively. These two beams interfere with each other in a configuration of common path, and the phase of the interference signal provides the thickness of the film. In order to measure a thickness larger than a wavelength of the light source or a thickness variation with a high accuracy of a few nanometers, a temporal wavelength-scanning is required to generate a phase modulation in the interference signal. When the temporal wavelength scanning is linear, it is difficult to measure a thickness variation less than half wavelength because the integral multiple of the period of the interference signal is not always exactly to the scanning period. In this paper, sinusoidal wavelength-scanning is used to measure the thickness variation. In the sinusoidal phase-modulated interference signal the phase-modulation amplitude is proportional to the thickness of the film, and the phase can be measured with a high accuracy of about 0.02rad by calculating Fourier transform of the interference signal. Moreover, in order to achieve a high spatial resolution and a wide measurement region a focused beam is scanned on the surface of the film with a rotating mirror.

In experiments, the wavelength scanning of 15 KHz was carried out with an acousto-optic tunable filter (AOTF). The amplitude of the wavelength scanning was 5 nm with a central wavelength of 844 nm so that the phase-modulation amplitude became 2.6rad for a glass film of 20 micron thickness. A thickness variation was measured at 180 points along a line of 12mm with a measurement time of 12 ms. The magnitude of thickness variation over the 12mm line was 177 nm.

7855-28, Session 4

Error analysis for 3D shape measurement with projector defocusing

S. Zhang, Iowa State Univ. (United States)

This paper analyzes the phase error for a 3-D shape measurement system that utilizes our recently proposed projector defocusing technique. By defocusing binary patterns, seemingly sinusoidal fringe patterns can be generated, thus 3-D shape measurement can be performed by fringe analysis. This technique has been demonstrated to be advantageous over a conventional digital fringe projection method especially for high-speed applications. However, we found that the residual high-frequency harmonics introduce significant phase error if the object is not within a certain range. Therefore, finding the relationship between the phase error and the depth is essential in order to reduce this type of measurement error. In this research, we experimentally studied a very large range of depth, where the fringe patterns range from close to binary to be severely blurred. To quantify the phase error, a uniform flat board is placed in front of the system with different distances from the system. The phase error is analyzed for each position and stored into a look-up table (LUT). This LUT is then used to compensate for the phase error when a real experiment is performed. Experiments will be presented to verify the performance of the proposed technique.

7855-29, Session 4

Calibration of a phase-based 3D imaging system based on uneven fringe projection technique

Z. Zhang, H. Ma, H. Feng, Z. Jing, S. Zhang, Hebei Univ. of Technology (China)

Phase-based fringe projection 3D imaging systems have been widely studied in academics and applied to many industrial application fields because of their advantages of full-field, high accuracy, fast acquisition, and automatic processing. One important step of phase-based 3D systems is calibration, which builds up the relationship between the absolute phase map and the depth data. The existing calibration methods are complicated, and mostly limited to be finished in a laboratory environment due to the usage of an accurate translating stage. In this paper, a simple calibration method of the phase-based 3D imaging systems is presented based on the uneven fringe projection method and a virtual reference plane1. When uneven fringe pattern is generated at the projector, the projected fringe pattern has constant fringe spacing on a plane perpendicular to the imaging axis. The relationship between the absolute phase and the depth is linear and independent of pixel position. A polynomial can represent the relationship. Therefore, it is possible to calibrate the 3D imaging system if there are several discrete markers with known absolute phase and distance in between. By designing a plate having markers on the surface with known distance in between and projecting uneven fringe pattern onto it, one can calculate the absolute phase of each marker. In the meantime, the 3D coordinates of all the markers can be obtained by one general CCD camera calibration method2,3. A virtual reference plane technique is applied to convert the 3D coordinate into the depth for each marker. So the coefficient set of the polynomial are determined by using the obtained absolute phase and depth of all the markers. The proposed method will be applied to calibrate the developed phase-based 3D imaging system. In comparison, the calibrated system was evaluated by measuring an accurately positioned white plate at several known distances. Experimental results and performance evaluation show that the proposed calibration method can easily build up the accurate relationship between the absolute phase and the depth information.

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2. Z. Zhang, “A flexible new technique for camera calibration,” IEEE Transactions on Pattern Analysis and Machine Intelligence, 2000, 22(11),1330-1334.

3. http://www.vision.caltech.edu/bouguetj/calib_doc/

7855-30, Session 4

Calibration strategy of 3D vision inspection system for large-scale and shell-shape engineering objects

Y. Yin, Tianjin Univ. (China) and Shenzhen Univ. (China); X. Liu, A. Li, Shenzhen Univ. (China); X. Peng, Shenzhen Univ. (China) and Tianjin Univ. (China)

It is usually difficult to calibrate the three-dimensional (3-D) vision inspection system that may be employed to measure the large-scale (up to 1 meter) and shell-shape engineering objects. One of the challenges is how to in-situ build-up a large and precise calibration target in a measurement volume. In this paper, we present a calibration strategy to solve such in-situ calibration problem. First, we choose one of the said engineering objects to be inspected as a calibration target, on which we paste coded markers on the object surface, and these coded markers can be taken as reference points in the calibration process. The centroid coordinates of these markers is determined by use of photogrammetry technique, resulting in a high-precision target that covers the required measurement volume. On the next step, all the cameras of the 3-D vision inspection system are calibrated with obtained coordinates of the reference points. With proposed technique, the extrinsic parameters of all the cameras are unified to the target coordinate system. Finally, the structure parameters and position relationships of the 3-D vision inspection system can be accurately derived. There are three advantages of proposed calibration strategy. First, location accuracy of reference points does not depend on the precision of making the reference points any more. Second, the calibration volume is adapted to the measured object size. This strategy especially fits into the measurement of large-scale and topology complexity engineering objects. Third, the established calibration target covers the whole measurement volume encompassing objects to be tested, so it facilitates the in-situ inspection. This calibration strategy has been successfully applied to an industrial project, validating the proposed method.

7855-31, Session 4

Phase error correction based on Inverse Function Shift Estimation in Phase Shifting Profilometry using a digital video projector

Y. Liu, J. Xi, Y. Yu, J. F. Chicharo, Univ. of Wollongong (Australia)

Phase Shifting Profilometry (PSP) is one of the most popular approaches in non-contact 3D surface measuring technology. Having many advantages to legacy projection systems, digital projectors are extensively employed in PSP. However, the performance suffers from a nonlinear distortion referred to as gamma distortion, namely nonlinear response to input signals, which introduces remarkable error to PSP. Many approaches have been proposed to remedy this problem, such as Look Up Table (LUT), neural network, and double three-step PSP. However these methods either require additional equipments or significantly increase measuring time. In this paper, we propose a novel method to eliminate the nonlinear distortions. Traditionally, height is calculated according to difference of phase between reference plane and object surface. With a digital projector, this method causes errors in measuring results. It is known that object surfaces modify captured images by shifting phases of projected fringe. Phase shift and surface height always obey triangle similarity rules, despite that phase is distorted by gamma distortion. In our paper, height is determined based on phase shift rather than phase difference. We also proposed a method to calculate phase shift, based on Inverse Function Analysis (IFA). First, a phase map of a reference plane can be obtained by three-step PSP, which suffers from gamma distortion. Then we calculate an inverse function of the reference plane, using polynomial curve fitting. After substituting a phase map of object surfaces into the inverse function, we can derive phase shifts between the two maps. Surface height distribution without distortions can be reconstructed from triangulation and the phase shifts. Simulation and experimental results demonstrate that the proposed method can significantly reduce errors caused by a projector's nonlinearity in three-step PSP. Our method does not require extra equipments or long computing time. Hence, it can achieve automatic and fast 3D surface measuring.

7855-32, Session 4

Fast quality-guided phase unwrapping algorithm for three-dimensional fringe pattern profilometry

K. Chen, J. Xi, Y. Yu, J. F. Chicharo, Univ. of Wollongong (Australia)

In 3D Fringe Pattern Profilometry (FPP) system, the phase unwrapping is a critical step to measure the surface height distribution information of measured object. This step aims at retrieving a wrapped phase that varies periodically from -pi to pi to construct a continuous natural phase. In practice, especially when a complex object is measured, abrupt and irregular changes in the measured surface may result in phase discontinuity in the fringe pattern. The maximum phase change between adjacent pixels in the areas of phase discontinuity may be more than pi, which means it is impossible to retrieve correct natural phase without any phase unwrapping algorithms in such areas. Thus, phase unwrapping algorithms are quite need. Practically, there are two most popular algorithms applied in FPP systems, path-following and quality-guided. The path-following does the phase unwrapping rapidly but low accuracy especially when measuring a complex object, while quality-guided does the process accurately but time consuming. The proposed method combines the merits of these two algorithms together. In the proposed method, the wrapped phase map is divided into several areas as rapid and smooth phase undulating areas according to the quality map. By applying conventional quality-guided algorithm in rapid phase undulating areas and path-following algorithm in smooth phase undulating areas, then well connect those areas, the unwrapping precision and time consumption of the proposed method can both reach a satisfactory level.

7855-33, Session 4

Calibration and image enhancement algorithm of portable structured light 3D gauge system for improving accuracy

L. Tao, GE Global Research (China); K. Harding, GE Global Research (United States); M. Jia, G. Song, GE Global Research (China)

Structured light based 3D measurement is a typical optic method used to detect surface depth profile. The primary system usually projects out a structured pattern onto the measured surface. The depth profile is recorded by the stripe deformation in the patterns. Through the use of phase shifting analysis, the depth profile is extracted with a high resolution. GE has invented a portable device using the structured light method that has been a useful tool to inspect edge breaks and corrosion depth on turbine system parts. As a portable device, it requires a compact design and a ruggedized system. Due to the variations in how the tool much be used, it is difficult to operate the device in a consistent mode. To maintain good inspection accuracy requires a simple calibration process and algorithms to mitigate the variations in use and system noise. In this paper, we introduced an effective calibration method to minimize the measurement errors and to calculate the system parameters with a simple process. The parameters of the calibration image are extracted automatically without any user operations. Image enhancement and filtering algorithms are

introduced that focus on the typical noise types Expected (e.g. random noise, back ground variations). Intensity drops in the phase map are detected through the use of a gradient calculation, then smoothing is applied along the intensity drop direction. The noise within the phase map is mitigated without a decrease of the measurement resolution. The results are demonstrated through the calibration of a prototype system. Measurement results are presented for sample surface using the filtering. The results shows that the noise can be effectively removed while maintaining good measurement accuracy.

7855-34, Session 4

Measuring method for the object pose based on monocular vision technology

C. Sun, Z. Zhang, Tianjin Univ. (China)

Position and orientation estimation of the object, which can be widely applied in the fields as robot navigation, electro-optic aiming system, etc, has an important value. The monocular vision positioning algorithm which is based on the point characteristics is studied and new measurement method is proposed. First, calculates the approximate coordinates of the five reference points which can be used as the initial value of iteration in the camera coordinate system; Second, gets the exact coordinates of the reference points in the camera coordinate system through iterative calculation with the constraints relationship of the five reference points; Finally gets the position and orientation of the object. So the measurement model of monocular vision is constructed. In order to verify the accuracy of monocular vision measurement model, a plane target using infrared LED as feature points is designed to finish the vertification of the measurement method and the corresponding image processing algorithm is studied. And then the monocular vision experimental system is established. Experimental results show that the translational positioning accuracy reaches ±0.05mm and rotation positioning accuracy reaches ±0.02°.

7855-35, Session 4

Effect of color illumination on color contrast in color vision application

Z. Zhu, X. Qu, H. Liang, G. Jia, Tianjin Univ. (China)

Color information is useful for automatic vision inspection in industrial production. Good lighting can often transform what would otherwise be an extremely difficult automated inspection application into one that requires only very simple image processing operations. We present a technique to choose appropriate light source for maximizing the contrast between the object and the background surfaces in color vision application. From the physics of color image formation, three parameters which affect generating signal of color digital camera are researched. The spectral distribution of illumination, the reflectance function of each surface and the spectral response functions of color CCD camera. The response function of color CCD camera was determined. Therefore, the discrimination can be enhanced by selecting appropriate light source with respect to colored surface. An optimal color illumination for enhancing color contrast can be found by maximizing these surfaces spectral reflectance. The discrimination of these surfaces spectral reflectance was estimated by using average color difference in CIELab color space. A printed color patch which have seven several colored characters was used for experiment. A LED illumination with color adjustable was used to demonstrate the approach. For each colored character, appropriate single color or two colors combination of LED (Light Emitting Diode) illumination was selected to maximize the discriminability. Compared to the standard D65 illumination, almost for each colored character, appropriate colors of LED illumination were better to discriminate the object and the background surfaces. These experiments illustrate that appropriate colors of LED illumination is more suitable than white illumination for discriminating differently colored object. The results show this method is usefulness for color vision application.

7855-36, Session 4

An anti-noise subpixel algorithm based on phase-shifting of Fourier transform and its application in CCD photoelectric autocollimator

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The image locating precision is directly related to the measuring accuracy of the CCD photoelectric autocollimator. An anti-noise subpixel algorithm based on phase-shifting of Fourier transform was presented. Firstly the peak position of the image signal was obtained, then according to auto-registration and shift theorem of Fourier transform, the phase shift of the fundamental component of the image signal was extracted to revise the peak position. The phase-shifting errors caused by noises can be overcomed and the image locating accuracy with the order of subpixel was acquired. The image signal with bimodal, multimodal or asymmetric distribution caused by various factors were physically simulated by using the rectangular prism with errors in the light path of the autocollimator, and in this case, the measuring accuracies of the normally-used barycenter, shape center, Gaussian fitting algorithm and the algorithm presented in this paper were compared. Experiment results show, the subpixel algorithm demonstrated here has the advantages of strong anti-noise ability and high precision. When applied to the one-dimensional CCD photoelectric autocaollimator, fine linearity and ±3” measurement accuracy were simutaneously obtained in the whole ±3600” measurement range.

7855-37, Session 4

Effect of structural parameters on the performance of fiber distance sensor with single mode illumination and inclined-fiber receiving

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In order to study the effect of structural parameters on the performance of fiber distance sensor with one normal single mode fiber for illuminating and one inclined multimode fiber for receiving, a theoretical power-distance model is established to describe the influence of the inclination fiber angle, the separation distance between the two fiber tips, the offset distance between the two fiber tips and/or reflector angle on the modulation performance of the fiber distance sensor. Numerical simulation results indicate that for the sensitivity of the sensor, it increases as the inclination fiber angle increases, the separation distance decreases, the offset distance decreases and/or the reflector angle increases. For the linear region, it increases as the separation distance increases, and/or the reflector angle decreases, however, it change less obviously as the inclination fiber angle increases, and even remains unchanged as the offset distance is changeable. For the dead zone, it decreases as the separation distance decreases, and/or the offset distance increases, and the study would help the design of the inclined-fiber receiving distance sensor to the desired modulation performance.

7855-38, Session 5

3D profilometry: next requests from the industrial viewpoint

K. Harding, GE Global Research (United States)

Optical 3D Profile measurements have seen an increasing use in industry from electronics packaging to turbine engine airfoils. This paper will review a number of industrial applications of optical 3D profilometry, what has been achieved, and where new opportunities may be arising. Based upon the current applications, we will identify some of the key barriers to successful implimentation, and what is needed to address these barriers from an industrial perspective. Finally, this paper will suggest some possible development areas that may greatly expand the application and acceptance of 3D profilometry.

7855-39, Session 5

Optical coherence tomography used for jade industry

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As an expensive natural stone, jade has a huge worldwide market. In the jade industry, the inspection and analysis basically rely on the human eye and experience, which cause unavoidable waste and damage of these expensive materials. Optical Coherence Tomography (OCT) is a fundamentally new type of optical sensing technology, which can perform high resolution, cross-sectional sensing of the internal structure of materials. Besides its low cost and portable size, its tiny optical fibre, 250 micrometer in diameter, makes the probing space extremely small. Considering jade is almost translucent to infra red light, OCT becomes an ideal tool to change the traditional procedure to volume data based machine vision system. This paper describes how OCT system and algorithms are developed to distinguish jade from non-jade material wrapping around it and how the purity and quality of jade is numerically expressed. For the jade with different internal texture patterns, statistics based algorithms have been developed to classify the jades types.

OCT can also be used for anti-counterfeit of the expensive jade ware. The real ancient jade always carries some ooze and deposit upon and beneath the surface, after burial for hundreds or thousands of years. The micro level cross-sectional 3D data can provide more details of these substances to distinguish the real antique jade from fake ones. Even for the expensive non-antique jades, there are severe counterfeiter issues on the market. OCT technology could also be used to recognize the artificial ones by analysing the optical and structural features of samples.

7855-40, Session 5

A fast three-dimensional reconstruction method applied for the fabric defect detection

L. Song, C. Zhang, Tianjin Polytechnic Univ. (China)

The fabric quality defect detection is very useful for improving the qualities of the products. It is also very important to increase the reputation and the economic benefits of a company. However, there are some shortcomings in the traditional manual detection methods, such as the low detection efficiency, the fatigue problem of the operator, and the detection inaccuracy, etc. The existing 2D image processing methods are difficult to solve the interference which is caused by non-defect case, just like the cloth folds, the flying thick silk floss, the noise from the background light and ambient light, etc. In order to solve those problem, the BCCSL (Binocular Camera Color Structure Light) method and SFMS (Shape from Multi Shading) method is proposed in this paper. The three-dimensional color coordinates of the fabric can be quickly and highly-precision obtained, thus to judge the defects shape and location.

The BCCSL method and SFMS method can quickly obtain the three-dimensional coordinates' information of the fabric defects. The BCCSL method collects the 3D skeleton's information of a fabric image through the binocular video capture device and the color structured light projection device in real-time. And the proposed SFMS method obtains the three-dimensional coordinates' information of the details of a fabric outside strip structural. The interference information, such as the cloth fold, the flying thick silk floss, and the noise from the background light and ambient light can be excluded by using the three-dimensional defect identification. What is more, according to the characteristics of 3D structure of the defect, the fabric can be identified and classified. Further more, the possible problems from the production line can be summarized.

7855-41, Session 5

A novel method to measure wheelset parameters based on laser displacement sensor on line

Z. Zhang, Zhengzhou Univ. of Light Industry (China)

The flange thickness, and rim width, and the wheelset's inner distance are key parameters that influence the wheel-rail contact. The online measurement of these parameters is important for ensuring the safety of train vehicle and increasing the reliability and efficiency of maintaining. This system is based on the laser displacement sensor and composed of six laser displacement sensors fixed on the rails and can measure the wheelset's parameters when trains pass through it. The measurement results are obtained by comparing to the normal wheelset's results for reducing errors. The measuring results are improved by the wavelet de-noised. The average value difference is between 0-0.3mm comparing the system and the manual that shows two methods are coincided. When wheelsets passes through the measuring system at the speed of 10km/h, measuring results shows that the system can meet with the measuring requirement on line.

7855-42, Session 5

Steam wetness measurement using CCD imaging methods in low-pressure turbine

W. Wei, S. Qin, National Univ. of Defense Technology (China)

The steam flow in low-pressure turbine contained abundant water droplets, which will decrease the work efficiency and pose potential threaten to operation safety, so measurement of steam wetness has brought great interest in electricity generation industry. In this paper, a new measuring method using CCD (Charge Coupled Device) imaging technique was proposed to determine the wetness in steam turbine based on the forward small angle light scattering theory. A simulated steam turbine facility was designed to generate the wet steam, and light scattering experiments were carried out at various working conditions in this device. The steam wetness parameters and droplet size distribution were obtained by means of numerical inversion of the light intensity distribution based on Mie scattering theory. The results demonstrate that the obtained data from the present analysis are in good agreement with the results of the theory analysis and previous study, and the proposed method is proved to be suitable for steam wetness measuring and monitoring by further development.

7855-43, Session 5

Detection of the bottle defect of glass container based on fast image processing algorithm

Y. Luo, Jinan Univ. (China)

Defect detection in glass containers requirements of high testing speed and high detection accuracy (accuracy of identifiable defects 0.5mm, the minimum test period of 0.5s, detection range: 45mm-205mm). This work is mainly about research and Implementation of an online real-time high speed image acquisition and processing system, the collection module via high-speed real-time online monitoring of defects in glass containers. In the core processing unit, high-speed floating-point "DSP + CPLD" is employed for real-time image processing and real-time control. And processing algorithms based on image analysis, image segmentation and image compression approach are used to achieve defect extraction and detection. As the final resutl, detection accuracy up to0.5mm, detection rate: 120 / minute, defect detection success rate above99.999%. this system has been put into online real-time bottle defects detection of Glass container.

7855-45, Session 5

Green inspection station

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Products are produced by globalization more and more scattered. Due to the manufacturing processes, (sub-) products are being transported back and forth and rearranged until they can finally reach the consumer. Not only the environment is increasingly burdened, but also the natural resources are wasted increasingly thoughtless.

In this paper a solution is presented to combat the waste of resources through a new concept in the field of automatic inspection of products. An inspection station can be used more intensively and efficient and resource-friendly with the aid of a sensor-magazine, an assistance system and a configuration system. We call such a station as a Green Inspection Station (GINS). The GINS is designed for both 2-D and 3-D metric and logical quality monitoring. All sensor systems are placed on the sensor magazine and are ready to use immediately after docking to the robot arm.

The added value of GINS is that different test tasks can be performed on the same inspection station. Unnecessary transport costs and waiting time for quality monitoring can be minimized. The GINS may serve as a model station for research or laboratory investigation. Inspection cycles of different inspection tasks can be configured by the assistance system and tested on the GINS. A collected inspection cycle can be reproduced on other GINS for the same inspection task in factories. The conversion period for machines can be reduced considerably. The calibration of each inspection station must be done individually. Using an example, the reconfigurable GINS is explained in detail.

7855-46, Poster Session

A quaternion pose determination solution based on monocular vision model

J. Chen, Luoyang Institute of Electro-Optical Equipment (China)

Determination of relative three-dimensional position and orientation between two reference frames can be solved by the pose measuring methods based on monocular vision model. With research on PnP (Perspective-n-Point) problem and quaternion transformation, the calculating formulas of elements in the rotational matrix were deduced from the coordinates of feature points in camera frame as well as the converting vector which was also introduced into the process. An approximate pose could be found by the assumption of zero difference in depth of all points in camera frame, then the converting vector should be initialized by the third row of current rotational matrix. The principle of computing priority of the max value in quaternion expression was proposed to ensure the convergence of the iteration loop through which the final pose was achieved in a few iterations. Simulation experiments show the validity of the solution and analysis of the calculating precision was made in detail. The measuring orientation error is constringing when the relative distance from camera focus to target object is reducing.

7855-47, Poster Session

The influence of BRDF calibration to CT industry NDT

Z. Liu, N. Liao, Beijing Institute of Technology (China)

Computed Tomographic(CT) testing is an important non-destructive testing technology in industry inspection. So the important work of CT development is the value calibration and the precise result judgment. Bi-directional reflection distribution function(BRDF) as the common spatial characteristic parameter can be fit for the CT data structure in theory level and the CT data cube can be calibrated using BRDF in both spectral and spatial. Deferent processing calibrated images can be achieved by calibrating CT data in deferent dynamic range using corresponding BRDF absolute value. Thus the influence of BRDF calibration to CT data can be achieved from these serial calibration data and the optimized arithmetic model for this calibration is established. Furthermore, the uncertainty of this value traceability and calibration is analyzed and a corresponding example in CT industry NDT is given which illustrate that this calibration is useful in analysis of PT image because it provide more true image and reduce the probability of error judgment.

7855-48, Poster Session

The study of interferometer spectrometer based on DSP and linear CCD

H. Kang, Beijing Univ. of Technology (China)

In this paper, general theory of Fourier-transform spectrometer and polarization interferometer is presented. A new design is proposed for Fourier-transform spectrometer based on polarization interferometer with Wollaston prisms and linear CCD. Firstly, Measured light is changed into linear polarization light by polarization plate. And then the light can be split into ordinary and extraordinary lights by going through one Wollaston prism. At last, after going through another Wollaston prism and analyzer, interfering fringe can be formed on linear CCD behind the analyzer. The linear CCD TCD1304DG with 3648 pixels is driven by CPLD to output amplitude of interfering fringe and synchronous signals of frames and pixels. DSP TMS320F2812 is used to collect interference pattern signals from CCD with its inner 12-bit A/D converter and the digital data of interfering fringe is processed by using 2048-point-FFT. Finally, optical spectrum of measured light can be display on LCD connected to DSP with RS232. In this paper, details on the configuration of electric circuit and the principle of research work are introduced, especially on the part of TMS320F2812 and CCD driver. And then, details on the configuration of program and its flow chart, which control the spectrometer and complete digital signal processing, are introduced too, especially on the part of computing 2048-piont-FFT. The spectrometer will possess the features of firmness, portability and the ability of real-time analyzing. The work will provide a convenient and significant foundation for application of more high accuracy of Fourier-transform spectrometer.

7855-49, Poster Session

Study on a novel illuminance calibration method for signal to noise ratio measurement of image intensifier

J. Shi, H. Li, D. Cui, F. Cao, Y. Sun, Q. Xie, Xi'an Institute of Applied Optics (China)

Signal to noise ratio is a fundamental performance of a image intensifier, which shows the photons detection ability from object in low light level, and its determine detection range and image definition. The input illuminated circular area must be 0.2mm in diameter on the photocathode, input illuminance must be 1.02×10-4lx in signal to noise ratio value measurement of Image intensifier . So the paper study a novel illuminance calibration method, which uses PMT photon counting detection technique. The method can directly calibrate illuminance value of very low light sources in signal to noise ratio measurement device of image intensifier. First, we research the radiation characteristic of standard light source with 2856K color temperature and calculate its output photon number. we research the pulse output characteristic of PMT and develop the low illuminance measurement model for the quasi-point light sources. Secondly we design quasi-point low light luminometer, which adopts the photon counting detection technique and is fitted with a well-defined limiting aperture. For high accuracy measurement on quasi-point sources, vision function correction, linearity correction, and cosine correction is made. Lastly, we research the traceability diagram of this luminometer, which is traceable to our primary photometry metrology standard device. The experimental results indicate the novel illuminance calibration method can accurately directly measure illuminance of quasi-point sources. Comparing with the conventional calibration method this novel method avoids the transfer error. The absolute illuminance calibration uncertainty is analyzed. These analysis results are useful as a evaluating method for improving signal to noise ratio of Image intensifier.

7855-50, Poster Session

3D profile measurement by using projection speckle pattern correlation method

E. Hu, China Univ. of Mining and Technology (China)

Optical projection grating profilometry has been widely used in 3-D sensing, machine vision, industry monitoring, etc. because of the advantages of high speed measurement, full field measurement and high resolution. The projected grating intensity is modulated by a sinusoidal pattern. The profile information and deformation are obtained by phase-shifting technique or Fourier transform profilometry. However, in this paper, a computer simulated speckle is used for the optical speckle projecting. The digital speckle is projected by a LCD projector, the speckle images corresponding to the reference plane and the detected object are captured quickly by a CCD camera. The object surface profile information is computed based on the triangulation method and digital speckle correlation method.

7855-51, Poster Session

Design of 3D vision probe based on auto-focus

Q. Liu, Chinese Academy of Engineering Physics (China)

Machine vision now is widely used as non-contact metrology which is a trend of measurement. In this article, a 3D machine vision probe for engineering is designed. The XY axial measurement is done by 2D vision metrology, while the Z axial height is measured by microscope through auto-focus(AF).

As the critical part of probe, a long work distance (WD) microscope is well designed. To attain the long WD, a positive and a negative lens group configure the microscope. The two lens groups, positive forward while negative behind, have a long interval. The microscope, with a resolution of 1μm and WD of 35mm, is quite closed to diffraction limited as evidenced from MTF (Modulation Transfer Function) chart.

The AF, a key technology in probe designing, is particularly introduced. Images acquired by microscope are calculated to get the AF curve data. To make the AF curve smooth, the images are denoised and the curve are processed with a low pass filter (LPF). And a new method of curve fitting is involved to get a accuracy positioning of Z axial.

The measurement with probe shows that the uncertainty is 0.03μm at XY axial plane, while the uncertainty is less than 4μm at Z axial height. It indicates that our probe achieves requirements.

7855-52, Poster Session

Principle of a novel displacement sensor based on infrared He-Ne laser

Z. Zhao, S. Zhang, Y. Li, Tsinghua Univ. (China)

The principle for using an infrared He-Ne laser as a displacement sensor is presented. By inserting birefringent element into the laser cavity, one laser beam is splitted into two orthogonally polarized laser beams. When the cavity length is changing, two beams appear one after another and the power tuning curves are formed. Compared to red He-Ne laser, infrared He-Ne laser has the feature of higher gain and narrower lasing bandwidth. So the power tuning curves can maintain in larger range of laser cavity. By counting the numbers of equal-intensity points and combining subdivision techniques, the displacement sensor based on infrared He-Ne laser can be expected to afford a measurement range of 100mm with the resolution of 10 nm.

7855-53, Poster Session

Study on the pose estimation method from four corresponding points with a single camera

P. Wang, Y. Zhou, Q. Zhang, Luoyang Institute of Electro-Optical Equipment (China)

Finding the position and orientation between a camera and a target with respect to a scene object from n correspondence points is crucial for many computer and robot vision tasks. With a limited number of correspondence points, the closed-from solution is applied to solve the pose estimation problem. To estimate the pose between the camera and the target from the four reference point, a pose estimate model is built with the four projection line between the 3D space point and 2D image point, under the full perspective projection of the camera. The transformation matrix is determined by the coordinates of four reference points in camera coordinate system and the target coordinate system respectively. To figure out the transformation matrix, the distance factor of the four reference points in camera system must be calculated. Considering the quality of the triangle, the pose estimate model with is simplified, which avoid the iteration, as while as taking the advantage of the data redundancy. Considering the specific relationship of the four reference points, the Levenberg-Marquardt algorithm is used to figure out the unknown parameters in the pose estimate model. Then the position and orientation between the camera and the target is obtained with respect to the coordinate transformation matrix from the camera coordinates to the target coordinates. In the experiment, using a high precision translation stage, the position of the target with four reference points is changed in the field of the camera's view to test the pose estimate algorithms.

7855-54, Poster Session

Ultraviolet bidirectional reflectance distribution function measurement and analysis of typical roughness surface

B. Lu, H. Zhang, Z. Wu, H. Li, Xidian Univ. (China); S. Wang, Anhui Institute of Optics and Fine Mechanics (China)

Optical scattering is often a powerful tool for process in situ monitoring because of its non contact and non destructive nature. Bidirectional reflectance distribution function (BRDF) is often used as a useful method in describing the directional dependence of scattering properties of a surface. And there are lots of paper discusses the measurement or model method in visible to infrared band. But few references discuss BRDF in ultraviolet band. Recently, there has been increasing interest in the study of scattering and reflective properties in ultraviolet band (200 to 400 nm). Such as ultraviolet space objects detection and subsurface defects short wavelength monitoring in semiconductor industry etc.

In this paper, the experiment measuring system is introduced. A schematic diagram of an instrument used for performing scatter measurements is presented. Angle-resolved single-band and multispectral bidirectional reflectance distribution function measurements are operate at 0, 30,45,50,60 degree incident angle in ultraviolet band. Hemisphere spectral reflectivity of some samples is measured through our experimental equipment.

An optimizing modeling method, Genetic Simulated Annealing Algorithm (GSAA) is used to model the laser single-band BRDF data of typical samples. The results are fitted with the models developed above using genetic algorithm to get the parameters. Spectral BRDF and Directional Hemisphere Reflectance (DHR) of samples calculated with the model are in good agreement with the measured data, which indicate that the means and result of spectral BRDF modeling are reliable.

And these kinds of study about measuring and optimizing modeling of typical roughness target samples in ultraviolet band have significative meanings in a lot of related fields.

7855-55, Poster Session

The application of the photoelectric autocollimator in detecting position precision of NC motorized stage

B. Yan, N. Lv, Beijing Information Science and Technology Univ. (China); Q. Tan, Beijing Univ. of Posts and Telecommunications (China)

Composed of an optical autocollimator and an area CCD, a photoelectric autocollimator which is calibrated by a dual-frequency laser interferometer of HP5528A is applied to the detection of positional precision of NC motorized stage in the paper. The positional error data of the stage is measured with the photoelectric autocollimator and an optical polyhedron automatically and quickly when the polyhedron and the stage both revolve with the same axis, then the error is sent back into the controlling system of the stage manually or automatically to finish the error compensation of the stage. Both the formulation method and adjacent multi-points linear interpolation method to calibrate the autocollimator are used and compared in the experiment. The result shows that two methods are consistent and have the same precision with the standard deviation less than 0.5 , which is sufficient for detecting a NC motorized stage. A polygon with 12 sides is used in detecting an accurate stage made in Japan, the autocollimator measures the stage every 30 degrees while it is turned 5 cycles respectively clockwise and counterclockwise. The repeatability of positioning and the accuracy of positioning of the stage are then calculated according to GB/T 17421.2-2000, the results of which are consistent with the specification of the stage.

7855-56, Poster Session

Distance measurements for non-planar surface based on modified confocal technique

J. Luo, Y. Liang, Zhejiang Univ. (China); W. Ding, Hangzhou Special Equipment Inspection Institute (China); L. Chen, Zhejiang Univ. (China)

A new method is presented for measuring the distance between the focus of an objective lens and the non-planar surface. Based on the conventional confocal microscopy, the method modifies the signal receiving part of optical system by modulating the pinhole immediately before the detector. And through demodulating the receiving intensity signal, a focus error signal is presented, which shows the linear relation to the defocus, or the distance between the focus of the objective lens and the non-planar surface. The focus error signal of this method features not only the possession of direction information of defocus and a wide linear range, but also the independence of the tilt angle of non planar surface, the power fluctuation and the like.

The merits of the method are that the optical system setup and algorithm for reliable and accurate detection are easily realized compared with conventional methods. More importantly, the focus error signal of this method shows superior performances. The method presented in this paper can be used in non-planar surface measurement, and laser direct writing on non-planar surface etc. The theory analyses of this method are described in detail, and the experimental setup and results are also presented to show the feasibility of this method.

7855-57, Poster Session

Fluorescence rejection by shifted excitation Raman difference spectroscopy

W. Zou, Z. Cai, J. Wu, Soochow Univ. (China)

The application of Raman spectroscopy is often limited by high fluorescence background that can easily bury the much weaker Raman signal. One of the most widely used techniques to reject the fluorescence disturbance is shifted excitation Raman difference spectroscopy (SERDS), which incorporates multiple wavelengths as excitation sources and obtains the difference spectrum for canceling out the fluorescence spectra while keeping the Raman signal. In this paper, a SERDS system with 532nm and 526.5nm DPSS lasers as the excitation sources is presented, and a home-made holographic notch filter is fabricated specifically to reject the Rayleigh scattering. In this system, two diode lasers are fibre-coupled to the external optics of a Raman spectrometer to illuminate the sample. Two corresponding shutters are used to switch on/off the two lasers alternatively. The inelastic scattering light from the sample passes through the notch filter and is collected into the spectrometer. The resulting spectra are acquired by a TE cooled CCD and then used to generate the difference spectrum. Since the Raman peaks shift along with the excitation wavelength while the fluorescence background is not sensitive to the excitation wavelength, the fluorescence can be effectively eliminated in the difference spectrum, so that the Raman signal can be highlighted. In addition to the hardware setup, a proper difference spectra data processing method is also very important for fluorescence rejection. Here a constrained least square algorithm is proposed to reconstruct the conventional Raman spectrum from the difference spectrum. Computer simulation of this algorithm is provided and Raman measurements are implemented on the proposed system. The experimental results show that this system can effectively reject the fluorescence and greatly improve the signal-to-noise ratio of Raman measurement. Compared with the reconstructed spectrum by Fourier deconvolution, the spectrum reconstructed by proposed algorithm has better quality, and higher signal-to-noise ratio.

7855-58, Poster Session

Detection of glass container mold number based on wavelet analysis advanced image recognition technology

Y. Luo, Jinan Univ. (China)

Model number of glass container are generally managed with through coding method, in which transparency bump array are implemented on the bottom of the container according to certain rules. As the glass color qualities are uneven and measurement points are irregular and transparent, it cause the realization of conventional sensing methods difficulty, and low identification rate. In this research, rapid and efficient detection of model number are achieved, through the invistigation and development in acquisition and processing units. In the acquistion unit, high-speed linear CCD signal acquisition and signal conversion are used. And in the processing unit, the method of edge extraction and wavelet analysis are used for model number feature detection and extraction. The results shouws that the image processing algorithms here could achieve the purpose of model identification number, and are wishful in the industry of glass packaging products rapid batch testing and treatment.

7855-59, Poster Session

An improved algorithm for eliminating phase-stepping error

G. Wang, Beijing Institute of Technology (China)

When applying phase-stepping interferometry to measure wavefront with aberration, distortion is caused by various factors and the main one is error from phase shifter. Base on a four-frame interferogram, an algorithm can eliminate the phase-stepping error. In this method, the final phase is irrelevant to the phase-stepping error. By computer simulating and actual interferogram test, it shows this algorithm is effective.

7855-60, Poster Session

Birefringence measurement system for LCD glass substrates

B. Wang, A. Breninger, C. Mansfield, A. Leadbetter, A. Gezahegn, D. Mark, D. Bentley, Hinds Instruments, Inc. (United States)

We have developed several models of Exicor® linear birefringence measurement systems to meet specific industrial needs in recent years. A particular set of Exicor models is designed to measure accurately the residual birefringence and stress in the glass substrates of liquid crystal displays (LCDs). The LCD glass substrates are typically thinner than 1 mm, thus they have extremely low values of residual birefringence and stress. The LCD glass substrates are very large in size, thus demanding fast measurement speed. In designing these Exicor systems, we have focused on achieving the highest measurement sensitivity at a high measuring speed. In this paper, we describe this type of instruments, its technical performance and its application to measuring LCD glass substrates.

7855-61, Poster Session

A real-time multipoints tracking system based on FPGA for multi-touch and motion tracking

X. Hu, Q. Li, X. Lee, Beijing Institute of Technology (China)

Blob detection which focuses on detecting points or regions of a different intensity than the surrounding image is increasingly used in consumer products such as human-computer interfaces and motion tracking. Because blob detection is computationally intensive but requires relatively simple arithmetic operations, it is an ideal candidate for parallelization in hardware. The main goal of this paper is to develop a hardware implementation for blob detection structure that is able to detect an arbitrary number of blobs in a video image on a Xilinx FPGA platform. This system consists of three functional blocks. The first block use a dual port memory to get the histogram of video data and then to obtain the threshold value for the image frame. The second block applies the threshold value to the video stream data and get the line connected component, and these components are then transfered into the third block by Fast Simplex Link (FSL). The third block is the microblaze processor which do the label connection of different rows and get the centor of points. The implemented is implemented on a Xilinx Spartan3 chip up to 30Hz with 640X480 reslution, and the detail such as used resource and speed are also discussed in this paper.It can be used in various low cost consumer applications.

7855-62, Poster Session

A single-track absolute angular encoder using the linear detector

Y. Tan, B. Yuan, Zhejiang Univ. (China)

The resolution and the response speed are the key technical parameters for an absolute angular encoder. In the present study, a new photoelectric absolute angular encoder system based on the single-track coded disc and the linear detector was proposed not only to improve the angular resolution, but also to attain the high response speed. The coded disc, which has a much less complex pattern than the traditional one, was specially designed and manufactured to cooperatively work with the linear detector. It has only one track to recorder the angular information, which includes 128 index codes and 128 reference holes. The index codes and reference holes are arranged alternatively along the circumference with the angular interval of 2.8125o. The index code is a 7 bits Gray code, which is presented by a group of 7 light or shade stripes in the disc. The reference hole, which is used to differentiate the two neighboring index codes and interpolate, has only one light stripe, whose width is the half of that of the index code's stripe. The slits, which are applied to separate the index code and reference hole, are fixed respectively on each side of reference hole. In order to get the image of coded disc, the linear detector is fixed on the tangential direction under the track of coded disc. A integrated 7 bits Gray code can be certainly obtained by image processing, for there are at least two reference holes in the filed of linear detector. Then the minimum code is subdivided by the detector's pixels. The combination of code recognition and code subdivision makes it possible to execute angle measurement with high resolution.

7855-63, Poster Session

Profile measurement of reflective objects using two-frequency shadow moiré profilometry with phase shifting

D. Liu, B. Lin, Zhejiang Univ. (China)

It is presented that a shadow moiré profilometry using two-frequency grating, which denotes that some red lines are inserted in a certain manner on Ronchi grating. It employs a phase shifting method using contouring fringe to measure reflective objects such as silicon chip and optical disks. The two-frequency shadow moiré profilometry gives oblique intersection lines, which help in determining the variable quantity of fringe's order, when the phase is shifting by rotating the grating and change the vertical distance of the object and the grating, and four images are captured by a color CCD at different angles. The experimental results of measuring the silicon chip show that this technique has a high sensitivity and accuracy.

7855-64, Poster Session

The research of on-line inspection method of printed matter based on optical information processing

J. Wang, Beijing Institute of Graphic Communication (China)

Abstract: Two on-line inspection methods of printed matter based on optical image subtraction are proposed, using two kinds of spatial light modulation (SLM) respectively, which are TFT-LCD and CRT-LCLV. The test image of printed matter is obtained by CCD, while the standard image of printed matter is saved in computer. The test image and standard image are jointly displayed on SLM by computer as the input image of an optical image subtraction system, which is an optical 4f system with a sine-grating between two lenses. The subtraction image will occur at the output plane, which contain all defects of the test image. Comparing to machine vision method, this inspection method of printed matter based on optical image subtraction is advantaged because the inspection process is accomplished by the optical system, avoiding any complicated arithmetic. The precision of printed matter inspection is defined by the frequency of SLM and the sine-grating. The relationship between parameters of the subtraction image and parameters of optical system is analyzed.

7855-65, Poster Session

A laser self-mixing interference vibrometer based on current modulation and DSP demodulation

W. Xia, M. Wang, Nanjing Normal Univ. (China)

It has been confirmed that the vibration displacement of a loudspeaker can be measured by using of a self-mixing semiconductor laser diode. However, the demodulation method of the above-mentioned vibrometer utilizes the asymmetry of the sawtooth-like self-mixing signal, which is much sensitive to feedback strength and surrounding environment, to decide the displacement direction of a moving target. In order to overcome the difficulty of the previous apparatus, a compact current modulated vibrometer employing a self-mixing laser diode is proposed. The displacement measurement principle is based on time integration of each sampled velocity measured during every modulation period. The number of self-mixing interference fringe produced by injected current modulation in the first half modulation period equals to that in the second half modulation period. As a result, the difference of the number of self-mixing interference fringes in the first and second half modulation period is only yielded by the actual displacement of the moving object. The vibration waveform is reconstructed by algebraically summing up the aforementioned "difference of number of fringes" during every modulation period. Theoretical analysis, simulation results, error evaluation, modulation and demodulation technology are presented in this paper. The vibration waveform reconstruction accuracy is 0.325 micron in a wide dynamic range. Experiments results show a good agreement with the simulative results. The vibrometer is small-sized, inexpensive, easy to collimate and can measure an object whose vibration frequency range arrives 5KHz. This method can be applied to various vibrational measurements for its simplicity.

7855-66, Poster Session

Modified stripe boundary encoding for dynamic 3D shape acquisition of moving object

J. Guo, X. Liu, X. Peng, Shenzhen Univ. (China)

Dynamic 3D shape acquisition is the prerequisite of pipelined 3D modeling and 3D digital video generating. Efficient encoding method is the key of dynamic 3D acquisition. Stripe boundary codes reported previously is one of the efficient methods, which was based, in the theory, a principle of space-time correlation. Nevertheless the ghost boundaries existed in this method brought suspicious problems to boundary tracking, leaded to erroneous range data with low accuracy and low range data density. Moreover, the previously reported method needs to track the boundary three times through the stripes, result in low reconstruction efficiency and high probability of decoding errors. Against these problems caused by ghost boundaries, we design a modified technique for stripe boundary encoding, by using two color-stripe patterns instead of four-frame binary stripes used in the previous method. These two color-stripe patterns are generated by assigning the four-frame binary stripes into the red and blue channels of a color representation device, respectively. The ghost boundaries are all picked out and all correct boundaries can be extracted from the two color-stripe patterns directly. Furthermore, all range data on the located boundaries can be reconstructed with higher data density. Moreover, the proposed method needs to track the boundaries only one time results in less decoding errors and obtains higher range data accuracy. The experiment results show that the proposed technique is able to acquire the 3D shape of moving object with high range data density and proper accuracy, and therefore can be a promising candidate for dynamically pipelined 3D modeling.

7855-67, Poster Session

The development of optical fringe measurement system integrated with a CMM for products inspection

H. Xiong, Guangdong Univ. of Technology (China)

In the field of industrial product inspection, a CMM (Coordinate Measurement Machine) is indispensable to get high precise dimensions, and it is tedious to inspect a complex shape by manual. For many products, high precise dimensions are only needed on some special features, such as cylinders, holes, and plans. In this paper, an optical fringe measurement system is implemented based on Gray code, and a Canon DSL camera with high resolution is adopted to capture the projection patterns and the coded markers glued on the CMM. The range images from the optical measurement system are automatically aligned with the CMM coordinate system through the coded markers. A greedy feature fitting algorithm is used to processing the obtained points cloud, and the special features are extracted, which are used to direct the CMM to obtain more precise parameters. In this integration system, the whole inspection procedure is automated regardless of the existence of the CAD model of the product. The data from different sensors are fused together by an overlap patch algorithm. As a result, the full surface is scanned, and the necessary precision is guaranteed on some special locations. The design principle and workflow of the integration method are presented, and a detail example is given.

7855-68, Poster Session

Study on intersection measurement and error analysis

L. Su, Beijing Institute of Technology (China)

Photoelectric theodolite is widely used in large size industrial measurement because it has many advantages such as real-time, high precision, dynamic tracking, simple and reliable operation, and strong anti-interference ability. However, photoelectric theodolite only provides angle value of measured objective. So, it is impossible for one photoelectric theodolite to obtain spatial coordinate of target, and two or more photoelectric theodolites are used in intersection measurement in order to complete measurement. Because of this, this paper introduces three primary theodolites intersection algorithms they are important parts of some complex and multi-station intersection algorithms. Different intersection method will cause different calculation precision because of measurement error, and precision also will change with different intersection area. Thus, the accuracy of measured coordinate and experiment conclusion would be effected by used intersection method. The paper discusses principles and corresponding formulas of algorithms, besides, it analyzes in detail the precision of every intersection method and deduces all formulas of precision. Finally, paper compares and summarizes the corresponding applicable situation and features of before-mentioned algorithms according to precision formulation.

7855-69, Poster Session

Wide field of view and two-dimensional dynamic measurement system based on linear CCD

C. Peng, Z. Zheng, H. Li, X. Liu, Zhejiang Univ. (China)

Wide field of view and two-dimensional dynamic measurement system based on linear array charge-coupled device (CCD) camera is proposed for the interactive whiteboard. This system includes three parts as follows: the object to be located, CCD camera device and signal processing circuit. The information of object on 2-D plane is obtained by the CCD camera. Processing the signal comes from CCD camera by the method of coordinate transformation we specially designed in signal processing circuit, we can get the precise position of the object on 2-D plane. The location distance of the system is 1360mm, scale of the 2-D plane is 1574mm×1260mm and location precision should be more than 2mm. We set up this system and the experimental results show that we can reach the precision requirement proposed above.

7855-70, Poster Session

Influence of target surface material characteristics on 3D laser radar imaging

B. Wang, Z. Wu, Xidian Univ. (China)

Characteristics of laser radar (ladar) 3D image depend on ladar transceivers, propagation effects, target/beam interactions, and data processing. Process of target/beam interaction is determined by target surface optical scattering properties, which are characterized by bidirectional reflectivity distribution function (BRDF). Based on alternative monostatic BRDF models, we report here the influence of material properties on laser radar 3D image. This is useful in object identification, and can also be helpful in ladar system simulation.

There are several waveforms for 3D ladar imaging based on time of flight method, such as FMCW, chirped AM and pulse burst, for different applications. Single pulse method is used here for the simulation. A single laser pulse is flood illuminated on the entire object of interest. The reflected light is imaged onto a two-dimensional array of detectors. The time of flight for each pixel is recorded with a auxiliary detector, which has separate independent range finder circuitry for each pixel. The time of flight is proportional to the distance between the point of reflection on the target and the sensor system. With range measured for each pixel, the ladar produces a 3D image. When light is backscattered, its imaged far-field distribution leads to a very high complex pattern of light. This pattern, known as subjective speckle, is caused by the differences in phase, amplitude of various backscattering spread functions. The amplitude is essentially dependent on BRDF, the random phase uniformly distributed over 2π radians accounts for the surface roughness.

Here we consider BRDF model derived theoretically as well as a five parameter BRDF model derived from empirical data. The speckle pattern in the image plane of the burst illumination imaging ladar system has two origins: the target roughness and the turbulence perturbation. Here a non turbulent atmosphere case is considered.

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7855-71, Poster Session

High-speed image acquisition and processing technique for wheel set wear measurement

J. Fan, K. Wu, Hangzhou Dianzi Univ. (China)

In recent years, China Railway High-speed (CRH) train had rapid development. Running safety of CRH train become more prominent. Wheel set wear measurement was an effective way to ensure CRH train's safety. However, for high-speed running condition, traditional detection method could't detect. So designing an effective wheel set wear measurement for high-speed running train was very important.

A high-speed image acquisition and processing technique for wheel set wear measurement was proposed based on structured light image, high-speed CCD with 500fps and dual image processing units.

(1) A high-speed image acquisition system was designed based on structured light image and asynchronous reset of high-speed CCD with 500fps. Asynchronous reset pulse generation circuits were designed. Time accuracy of asynchronous reset reached 1us. Programs of image acquisition, transporting, and storaging were designed by using vc++.

(2) A high-speed image processing system was designed based on dual image processing units. System contained the PC unit and high-speed digital signal processor TMS320DM6467 unit. PC unit and TMS320DM6467 unit parallel processed image data. For PC unit and TMS320DM6467 unit, high-speed image processing algorithms were designed.

(3) For data exchange and communication between PC unit and TMS320DM6467 unit, Ethernet transport and communication programs were designed.

(4) Optimize method of high-speed image processing system was designed. For TMS320DM6467, the rate of CPU utilization was greatly improved by using Ping-pong buffering (implementing parallel operation of EDMA data transfer and CPU image processing) and coding optimization.

The experimental results showed that the speed of the measured CRH train was up to 80-120km/h. A time of 3-5 minutes was cost to complete the whole measurement process.

7855-72, Poster Session

CCD calibration method for wheel set wear online measurement

J. Chen, K. Wu, T. Ban, Hangzhou Dianzi Univ. (China)

Wheel set is an important component for the safety of train running. Measuring the wear parameters of the wheel set is necessary. The non-contact measure method using CCD and Struct light is applied to the wheel set wear online measurement .The space angle and the object distance between CCD and measured target are two critical parameters. This two parameters influence the test precision directly, so they need to be calibrated in the first place.

A method of the CCD calibration for wheel set wear online measurement was proposed based on pinhole camera model and perspective projection.

(1)According to the limitation of rail environment, a set of mechanical devices for CCD calibration was designed. It included CCD adjusting equipment and a plane calibration board with a group of feature points. The size of the feature points was designed according to the design field of view.

(2)A novel CCD calibration algorithm was proposed by using pinhole camera model and perspective projection. Firstly, the theoretical pixel coordinates of the feature points were calculated according to the design value of the space angle and the object distance. Then the CCD was adjusted to a position close to the design value. The actual pixel coordinates of the feature points were obtained.

Finally, a novel iterative algorithm was designed for acquiring the actual space angle and object distance. New theoretical pixel coordinates were calculated according to the parameters near the design value. When error of the actual pixel coordinates and the new theoretical pixel coordinates reached a minimum value, the optimal space angle and object distance were determined.

(3)Based on the CCD calibration algorithm, software was designed by using vc++.

The software had a user-friendly interface and helped the calibration procedure rapidly.

The experimental results showed that the CCD calibration method was effective and meet the demands of the wheel set wear measurement. The space angle achieved a error of 0.1°, and the object distance achieved a error of 1 mm.

7855-73, Poster Session

Three registration strategies for points cloud in optical inspection of plastic products

H. Xiong, Guangdong Univ. of Technology (China)

Plastic is used widely for its cheapness and light weight. In the manufacture of plastic products, optical measurement is always adopted for inspection purpose. There are three phases for a plastic product to be made. First, the rude injection mold must be refined to generate qualified products; then, the technological parameters of the injection machine must be adjusted to produce conforming products efficiently; in the end, the finished products are given. For each phase, optical devices are adopted to obtain points cloud of plastic samples, which is compared with the CAD model, so a registration operation is needed to align the points cloud with CAD model. In this paper, three different evaluation metrics for registration are put forward for each manufacture phase to meet its special demands. In mold modification phase, a most overlap metric is used to find out the most distortion regions of the mold. In technological parameters adjustment phase, a combined weighted overlap metrics are used to evaluate how close the plastic samples to the CAD model. In the production phase, the samples are placed over a fixture, and a simple feature based registration is used. For each evaluation metric, a suitable algorithm is developed to realize the registration operation. A car's interior panel is used to verify the idea, and the test results proof the validity of the method.

7855-74, Poster Session

Measurement of particle by projection imaging

C. Wang, E. Li, C. Tang, Tianjin Univ. (China)

Particle size is an important parameter in fields of production and research. Furthermore, particle size have become an important subject of measuring technology and been widely concerned. In connection with particle size detection, there have already been sets of techniques. However, for non-spherical particle or even erratic particle, the measurement of height plays a more salient role.

This paper presents one method of rapid measurement of the substrate particles, using micro optical imaging and oblique incidence of parallel light projection by digital image processing and on-line real-time calibration, then proposes advanced particle measuring technique which is based upon digital graphic processing and projection imaging. Through utilizing computer and digital graphic sensor, this paper builds an experimental particle detecting and measuring system for a new attempt which achieved analysis and measurement of particle size on the basis of usage of digital graphic processing technique.

This method is very accurate, simple and easy to implement, with no special requirements about particle shape. What's more, it has the feature of real-time online calibration.

7855-75, Poster Session

An algorithm for determining line centre with microscope measuring system

H. Wei, W. Wang, G. Ren, L. Pei, National Institute of Metrology (China)

A new method for determining line centre is proposed within a microscope imaging measurement system. Due to the diffraction effect the image of the each line on the scale is stripe -shaped. The strip can be molded as two edges that close together. With the gradient algorithm all the local maximum and minimum in the line scale image is detected. Therefore the rising and falling edge can be positioned in pixel level. The line centre is then the middle of between the rising and falling edge. To obtained a high level accuracy of the centre position, a least-squares line fitting algorithm is used with the points near the line centre in the gradient image. Experiments have been performed with a standard line scale. Results indicate the effectiveness of the method.

7855-76, Poster Session

An in-situ monitoring system on the grinding process

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We present a non-contact type monitoring system specially devised to control the cutting depth on the grinding process. This system comprises a one axis scanning stage and the imaging system using line camera and collimated white light source. Experimental results prove that the proposed system is useful, especially for the monitoring system in grinding the piston grove on the cylinder with a few micrometer accuracy in the dozens of millimeter area.

7855-77, Poster Session

a research on 3D point clouds automatic registration method

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3D point clouds registration is a crucial problem on research of reverse engineering. As the complexity and diversity of 3D objects and messiness of point-clouds, it has been a difficult deal. Aiming at the problem of point clouds registration without prior information on transformation, a novel registration method is proposed based on geometric properties of point clouds. The method has four parts: selecting public areas, seeking normal vector and curvature, finding corresponding points and further precise registration. Firstly, the public areas of point clouds can be selected and obtained through the scan order of the points, and then the normal vector and curvature of each point in the public areas can be calculated through surface fitting. Secondly, by taking the curvatures of point clouds as the registration relationship and setting a curvature threshold to find the matching points, all the pair-wise points are extracted while the curvatures of them are same or similar, then using the properties of distance invariance in rigid body transformation to match the pair-wise points. Thirdly, by introducing the neighborhood characteristics of each match point and comparing the curvature of each neighborhood point to eliminate the mismatch points, this method can obtain the effective coupling points, after that the algorithm of quaternion is used to compute original transform matrix. Finally, by using ICP algorithm to modify the former result, the optimal registration can be achieved. Experimental results show that the proposed method is robust and can register the point clouds of different scans.

7855-78, Poster Session

Research on performance evaluation of non-arm coordinate measuring machine (NACMM)

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The methods for performance evaluation of Articulated Arm Coordinate Measuring Machine (AACMM) have been published. Non-arm Coordinate Measuring Machine (NACMM) is similar with AACMM in function, and then the performance evaluation methods should be also similar. The research based on comparing the principle and error resources of the both systems, set up a new combination of the position, orientation and test number, try to locate a more reasonable procedure in evaluate the performance of NACMM which can be comparable with ASME B89.4.22-2004, but better for find the characteristic of accuracy changing in measurement volume . The procedure is confirmed by testing of different NACMMs.

7855-79, Poster Session

Optimization design of structured light vision system based on LM algorithm

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As the traditional calibration is difficult to ensure the accuracy of calibration, and the accuracy of a good calibration system can also become poor when collisions and other factors occur during use, A recalibration can be required according to the traditional method. In order to avoid the complex and cumbersome recalibration, We propose a optimization.design of structured light vision system based on Levenberg-Marquard (LM) algorithm. First,We capture three images of standard block under normal conditions. Second, We do the image processing of smoothing, thinning,reconstruction,Third,we obtain objective function which LM algorithm is required in the spatial domain, Last, We solve the optimization problem with LM algorithm .Now,We have achieved the optimization and correction of existing calibration. Experimental results show the proposed algorithm has Significant effect on improvement of accuracy and correction of collisions,and the system is more stable.

7855-80, Poster Session

position and orientation measurement for Large-size workspieces based on binocular vision

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In the process of digital assembly and alignment of large-size workpieces, to get the position and orientation of the workpieces quickly and exactly is important. The key to the process is to get the transformation matrix from the coordinate system of workpieces to the coordinate system of CAD model. Based on the CAD model of the workpieces, a method to obtain automatically the position and orientation of the workpieces without contact is proposed. The method consists of two steps. The first step is rough location. Several hundreds of light dots are projected onto the workpiece surface as the measure targets. Three-dimension coordinates of the light dots are calculated with the technique of binocular vision. A bi-cubic non-uniform B-spline surface is interpolated using the measurement points. The surface of the CAD model is grid-subdivided to get several hundreds of point and curvatures of the measure points on the workpiece and the discrete point on the CAD are computed. Surface features of workpiece and CAD, such as convex, concave, saddle and flat, by their curvatures. Comparing the surface feature between the bi-cubic B-spline surface and the CAD surface, the most similar features are considered as the correspondences. The second step is fine location. The ICP (Iterative Closest Point) algorithm is used to get the position and the orientation of large-size workpieces relative to CAD model. In the process of ICP algorithm, grid-subdividing is used to find the nearest distances from the measure points to the CAD surface points to decide correspondences. The grid-subdividing method avoids some complex computation and ensures the precision. An experiment was carried out to demonstrate the method is efficient and robust.

7855-81, Poster Session

UV light source adaptive sensing technology for flue gas measurement

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Abstract: The UV absorption spectrometry technique DOAS(Differential Optical Absorption Spectroscopy) has been widely used in continuous monitoring of flue gas, and has achieved good results. DOAS method is based on the basic law of light absorption--Lambert-Beer's law. The UV absorption characteristics of SO2, NOX and other gases which are the principal component of the flue gas are considered by DOAS method at the same time. And certain mathematical methods are used for concentrations measuring. The Continuous Emission Monitoring System (CEMS) based on the principle of DOAS mainly has two probe-styles present: in-situ probe-style and extractive probe-style.

For the In-situ probe-style CEMS based on DOAS method, prolonged use for the UV light source, contaminated lens caused by floating oil and complex environment of the flue will all bring attenuation of the spectral intensity, it will affect the measurement accuracy.

In this article, an In-situ continuous monitoring system based on DOAS method is described, and a component adaptive sensing technology is

proposed. By using this adaptive sensing technology, CEMS can adjust the integral time of the spectrometer according to the non-measuring attenuation of the light source intensity and automatically compensate the loss of spectral intensity. Under the laboratory conditions, the experiments for SO2, NO standard gas measurement using adaptive sensing technology is made. Many different levels of light intensity attenuation are considered in the experiments. The results show that the adaptive sensing technology can well compensate the non-measuring loss of spectral intensity, the concentration measurement error is no more than 2% FS. In the field measurement, the technology can well reduce the measurement error brought by attenuation of light intensity, compared with the instrument equipment, the concentration measurement error is less than 2% FS.

7855-82, Poster Session

Design and implementation of automatically opto-electrical detection system for spheroidal graphite cast iron metallographic phase

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Spheroidal graphite cast iron, with excellent mechanical properties, is widely used in manufacturing crankshaft, gears, pistons and other advanced castings and a variety of machine parts, and its microstructure morphology reflects the quality performance of the products.Therefore,it is urgent for a simple, accurate, automatic microstructure morphology detection method to inspect the quality of spheroidal graphite cast iron. In the paper, opto-electrical detection technology is applied to design a spheroidal graphite cast iron microstructure automatic detection system, in which the microstructure is imaged by optical microscopy systems, and the digital images are acquired by industrial cameras and sent into the computer. In the computer, gray transformation, binarization,edge detection,image morphology and seed filling,etc., a series of digital image processing algorithms are adopted to calculate and analyze the microstructure images.The morphology and microstructure analysis methods are combined to analyse the images of the spheroidal graphite in samples,in order to obtain the characteristic parameters such as the size of the of graphite, the number of graphite nodules and so on. Then,according to the correlative national standards, the level of the ball classification is determined. The result shows that: This method is simple, fast, and accurate and can be employed for assessment of the spheroidal graphite cast iron metallographic phase instead of manual detection.

7855-83, Poster Session

The influence factors of flame fusion method synthetic ruby's red color difference

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The correlations of lightness, chroma and hue angle were studied to confirm the lightness is the key affecting factor to the ruby color appearance with the color difference research. Based on the uniform color space CIE 1976 L*a*b*, the lightness is correlated with hue angle. Combined with the naked eye, purplish red rubies with the medium lightness(L*=40 50) and relatively high chroma (C*=25 35) display the best visual appearance. The result of partial correlation analysis revealed the correlation between L* and E* (rΔL*×ΔE* =-0.992) was relatively higher than r(ΔC*×ΔE*)=0.919 and r(ΔH*×ΔE*)=0.885; it showed that the change of ruby's color was mostly affected by lightness change, C* and H* had the fewer impact on E*. It is concluded that evaluating the red color of ruby should be primarily based on lightness difference, and then followed by the change of chroma and hue.