Technical Programme

SPIE Europe International Symposium

Optical Systems Design

12–16 September 2005
Friedrich-Schiller-Universität Jena
Jena, Germany

Symposium Chair
Andreas Tünnermann, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)

Symposium Co-Chair
Jean-Louis Meyzonnette, Institut d'Optique/Ecole Supérieure d'Optique (France)

Conferences • Plenary Presentation • Courses • Tabletop Exhibition

Optical Design and Engineering

Advances in Optical Thin Films

Detectors and Associated Signal Processing

Optical Fabrication, Testing, and Metrology

SPIE*Europe*

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Welcome!

Optical instruments are addressing an ever-increasing number of industrial and research applications: imaging and vision, defense, space, telecommunications, transportation, industrial process control, laser fusion, etc. As users are expecting more demanding performances, optical systems designers and manufacturers are faced with growing challenges.

This symposium on Optical Systems Design in Jena will be the fifth of its kind in Europe. It is intended to provide an interdisciplinary forum for technicians, engineers, researchers, and managers who are involved in instrumental optics at all levels: design, specification, production, and test.

Jena is located in Thuringia, the geographical center of Germany. It is well known by its longstanding tradition in optical manufacturing and research founded by Carl Zeiss and Ernst Abbe in the middle of the 19th century. One of Germany´s oldest universities provides a backdrop to this cosmopolitan city with an interesting mix of student life and local markets, old historical buildings integrated with the modern offices of Germany's most innovative companies in optics.

Nowadays a number of modern research institutes and companies working in the field of optical technologies are concentrated in Jena and its surroundings. More than 8,000 people are working in optics, generating a total turn over of about € 1.5 Bill.

The historical part of Jena is played by Goethe, Schiller and the nearby area with Napoleonic battlefields, castles and famous neighbouring cities such as Leipzig and Weimar.

There is no doubt that Jena will be the perfect host for the Optical Systems Design 2005 Symposium, and hence we look forward to meeting you and having a productive week.

Andreas Tünnermann
Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)
Symposium Chair

Jean-Louis Meyzonnette
Institut d'Optique/Ecole Supérieure d'Optique (France)
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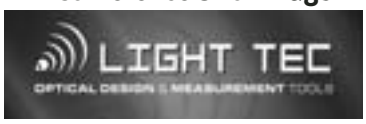

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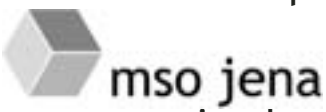

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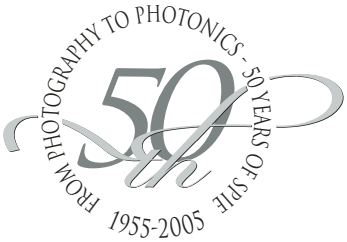

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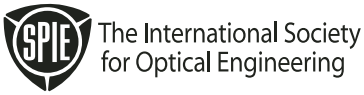

SPIE—The International Society for Optical Engineering is dedicated to advancing scientific research and engineering applications of optical, photonic, imaging, and optoelectronic technologies through its meetings, education programs, and publications.

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Coinciding with the 100th anniversary of Albert Einstein's "Miraculous Year," the events of the World Year of Physics 2005 aim to raise worldwide public awareness for physics and more generally for physical sciences.

Contents

SPIE would like to express its deepest appreciation to the symposium and conference chairs and cochairs, and programme committee members who have so generously given of their time and advice to make this symposium possible. The symposium, like our other conferences and activities, would not be possible without the dedicated contribution of our participants and members.

This Advance Programme is based on commitments received up to the time of publication and is subject to change without notice.

SPIE's Project Manager for this symposium is Karin Burger. For information about the technical programme, email: meetinginfo@spie.org.

Daily Schedule

Monday	Tuesday	Wednesday	Thursday	Friday
	Exhibition 10.00 to 17.00	Exhibition 10.00 to 17.00	10.00 to 16.00	
Welcome Reception, 19.00 to 20.30	**Carl-Zeiss Planetarium Excursion and Conference Dinner,** p. 3	**Poster Session,** 18.30 to 20.00, p. 3		
	Opening Ceremonies, *Plenary Session:* **Jena, the city of optics: yesterday-today-tomorrow,** 8.40 to 10.00, p. 3			

Conferences

Conf. 5962 Optical Design and Engineering II, *(Mazuray, Wartmann),* p. 5-7

Conf. 5963 Advances in Optical Thin Films II, *(Amra, Kaiser, Macleod),* p. 8-10

Conf. 5964 Detectors and Associated Signal Processing II, *(Chatard, Dennis),* p. 11-12

Conf. 5965 Optical Fabrication, Testing, and Metrology II, *(Duparré, Geyl, Wang),* p. 13-15

Courses

SC730 **Optical Coating on Plastics,** (Schulz), $240 / $270, 8.30 to 12.30

SC731 **Laser Beam Characterization,** (Eppich), $175 / $205, 13.30 to 17.30

SC732 **Infrared FPAs: Cooled and Uncooled Detectors,** (Tribolet, Tissot), $175 / $205, 8.30 to 12.30

SC733 **Ellipsometry: Determining Optical Properties at the Nano Scale,** (Schubert, Arwin), $310 / $370, 8.30 to 17.30

Register for Courses onsite at the Registration Desk.

Opening Ceremonies

Hörsaal 2

Tuesday, 13 September ..... 8.40 to 10.00

Welcome and Introduction 8.40
Andreas Tünnermann, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)

Plenary Presentation 9.00
Jena, the city of optics: yesterday - today - tomorrow
Norbert Thiel, JENOPTIK AG

Kidger Memorial Scholarship 9.40
In 1998, Tina Kidger, in conjunction with colleagues and friends of Michael Kidger, created a scholarship for deserving students in optical design. Tina has kindly offered to explain how to apply for this scholarship to students present in the audience.

Welcome Reception

Monday, 12 September ..... 19.00 to 20.30
Friedrich-Schiller-Universität has kindly invited all attendees to this welcome reception. Directions will be available onsite.

Carl-Zeiss Planetarium Excursion and Conference Dinner

Carl Zeiss Planetarium

Tuesday, 13 September
Friedrich-Schiller-University has kindly invited all attendees of EOD 2005 to a conference dinner and laser show held at the Carl Zeiss Planetarium. Spaces are limited, and we therefore ask that you register your attendance by ticking the appropriate box on the registration form. Bookings for this dinner need to be received by 26 August 2005; only a very limited number of dinner tickets will be available on a first-come, first-served basis at the event. Guests can purchase tickets as part of their guest pass for €70.00.

Poster Session

Wednesday, 14 September ..... 18.30 to 20.00
Poster authors will be able to set up starting at 09.30 hrs. on Wednesday. Authors are asked to sign in at the poster desk. Presenters will be at their poster papers to answer questions from 18.30 hrs. to 20.00 hrs. It is the authors' responsibility to remove their posters at the end of the session. Papers not removed will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of the poster session.

Plenary Presentation

Jena, the city of optics: yesterday-today-tomorrow

Tuesday 13 September ..... 9.00 to 9.40

Norbert Thiel, JENOPTIK AG
Member of the Management Board

The story of Jena as the city of optics began 160 years ago. Carl Zeiss had opened a small workshop for mechanical and optical instruments suitable for biological, medical, physical and astronomical research. After twenty years of "trial and error" in manufacturing, Ernst Abbe, professor of physics at Jena University, joined the company. This was the birth of a close and fruitful cooperation sustained to date and mutually profitable between the optics industry and the university. The optical instruments were designed on a scientific basis, and by starting the glass works by Otto Schott, new optical glasses became available. The companies continued to grow rapidly as well as the city, which had grown from about 6,000 inhabitants to 100,000 today.

In the long period until the reunification of Germany in 1990 Jena was dominated by Zeiss and Schott companies. After 1990 the industrial structure of the region had been abruptly broken due to the collapse of the industrial market. However, this was also a chance for a new beginning.

Today in the Jena region more than 10,000 people are employed by several large companies like Jenoptik, Zeiss, and Schott and also by a number of highly innovative SME. The product portfolios are oriented to high-tech sectors like microelectronics, life sciences and health, automotive, environmental and safety techniques, machining, and high precision measuring. The product families comprise high- and ultra-high-precision lenses, plastic lenses and microoptics, lasers and laser applications, optical sensors, cameras and displays, lithographic and test equipment, complex systems for spectroscopy and medical diagnosis and therapy.

Photonics is the main focus of the research fields at the Jena University and at a number of research institutes in Jena. About 600 scientists and technicians work in basic and applied research in ultra-high-power solid state lasers, fiber lasers and their applications, ultra-short-pulse laser physics, optical measurement technique, micro- and nano-optics, and biophotonics. Broad activities in applied optics and ultraprecision engineering in cooperation with the industry drive the development of new products and technologies for the market of the future. The growth of "Jena Valley of Optics" is going on rapidly.

Biography: **Norbert Thiel** was born on January 7, 1958 in Wittlich, Rhineland-Palatinate, Germany.

Dr. Thiel studied physics at the University of Cologne from 1977 to 1983 and was a member of the faculty of the Institute of Metal Physics at the University of Cologne from 1984 to 1985. Between 1985 to 1995 he worked at a number of managerial positions within Carl Zeiss Oberkochen's electron microscope unit. From 1995 to 1998, he was sales manager of LEO Elektronenmikroskope, a joint venture of Carl Zeiss and Leica.

From 1998 to June 2002 Norbert Thiel was the general manager of JENOPTIK Laser, Optik, Systeme GmbH, and was responsible for the optics and laser technology units as well as all their subsidiaries.

Sine 1 July 2002, Dr. Thiel has been a member of the JENOPTIK AG executive board in charge of the Photonics business division and of quality and environmental management.

General Information

Registration Hours

Monday, 12 September ..... 07.00 to 18.00
Tuesday-Thursday, 13-15 September ..... 08.00 to 17.00
Friday, 16 September ..... 08.00 to 10.30

Exhibition

Tuesday, 13 September ..... 10.00 to 17.30
Wednesday, 14 September ..... 10.00 to 17.30
Thursday, 15 September ..... 10.00 to 16.00

Standard Audiovisual Equipment

LCD projector, overhead projector, screen, and lapel microphone will be provided. Note: Speakers must supply their own laptops.

Video/Digital Recording Policy

For copyright reasons, video or digital recording of any conference session, short course or poster is strictly prohibited without written prior consent from each specific presenter to be recorded. Individuals not complying with this policy will be asked to leave a given session and to surrender their film or disc. It is the responsibility of the presenter to notify SPIE if consent is given.

Air Travel

SPIE thanks AmericanAirlines® for offering special meeting fares for all attendees of SPIE's Optical System Design Meeting.

Jena

Jena, the geographical centre of Germany, is nowadays known as "Innovation City". Set in the heart of the state of Thuringia, Jena is at the same time steeped in culture and history. One of Germany's oldest universities provides the backdrop for a cosmopolitan city with an interesting mix of student life and local markets, and old historical buildings integrate with the modern offices of some of Germany's most innovative companies: Carl Zeiss, Jenoptik, and Schott Glass. Historically speaking the area is famous for Goethe, Schiller and the surrounding area with Napoleonic battle fields, castles and famous neighbouring cities such as Dresden, Leipzig and Weimar, the European culture capital of 1999.

Tuesday-Friday 13-16 September 2005 • Proceedings of SPIE Vol. 5962

Optical Design and Engineering II

Conference Chairs: **Laurent Mazuray**, EADS Astrium (France); **Rolf Wartmann**, Carl Zeiss (Germany)

Program Committee: **Michael A. Cutter**, Sira Technology Ltd. (United Kingdom); **Michael R. Duparre**, Friedrich-Schiller-Univ. Jena (Germany); **Edgar Fischer**, Contraves Space AG (Switzerland); **Herbert Gross**, Carl Zeiss AG (Germany); **Tina E. Kidger**, Kidger Optics Associates (United Kingdom); **Robert Lange**, Tesat-Spacecom GmbH & Co. KG (Germany); **Andrea Mariani**, Galileo Avionica (Italy); **Jannick P. Rolland**, CREOL/Univ. of Central Florida (USA); **Joël Rollin**, Thales Angénieux SA (France); **Simon Thibault**, Institut National d'Optique (Canada); **Maria J. Yzuel**, Univ. Autònoma de Barcelona (Spain)

Tuesday 13 September

SESSION 1

Room: Hörsaal 4 ..... Tues. 10.30 to 12.20

Optical Theory, Simulation and Modelling

Chair: **Tina E. Kidger**, Kidger Optics Associates (United Kingdom)

10.30: **In the tradition of Ernst Abbe: innovation through wave optics in optical engineering *(Invited Paper),*** F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany); H. Schimmel, LightTrans GmbH (Germany) ..... [5962-01]

10.50: **Benchmark for optical simulation tools in the European network of excellence on microoptics NEMO,** N. Lindlein, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany) ..... [5962-02]

11.05: **Full-wave analysis of filtering behaviour for laminated structures,** A. Massaro, L. Pierantoni, T. Rozzi, Univ. Politecnica delle Marche (Italy) ..... [5962-03]

11.20: **Optical systems design with integrated rigorous vector diffraction,** B. H. Kleemann, J. Ruoff, M. Seeßelberg, J. Kaltenbach, C. Menke, Carl Zeiss AG (Germany) ..... [5962-04]

11.35: **Robust method for the propagation of an electromagnetic wavefront in an arbitrary optical system,** C. Pizarro, A. F. Cifuentes, J. Arasa, Univ. Politècnica de Catalunya (Spain); P. Blanco, Simulacions Optiques S.L. (Spain) and Univ. Politècnica de Catalunya (Spain) ..... [5962-05]

11.50: **Extended depth of focus as a process of pupil manipulation,** S. Förster, Carl Zeiss AG (Germany); H. Gross, Carl Zeiss Jena GmbH (Germany); F. S. Höller, L. Höring, Carl Zeiss AG (Germany) ..... [5962-06]

12.05: **Modeling pulsed beam propagation through homogeneous and inhomogeneous linear media,** S. Poyyil Veetil, Friedrich-Schiller-Univ. Jena (Germany); H. Schimmel II, LightTrans GmbH (Germany); F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany) ..... [5962-07]

Lunch/Exhibition Break ..... 12.20 to 13.50

SESSION 2

Room: Hörsaal 4 ..... Tues. 13.50 to 16.50

Optical Theory, Simulation and Modelling II

Chair: **Maria J. Yzuel**, Univ. Autònoma de Barcelona (Spain)

13.50: **Evolutionary algorithms applied to lens design,** S. Thibault, Institut National d'Optique (Canada); C. Gagné, M. Parizeau, Univ. Laval (Canada) ..... [5962-08]

14.05: **Using software interoperability to achieve a virtual design environment,** G. G. Gregory, R. J. Koshel, Lambda Research Corp. (USA) ..... [5962-09]

14.20: **Automated optimization of non-imaging optics for luminaries,** S. V. Kudaev, P. Schreiber, Fraunhofer-Institut für Optik und Feinmechanik (Germany) .... [5962-10]

14.35: **Concepts for modern optics software,** H. Schimmel, LightTrans GmbH (Germany); F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany); T. Paul, LightTrans GmbH (Germany) ..... [5962-11]

14.50: **Modeling surface and volume scattering with raytracing software,** H. J. Frasch, G. Steinmetz, Carl Zeiss AG (Germany) ..... [5962-12]

15.05: **Macros for the automatic layout of zoom lenses,** L. R. Gardner, Lambda Research Corp. (USA) ..... [5962-13]

15.20: **Making effective use of tolerancing,** J. Perrin, JCPC (France) ..... [5962-14]

Coffee Break ..... 15.35 to 16.05

16.05: **OPIC: a kit for rapid merit function construction for use with all versions of OSLO, including OSLO-EDU,** B. Blandford, Consultant (United Kingdom) .. [5962-15]

16.20: **Use of aplanatism condition to sample extended objects: application to merit function segmentation,** J. Arasa, Univ. Politècnica de Catalunya (Spain); J. A. Diaz, Univ. de Granada (Spain); C. Pizarro, Univ. Politècnica de Catalunya (Spain) [5962-16]

16.35: **Design of a wide-field unity magnification dive-mask,** J. R. Rogers, Optical Research Associates (USA) ..... [5962-117]

SESSION 3

Room: Hörsaal 4 ..... Tues. 16.50 to 18.20

Testing and Analysing

Chair: **Jannick P. Rolland**, College of Optics and Photonics/Univ. of Central Florida (USA)

16.50: **Correcting lens distortion in 3D measuring systems using fringe projection,** C. Bräuer-Burchardt, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5962-17]

17.05: **The atmospheric differential refraction system for the VST Telescope,** M. Brescia, F. Cortecchia, G. Marra, P. Schipani, G. Spirito, Osservatorio Astronomico di Capodimonte (Italy) ..... [5962-19]

17.20: **An equipment for measuring 3D bi-directional scattering distribution function of black painted and differently machined surfaces,** M. Barilli, A. Mazzoni, Galileo Avionica (Italy) ..... [5962-20]

17.35: **Design of a versatile clinical aberrometer,** M. T. Sheehan, National Univ. of Ireland/Galway (Ireland) and Dublin Institute of Technology (Ireland); A. Goncharov, C. Dainty, National Univ. of Ireland/Galway (Ireland) ..... [5962-21]

17.50: **Reference source elongation compensator in wavefront sensing systems,** A. V. Goncharov, C. J. Dainty, National Univ. of Ireland/Galway (Ireland) ..... [5962-22]

18.05: **In situ characterization of semiconductor saturable absorber mirrors used for passive modelocking,** G. Paunescu, J. Hein, R. Sauerbrey, Friedrich-Schiller-Univ. Jena (Germany) ..... [5962-84]

Wednesday 14 September

SESSION 4

Room: Hörsaal 4 ..... Wed. 08.00 to 12.35

Lens Design and Enhancements I

Chairs: **Rolf Wartmann**, Carl Zeiss AG (Germany); **Joël Rollin**, Thales Angénieux S.A. (France)

08.00: **Developments and design of optical systems for microscopes at Carl Zeiss *(Invited Paper),*** K. Uhlendorf, Carl Zeiss Jena GmbH (Germany); L. Schreiber, R. Wartmann, Carl Zeiss AG (Germany); H. Gross, Carl Zeiss Jena GmbH (Germany) ..... [5962-23]

08.20: **Reversible lens: theoretical limit of performance and real design,** A. Yabe, Consultant (Germany) ..... [5962-24]

08.35: **Imaging properties of different optics for EUV radiation,** A. Bayer, F. Barkusky, C. Peth, H. Toettger, K. R. Mann, Laser-Lab. Göttingen e.V. (Germany); T. Feigl, N. Kaiser, Fraunhofer Institut fuer Angewandte Optik und Feinmechanik (Germany) ..... [5962-25]

08.50: **Generating saddle points in the merit function landscape of optical systems,** F. Bociort, M. van Turnhout, Technische Univ. Delft (Netherlands) ..... [5962-27]

09.05: **Saddle points in the merit function landscape of lithographic objectives,** O. Marinescu, F. Bociort, Technische Univ. Delft (Netherlands) ..... [5962-26]

09.20: **Weight optimization in lens design,** W. Besenmatter, Independent Consultant (Germany) ..... [5962-28]

09.35: **Aspheres for high-speed cine lenses,** C. Beder, Carl Zeiss AG (Germany) ..... [5962-30]

09:50: **Design of a lens system for microlens lithography,** H. R. Fallah, A. Karimzadeh, Univ. of Isfahan (Iran) ..... [5962-112]

Coffee Break ..... 10.05 to 10.35

10.35: **System concept and optical design of miniaturized projection and imaging systems with OLED microdisplays,** S. Riehemann, M. Palme, U. Lippmann, G. Notni, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) .. [5962-31]

10.50: **Catadioptric projection lenses for immersion lithography,** H. Feldmann, A. Dodoc, A. Epple, H. Rostalski, Carl Zeiss SMT AG (Germany); D. R. Shafer, Dave Shafer Optical Design (USA); W. Ulrich, Carl Zeiss SMT AG (Germany) ..... [5962-32]

11.05: **A wide-angle catadioptric lens with the rectilinear projection,** G. Kweon, S. Choi, Honam Univ. (South Korea); G. Kim, S. Yang, Korea Basic Science Institute (South Korea); Y. Lee, Hannam Univ. (South Korea) ..... [5962-33]

11.20: **Optics design key points for high-gain photovoltaic solar energy concentrators,** J. L. Alvarez Rico, V. Diaz, J. Alonso, Isofoton (Spain); I. Anton, G. Sala, C. Dominguez, Univ. Politécnica de Madrid (Spain) . . . . . [5962-34]

11.35: **Enhanced optical system using distortion control,** S. Thibault, J. Gauvin, M. Doucet, Institut National d'Optique (Canada) . . . . . [5962-35]

11.50: **Design of a stationary Fourier transform spectroradiometer with accurate modeling of optical system aberrations,** H. Sauer, Y. Ferrec, C. Armellin, J. Taboury, Institut d'Optique (France) and CNRS (France) and Univ. Paris-Sud II (France); P. Cymbalista, N. Guérineau, M. Martin, J. Primot, ONERA (France) . . . . . [5962-36]

12.05: **Telephoto axicon,** A. Burvall, A. V. Goncharov, J. C. Dainty, National Univ. of Ireland/Galway (Ireland) . . . . . [5962-37]

12.20: **Reflective high-NA projection lenses,** H. Mann, W. Ulrich, Carl Zeiss SMT AG (Germany) . . . . . [5962-38]

Lunch/Exhibition Break . . . . . 12.20 to 14.05

SESSION 5

Room: Hörsaal 4 . . . . . Wed. 14.05 to 16.50

Lens Design and Enhancements II: DOEs

Chair: **Michael R. Duparré,** Friedrich-Schiller Univ. Jena (Germany)

14.05: **Variable phaseplates for focus invariant optics,** T. Hellmuth, A. Bich, A. Holschbach, Fachhochschule Aalen (Germany) . . . . . [5962-39]

14.20: **Extend focal depth of a tracking lens by phase apodizers,** X. K. Cai, S. Chang, National Research Council Canada (Canada) . . . . . [5962-40]

14.35: **Tolerance analysis of optical systems containing sampling devices,** G. C. Curatu, C. E. Curatu, Univ. of Central Florida (USA) . . . . . [5962-41]

14.50: **Design of off-axis diffractive optical elements in the resonance domain of light diffraction,** M. A. Golub, A. A. Friesem, Weizmann Institute of Science (Israel)[5962-42]

15.05: **High-efficiency transmission gratings for unpolarized illumination: an intelligible analysis of the diffraction process,** T. Clausnitzer, E. Kley, H. Fuchs, A. Tünnermann, Friedrich-Schiller Univ. Jena (Germany); A. Tishchenko, O. Parriaux, Univ. Jean Monnet Saint-Etienne (France) . . . . . [5962-43]

15.20: **Use of diffractive optical elements in lithographic projection lenses,** H. Rostalski, A. Epple, H. Feldmann, Carl Zeiss SMT AG (Germany) . . . . . [5962-44]

Coffee Break . . . . . 15.35 to 16.05

16.05: **Combined elements for beam shaping and polarization management,** M. Cumme, P. Triebel, D. Mademann, R. Pechmann, M. Schrenk, P. Weissbrodt, JENOPTIK Laser, Optik, Systeme GmbH (Germany) . . . . . [5962-45]

16.20: **Diffuser technology for illumination,** H. Schimmel, LightTrans GmbH (Germany); F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany) . . . . . [5962-46]

16.35: **Design of a tessar lens including a diffractive optical element,** U. G. Fotheringham, W. Pannhorst, SCHOTT AG (Germany); R. E. Fischer, OPTICS 1 Inc. (USA) . . . . . [5962-47]

SESSION 6

Room: Hörsaal 4 . . . . . Wed. 16.50 to 18.05

Microscopy

Chair: **Herbert Gross**, Carl Zeiss Jena GmbH (Germany)

16.50: **Spiral phase contrast microscopy,** S. Bernet, A. Jesacher, S. Fürhapter, M. A. Ritsch-Marte, Innsbruck Medical Univ. (Austria) . . . . . [5962-48]

17.05: **Interference imaging with a spatial spiral phase filter,** S. Fürhapter, A. Jesacher, S. Bernet, M. Ritsch-Marte, Innsbruck Medical Univ. (Austria) . . . . . [5962-49]

17.20: **Design of a microscopy illumination using a partial coherent light source,** M. Wald, M. Burkhardt, A. Pesch, J. N. Greif-Wüstenbecker, Carl Zeiss Jena GmbH (Germany) . . . . . [5962-50]

17.35: **Mounting an EUV Schwarzschild microscope lens,** T. Peschel, H. Banse, C. Damm, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); R. Eberhardt, FraFraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) . . . . . [5962-51]

17.50: **Designing considerations of an afocal optical system adaptable to high-precision microscopes,** A. Molnar, Jr., Optimal Optik Kft. (Hungary) . . . . . [5962-52]

✔ Posters-Wednesday

The following posters will be displayed all day Wednesday in the Conference Area Hallway. A poster reception, with authors present at their posters, will be held from 18.30 to 20.00. Poster authors will be able to set up their poster papers in the poster area starting on Wednesday at 10:00 hrs. Further information for poster authors can be found in General Information.

✔ **The removal speckle using a computer-generated random-phase hologram plate in green wavelength(532 nm),** S. Shin, C. Park, LG Electronics Inc. (South Korea) . . . . . [5962-92]

✔ **Concept, design and analysis of a large format autostereoscopic display system,** F. Knocke, R. de Jongh, M. Frömel, Xetos AG (Germany) . . . . . [5962-93]

✔ **CAD/CAM for lasers and optomechatronics,** H. Zhou, Xiamen Univ. (China) . . . . . [5962-94]

✔ **Optical design of infrared thermal imager,** S. Cheng, Shanghai Intitute of Technical Physics (China) . . . . . [5962-95]

✔ **Formation of radially and azimuthally polarized Bessel light beams under the interaction with a layered periodical medium having defect inclusions,** S. N. Kurilkina, B.I. Stepanov Institute of Physics (Belarus); M. Kroening, Fraunhofer-Institut für Zerstörungsfreie Prüfverfahren (Germany); N. Kazak, V. Belyi, N. Khilo, B.I. Stepanov Institute of Physics (Belarus) . . . . . [5962-96]

✔ **Design and simulation of a high-resolution superposition compound eye,** H. R. Fallah, A. Karimzadeh, Univ. of Isfahan (Iran) . . . . . [5962-97]

✔ **Evaluation of contrast loss introduced by scattering effects at optical mounts: field dependence in the IR region,** C. Pizarro, Univ. Politècnica de Catalunya (Spain); P. Blanco, Simulacions Optiques S.L. (Spain) and Univ. Politècnica de Catalunya (Spain); J. Arasa, A. F. Cifuentes, Univ. Politècnica de Catalunya (Spain) [5962-98]

✔ **Schmidt-like spherical aberration corrector for large spectral region intended for the space optics,** G. M. Popov, E. Popov, Crimean Astrophysical Observatory (Ukraine) . . . . . [5962-99]

✔ **DOE-generated laser beams with given orbital angular moment: application for micromanipulation,** S. N. Khonina, Samara Institute of Image Processing Systems (Russia) and Samara State Aerospace Univ. (Russia); R. V. Skidanov, Samara Institute of Image Processing Systems (Russia); V. V. Kotlyar, V. A. Soifer, Samara Institute of Image Processing Systems (Russia) and Samara State Aerospace Univ. (Russia); J. Turunen, Univ. of Joensuu (Finland) . . . . . [5962-100]

✔ **Characterization of new electrooptical PMN-PT single crystal,** V. Pavlenko, B.I. Stepanov Institute of Physics (Belarus); A. Akimov, Institute of Solid State and Semiconductor Physics (Belarus); S. Kurilkina, I. Utkin, B.I. Stepanov Institute of Physics (Belarus); H. Lee, Korea Electronics Technology Institute (South Korea) . . . . . [5962-101]

✔ **Mask tilt effects counteracted by wafer tilt in an SO-based EUV lithography setup,** A. Torre, S. Bollanti, P. Di Lazzaro, F. Flora, L. Mezi, D. Murra, ENEA (Italy)[5962-102]

✔ **Design of diffractive optical microrelief for waveguided beam focusing,** V. S. Pavelyev, Samara Institute of Image Processing Systems (Russia) . . . . [5962-103]

✔ **Technology-oriented stochastic optimization of radially symmetric DOEs,** V. S. Pavelyev, Samara Institute of Image Processing Systems (Russia) . . . . [5962-104]

✔ **Design of a frequency stabilization system using polarization spectrum in Cr atom lithography,** M. Zhao, F. Li, B. Zhang, Z. Wang, Tongji Univ. (China) . . . [5962-105]

✔ **Optical design in CAD software,** J. Venturino, OPTIS (France) . . . . . [5962-106]

✔ **Zoom lens design,** A. Miks, J. Novák, P. Novák, Czech Technical Univ. in Prague (Czech Republic) . . . . . [5962-107]

✔ **Calculation of polychromatic aberration coefficients,** A. Miks, J. Novák, P. Novak, Czech Technical Univ. in Prague (Czech Republic) . . . . . [5962-108]

✔ **Formulation of wave aberration coefficients using correction zones,** A. Miks, J. Novák, Czech Technical Univ. in Prague (Czech Republic) . . . . . [5962-109]

✔ **Fast approach for optical transfer function computation due to image motion and vibrations,** G. Wang, Changchun Institute of Optics, Fine Mechanics and Physics (China) . . . . . [5962-110]

✔ **Pupil filters for wavefront coding: design for improved off axis performance,** F. Gómez-Morales, R. Tudela, Univ. de Barcelona (Spain); J. Ferre-Borrull, Univ. Rovira i Virgili (Spain); S. Bosch Puig, Univ. de Barcelona (Spain); M. C. de la Fuente, Indra Sistemas S.A (Spain) . . . . . [5962-113]

✔ **Implementation of a new LCD polarized stereoscopic projection system with improved light efficiency,** E. Kim, S. C. Kim, D. Lee, Kwangwoon Univ. (South Korea) . . . . . [5962-114]

Thursday 15 September

SESSION 7

Room: Hörsaal 4 . . . . . Thurs. 08.30 to 12.10

Optical Systems I: Space Systems

Chairs: **Laurent Mazuray**, EADS Astrium (France); **Edgar Fischer**, Contraves Space AG (Switzerland)

08.30: **Development of large aperture cooled telescopes for the space infrared telescope for cosmology and astrophysics (SPICA) mission *(Invited Paper),*** T. Onaka, The Univ. of Tokyo (Japan); H. Kaneda, K. Enya, T. Nakagawa, H. Murakiami, H. Matsuhara, H. Kataza, Japan Aerospace Exploration Agency (Japan) . . . . . [5962-53]

08.50: **Wide-angle optical systems with moderate spectral resolution, for monitoring the oceans from low Earth orbit,** D. R. Lobb, Sira Technology Ltd. (United Kingdom) . . . . . [5962-54]

09.05: **Ozone monitoring instrument in-flight performance and calibration,** M. R. Dobber, Koninklijk Nederlands Meteorologisch Instituut (Netherlands); R. J. Dirksen, Koninklijk Nederlands Meteorologisch Instituut (Netherlands) and Space Research Organisation Netherlands (Netherlands); P. F. Levelt, G. H. J. van den Oord, R. Voors, Q. Kleipool, Koninklijk Nederlands Meteorologisch Instituut (Netherlands); G. Jaross, M. Kowalewski, Science Systems and Applications, Inc. (USA) . . . . . [5962-55]

09.20: **Metal mirror TMA telescopes of Jena spaceborne scanners: design and analysis,** S. Kirschstein, J. Schöneich, F. Döngi, Jena-Optronik GmbH (Germany) . . . . . [5962-56]

09.35: **Design trade-offs for MET image spaceborne imaging radiometer,** B. Voss, G. Thorwirth, Jena-Optronik GmbH (Germany) . . . . . [5962-57]

09.50: **Optical design of a high-resolution imaging channel for the BepiColombo space mission,** G. Marra, L. Colangeli, E. Mazzotta Epifani, Osservatorio Astronomico di Capodimonte (Italy); P. Palumbo, Parthenope Univ. (Italy); E. Flamini, Agenzia Spaziale Italiana (Italy); S. Debei, Univ. degli Studi di Padova (Italy) . . . . . [5962-58]

Coffee Break . . . . . 10.05 to 10.40

10.40: **Design and performances for the heliospheric imager of the STEREO mission,** E. Mazy, J. Defise, J. Halain, P. Ronchain, Univ. de Liège (Belgium); R. A. Howard, J. D. Moses, Naval Research Lab. (USA); R. Harrison, Rutherford Appleton Lab. (United Kingdom) . . . . . [5962-59]

10.55: **Light weight monolithic silicon carbide telescope for space application,** D. Logut, J. Breysse, EADS Astrium (France) . . . . . [5962-60]

11.10: **Suppression of sun interference in the star sensor baffling stray light by total internal reflection,** H. Kawano, H. Shimoji, S. Yoshikawa, K. Miyatake, Mitsubishi Electric Corp. (Japan); K. Hama, S. Nakamura, USEF (Japan) . . . . . [5962-61]

11.25: **Advanced multispectral focal plate assembly for commercial space-borne instruments,** I. Walter, DLR (Germany) . . . . . [5962-62]

11.40: **Design and fabrication of multifoil hard x-ray telescope for space observations,** Y. Ogasaka, K. Tamura, R. Shibata, K. Yamashita, Nagoya Univ. (Japan) . . . [5962-63]

Lunch/Exhibition Break . . . . . 11.55 to 13.30

SESSION 8

Room: Hörsaal 4 . . . . . Thurs. 13.30 to 15.00

Optical Systems II: Space Systems

Chair: **Michael A. Cutter**, Sira Technology Ltd. (United Kingdom)

13.30: **Comparison of microwave and light wave communication systems in space applications,** M. Toyoshima, Technische Univ. Wien (Austria) and National Institute of Information and Communications Technology (Japan); W. R. Leeb, Technische Univ. Wien (Austria); H. Kunimori, National Institute of Information and Communications Technology (Japan); T. Takano, Japan Aerospace Exploration Agency (Japan)[5962-64]

13.45: **Optical design of the near-infrared spectrograph NIRSpec,** J. Köhler, M. Melf, W. Posselt, W. Holota, EADS Astrium GmbH (Germany); M. B. J. te Plate, European Space Agency (Netherlands) . . . . . [5962-65]

14.00: **Straylight analysis and minimization strategy in Planck low-frequency instrument,** M. Sandri, F. Villa, C. Burigana, Istituto di Astrofisica Spaziale e Fisica Cosmica (Italy); R. Nesti, Osservatorio Astrofisico di Arcetri (Italy); N. Mandolesi, Istituto di Astrofisica Spaziale e Fisica Cosmica (Italy); M. Bersanelli, Univ. degli Studi di Milano (Italy) . . . . . [5962-66]

14.15: **Technological challenges in designing, manufacturing, and testing the optical subassembly of Herschel/HIFI wide-band spectrometer,** M. Barilli, G. Basile, Galileo Avionica (Italy); C. Gal, Univ. zu Köln (Germany); V. Natale, Consiglio Nazionale delle Ricerche (Italy); R. T. Schieder, O. Sieberts, Univ. zu Köln (Germany) . . . . . [5962-67]

14.30: **Application of high-strength RS-SiC to light-weight large optical mirror,** Y. Y. Yui, T. Kimura, Y. Tange, K. Enya, Japan Aerospace Exploration Agency (Japan)[5962-29]

14.45: **ALADIN transmit-receive optics (TRO): the optical interface between laser, telescope and spectrometers,** H. W. Mosebach, E. Schmidt, M. Erhard, Kayser-Threde GmbH (Germany); F. Camus, EADS Astrium (France) . . . . . [5962-68]

Coffee Break . . . . . 15.00 to 15.30

SESSION 9

Room: Hörsaal 4 . . . . . Thurs. 15.30 to 17.30

Optical Systems III: Astronomy and Ground Applications

Chair: **Andrea Mariani**, Galileo Avionica (Italy)

15.30: **VST optics design strategy and foreseen performance from U to I bands,** G. Marra, D. Mancini, Osservatorio Astronomico di Capodimonte (Italy) . . . . . [5962-69]

15.45: **VST optomechanical technical specifications versus error budget,** G. Marra, D. Mancini, F. Cortecchia, Osservatorio Astronomico di Capodimonte (Italy); G. Sedmak, Osservatorio Astronomico di Trieste (Italy); O. Caputi, D. Fierro, L. Ferragina, G. Mancini, Osservatorio Astronomico di Capodimonte (Italy) . . . . . [5962-70]

16.00: **PRIMA FSU: a fringe sensor unit for the VLTI,** S. Mottini, S. Cesare, G. Nicolini, Alenia Spazio S.p.A. (Italy) . . . . . [5962-71]

16.15: **VST active optics system design,** F. Cortecchia, G. Marra, D. Mancini, F. Perrotta, Osservatorio Astronomico di Capodimonte (Italy); G. Sedmak, Osservatorio Astronomico di Trieste (Italy); M. Capaccioli, Osservatorio Astronomico di Capodimonte (Italy) . . . . . [5962-72]

16.30: **Launch telescope for astronomical adaptive optics,** A. Caruso, A. Novi, G. Basile, Galileo Avionica (Italy) . . . . . [5962-73]

16.45: **Improved grating microspectrometer,** A. Last, C. J. Moran-Iglesias, J. Mohr, Forschungszentrum Karlsruhe (Germany) . . . . . [5962-74]

17.00: **Simple electronic speckle pattern shearing interferometer with a holographic grating as a shearing element,** E. M. Mihaylova, I. G. Naydenova, S. Martin, V. Toal, Dublin Institute of Technology (Ireland) . . . . . [5962-76]

17.15: **Optical design and cryogenic mounting of the optics for a pyramid wavefront sensor working in the near-infrared wavelength range,** P. Bizenberger, H. Baumeister, Max-Planck-Institut für Astronomie (Germany); J. Büchler Costa, Univ. do Minho (Portugal); H. Baumeister, Max-Planck-Institut für Astronomie (Germany) [5962-116]

Friday 16 September

SESSION 10

Room: Hörsaal 4 . . . . . Fri. 08.00 to 09.20

Lens Design and Enhancements III: Micro-optics

Chair: **Simon Thibault**, ImmerVision (Canada)

08.00: **Add-on laser reading device for a camera phone *(Invited Paper),*** J. Mäkinen, J. K. Aikio, K. Niemelä, H. Vasama, R. Mattila, M. Aikio, VTT Elektroniikka (Finland) . . . . . [5962-77]

08.20: **Microlens design for CMOS image sensor,** C. Fossati, Institut Fresnel (France) and EGIM (France); O. Gagliano, STMicroelectronics (France); M. Commandre, Institut Fresnel (France) and EGIM (France); B. Dunne, STMicroelectronics (France) [5962-78]

08.35: **Micro-optical artificial compound eyes: from design to experimental verification of two different concepts,** J. W. Duparré, F. Wippermann, P. Dannberg, P. Schreiber, A. H. Bräuer, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); R. Völkel, SUSS MicroOptics SA (Switzerland); T. Scharf, Univ. de Neuchâtel (Switzerland) . . . . . [5962-79]

08.50: **Design considerations for integrated microoptical systems combining refractive and diffractive optical components,** S. Sinzinger, M. Amberg, B. Mitschunas, Technische Univ. Ilmenau (Germany) . . . . . [5962-80]

09.05: **Design and fabrication of a chirped array of refractive ellipsoidal micro-lenses for an apposition eye camera objective,** F. C. Wippermann, J. W. Duparré, P. Schreiber, P. Dannberg, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) . . . . . [5962-81]

SESSION 11

Room: Hörsaal 4 . . . . . Fri. 09.20 to 12.25

Lasers

Chair: **Robert Lange**, Tesat-Spacecom GmbH & Co. KG (Germany)

09.20: **Measurement of the four-dimensional Wigner distribution of paraxial light sources,** B. Eppich, G. Mann, H. Weber, Technische Univ. Berlin (Germany) [5962-18]

09.35: **Characterization and control of beam propagation parameters and spatial coherence properties using Hartmann-Shack wavefront sensors,** B. Schäfer, Laser-Lab. Goettingen eV (Germany); A. Bayer, M. Lübbecke, K. R. Mann, Laser-Lab. Göttingen e.V. (Germany) . . . . . [5962-115]

09.50: **Characterization of a general astigmatic laser beam by measuring its ten second order moments,** A. Letsch, A. Giesen, Univ. Stuttgart (Germany) . [5962-86]

10.05: **On-line characterization of Nd:YAG laser beams by means of modal decomposition using diffractive optical correlation filters,** M. R. Duparré, B. Lüdge, Friedrich-Schiller-Univ. Jena (Germany); S. Schröter, Institut für Physikalische Hochtechnologie e.V. (Germany) . . . . . [5962-89]

Coffee Break . . . . . 10.20 to 10.40

10.40: **Laser beam diagnostics according to ISO and their impact on practical application,** R. Kramer, H. Schwede, V. Brandl, PRIMES GmbH (Germany) [5962-118]

10.55: **Profile homogenization and monitoring for a multiple 100 J diode-laser pumping system,** M. Siebold, S. Podleska, J. Hein, R. Bödefeld, M. Hornung, M. Schnepp, R. A. Sauerbrey, Friedrich-Schiller-Univ. Jena (Germany) . . . . . [5962-82]

11.10: **Ultra-short pulse laser safety: a challenge to materials science,** A. Hertwig, S. Martin, Bundesanstalt für Materialforschung und -prüfung (Germany); W. Kautek, Univ. Wien (Austria); J. Krüger, Bundesanstalt für Materialforschung und -prüfung (Germany) . . . . . [5962-83]

11.25: **Alignment of a multigrating mosaic compressor in a PW-class CPA-laser,** R. Bödefeld, M. Hornung, M. Siebold, J. Hein, R. Sauerbrey, Friedrich-Schiller-Univ. Jena (Germany) . . . . . [5962-85]

11.40: **Optics for focusing of ultrashort laser pulses,** U. Fuchs, U. D. Zeitner, A. Tünnermann, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) . . . . . [5962-87]

11.55: **Design and construction of diffractive gratings for multipetawatt laser compressors,** N. Bonod, J. Néauport, Commissariat à l'Energie Atomique (France) . . . . . [5962-88]

12.10: **Multifunctional laser devices for new technologies in oncology,** V. N. Svirin, POLYUS Research & Development Institute (Russia) . . . . . [5962-91]

Tuesday-Thursday 13-15 September 2005 • Proceedings of SPIE Vol. 5963

Advances in Optical Thin Films II

Conference Chairs: **Claude Amra**, Institut Fresnel (France); **Norbert Kaiser**, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); **H. Angus Macleod**, Thin Film Center Inc. (USA)

Program Committee: **Salvador Bosch Puig**, Univ. de Barcelona (Spain); **Bertrand Bovard**, Rockwell Scientific (USA); **Mireille Commandré**, Institut Fresnel (France); **Angela Duparré**, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); **Michel Lequime**, Institut Fresnel (France); **Keith L. Lewis**, QinetiQ Ltd. (United Kingdom); **Ludvik Martinu**, École Polytechnique de Montréal (Canada); **Angela M. Piegari**, ENEA (Italy); **Guillaume L. Ravel**, CEA-LETI (France); **Carl G. Ribbing**, Uppsala Univ. (Sweden); **Detlev Ristau**, Laser Zentrum Hannover e.V. (Germany); **Christopher J. Stolz**, Lawrence Livermore National Lab. (USA); **Hrvoje Zorc**, Institut Ruder Boskovic (Croatia)

Tuesday 13 September

SESSION 1

Room: Hörsaal 5 ..... Tues. 10.30 to 12.00

Invited Session

Chairs: **Claude Amra**, Institut Fresnel (France); **Norbert Kaiser**, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)

10.30: **Milestones in optical coating technology-from A. Smakula/John Strong until today *(Invited Paper)*,** A. J. Thelen, Ingenieursburo Thelen (Germany) ..... [5963-01]

11.00: **History of optical coatings in Jena *(Invited Paper)*,** H. Bernitzki, JENOPTIK Laser, Optik, Systeme GmbH (Germany); E. J. Hacker, High Tech Private Equity GmbH (Germany); N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); H. Lauth, JENOPTIK Laser, Optik, Systeme GmbH (Germany) ... [5963-02]

11.30: **Antireflection coatings: key optical components *(Invited Paper)*,** J. A. Dobrowolski, National Research Council Canada (Canada) ..... [5963-03]

Lunch/Exhibition Break ..... 12.00 to 13.30

SESSION 2

Room: Hörsaal 5 ..... Tues. 13.30 to 15.10

Design

Chairs: **Alfred J. Thelen**, Ingenieursburo Thelen (Germany); **Jerzy A. Dobrowolski**, National Research Council Canada (Canada)

13.30: **New optimization algorithm for the synthesis of rugate optical coatings *(Invited Paper)*,** A. V. Tikhonravov, M. K. Trubetskov, T. V. Amotchkina, M. A. Kokarev, M.V. Lomonosov Moscow State Univ. (Russia); N. Kaiser, O. Stenzel, S. Wilbrandt, D. Gaebler, Fraunhofer-Institut für Optik und Feinmechanik (Germany) ..... [5963-04]

14.00: **Colorimetry in optical coating *(Invited Paper)*,** C. Oleari, Univ. degli Studi di Parma (Italy) ..... [5963-05]

14.30: **Fourier transform estimation of optical thin film thickness,** P. G. Verly, National Research Council Canada (Canada) ..... [5963-06]

14.50: **Thin-film coatings and transmission-polarization-devices: negative system,** A. R. M. Zaghloul, M. Elshazly-Zaghloul, Georgia Institute of Technology (USA) and ITR Technologies, Inc (USA) ..... [5963-07]

Coffee Break ..... 15.10 to 15.40

SESSION 3

Room: Hörsaal 5 ..... Tues. 15.40 to 17.50

Filters

Chairs: **Mireille Commandré**, Institut Fresnel (France); **Pierre G. Verly**, National Research Council Canada (Canada)

15.40: **Laser trimming of thin-film filters *(Invited Paper)*,** M. Lequime, Institut Fresnel (France) ..... [5963-08]

16.10: **Optical coatings for artwork preservation and enhanced viewing *(Invited Paper)*,** A. M. Piegari, ENEA (Italy) ..... [5963-09]

16.40: **Steep-edge filter designs with equivalent layers,** U. B. Schallenberg, mso jena Mikroschichtoptik GmbH (Germany) ..... [5963-10]

17.00: **Manufacturing of linear variable filters with straight iso-thickness lines,** L. Abel-Tiberini, F. Lemarquis, G. Marchand, L. Roussel, G. Albrand, M. Lequime, Institut Fresnel (France) ..... [5963-11]

17.20: **Studies on superprism effects in multilayer thin film stacks *(Invited Paper)*,** X. Liu, P. Gu, Zhejiang Univ. (China) ..... [5963-12]

Wednesday 14 September

SESSION 4

Room: Hörsaal 5 ..... Wed. 08.20 to 10.10

Monitoring

Chairs: **Ulrike Schulz**, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); **Michel Lequime**, Institut Fresnel (France)

08.20: **Substantial progress in optical monitoring by intermittent measurement technique *(Invited Paper)*,** A. Zoeller, Leybold Optics GmbH (Germany) ... [5963-13]

08.50: **Use of real-time lateral optical monitoring for the fabrication of complex multilayer stacks,** C. M. Grèzes-Besset, D. Torricini, F. Chazallet, CILAS Marseille (France) ..... [5963-14]

09.10: **Re-engineering of inhomogeneous coatings based on in-situ optical broadband monitoring data,** S. Wilbrandt, O. Stenzel, D. Gäbler, N. Kaiser, Fraunhofer Institut Angewandte Optik und Feinmechanik (Germany) ..... [5963-15]

09.30: **Plasma monitoring of the RLVIP-process with a Langmuir probe,** D. Huber, A. Hallbauer, H. K. Pulker, Leopold-Franzens-Univ. Innsbruck (Austria) ..... [5963-16]

09.50: **Ion-source characterization based on an array of retarding field analyzers,** N. Beermann, H. Ehlers, D. Ristau, Laser Zentrum Hannover e.V. (Germany) .. [5963-17]

Coffee Break ..... 10.10 to 10.40

SESSION 5

Room: Hörsaal 5 ..... Wed. 10.40 to 12.20

DUV/VUV Coatings I

Chairs: **Angela M. Piegari**, ENEA (Italy); **Roland Thielsch**, Southwall Europe GmbH (Germany)

10.40: **IBS deposition of dense fluoride coatings for the vacuum ultraviolet free electron laser,** S. Günster, B. Görtz, D. Ristau, Laser Zentrum Hannover e.V. (Germany); E. Quesnel, G. L. Ravel, CEA-LETI (France); M. Trovó, M. B. Danailov, Sincrotrone Trieste S.C.p.A. (Italy) ..... [5963-18]

11.00: **Performance data of a variable transmission phase shifting mask blank for 193nm lithography enhanced by inspection contrast tuning,** H. W. Becker, M. Renno, U. Buttgereit, G. Hess, K. Kanpp, SCHOTT Lithotec AG (Germany) ..... [5963-19]

11.20: **Influence of the amorphous character of Al_2O_3 layers on their use in the deep UV spectral range,** B. von Blanckenhagen, D. A. Tonova, Carl Zeiss AG (Germany); T. Koslowski, Univ. Freiburg (Germany) ..... [5963-20]

11.40: **Oxide and fluoride coatings for the excimer wavelength 193nm,** R. K. Goetzelmann, H. Hagedorn, A. Zoeller, A. Kobiak, W. Klug, Leybold Optics GmbH (Germany) ..... [5963-21]

12.00: **Aluminium-enhanced optical coatings for the VUV spectral range,** M. Yang, A. Gatto, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5963-22]

Lunch/Exhibition Break ..... 12.10 to 13.50

SESSION 6

Room: Hörsaal 5 ..... Wed. 13.50 to 15.30

DUV/VUV Coatings II

Chairs: **Angela Duparré**, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); **Xu Liu**, Zhejiang Univ. (China)

13.50: **Lanthanide tri-fluorides: a survey of the optical, mechanical and structural properties of thin films with emphasis of their use in the DUV- VUV-spectral range,** H. Uhlig, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); R. Thielsch, Southwall Europe GmbH (Germany); J. Heber, Fraunhofer-Institut für Photonische Mikrosysteme (Germany); N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5963-23]

14.10: **Optical, structural, and mechanical properties of gadolinium tri-fluoride thin films grown on amorphous substrates,** R. Thielsch, Southwall Europe GmbH (Germany); J. Heber, Fraunhofer-Institut für Photonische Mikrosysteme (Germany); H. Uhlig, N. Kaiser, Fraunhofer-Institut für Optik und Feinmechanik (Germany) [5963-24]

14.30: **Absorption and fluorescence measurements of DUV/VUV coatings,** C. Mühlig, W. Triebel, Institut für Physikalische Hochtechnologie e.V. (Germany); H. Bernitzki, M. Klaus, JENOPTIK Laser, Optik, Systeme GmbH (Germany); J. Bergmann, S. Kufert, S. Bublitz, Institut für Physikalische Hochtechnologie e.V. (Germany) ..... [5963-25]

14.50: **Lessons learned from 157 nm,** H. Bernitzki, D. Fasold, M. Klaus, S. Laux, H. Lauth, JENOPTIK Laser, Optik, Systeme GmbH (Germany) ..... [5963-26]

15.10: **Nanostructure and optical properties of fluoride films for high-quality DUV/VUV optical components,** S. Schröder, H. Uhlig, A. Duparré, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5963-27]

Coffee Break ..... 15.10 to 15.40

SESSION 7

Room: Hörsaal 5 ..... Wed. 16.00 to 18.30

XUV Coatings

Chairs: **Christopher J. Stolz**, Lawrence Livermore National Lab. (USA); **Detlev Ristau**, Laser Zentrum Hannover e.V. (Germany)

16.00: **Multilayers for the EUV and soft x-ray region *(Invited Paper),*** Z. Wang, Tongji Univ. (China) ..... [5963-28]

16.30: **Laterally graded EUV multilayers,** T. Feigl, S. A. Yulin, N. Benoit, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) .. [5963-29]

16.50: **Interface-engineered multilayer mirrors,** S. A. Yulin, N. Benoit, T. Feigl, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5963-30]

17.10: **Improved nanometer multilayers for x-ray fluorescence analysis,** S. Braun, T. Foltyn, W. Friedrich, A. Leson, Fraunhofer-Institut für Werkstoff- und Strahltechnik (Germany); F. Schaefers, BESSY GmbH (Germany) ..... [5963-31]

17.30: **X-UV chirped mirror fabrication for phase control of attosecond pulses,** A. Morlens, École Nationale Supérieure de Techniques Avancées (France); M. Ravet, Univ. Paris-Sud II (France); V. Laude, Institut FEMTO-ST (France); R. López-Martens, École Nationale Supérieure de Techniques Avancées (France); M. Roulliay, A. Jerome, F. Delmotte, F. Bridou, K. Sophie, Univ. Paris-Sud II (France); P. Balcou, P. Zeitoun, École Nationale Supérieure de Techniques Avancées (France) ..... [5963-32]

17.50: **Performances and stability of Sc/Si multilayers with barrier layers for wavelengths around 46 nm,** J. Gautier, F. Delmotte, M. Roulliay, M. Ravet, F. Bridou, A. Jerome, Institut d'Optique (France); A. Giglia, S. Nannarone, Instituto Nazionale per la Fisica della Materia (Italy) ..... [5963-33]

18.10: **Study of potential quantization effects in designs for 12.4 nm mirrors,** R. R. Willey, Willey Optical (USA) ..... [5963-92]

✔ Posters-Wednesday

The following posters will be displayed all day Wednesday in the Conference Area Hallway. A poster reception, with authors present at their posters, will be held from 18.30 to 20.00. Poster authors will be able to set up their poster papers in the poster area starting on Wednesday at 10:00 hrs. Further information for poster authors can be found in General Information.

✔ **Comparison optical resistance of ion-assisted deposition and standard electron-beam deposition methods for high-reflectance dielectric coatings,** A. Melninkaitis, M. Maciulevicius, T. Rakickas, D. Miksys, R. Grigonis, V. Sirutkaitis, Vilnius Univ. (Lithuania); A. Skrebutenas, Optida Co. (Lithuania); R. Buzelis, R. Drazdys, G. Abromavicius, Institute of Physics (Lithuania); R. Juskenas, A. Selskis, Institute of Chemistry (Lithuania) ..... [5963-53]

✔ **Multiple pulse laser-induced damage of AR-coated lithium borate,** A. Melninkaitis, D. Miksys, R. Grigonis, V. Sirutkaitis, Vilnius Univ. (Lithuania); D. Tumosa, G. R. Skokov, D. Kuzma, EKSPLA Ltd. (Lithuania) ..... [5963-54]

✔ **Investigation to planar optical waveguides based on oxidised porous silicon/ PMMA by dark mode spectroscopy method,** Z. Jia, Xinjiang Univ. (China) [5963-55]

✔ **Optical sensitivity of thin films to hydrocarbons and ozone,** T. Mazingue, L. Spalluto, L. Escoubas, F. Flory, Institut Fresnel (France); M. Jelinek, Institute of Physics (Czech Republic); I. Mihalescu, National Institute for Lasers, Plasma and Radiation Physics (Romania); E. Kaminska, A. B. Piotrowska, Instytut Technologii Elektronowej (Poland); A. Perrone, Univ. degli Studi di Lecce (Italy) .... [5963-56]

✔ **Growth and thermal stability of interfaces in ion beam sputtered Mo/Si mirrors,** E. Quesnel, C. Largeron, V. Muffato, CEA-LETI (France); F. Hodaj, Institut National Polytechnique de Grenoble (France); J. Thibault, Ctr. National de la Recherche Scientifique (France) ..... [5963-57]

✔ **Zr-silicate thin films,** J. Ciosek, Instytut Technologii Elektronowej (Poland); W. Paszkowicz, Institute of Physics (Poland); A. Kudla, Instytut Technologii Elektronowej (Poland); P. Pankowski, Institute of Physics (Poland); U. Stanislawek, Military Univ. of Technology (Poland) ..... [5963-58]

✔ **Properties of chirped mirrors manufactured by plasma-assisted electron-beam evaporation,** M. Bischoff, O. Stenzel, D. Gäbler, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5963-59]

✔ **Comparison of gradient index and classical designs of a narrow notch filter,** V. Janicki, Ruder Boskovic Institute (Croatia); M. Lappschies, B. Görtz, Laser Zentrum Hannover e.V. (Germany); U. B. Schallenberg, mso jena Mikroschichtoptik GmbH (Germany); O. Stenzel, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5963-60]

✔ **Synthesis and manufacturing the mirrors for ultrafast optics,** V. J. Pervak, S. Naumov, Max-Planck-Institut für Quantenoptik (Germany); G. Tempea, Femtolasers Produktions GmbH (Austria); V. S. Yakovlev, Ludwig-Maximilians-Univ. München (Germany); F. Krausz, Max-Planck-Institut für Quantenoptik (Germany) and Ludwig-Maximilians-Univ. München (Germany); A. A. Apolonskiy, Max-Planck-Institut für Quantenoptik (Germany) ..... [5963-62]

✔ **Optical thin films deposition by MDECR-PECVD,** B. H. Haj Ibrahim, P. V. Bulkin, D. Daineka, B. Drevillon, Ecole Polytechnique (France) ..... [5963-63]

✔ **Ageing of optical components under laser irradiation at 532nm,** S. Becker, L. Delrive, P. R. Bouchut, B. André, F. Geffraye, CEA-LETI (France) ..... [5963-64]

✔ **Determination of complex optical indices in the 80-140nm VUV wavelength region from reflectivity measurements under normal incidence: application to ZnSe,** F. Bridou, M. Cuniot-Ponsard, J. Desvignes, Institut d'Optique (France) and Univ. Paris-Sud II (France) ..... [5963-65]

✔ **High-performance Cr/Sc multilayers for the soft x-ray range,** S. A. Yulin, T. Feigl, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5963-66]

✔ **Ion-assisted deposition of SiO2 film from silicon,** P. H. Tuan, National Ctr. for Technology (Vietnam); C. x. Dang, National Ctr. for Technology (Vietnam) [5963-67]

✔ **B4C/Mo/Si multilayers for 20-40 nm wavelengths: application to broadband mirrors,** F. Delmotte, Institut d'Optique (France); J. Gautier, Institut d'optique (France); M. Roulliay, F. Bridou, M. Ravet, A. Jerome, Institut d'Optique (France) ..... [5963-68]

✔ **Spectral properties of the new emulsion nanocomposite material based on silicon,** A. Sviridova, K. Zaitseva, A. I. Belogorokhov, P. Storozhenko, A. O. Rybaltovskii, I. A. Tutorskii, A. A. Ischenko, Moscow Lomonosov State Academy of Fine Chemical Technology (Russia) ..... [5963-69]

✔ **Dichroic beam splitter with two silver layers for visible transmission and infrared reflection,** D. Liu, D. An, F. Zhang, Y. Yan, Shanghai Institute of Technical Physics (China) ..... [5963-70]

✔ **Deposition of innovative optical coatings by reactive magnetron sputtering methods,** M. Vergöhl, C. Rickers, K. Ulrich, Fraunhofer-Institut für Schicht- und Oberflächentechnik (Germany) ..... [5963-71]

✔ **Optical monitoring of rugate filters,** M. Lappschies, B. Görtz, D. Ristau, Laser Zentrum Hannover e.V. (Germany) ..... [5963-72]

✔ **Effective medium models for metal-dielectric composites: an analysis based on the spectral density theory,** J. Sancho-Parramon, Univ. de Barcelona (Spain) and Martin-Luther Univ. Halle-Wittenberg (Germany); S. Bosch Puig, Univ. de Barcelona (Spain); A. Abdolvand, A. Podlipensky, G. Seifert, H. Graener, Martin-Luther Univ. Halle-Wittenberg (Germany) ..... [5963-73]

✔ **Design elements of porous silicon omnidirectional mirrors,** J. Ferré-Borrull, Univ. Rovira i Virgili (Spain) ..... [5963-74]

✔ **VUV optical coatings for the next-generation micro-mechanical mirrors,** M. Yang, A. Gatto, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); J. U. Schmidt, T. Sandner, J. Heber, H. Schenk, H. Lakner, Fraunhofer-Institut für Photonische Mikrosysteme (Germany) ..... [5963-75]

✔ **Resonance effects on quasi dense thin aluminum metal films,** T. Erdmann, Friedrich-Schiller-Univ. Jena (Germany); P. Triebel, JENOPTIK Laser, Optik, Systeme GmbH (Germany); E. Kley, A. Tünnermann, Friedrich-Schiller-Univ. Jena (Germany) ..... [5963-76]

✔ **High-resolution video-based inspection method for LIDT investigations of thin-disc laser crystals,** M. Jupé, L. S. Jensen, K. Starke, D. Ristau, Laser Zentrum Hannover e.V. (Germany); A. Melninkaitis, V. Sirutkaitis, Vilnius Univ. (Lithuania) . [5963-77]

✔ **Surface roughness of Mo and Si thin films and Mo/Si multilayers,** A. Köhler, Von Ardenne Anlagentechnik Gmbh (Germany) and Institut für Oberflaechen-modifizierung IOM (Germany); J. W. Gerlach, Institut für Oberflaechen-modifizierung IOM (Germany) ..... [5963-78]

✔ **Laser ablation of SiOx thin films for direct mask writing,** J. Heber, Fraunhofer-Institut für Photonische Mikrosysteme (Germany); M. Schulz-Ruhtenberg, Laser Laboratorium Gottingen e.V. (Germany); J. Ihlemann, Laser Laboratorium Göttingen e.V. (Germany); J. U. Schmidt, Fraunhofer-Institut für Photonische Mikrosysteme (Germany) ..... [5963-79]

✔ **Deposition of broadband antireflection coatings on plastic substrates by evaporation and reactive pulse magnetron sputtering,** J. C. Weber, Fraunhofer Institut Elektronenstrahl- und Plasmatechnik (Germany); U. Schulz, Fraunhofer Institut für Angewandte Optik und Feinmechanik (Germany); H. Bartzsch, P. Frach, Fraunhofer Institut Elektronenstrahl- und Plasmatechnik (Germany); N. Kaiser, Fraunhofer Institut für Angewandte Optik und Feinmechanik (Germany) [5963-80]

✔ **New advances in improving low-temperature performance of infrared thin-film interference filters,** B. Li, S. Zhang, F. Zhang, Shanghai Institute of Technical Physics (China) ..... [5963-81]

✔ **Optical characterization of nonuniform thin films using imaging spectrophotometry,** M. Ohlidal, V. Cudek, Brno Univ. of Technology (Czech Republic); I. Ohlidal, Masaryk Univ. (Czech Republic); P. Klapetek, Czech Metrology Institute (Czech Republic) ..... [5963-82]

✔ **Deposition of robust multilayer mirror coatings for storage ring FEL lasing at 176nm,** S. Günster, D. Ristau, Laser Zentrum Hannover e.V. (Germany); M. Trovó, M. B. Danailov, Sincrotrone Trieste S.C.p.A. (Italy); A. Gatto, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); F. Sarto, A. M. Piegari, ENEA (Italy) ..... [5963-83]

✔ **Spatial beam switching using the superprism effect in nonlinear thin-film stacks,** F. Glöckler, M. Gerken, U. Lemmer, Univ. Karlsruhe (Germany) . . . . . [5963-85]

✔ **Preparation and characterization of multilayers for EUV applications,** T. Foltyn, S. Braun, L. van Loyen, A. Leson, Fraunhofer-Institut für Werkstoff- und Strahltechnik (Germany) . . . . . [5963-86]

✔ **Generation of coherence and elliptically and circularly polarized infrared waves by incidence of randomly polarized light through a-quartz,** C. Tan, L. Cao, Nanjing Univ. (China) . . . . . [5963-87]

✔ **Genetic algorithm design of reflection thin-film coatings and polarization-devices,** A. R. M. Zaghloul, Y. A. Zaghloul, Georgia Institute of Technology (USA) and ITR Technologies, Inc (USA) . . . . . [5963-88]

✔ **High reflectivity measurement with cavity ring-down technique,** L. Gao, Institute of Optics and Electronics (China) . . . . . [5963-89]

✔ **Thin film optical fiters design by search and optimization methods,** R. Li Voti, C. Sibilia, G. Leahu, A. Bosco, E. Fazio, S. Gaetani, R. Ostuni, M. Bertolotti, Z. Del Prete, M. C. Larciprete, Univ. degli Studi di Roma/La Sapienza (Italy) . . [5963-90]

✔ **Characterization of optical thin films exhibiting defects,** D. Franta, I. Ohlidal, Masaryk Univ. (Czech Republic); D. Petrydes, Institute of Chemical Technology (Czech Republic) . . . . . [5963-91]

Thursday 15 September

SESSION 8

Room: Hörsaal 5 . . . . . Thurs. 08.20 to 10.20

Radiation Resistant Coatings

Chairs: **Zhanshan Wang**, Tongji Univ. (China); **Alfons Zoeller**, Leybold Optics GmbH (Germany)

08.20: **Engineering meter-scale laser resistant coatings for the near IR *(Invited Paper),*** C. J. Stolz, Lawrence Livermore National Lab. (USA) . . . . . [5963-34]

08.50: **Comparative study of IR and UV laser damage resistance of silica thin films deposited by EBD, IP, DIBS and IAD,** L. Gallais, M. Cathelinaud, L. Roussel, G. Albrand, H. T. Krol, J. Capoulade, B. Bertussi, J. Y. Natoli, M. Commandré, M. Lequime, C. Amra, Institut Fresnel (France) . . . . . [5963-35]

09.10: **Sol-gel protective coating for high-power laser amplifier silvered reflectors,** P. Prené, Y. Montouillout, L. Beaurain, C. Bonnin, P. F. Belleville, CEA Le Ripault (France) . . . . . [5963-36]

09.30: **LIDT improvement of multilayer coatings by accurate analysis of fabrication steps,** H. T. Krol, Institut Fresnel (France) and CILAS Marseille (France); L. Gallais, M. Commandré, Institut Fresnel (France); C. Grezes-Besset, D. Torricini, G. Lagier, CILAS Marseille (France) . . . . . [5963-37]

09.50: **Laser-thin films with very-high damage threshold *(Invited Paper),*** J. Shao, Z. Fan, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [5963-38]

Coffee Break . . . . . 10.20 to 10.50

SESSION 9

Room: Hörsaal 5 . . . . . Thurs. 10.50 to 12.20

Manufacturing I

Chairs: **Jianda Shao**, Shanghai Institute of Optics and Fine Mechanics (China); **Catherine Grezes-Besset**, Cilas Marseille (France)

10.50: **Ion beam sputter coatings for laser technology *(Invited Paper),*** D. Ristau, Laser Zentrum Hannover e.V. (Germany) . . . . . [5963-39]

11.20: **Highly reflective thin-film coatings for high-power applications of micromechanical scanning mirrors in the NIR-VIS spectral region,** T. Sandner, J. U. Schmidt, H. Schenk, H. K. Lakner, Fraunhofer-Institut für Photonische Mikrosysteme (Germany); S. Braun, T. Foltyn, A. Leson, Fraunhofer-Institut für Werkstoff- und Strahltechnik (Germany) . . . . . [5963-40]

11.40: **Investigation of the temperature stability of optical thin films,** M. Vergöhl, Fraunhofer-Institut für Schicht- und Oberflächentechnik (Germany); A. Ritz, Philips Research Labs. (Germany) . . . . . [5963-41]

12.00: **High-performance cold light mirror production with plasma ion assisted deposition (PIAD),** W. Klug, R. Goetzelmann, H. Hagedorn, A. Zoeller, Leybold Optics GmbH (Germany) . . . . . [5963-42]

Lunch/Exhibition Break . . . . . 12.20 to 13.50

SESSION 10

Room: Hörsaal 5 . . . . . Thurs. 13.50 to 15.30

Manufacturing II

Chair: **Alexander V. Tikhonravov**, M.V. Lomonosov Moscow State Univ. (Russia)

13.50: **Correlation between the optical performance of TiO2-Ag-TiO2 multilayers and the interface roughness between the layers,** D. A. Tonova, B. von Blanckenhagen, Carl Zeiss AG (Germany) . . . . . [5963-43]

14.10: **High-rate deposition of optical coatings by closed-field magnetron sputtering,** D. R. Gibson, Applied Multilayers Ltd. (United Kingdom); I. T. Brinkley, Applied Multilayers Ltd (United Kingdom); E. M. Waddell, M. Walls, Applied Multilayers Ltd. (United Kingdom) . . . . . [5963-44]

14.30: **Innovative production of thin film laser components,** M. Scherer, H. Hagedorn, W. Lehnert, J. Pistner, Leybold Optics GmbH (Germany) . . . . . [5963-45]

14.50: **Thorium-free interference coatings for infrared applications,** S. Laux, E. Gittler, H. Bernitzki, F. Schmidt, G. Wurlitzer, T. Wey, JENOPTIK Laser, Optik, Systeme GmbH (Germany) . . . . . [5963-46]

15.10: **Precision optical and antireflection multilayer and gradient coatings containing reactively sputtered oxides, nitrides and fluorides,** H. Bartzsch, P. Frach, Fraunhofer Institut Elektronenstrahl- und Plasmatechnik (Germany) . . . . . [5963-47]

Coffee Break . . . . . 15.30 to 16.00

SESSION 11

Room: Hörsaal 5 . . . . . Thurs. 16.00 to 17.40

Manufacturing III

Chair: **Helmut Bernitzki**, JENOPTIK Laser, Optik, Systeme GmbH (Germany)

16.00: **Organically modified SiO2 coatings on polycarbonate,** K. Lau, U. Schulz, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) . . . . . [5963-48]

16.20: **Design and fabrication of hybrid coatings composed of homogeneous layers and linear refractive index gradients,** R. Leitel, V. Janicki, D. Gäbler, S. Wilbrandt, O. Stenzel, N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) . . . . . [5963-49]

16.40: **Gravure printing of transparent conducting ITO coatings for display applications,** J. Puetz, S. Heusing, M. de Haro Moro, C. M. Ahlstedt, M. A. Aegerter, Leibniz-Institut für Neue Materialien GmbH (Germany) . . . . . [5963-50]

17.00: **Optical and mechanical properties of RLVIP Nb2O5-films,** A. Hallbauer, D. Huber, H. K. Pulker, Leopold-Franzens-Univ. Innsbruck (Austria) . . . . . [5963-51]

17.20: **Chemical vapour deposition of optical coatings onto small scale complex optical components,** M. L. Hitchman, D. R. Gibson, W. Manookian, E. M. Waddell, Thin Film Innovations Ltd. (United Kingdom) . . . . . [5963-52]

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Detectors and Associated Signal Processing II

Conference Chairs: **Jean-Pierre Chatard**, ULIS (France); **Peter N. J. Dennis**, QinetiQ (United Kingdom)

Program Committee: **Sylvie Boaglio**, ULIS (France); **Wolfgang A. Cabanski**, AEG Infrarot-Module GmbH (Germany); **Haimei Gong**, Shanghai Institute of Technical Physics (China); **Ernest Grimbert**, Opgal Optronic Industries Ltd. (Israel); **Pierre Magnan**, Ecole Nationale Supérieure de l'Aéronautique et de l'Espace (France); **Trevor Martin**, QinetiQ (United Kingdom); **Peter J. Pool**, e2v technologies ltd. (United Kingdom); **Pierre Potet**, CEDIP Infrared Systems (France); **Piotr Pregowski**, PIRS Pregowski Infrared Services (Poland); **Steffen R. Schmidt**, JENOPTIK Laser, Optik, Systeme GmbH (Germany); **Peter Seitz**, Ctr. Suisse d'Electronique et de Microtechnique SA (Switzerland); **Fiodor F. Sizov**, V. Lashkariov Institute of Semiconductor Physics (Ukraine)

Tuesday 13 September

SESSION 1

Room: Hörsaal 6 ..... Tues. 10.30 to 12.10

Detectors and Associated Signal Processing I

Chairs: **Peter N. J. Dennis**, QinetiQ (United Kingdom); **Haimei Gong**, Shanghai Institute of Technical Physics (China)

10.30: **2.5Gbit/s fiber receiver with integrated PIN photodiode in low-cost 0.6µm BiCMOS,** M. Förtsch, H. Zimmermann, Technische Univ. Wien (Austria) ... [5964-01]

10.50: **Status of AlGaN based focal plane arrays for UV solar blind detection,** J. Reverchon, Thales Research & Technology (France); A. Dussaigne, J. Duboz, Ctr. National de la Recherche Scientifique (France) ..... [5964-02]

11.10: **Fast-operating focal plane array of a 128x128 elements format on the basis of InSb with the frame-accurate accumulation and function of a range finder,** A. I. Dirochka, A. M. Filachev, I. D. Burlakov, V. F. Chishko, I. L. Kasatkin, A. A. Lopukhin, ORION Research Development and Production Ctr. (Russia) ..... [5964-03]

11.30: **Zinc diffusion process investigation of undoped InP,** C. Zhuang, Y. Lv, H. Gong, Shanghai Institute of Technical Physics (China) ..... [5964-04]

11.50: **Comparative analysis of low-doped bulk, MBE and LPE grown n-HgCdTe material and photoconductors based on it,** M. S. Nikitin, Federal State Unitary Enterprise ALPHA (Russia) ..... [5964-05]

Lunch/Exhibition Break ..... 12.10 to 13.30

SESSION 2

Room: Hörsaal 6 ..... Tues. 13.30 to 15.30

Detectors and Associated Signal Processing II

Chairs: **Peter N. J. Dennis**, QinetiQ (United Kingdom); **Piotr Pregowski**, Pregowski Infrared Services (Poland)

13.30: **High-resolution FPAs on MBE-grown HgCdTe/CdTe/Ge,** G. Badano, P. Ballet, J. Zanatta, A. Millon, C. Largeron, J. P. Baylet, J. Rothman, O. Gravrand, P. Castelein, J. Chamonal, G. L. Destefanis, CEA-LETI (France); S. Mibord, P. Costa, SOFRADIR (France) ..... [5964-51]

13.50: **The third generation cooled IR detector approach in France,** P. M. Tribolet, SOFRADIR (France) ..... [5964-06]

14.10: **Low-energy inductively coupled plasma etching of HgCdTe,** X. Hu, Z. Ye, R. Ding, L. He, Shanghai Institute of Technical Physics (China) ..... [5964-07]

14.30: **Short wavelength Hg1-xCdxTe infrared detectors prepared by loophole technique,** Y. Shi, Y. Cai, Kunming Institute of Physics (China) ..... [5964-08]

14.50: **MWIR and LWIR detectors based on HgCdTe/CdZnTe/GaAs heterostructures,** S. A. Dvoretsky, V. S. Varavin, N. N. Mikhailov, Y. G. Sidorov, V. V. Vasiliev, V. N. Ovsyuk, Institute of Semiconductor Physics (Russia); M. S. Nikitin, I. Y. Lartsev, Federal State Unitary Enterprise ALPHA (Russia); A. L. Aseev, Institute of Semiconductor Physics (Russia) ..... [5964-09]

15.10: **Four-band infrared detector for FY-2C application,** H. Gong, G. Xu, S. Zhu, H. Qiu, X. Li, D. Liu, L. Zhu, X. Lin, Y. Zhang, J. Fang, Shanghai Institute of Technical Physics (China) ..... [5964-53]

Coffee Break ..... 15.30 to 15.50

SESSION 3

Room: Hörsaal 6 ..... Tues. 15.50 to 17.10

Detectors and Associated Signal Processing III

Chairs: **Peter N. J. Dennis**, QinetiQ (United Kingdom); **Fiodor F. Sizov**, Institute of Semiconductor Physics (Ukraine)

15.50: **Far-infrared and submillimeter photosensitive devices based on Pb1-xSnxTe<In> films: results and perspectives,** A. E. Klimov, V. N. Shumsky, Institute of Semiconductor Physics (Russia) ..... [5964-10]

16.10: **A parallel analogue-digital photodiode array processor chip with hard-wired morphologic algorithms,** L. Hoppe, D. Fey, Friedrich-Schiller-Univ. Jena (Germany); M. Förtsch, H. Zimmermann, Technische Univ. Wien (Austria); A. Loos, Friedrich-Schiller-Univ. Jena (Germany) ..... [5964-11]

16.30: **Restitution of technological parameters on a 320-240 MCT LWIR focal plane array by optical technique,** S. Rommeluere, N. Guerineau, J. Deschamps, ONERA (France); E. De Borniol, G. L. Destefanis, CEA-LETI (France) ..... [5964-12]

16.50: **Uncooled microbolometer detector: recent development at Ulis,** J. Tissot, C. Trouilleau, ULIS (France) ..... [5964-13]

SESSION 4

Room: Hörsaal 6 ..... Tues. 17.10 to 18.10

Detectors and Associated Signal Processing IV

Chairs: **Peter N. J. Dennis**, QinetiQ (United Kingdom); **Trevor Martin**, QinetiQ (United Kingdom)

17.10: **Improvement of the dynamics of the bolometric detector working with high sensitivity,** R. Danych, Czaki Therom-Product (Poland); S. Zwolenik, Czaki Thermo-Product (Poland) and neoVision (Poland); J. Grodowski, Czaki Thermo-Product (Poland) ..... [5964-14]

17.30: **PIN-photodiode based pixel architecture for high-speed optical distance measurement systems,** K. Oberhauser, A. Nemecek, H. Zimmermann, Technische Univ. Wien (Austria) ..... [5964-16]

17.50: **Signal processing for a single detector MOEMS based NIR microspectrometer,** A. Heberer, H. Grueger, F. Zimmer, H. Schenk, Fraunhofer-Institut für Photonische Mikrosysteme (Germany); A. Frank, A. Kenda, W. Scherf, CTR AG (Austria) . [5964-17]

Wednesday 14 September

SESSION 5

Room: Hörsaal 6 ..... Wed. 09.00 to 10.00

Systems and Applications I

Chairs: **Jean-Pierre Chatard**, ULIS (France); **Ernest Grimbert**, Opgal Optronic Industries Ltd. (Israel)

09.00: **An intelligent error correction method applied on an active pixel sensor based star tracker,** U. Schmidt, Jena-Optronik GmbH (Germany) ..... [5964-18]

09.20: **An analytical method to find the optimal parameters for gas detectors based on correlation spectroscopy using a Fabry-Perot interferometer,** E. Vargas-Rodriguez, H. N. Rutt, Univ. of Southampton (United Kingdom) ..... [5964-19]

09.40: **Bessel beam based optical profilometry,** V. N. Belyi, B.I. Stepanov Institute of Physics (Belarus); M. Kroening, Fraunhofer-Institut für Zerstörungsfreie Prüfverfahren (Germany); N. S. Kazak, N. A. Khilo, A. Mashchenko, P. Ropot, B.I. Stepanov Institute of Physics (Belarus) ..... [5964-20]

Coffee Break ..... 10.00 to 10.30

Conference 5964 • Room: Hörsaal 6

SESSION 6

Room: Hörsaal 6 ..... Wed. 10.30 to 11.50

Systems and Applications II

Chairs: **Jean-Pierre Chatard**, ULIS (France); **Steffen R. Schmidt**, JENOPTIK Laser, Optik, Systeme GmbH (Germany)

10.30: **Diffuse optical tomography with an amplified ultrafast laser and a single-shot streak camera: application to real-time in-vivo songbird neuro-imaging,** H. Guillet de Chatellus, Univ. Jean Monnet Saint-Etienne (France); C. Vignal, Univ. Jean Monnet Saint-Etienne (France) and Univ. Paris XI (France); S. Ramstein, S. Mottin, Univ. Jean Monnet Saint-Etienne (France); N. Mathevon, Univ. Jean Monnet Saint-Etienne (France) and Univ. Paris XI (France) ..... [5964-22]

10.50: **Technical challenges for the construction of a medical IR digital image database,** F. J. Ring, Univ. of Glamorgan (United Kingdom); K. Ammer, Ludwig Boltzmann Institut (Austria); B. Wiecek, Politechnika Lódzka (Poland); P. Plassmann, Univ. of Glamorgan (United Kingdom) ..... [5964-23]

11.10: **In-vivo optical tomography of corneal tissue based on the SHG and the multiphoton autofluorescence imaging excited by near-infrared femtosecond laser pulses,** B. Wang, Friedrich-Schiller-Univ. Jena (Germany) ..... [5964-41]

11.30: **Improvement of EVS II versus EVSI,** E. Grimberg, Opgal Optronic Industries Ltd. (Israel) ..... [5964-25]

Lunch/Exhibition Break ..... 11.50 to 13.50

SESSION 7

Room: Hörsaal 6 ..... Wed. 13.50 to 15.10

Systems and Applications III

Chairs: **Jean-Pierre Chatard**, ULIS (France); **Pierre Potet**, CEDIP Infrared Systems (France)

13.50: **Eye speed 300 system,** T. Avigdor, Opgal Optronic Industries Ltd. (Israel) ..... [5964-27]

14.10: **Dual-band infrared camera,** H. Vogel, H. Schlemmer, Carl Zeiss Optronics GmbH (Germany) ..... [5964-28]

14.30: **Aspects of paper characterization from on-line optical measurements,** M. K. Ejnarsson, C. M. Nilsson, Halmstad Univ. (Sweden) ..... [5964-29]

14.50: **Remote online processing of multispectral image data,** C. Groh, H. Rothe, Univ. der Bundeswehr Hamburg (Germany) ..... [5964-30]

Coffee Break ..... 15.10 to 15.40

SESSION 8

Room: Hörsaal 6 ..... Wed. 15.40 to 16.40

Systems and Applications IV

Chairs: **Jean-Pierre Chatard**, ULIS (France); **Wolfgang A. Cabanski**, AIM Infrarot-Module GmbH (Germany)

15.40: **Microbolometer-based infrared camera for the 3-5 μm spectral range,** H. Budzier, V. Krause, G. U. Gerlach, Technische Univ. Dresden (Germany); D. Wassilew, DIAS Infrared GmbH (Germany) ..... [5964-33]

16.00: **Uncooled camera application,** E. Grimberg, Opgal Optronic Industries Ltd. (Israel) ..... [5964-34]

16.20: **Hardware-software complex for chlorophyll estimation in phytocenoses under field conditions,** S. M. Kochubey, Institute of Plant Physiology and Genetics (Ukraine); V. A. Yatsenko, Institute of Space Research (Ukraine); V. Donets, P. Chichik, Central Design Bureau Arsenal (Ukraine) ..... [5964-35]

✔ Posters-Wednesday

The following posters will be displayed all day Wednesday. A poster reception, with authors present at their posters, will be held from 18.30 to 20.00. Poster authors will be able to set up their poster papers in the poster area starting on Wednesday at 10:00 hrs. Further information for poster authors can be found in General Information.

✔ **Effects of surface processing on the surface properties of p-type Hg1-xCdxTe grown by LPE,** Y. Shi, Y. Yao, J. Zhuang, Y. Cai, Kunming Institute of Physics (China) ..... [5964-37]

✔ **The response time of GaN photoconductive detector under various ultraviolet-radiation intensities,** J. Xu, Y. Tang, X. Li, H. Gong, Shanghai Institute of Technical Physics (China) ..... [5964-38]

✔ **Homogeneity of composition in evaporated Pb1-xGexTe thin films,** B. Li, S. Zhang, F. Zhang, Shanghai Institute of Technical Physics (China) ..... [5964-39]

✔ **Design of MCT1024x1 short wave infrared thermal camera,** X. Jian, Shanghai Univ. of Science and Technology (China) ..... [5964-40]

✔ **The research of microsized bionic insect vision exploration technology,** P. Feng, S. Chen, Huazhong Univ. of Science and Technology (China) ..... [5964-42]

✔ **Simple-laser microinterferometer for spaceborne measurements,** G. M. Popov, E. Popov, Crimean Astrophysical Observatory (Ukraine) ..... [5964-43]

✔ **A demo-imaging system based on GaN UV detectors,** Y. Huang, X. Li, H. Gong, Shanghai Institute of Technical Physics (China) ..... [5964-45]

✔ **Failure analysis of PC MCT caused by current,** D. Liu, H. Gong, Shanghai Institute of Technical Physics (China) ..... [5964-46]

✔ **Comparative analysis of 4x288 readouts and FPAs,** F. F. Sizov, Institute of Semiconductor Physics (Ukraine); V. P. Reva, Y. P. Derkach, Institute of Microdevices (Ukraine); V. V. Vasiliev, Institute of Semiconductor Physics (Russia) ... [5964-47]

✔ **Optoelectronic system for NO_2 detection,** Z. Bielecki, J. Wojtas, Military Univ. of Technology (Poland) and Institute of Optoelectronics (Poland); P. Pregowski, Pregowski Infrared Services (Poland) ..... [5964-48]

✔ **Excess power penalty to compensate modal noise in fiber-optics communication,** C. M. Jadhao, G.S.College of Khamgaon (India) and Amravati Univ. (India)[5964-50]

✔ **A mixed process with differential amplification and multiple sampling behind infrared FPA,** Y. Fu, X. Niu, Q. Zheng, Shanghai Institute of Technical Physics (China) ..... [5964-52]

Tuesday-Thursday 13-15 September 2005 • Proceedings of SPIE Vol. 5965

Optical Fabrication, Testing, and Metrology II

Conference Chairs: **Angela Duparré**, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); **Roland Geyl**, Sagem SA (France); **Lingli Wang**, Philips Lighting, Central Development Lighting (Netherlands)

Cochair: **David Rimmer**, OpTIC Technium (United Kingdom)

Program Committee: **Lionel R. Baker**, L.B. Consultants (United Kingdom); **Michael Bray**, MB Optique SARL (France); **Genevieve Chabassier**, CEA-CESTA (France); **Sead Doric**, Doric Lenses Inc. (Canada); **Thomas A. Germer**, National Institute of Standards and Technology (USA); **Ernst-Bernhard Kley**, Friedrich Schiller Universität Jena (Germany) (USA); **Jacques Mangin**, Univ. de Bourgogne (France); **Raymond Mercier**, Univ. de Paris-Sud (France); **Alexander Pagis**, ELOP Electrooptics Industries, Ltd. (Israel); **Olivier M. Parriaux**, Univ. Jean Monnet Saint-Etienne (France); **Joanna Schmit**, Veeco Instruments Inc. (USA); **Hans J. Tiziani**, Univ. Stuttgart (Germany); **Theo T. Tschudi**, Technische Univ. Darmstadt (Germany); **Thierry Vandevelde**, Umnicore (Belgium)

Tuesday 13 September

SESSION 1

Room: Hörsaal 8 ..... Tues. 10.30 to 12.20

Micro-optics

Chairs: **Angela Duparré**, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); **Roland Geyl**, SAGEM SA (France)

10.30: **Micro-optics: manufacturing and characterization *(Invited Paper)*,** R. Voelkel, M. Eisner, K. J. Weible, SUSS MicroOptics SA (Switzerland) ..... [5965-01]

11.00: **Replication and surface enhancement of microstructured optical components,** H. Bitzer, J. Zosel, M. Gebhardt, Reflexite Corp. (USA) ..... [5965-02]

11.20: **Design and fabrication of refractive and diffractive micro-optical elements, used in holographic recording setups,** T. Kaempfe, E. Kley, A. Tuennermann, Friedrich-Schiller-Univ. Jena (Germany) ..... [5965-03]

11.40: **Novel fabrication technique of continuous profiles for micro-optics and integrated optics,** T. Käsebier, H. Hartung, E. Kley, A. Tünnermann, Friedrich-Schiller-Univ. Jena (Germany) ..... [5965-04]

12.00: **Near-field holography with a two-dimensional phase mask for fabrication of two-dimensional structures in a single exposure step,** H. Hartung, T. Clausnitzer, E. Kley, A. Tuennermann, Friedrich-Schiller-Univ. Jena (Germany) ..... [5965-05]

Lunch/Exhibition Break ..... 12.20 to 13.50

SESSION 2

Room: Hörsaal 8 ..... Tues. 13.50 to 15.40

Nano and Micrometrology I

Chair: **Olivier M. Parriaux**, Univ. Jean Monnet Saint-Etienne (France)

13.50: **Characterization of resonance domain diffractive optical elements *(Invited Paper)*,** M. A. Golub, A. A. Friesem, L. Eisen, M. Meyklyar, Weizmann Institute of Science (Israel) ..... [5965-06]

14.20: **A multisensor metrology tool for nanometer to meter measurements,** T. Fries, FRT GmbH (Germany) ..... [5965-07]

14.40: **Critical dimension metrology using optical diffraction microscopy,** P. Hansen, N. Agersnap, LuKa Optoscope (Denmark); J. C. Petersen, J. Garnaes, Danish Fundamental Metrology (Denmark); N. Destouches, O. M. Parriaux, Univ. Jean Monnet Saint-Etienne (France) ..... [5965-08]

15.00: **Nanopositioning and nanomeasuring machine for high accuracy measuring procedures of small features in large areas,** E. Manske, T. Hausotte, R. Mastylo, N. Hofmann, G. Jäger, Technische Univ. Ilmenau (Germany) ..... [5965-09]

15.20: **Scanning force microscopy for optical surface metrology,** M. Flemming, K. Roder, A. Duparré, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany) ..... [5965-10]

Coffee Break ..... 15.40 to 16.10

SESSION 3

Room: Hörsaal 8 ..... Tues. 16.10 to 18.10

Nano and Micrometrology II

Chair: **Thomas Fries**, FRT GmbH (Germany)

16.10: **Subaperture metrology technologies extend capabilities in optics manufacturing,** M. Tricard, G. W. Forbes, P. E. Murphy, QED Technologies Inc. (USA) [5965-11]

16.30: **Standardization in dimensional nanometrology: development of a calibration guideline for scanning probe microscopy,** T. Dziomba, L. Koenders, G. Wilkening, Physikalisch-Technische Bundesanstalt (Germany) ..... [5965-12]

16.50: **Modern topics in standardized laser-induced damage threshold measurements,** K. Starke, H. Blaschke, M. Jupé, D. Ristau, Laser Zentrum Hannover e.V. (Germany) ..... [5965-13]

17.10: **Digital signal processing in AFM topography and recognition imaging,** S. Adamsmair, A. Ebner, P. Hinterdorfer, B. G. Zagar, Johannes Kepler Univ. Linz (Austria) ..... [5965-14]

17.30: **Transmission measurements for the optical characterization of 2D-photonic crystals,** M. Gerken, R. Boschert, U. Lemmer, Univ. Karlsruhe (Germany) .. [5965-15]

17.50: **Classification of optical surface properties and material recognition using mutlispectral BRDF data measured with a semihemispherical spectro-radiometer in VIS and NIR,** C. F. Hahlweg, H. Rothe, Univ. of the Federal Armed Forces (Germany) ..... [5965-16]

Wednesday 14 September

SESSION 4

Room: Hörsaal 8 ..... Wed. 08.00 to 10.10

Manufacturing and Testing

Chair: **Lingli Wang**, Philips Lighting, Central Development Lighting (Netherlands)

08.00: **Manufacturing and testing of precision optical components: from substrate to coating and assembling *(Invited Paper)*,** R. P. Netterfield, Commonwealth Scientific & Industrial Research Organisation (Australia) ..... [5965-17]

08.30: **Aspheros: rapid fabrication of precise aspheres,** R. Boerret, Univ. of Applied Science Aalen (Germany); H. Wang, Carl Zeiss AG (Germany); V. Giggel, Carl Zeiss Jena GmbH (Germany) ..... [5965-18]

08.50: **Optical design, manufacturing and tests of the MUSE image slicer,** F. Laurent, R. Bacon, J. Dubois, F. Hénault, E. Renault, D. Robert, Observatoire de Lyon (France) ..... [5965-19]

09.10: **Design considerations for computer-generated holograms as supplement to Fizeau interferometers,** R. Schreiner, JENOPTIK Laser, Optik, Systeme GmbH (Germany) ..... [5965-20]

09.30: **Recent advances in subaperture finishing,** M. Tricard, A. B. Shorey, P. Dumas, QED Technologies Inc. (USA) ..... [5965-21]

09.50: **Synthesis of diamond diffractive optical elements for IR laser beam focusing,** V. S. Pavelyev, V. A. Soifer, N. L. Kazansky, A. V. Volkov, G. F. Kostyuk, Samara Institute of Image Processing Systems (Russia); V. V. Kononenko, V. I. Konov, S. M. Pimenov, General Physics Institute (Russia); M. R. Duparre, B. Luedge, Friedrich-Schiller-Univ. Jena (Germany) ..... [5965-22]

Coffee Break ..... 10.10 to 10.40

SESSION 5

Room: Hörsaal 8 ..... Wed. 10.40 to 12.30

Large and Complex Surfaces I

Chair: **Michael Bray**, MP Opitque SARL (France)

10.40: **Megajoule laser project and polishing process for high laser induced damage threshold at 351 nm *(Invited Paper)*,** J. Néauport, Commissariat à l'Energie Atomique (France) ..... [5965-23]

11.10: **The challenges of large laser optics manufacturing for laser fusion,** R. Geyl, J. Bernier, F. Houbre, SAGEM SA (France) ..... [5965-24]

11.30: **From VLT to GTC and towards the ELT,** R. Geyl, M. Tarreau, E. Ruch, M. Cayrel, SAGEM SA (France) ..... [5965-25]

11.50: **Design philosophy for the Cranfield ultraprecision big OptiX system,** P. R. Shore, P. M. Morantz, Cranfield Univ. (United Kingdom); R. F. Read, Cranfield Precision (United Kingdom) ..... [5965-26]

12.10: **CCPM (computer controlled polishing machine): combined fine grinding and polishing innovative tool for optics manufacturing,** D. Mancini, ATEC Robotics (Italy) and Osservatorio Astronomico di Capodimonte (Italy) ..... [5965-27]

Lunch/Exhibition Break ..... 12.30 to 14.00

SESSION 6

Room: Hörsaal 8 ..... Wed. 14.00 to 15.50

Large and Complex Surfaces II

Chair: **Roland Geyl**, SAGEM SA (France)

14.00: **Recent advances in the control of form and texture on free-form surfaces *(Invited Paper)*,** D. D. Walker, Univ. College London (United Kingdom) and Zeeko Ltd (United Kingdom); R. Morton, A. T. Beaucamp, Zeeko Ltd. (United Kingdom); G. McCavana, Zeeko Ltd (United Kingdom); V. Doubrovski, X. Wei, Zeeko Ltd. (United Kingdom); C. R. Dunn, Univ. College London (United Kingdom); R. R. Freeman, Zeeko Ltd. (United Kingdom) ..... [5965-28]

14.30: **Machining and measuring of an off-axis paraboloid,** U. P. Birnbaum, R. Schreiner, JENOPTIK Laser, Optik, Systeme GmbH (Germany) ..... [5965-29]

14.50: **Stitching interferometry and absolute metrology: an overview,** M. Bray, MB Optique SARL (France) ..... [5965-30]

15.10: **Stitching oil-on interferometry of large fused silica blanks,** D. Schönfeld, R. Takke, S. Thomas, Heraeus Quarzglas GmbH and Co (Germany) ..... [5965-31]

15.30: **Dynamic holography for the space qualification of large reflectors,** Y. Stockman, C. Thizy, P. C. Lemaire, Univ. de Liège (Belgium); D. B. Doyle, G. J. Ulbrich, European Space Research and Technology Ctr. (Netherlands) ..... [5965-32]

Coffee Break ..... 15.50 to 16.20

SESSION 7

Room: Hörsaal 8 ..... Wed. 16.20 to 18.30

Interferometry and Wavefront Measurement I

Chair: **Steven D. Knox**, National Physical Lab. (United Kingdom)

16.20: **Wavefront measurement of space infrared telescopes at cryogenic temperature *(Invited Paper)*,** H. Kaneda, Japan Aerospace Exploration Agency (Japan); T. Onaka, The Univ. of Tokyo (Japan); T. Nakagawa, K. Enya, H. Murakami, Japan Aerospace Exploration Agency (Japan); R. Yamashiro, Y. Numao, Y. Sugiyama, Nikon Corp. (Japan) ..... [5965-33]

16.50: **Measuring wavefront tilt using shearing interferometry,** H. Schreiber, Corning Tropel Corp. (USA) ..... [5965-34]

17.10: **Limitations of iterative least square methods in phase shifting interferometry in presence of vibrations,** J. Schmit, Veeco Instruments Inc. (USA) ..... [5965-35]

17.30: **Contact-free on-axis metrology for the fabrication and testing of complex optical systems,** A. Courteville, R. C. Wilhelm, Fogale nanotech (France) .. [5965-36]

17.50: **Nondestructive testing using real time opto-digital holographic interferometry,** L. L. Bouamama, Univ. Ferhat Abbas de Sétif (Algeria); S. Krüger, H. Gruber, G. K. Wernicke, Humboldt-Univ. zu Berlin (Germany) ..... [5965-37]

18.10: **The quadri-wave lateral shearing interferometer dedicated to wavefront metrology,** S. Velghe, J. Primot, N. Guérineau, ONERA (France); M. Cohen, B. Wattellier, École Polytechnique (France) ..... [5965-38]

✔ Posters-Wednesday

The following posters will be displayed all day Wednesday in the Conference Area Hallway. A poster reception, with authors present at their posters, will be held from 18.30 to 20.00. Poster authors will be able to set up their poster papers in the poster area starting on Wednesday at 10:00 hrs. Further information for poster authors can be found in General Information.

✔ **Optical study on GaN epilayer by infrared spectroscopic ellipsometry,** J. Wang, X. Li, Shanghai Institute of Technical Physics (China); J. Liu, Shandong Univ. (China) ..... [5965-60]

✔ **Self-organized antireflective nanostructures on PMMA by ion etching,** A. Kaless, U. Schulz, N. Kaiser, Fraunhofer-Institut für Optik und Feinmechanik (Germany) ..... [5965-61]

✔ **Optical properties of stochastic subwavelength surface structures,** R. Leitel, A. Kaless, J. Petschulat, U. Schulz, O. Stenzel, N. Kaiser, Fraunhofer-Institut für Optik und Feinmechanik (Germany) ..... [5965-62]

✔ **In-situ real-time characterization of the roughness of a growing film by x-ray scattering technique,** I. V. Kozhevnikov, A.V. Shubnikov Institute of Crystallography (Russia); L. Peverini, E. Ziegler, European Synchrotron Radiation Facility (France) ..... [5965-63]

✔ **Theoretical and experimental investigation of optical fiber coatings removal by laser irradiation,** C. Zhou, D. Jiang, R. Peng, Wuhan Univ. of Technology (China) ..... [5965-64]

✔ **Texture analysis of ultraprecision optical surfaces,** J. Ratteit, S. Schröder, S. Gliech, Fraunhofer-Institut für Optik und Feinmechanik (Germany) ..... [5965-65]

✔ **Off axis microspectrophotometer for optical coating characterization on complex surfaces,** H. R. Niederwald, L. Deisenroth, S. Nunnendorf, Carl Zeiss AG (Germany) ..... [5965-67]

✔ **Azimuthal ellipsometry of subsurface layer stresses of metal mirror,** L. V. Poperenko, M. V. Ozerov, Kiev Natl Taras Shevchenko Univ (Ukraine) ... [5965-68]

✔ **Spectral characterisation of scattering losses in sputtered oxide coatings,** F. Menchini, A. Krasilnikova, A. M. Piegari, ENEA (Italy) ..... [5965-69]

✔ **Spatially resolved spectroscopy for nonuniform thin film coatings: comparison of two dedicated set-ups,** A. Krasilnikova, A. M. Piegari, ENEA (Italy); M. Dami, Galileo Avionica (Italy); F. Lemarquis, M. Lequime, L. Abel-Tiberini, Institut Fresnel (France) ..... [5965-70]

✔ **Developments of a nanoscale linewidth-standard for high-resolution optical microscopy,** U. Huebner, W. Morgenroth, R. Boucher, Institut für Physikalische Hochtechnologie e.V. (Germany); W. Mirandé, E. Buhr, Physikalisch-Technische Bundesanstalt (Germany); T. Fries, N. Schwarz, FRT GmbH (Germany); G. Kunath-Fandrei, Carl Zeiss Jena GmbH (Germany); R. Hild, Hochschule für Technik, Wirtschaft und Kultur Leipzig (Germany) ..... [5965-71]

✔ **Investigations on process parameters influencing the quality of optical lenses formed by non-isothermal embossing of inorganic glasses,** M. Hug, D. Rieser, P. Manns, G. Kleer, Fraunhofer-Institute Werkstoffmechanik (Germany) .. [5965-72]

✔ **Surface microroughness characterisation of amorphous metallic ribbons during their relief modification,** K. Vinnichenko, L. V. Poperenko, Kiev Natl Taras Shevchenko Univ (Ukraine); S. I. Lysenko, Institute of Semiconductor Physics (Ukraine) ..... [5965-73]

✔ **A new optical metrology tool for measuring aspheres,** T. Fries, M. Meyer, G. Jakob, FRT GmbH (Germany) ..... [5965-74]

✔ **Active shape adjustable polishing tools,** V. Herold, S. Eckner, Friedrich-Schiller-Univ. Jena (Germany); C. Weber, J. Weiser, IGAM Ingenieurgesellschaft für angewandte Mechanik mbH (Germany); C. Weber, Carl Zeiss Jena GmbH (Germany) ..... [5965-75]

✔ **Synchrotron radiation mirror prototype made of monocrystalline tungsten,** V. Herold, R. Schwennicke, Friedrich-Schiller-Univ. Jena (Germany); H. Lammert, F. Siewert, BESSY GmbH (Germany); A. Schindler, Institut fuer Oberflaechen-modifizierung IOM (Germany) ..... [5965-76]

✔ **Light scattering techniques for measurement of precision laser optical surfaces and high-reflective mirrors,** V. V. Azarova, Y. D. Golyaev, G. Y. Kolodnyi, POLYUS Research & Development Institute (Russia) ..... [5965-77]

✔ **Optical surfacing of reflecting SiC mirrors of 520mm R-C system,** L. Yuan, B. Wang, Nanjing Institute of Astronomical Optics & Technology (China) ..... [5965-78]

✔ **Optical system alignment via optical state estimation using wavefront measurements,** N. Sigrist, D. C. Redding, Y. Zhang, J. Z. Lou, S. A. Basinger, Jet Propulsion Lab. (USA) ..... [5965-80]

✔ **Development of a CCD analyzer for the comprehensive characterization of the roughness of an optical surface,** M. Zerrad, C. Deumié-Raviol, M. Lequime, Institut Fresnel (France) ..... [5965-81]

✔ **Large, efficient, high damage threshold gratings for laser pulse compression,** J. Flamand, G. de Villele, A. Cotel, B. M. Touzet, HORIBA Jobin Yvon SAS (France); S. Kane, HORIBA Jobin Yvon Inc. (USA) ..... [5965-82]

✔ **New measurement tool to measure scattering of materials for 2D/3D scattered light measurements and BRDF/BTDF measurements cd,** A. Le Lay, Light Tec (France) ..... [5965-83]

✔ **Comparison of different MR polishing fluids,** M. Schinhaerl, E. G. Pitschke, R. Rascher, P. Sperber, Fachhochschule Deggendorf (Germany) ..... [5965-84]

Thursday 15 September

SESSION 8

Room: Hörsaal 8 ..... Thurs. 08.20 to 10.00

Interferometry and Wavefront Measurement II

Chair: **Joanna Schmit**, Veeco Instruments Inc. (USA)

08.20: **Wavefront sensing with varying transmission filters: past, present and future,** F. Hénault, Observatoire de Lyon (France) ..... [5965-39]

08.40: **Interferometric asphere testing in a spherical test setup,** T. Blümel, M. Bosse, FISBA OPTIK GmbH (Germany) ..... [5965-40]

09.00: **Characterisation of complex optical systems based on wavefront retrieval from point spread function,** B. Moeller, H. Gross, Carl Zeiss Jena GmbH (Germany)[5965-42]

09.20: **Traceable measurement of wavefront sensors,** S. D. Knox, S. R. Hall, R. F. Stevens, National Physical Lab. (United Kingdom) ..... [5965-43]

09.40: **Colorimetric method for phase evaluation in optical testing,** A. Miks, J. Novák, P. Novak, Czech Technical Univ. in Prague (Czech Republic) ..... [5965-44]

Coffee Break ..... 10.00 to 10.30

SESSION 9

Room: Hörsaal 8 ..... Thurs. 10.30 to 12.20

Scatter and Surface Roughness

Chair: **Angela Duparré**, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)

10.30: **Dos and don'ts in characterizing and cleaning optical surfaces *(Invited Paper)*,** J. M. Bennett, Consultant (USA) ..... [5965-45]

11.00: **Design of a full-hemispherical spectro-radiometer with high-dynamic range for characterization of surface properties using multispectral BRDF data from VIS to NIR,** C. F. Hahlweg, H. Rothe, Univ. of the Federal Armed Forces (Germany) and Univ. der Bundeswehr Hamburg (Germany) ..... [5965-46]

11.20: **Angle resolved scatter measurements on optical components,** P. Kadkhoda, H. Madebach, D. Ristau, Laser Zentrum Hannover e.V. (Germany) ..... [5965-47]

11.40: **Sensitive and flexible light scatter techniques from the VUV to IR regions,** S. Schröder, S. Gliech, A. Duparré, Fraunhofer-Institut für Optik und Feinmechanik (Germany) ..... [5965-48]

12.00: **Ellipsometry of scattering patterns from optical inhomogeneities,** C. Deumié-Raviol, G. Georges, O. Gilbert, C. Amra, Institut Fresnel (France) ..... [5965-49]

Lunch/Exhibition Break ..... 12.20 to 13.50

SESSION 10

Room: Hörsaal 8 ..... Thurs. 13.50 to 15.10

Material Properties

Chair: **Roger P. Netterfield**, Commonwealth Scientific & Industrial Research Organisation (Australia)

13.50: **Tailored properties of optical glasses,** R. Jedamzik, B. Hladik, P. Hartmann, SCHOTT AG (Germany) ..... [5965-50]

14.10: **Implementing a prototyping network for injection moulded imaging lenses in Finland,** K. Keränen, J. Mäkinen, VTT Elektroniikka (Finland); E. Pääkkönen, Perlos Corp. (Finland); M. Karttunen, VTT Elektroniikka (Finland); H. Heino, Helsinki Univ. of Technology (Finland); J. A. Hiltunen, P. Karioja, VTT Elektroniikka (Finland) . [5965-51]

14.30: **SiC-Be-Zerodur: material comparison on some real lightweight mirror cases,** R. Geyl, M. Cayrel, E. Ruch, SAGEM SA (France) ..... [5965-52]

14.50: **Angular dependent specular reflectance in UV/Vis/NIR,** I. Stemmler, PerkinElmer, Inc. (Germany) ..... [5965-54]

Coffee Break ..... 15.10 to 15.40

SESSION 11

Room: Hörsaal 8 ..... Thurs. 15.40 to 17.30

DUV Components

Chair: **Kai Starke**, Laser Zentrum Hannover e.V. (Germany)

15.40: **DUV-microscope objectives: technology driver forcing production to switch from micro- to nanometer scale *(Invited Paper)*,** T. Sure, Leica Microsystems Wetzlar GmbH (Germany) ..... [5965-55]

16.10: **A novel instrument for measurement of low-level scattering of optical components in the UV region,** A. Krasilnikova, ENEA (Italy); J. Bulir, Institute of Physics (Czech Republic) ..... [5965-56]

16.30: **Application of the laser-induced deflection (LID) technique for low absorption measurements in bulk materials and coatings,** W. Triebel, C. Mühlig, S. Kufert, Institut für Physikalische Hochtechnologie e.V. (Germany) ..... [5965-57]

16.50: **Nondestructive optical characterization of KDP crystals inhomogeneities and adapted excimer laser conditioning procedure,** M. Pommies, D. Damiani, H. Piombini, H. Mathis, Commissariat à l'Energie Atomique (France) ..... [5965-58]

17.10: **VUV spectrophotometry for photomasks characterization at 193 nm,** M. Yang, J. Leiterer, A. Gatto, N. Kaiser, Fraunhofer-Institut für Optik und Feinmechanik (Germany); I. Höllein, S. Teuber, K. Bubke, Advanced Mask Technology Ctr. (Germany) ..... [5965-59]

Optical Systems Design

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5962-01, Session 1

In the tradition of Ernst Abbe: innovation through wave optics in optical engineering

F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany); H. Schimmel, LightTrans GmbH (Germany)

An optical design conference in Jena in the year 2005 is a perfect place and time to remember Ernst Abbe (1840-1905), the pioneer of a scientific approach in optical engineering. By taking into account the wave nature of light in imaging systems he has presented the way to design high resolution optical devices. His ideas were most important for the successful development of the optical industry in Jena and Germany in general. Nowadays we experience an ever increasing importance of wave optics in optical engineering in order to exploit the innovative potential of optics and photonics. From an optical engineering point of view the reason for this development may be summarized as follows: Innovative applications typically require the control of at least a subset of the parameters of electromagnetic radiation. For instance, the manipulation and control of spatial and/or temporal distribution of the electromagnetic field turns out to be of concern in numerous applications. In order to allow the design of systems to generate tailored electromagnetic radiation, the designer needs a modelling which provides all these parameters in the output of the system. That naturally leads to optical engineering on the base of a wave-optical field representation, to which we refer to as wave-optical engineering. In the talk, basic concepts of wave-optical engineering will be presented. Besides theoretical considerations demonstrations will be shown using the optics software VirtualLab(tm).

5962-02, Session 1

Benchmark for optical simulation tools in the European network of excellence on microoptics NEMO

N. Lindlein, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany)

The European Network of Excellence on Micro-optics (NEMO) is a consortium of about 30 European institutes and companies which are working on micro-optics. The network is supported by the European Commission for a period of four years. One of its work packages is the Center for Modelling and Design consisting of about 20 partners.

In this work package a benchmark of the capabilities of commercial and internal software tools which are available among the partners will be made. The eleven test systems which are used for the benchmarking range from seemingly simple things like calculating the intensity distribution in the focus of a microlens to complete systems like for example an optical interconnect system with microlenses, DOEs and a prism. The paper will present some of the benchmark systems and first results of the benchmarking.

The aim of the benchmark is to see which software tools are most appropriate for which task concerning accuracy, speed and flexibility. There, the simulation method itself is not dictated for each system but only the parameters of the system, the input (light distribution) and the wanted output (merit function). So, it is in fact not only a comparison of different software tools but also of different simulation methods where the exact result is not known before and can only be tested by comparing it with experimental results, special cases which can be solved with an analytic rigorous method, and so on. One of the goals of the benchmarking is therefore also to detect vacant fields concerning modelling methods and software tools.

5962-03, Session 1

Full-wave analysis of filtering behaviour for laminated structures

A. Massaro, L. Pierantoni, T. Rozzi, Univ. Politecnica delle Marche (Italy)

In this contribution we present the accurate analysis and modeling of periodic optical structures that are finding wide application in photonics. The EM analysis is performed by two different 3D full-wave methods, the Transmission Line Matrix-Integral Equation (TLMIE) and the Generalized Transverse Resonance Diffraction (GTRD). TLMIE is a 3D full-wave hybrid technique in the time-domain which combines the advantages of the numerical TLM method and those of the analytical Green's functions representation for the free-space region, thus providing exact boundary conditions at optical frequencies. In GTRD the dyadic Green's function of a loaded box is used for the modeling of the layered structure, combined with Ohm's law formulation of the volume currents. By using the pre- and post-processing tools of TLMIE and GTRD methods, we investigate the dynamic of the EM field in and outside the structure and evaluate the frequency response of the laminated polarizer behaving as a negative uniaxial crystals. The calculated S-parametrs are compared with measured data showing good agreement.

5962-04, Session 1

Optical systems design with integrated rigorous vector diffraction

B. H. Kleemann, J. Ruoff, M. Seeßelberg, J. Kaltenbach, C. Menke, Carl Zeiss AG (Germany)

Depending on the specific application of a diffractive optical element (DOE) its polarization impact on the optical system must be taken into account. This may be necessary in imaging as well as in illumination optics, e.g. in miniaturized integrated optics or in high resolution photo-lithographic projection systems. Sometimes, polarization effects are unwanted and thus, have exactly to be characterized; in other cases a high polarization effect is the goal. It is well known how to calculate the point-spread function (PSF) of a single diffractive micro-Fresnel lens. To do the same for a complete optical system with source, lenses, coatings, mirrors, gratings and diffractive elements, an electrical vectorial field propagation along the geometric-optical path is introduced into a raytrace based optical systems design software in order to incorporate the entire electromagnetic polarization effects from the source to the image plane. This software also considers the complex diffraction amplitudes including polarization effects from DOEs by rigorous electromagnetic methods. Together with a plane wave decomposition and with the local-linear-grating assumption, we are able to rigorously investigate the impact of e.g. DOE-polarization on the PSF of the whole optical system.

Using this approach we compare conventional blazed DOEs with several types of sub-wavelength blazed ones such as binary blazed, blazed area-coded effective medium (BLACE) structures and combinations of them in a diffractive DVD pickup system under the aspects of spot intensity and focal properties. Additionally we study focal properties of radial and/or tangential polarization created by special simultaneously imaging and polarizing binary blazed DOEs. This may be of interest in the discussion how to obtain tighter spots through radial polarization in high NA lenses.

5962-05, Session 1

Robust method for the propagation of an electromagnetic wavefront in an arbitrary optical system

C. Pizarro, A. F. Cifuentes, J. Arasa, Univ. Politècnica de Catalunya (Spain); P. Blanco, Simulacions Optiques S.L. (Spain) and Univ. Politècnica de Catalunya (Spain)

In this paper we present a robust method for propagating an electromagnetic wavefront through an arbitrary optical system. The wavefront at the exit pupil is obtained by the discrete sampling of the wavefront in regular regions equally distributed on the entrance pupil and the optical properties of the system. The discretization permits us to treat each region as a plane wave, so long as the area is small compared to the area of the pupil, therefore allowing us to apply the electromagnetic laws of refraction and reflection during the transfer through an optical system. We can therefore account for amplitude and phase modulation of the wavefront due to the optical system, without making any assumptions about the shape of the optically active elements. Furthermore, our numerical integration method on an arbitrary plane avoids singularities due to the classical analytical integrals, while still obtaining results comparable to rigorous electromagnetic theory.

We have applied the method to simulating the interference of plane waves, spherical waves and a the combination of both. The well known interference patterns of classical experiments such Young's interference fringes or Newton's rings were reproduced accurately, with respect to results obtained applying analytical methods. We then successfully applied the method to analyze a Michelson interferometer set-up, demonstrating the robustness of the calculations. Since the propagation of the wavefront is possible with this method, in the future we plan to apply the method to

simulating electrically large diffractive optical elements within a complex optical system, for which rigorous analytical methods may not be available, and other numerical methods are generally require large computer resources.

5962-06, Session 1

Extended depth of focus as a process of pupil manipulation

S. Förster, Carl Zeiss AG (Germany); H. Gross, Carl Zeiss Jena GmbH (Germany); F. S. Höller, L. Höring, Carl Zeiss AG (Germany)

During the last few years, the understanding of pupil plane manipulation capabilities to achieve an enhanced image formation process and its theoretical limitations becomes more and more important. Particularly the increased potential of computer calculations and digital signal detection makes it possible to simulate this kind of manipulations very fast and efficient. At the same time there is the opportunity to change the optical system such, that a digital reconstruction of the image gives a higher amount of information. An analysis of the optical transfer function as an important parameter of imaging quality with special interest in extended depth of focus is presented. The performance of different pupil-plane masks is illustrated in comparison with standard optical systems. This means the basic features like depth of focus, resolution and contrast were derived and the limitations are shown. The mathematical principle of extended depth of focus with pupil manipulation is described and demonstrated with exemplary calculations. Furthermore, the relation between a given optical transfer function and the matching pupil function is shown. A robust and iterative algorithm is presented to calculate a pupil mask for a desired optical transfer function.

5962-07, Session 1

Modeling pulsed beam propagation through homogeneous and inhomogeneous linear media

S. Poyyil Veetil, Friedrich-Schiller-Univ. Jena (Germany); H. Schimmel II, LightTrans GmbH (Germany); F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany)

We studied the propagation of ultra short pulsed beams through homogeneous and inhomogeneous linear media. This include propagation through free space, apertures and lens systems. To this purpose we considered the pulsed beam in terms of its spectral equivalent- an ensemble of harmonic fields. Since the medium of propagation is linear, the principle of superposition holds so that linear combination of different harmonic fields are also solutions of Maxwell's equations. On propagation, besides the material dispersion the frequency dependent nature of diffraction causes angular dispersion which modifies the spectral content of the pulse and some times even the pulse shape. The result shows that spectral anomalies take place at certain locations in the propagated pulsed beam. It is found that at certain locations in the pulsed beam, the spectral content can be red shifted, blue shifted or split into two. A split in spectral content leads to a split in the pulse shape owing to a change in spectral phase. With our numerical approach, a pulsed beam with any arbitrary beam shape (spatial profile) and pulse shape (temporal shape) can be considered which is not possible with analytical expressions for the propagated fields since they don't give closed form solutions for arbitrary beam shape and pulse shapes.

5962-08, Session 2

Evolutionary algorithms applied to lens design

S. Thibault, Institut National d'Optique (Canada); C. Gagné, M. Parizeau, Univ. Laval (Canada)

Lens system design makes extensive use of optimization techniques to improve the performance of an optical system. We know that designing a lens system is a complex task currently done by experimented optical designers, using specialized optical design software tools. In order to contribute to this particular field, this paper presents a comparison between lens design done by optical designers and evolutionary algorithms lens based design. Evolutionary algorithms consist in population-based global search methods inspired by natural evolution. They are recognized to be particularly efficient for complex non-linear optimization problems. A lens is about as non-linear as anything in physics, evolutionary algorithms could be efficient. The evolutionary algorithms were applied to the monochromatic quartet that was presented to expert participant at the International Lens Design Conference in 1990 (a friendly competition). Comparative results demonstrate that the evolutionary is able to find solutions slightly better than those presented at the competition. Then a real-life imaging problem is tackled. Results show that evolutionary algorithms is again able to discover lens system comparable to design done after a reasonable effort by experts. We present and discuss the limit of this approach for automatic lens design and we concluded that human experience is still required.

5962-09, Session 2

Using software interoperability to achieve a virtual design environment

G. G. Gregory, R. J. Koshel, Lambda Research Corp. (USA)

A variety of simulation tools, including optical design and analysis, has benefited by many years of evolution in software functionality and computing power, thus making the notion of virtual design environments a reality. To simulate the optical characteristics of a system, one needs to include optical performance, mechanical design and manufacturing aspects simultaneously. To date, no single software program offers a universal solution. One approach to achieve an integrated environment is to select tools that offer a high degree of interoperability. This allows the selection of the best tools for each aspect of the design working in concert to solve the problem.

This paper discusses the issues of how to assemble a design environment and provides an example of a combination of tools for illumination design. We begin by offering a broad definition of interoperability from an optical analysis perspective. This definition includes aspects of file interchange formats, software communications protocols and customized applications. One example solution is proposed by combining SolidWorks for computer-aided design (CAD), TracePro for optical analysis and MATLAB as the mathematical engine for tolerance analysis. The resulting virtual tool will be applied to a lightpipe design task to illustrate how such a system can be used.

A universal design environment may not be immediately available to solve all optical design problems. But integrating existing tools can be achieved to improve productivity in design and analysis.

5962-10, Session 2

Automated optimization of non-imaging optics for luminaries

S. V. Kudaev, P. Schreiber, Fraunhofer-Institut für Optik und Feinmechanik (Germany)

Specifics of non-imaging optical systems require special algorithms of automated optimization. We have implemented into commercially available optical design software two methods, which are robust and numerically effective. The first one is a modification of an edge-ray principle. Optimization criterion in this case should be expressed in geometrical terms (like, for example, in a collimation of extended light source). This gives us a possibility to design not only CPC-like collimators, but also rather complex refractive-reflective (RXI-like) devices.

For the second (more general) case optimization criterion is expressed in energetic terms. Stochastic behavior of merit function due to Monte-Carlo ray-tracing procedure in this case limits the applicability of standard optimization routines, available in optical design software. We have realized a direct optimization algorithm, which does not calculates the derivatives of the merit function and, therefore, is less sensitive to local statistical deviations. Proposed algorithm is deterministic and does not suffer from redundant trials of random search.

Necessary condition for automated optimization is a parametric description of optimized objects. Using of NURBS or Bezier splines allows relative strong shape bending but also need to be controlled for intersections. One of a "red-blue intersection" reporting algorithm is realized as a constraint for optimization.

It is shown, that direct optimization algorithm can be applied also for design of free-shape optics, when optical element is designed as a superposition of simple surfaces. Optimisation of a visibility factor of each primitive in partially overlapped set ensures required target energy distribution.

5962-11, Session 2

Concepts for modern optics software

H. Schimmel, LightTrans GmbH (Germany); F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany); T. Paul, LightTrans GmbH (Germany)

In modern optical engineering the simulation of imaging and non-imaging optical systems on the base of wave optics is of increasing importance. A simulation based on wave optics means on one hand to use everywhere in the optical system a wave-optical description of light. This allows the evaluation of more general merit functions for the description of the system quality which requires for example access to amplitude, phase,

polarization, coherence information of light. On the other hand including wave optics in optical simulations means to model the light propagation exact enough to describe wave-optical propagation effects. That means in general not to perform all simulations without physical approximations but to use light propagation models that work with sufficient physical precision within the optical system.

The authors will discuss which needs follow for modern optical simulation software. This discussion includes a flexible handling of different models for simulation of light propagation, descriptions of different wave-optical light representations and considerations of numerical and physical simulation precision. These new concepts will be explained on examples in the field of laser optics.

5962-12, Session 2

Modeling surface and volume scattering with raytracing software

H. J. Frasch, G. Steinmetz, Carl Zeiss AG (Germany)

The main application of Monte Carlo methods in raytracing software lies in the field of scattering analysis. The basis for this simulation in raytracing software is the variation of the ray direction after refraction described by a Bidirectional Scattering Distribution Function (BSDF). In the simpliest case the scattering process is described by a BSDF which only depends on the scattering angle.

We have extended this simple approach in different directions. One extension enables the simulation of different surface scattering effects. For example with a BSDF, which varies with the ray height on the surface, the local variation of the surface roughness due to fabrication effects can be simulated.

Another extension allows the simulation of volume scattering. In this case the scattering properties of the material can be described by two functions: As before a scattering function determines the change in the ray direction due to local defects in the material. Additionally a function for the free path length is used e.g. to describe the density of local defects in the volume.

The requirements and the limitations of the methods are shown and discussed. Several examples of typical applications are presented.

5962-13, Session 2

Macros for the automatic layout of zoom lenses

L. R. Gardner, Lambda Research Corp. (USA)

Instructors of optical design usually emphasize the need to perform preliminary work when starting an optical design task. This work generally consists of reviewing design requirements, researching existing designs, performing preliminary design layout calculations and comparing candidate design forms. Even in educational environments, where the design task can be given “as is” (e.g. as a homework problem), the need to perform paraxial design layout calculations is usually stated as a requirement.

Therefore, it is interesting to note that commercial optical design software programs that are used for the later tasks of the optical design effort (i.e. performance analysis, optimization, tolerancing, ...etc.), are typically not very helpful in performing the preliminary layout or paraxial calculations. There are separate tools that are available (i.e. lens databases, first order layout instructional software, ...etc.), but these typically require extra steps to get the design into the proper format required by a comprehensive optical design program. The complexity of the of the situation is increased even more when applied to zoom lens systems.

This paper will present a series of macros and wizards which can be added to the user interface of a standard optical design code to automate the task of performing preliminary design work for both static and zoom lens systems. A detailed example will be shown of how the setup and subsequent design process for a complex zoom lens can be simplified by implementing these macros in OSLO.

5962-14, Session 2

Making effective use of tolerancing

J. Perrin, JCPC (France)

Tolerancing is one of the more complex task in optical design. It involves several disciplines, mainly optics and mechanics, where comprehensions and methods to treat the question may differ significantly.

Modern optical design software’s are offering several methods to model both optical and mechanical tolerances. These methods are presenting the results in a manner which may be not straightforward to interpret and discuss between the different disciplines involved.

Thank’s to integrated engineering, it is now possible to use more dedicated software’s as a complement to present the results in a much simpler manner.

We shall present how EXCEL and MATLAB can be used together with CODE V in the COM protocol (client-server) to do this job in a quick and efficient manner.

5962-15, Session 2

OPIC: a kit for rapid merit function construction for use with all versions of OSLO, including OSLO-EDU

B. Blandford, Consultant (United Kingdom)

The history of optical design software is sadly littered with accounts of excellent programs which fell by the wayside, either because of obsolescence in their support platforms, or because of the retirement or death of their principal authors.

One example of this is the Imperial College optical design program known as “Version 11/14/15,” developed throughout the 1970s and 1980s by Charles Wynne, Michael Kidger, Pru Wormall, and others. This program and its derivatives produced many excellent designs over the years. One reason was that the ray patterns and weighting factors for operands in the the default merit function had been carefully honed through experience, to produce rapid convergence on the global optimum from a likely starting point.

This paper describes a suite of optimisation ray-sets and weighted operands written in the C-like OSLO compiled macro language CCL. Appropriate to rotationally symmetric lenses, several versions are available for different apertures and fields. They will be familiar to anyone who has used either the Imperial College program or Kidger Optics Ltd SIGMA 2000. Their prime function is to provide a fast, easily understood introduction to merit function construction for the beginner.

One version is for use on OSLO EDU, the free version of OSLO, and it will be issued with the paper. A live attempt will be made to demonstrate how it can be used to locate, from a remote starting point, the global minimum of the “monochromatic quartet,” the lens design problem from the SPIE 1990 International Lens Design Conference.

5962-16, Session 2

Use of aplanatism condition to sample extended objects: application to merit function segmentation

J. Arasa, Univ. Politècnica de Catalunya (Spain); J. A. Diaz, Univ. de Granada (Spain); C. Pizarro, Univ. Politècnica de Catalunya (Spain)

The use of a segmented merit function in the optical design process is a good strategy to improve the optimization trajectories, the problem lies in that exceedingly good results are necessary to change the segmentation of the merit function during the optimization process. In this work we present a new application to the aplanatism condition, the use of the limit of aplanatism as a criterion to segment the merit function when extended objects are involved in the merit function definition.

Our method begins with an equally distributed first sampling of the object to evaluate how far the sampled points are from the aplanatic condition. These initial values collected are used to obtain a second sampling of the object that provides an appropriate number of object field points that must be taken into account to appropriately segment the merit function. The use of the aplantic condition to obtain dynamic merit function segmentation is especially important when large object fields are involved in the design process.

We have tested the method using a collection of wide field of view objectives. The final objective configuration was obtained two times, one with a standard segmentation of the field (on axis, zonal point and full field) and two, with our method. The quality criterion, the algorithm and the initial configuration used was the same for both methods.

5962-117, Session 2

Design of a wide-field unity magnification dive-mask

J. R. Rogers, Optical Research Associates (USA)

No abstract available

5962-17, Session 3

Correcting lens distortion in 3D measuring systems using fringe projection

C. Bräuer-Burchardt, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)

A new methodology for the determination and correction of lens distortion in fringe projection systems for 3D object measurement is introduced. It is shown that usual distortion modelling by functions especially using radial and decentering functions does not accurately enough describe the actually occurring distortion. The new technique uses a matrix of distortion vectors instead of distortion functions in order to describe the distortion most accurate.

A plane surface as a calibration body is the whole necessary additional device for the method.

The fringe pattern is used as the calibration pattern itself and no additional calibration mode of the measuring device is necessary. Thus the determination of the distortion can be performed in the usual state of the system with low effort.

The estimation of the undistorted observations uses a 2D-2D projective transform between projector and camera coordinates and can be applied both to systems using central projection and to systems using telecentric projection.

The distortion of the projector and the distortion of one camera are determined simultaneously by an iterative algorithm. The application of the algorithm allows a reduction of distortion errors up to 0.02 pixels in the projection and also in the camera chip. This is just near the possible resolution of the coordinates at all and reduces the distortion effects to a minimum.

Measuring results of 3D object measurements confirm this statement. The accuracy of measuring values could be significantly improved concerning to the results using former distortion correction methods.

5962-19, Session 3

The atmospheric differential refraction system for the VST Telescope

M. Brescia, F. Cortecchia, G. Marra, P. Schipani, G. Spirito, Osservatorio Astronomico di Capodimonte (Italy)

The effects of atmospheric differential refraction on astrophysical measurements are well known. In particular, as a ray of light passes through the atmosphere its direction is altered by the effects of atmospheric refraction. The amount of this effect depends basically on the variation of the refractive index along the path of the ray. The real accuracy needed in the atmosphere model and in the calculation of the correction to be applied is of course, considerably worse, especially at large zenith angles. On the VLT Survey Telescope (VST) the use of an Atmospheric Dispersion Corrector (ADC) is foreseen at a wide zenith distance range. This paper describes the design and implementation aspects regarding the analytical correction law discovered to correct the refraction effect during observations done with VST telescope.

5962-20, Session 3

An equipment for measuring 3D bi-directional scattering distribution function of black painted and differently machined surfaces

M. Barilli, A. Mazzoni, Galileo Avionica (Italy)

Bi-directional Reflectance Distribution Function (BRDF) measurements that characterise the scattering properties of surfaces are extremely important to the design of optical instruments. Sophisticated codes require the characterisation of the scattering function of optically black and/or differently machined surfaces at several angle of incidence in a wide range of detector angles. These data can be used to develop processes to achieve desired BRDF patterns or to improve stray light suppression techniques.

In this paper, we present the characteristics of a fully automatic, three dimensional, BRDF measurement set up that has been designed and developed at Galileo Avionica by the authors and the most significant experimental results of 3D BRDF data achieved on samples of aluminium alloys, gold and titanium, differently machined and/or black painted.

In particular, the reproducibility of blasting and peening techniques to achieve desired BRDF patterns as for the solar calibration target (SCT) experienced on the VIRTIS M spectrometer (on board of the Rosetta Mission) will be shown and a comparison of 3D BRDF profiles achieved on flat samples painted with Electrodag 501/502 used for absorbing baffles in the visible range will be presented too. The measurements have been taken at different illumination angles (from the normal incidence up to 70 degrees) and at different visible wavelengths (512, 650 and 810 nm).

The wide variety of possible applications that can be explored through the proposed equipment, jointed to its flexibility, constitute a reference point for future investigations on the characterisation of the scattering properties of machined materials and paintings.

5962-21, Session 3

Design of a versatile clinical aberrometer

M. T. Sheehan, National Univ. of Ireland/Galway (Ireland) and Dublin Institute of Technology (Ireland); A. Goncharov, C. Dainty, National Univ. of Ireland/Galway (Ireland)

We have designed an ocular aberrometer based on the Hartmann-Shack (HS) type wavefront sensor for use in a clinical setting. The optical system has four unique features that current clinical/commercial aberrometers do not allow. The system has the capability to sense both on-axis and off-axis aberrations in the eye within an unobstructed 20 degree retinal field. This capability is essential to gather large population data for off-axis aberrations in the eye. This data will be useful for designing future AO systems to enhance image quality of eccentric retinal areas, in particular, the optic nerve head. Additionally, the off-axis capability will provide aberration measurements for subjects with eccentric fixation.

The second unique aspect of design is the ability of the examiner to set the fixation target at different accommodation stimulus demands while sensing. This will allow population studies on the relationship between accommodation and higher order aberrations. The third unique aspect of the design is to combine the pupil alignment channel into a parallel path with the sensing channel. The system images these channels on a single CCD detector. This makes the instrument more compact, less expensive, and easier to synchronise pupil and wavefront alignment. The fourth advantage is a telecentric pass for reimaging HS dots, making the wavefront sensor robust to small longitudinal alignment errors. The entire optical system has been optimised with a ray tracing program and its prototype is currently under construction.

5962-22, Session 3

Reference source elongation compensator in wavefront sensing systems

A. V. Goncharov, C. J. Dainty, National Univ. of Ireland/Galway (Ireland)

It is a common practice to perform a wavefront sensing with multiple reference sources to extract three-dimensional information on the wavefront aberrations induced in the volume of aberrating media. Using such multi-reference wavefront sensor (WFS) and Adaptive Optics systems, one could reduce the aberrating effect of the media. An efficient wavefront correction is only possible if the WFS system provides accurate measurements of the wavefront. As in the case of the Shack-Hartmann sensor, spot displacements are measured in each sub-frame image. One of the factors limiting the accuracy in determining the spot location is the angular size of the reference sources as they appear in sub-apertures. This error is proportional to the angular size of the source, which can differ for x- and y-components and vary among the sub-apertures due to extended structure of the source or its perspective elongation. To improve the accuracy of wavefront sensing with elongated sources, one would wish to reduce the spot size along the elongated direction without decreasing the WFS sensitivity to spot displacements. A new elongation compensator based on standard optical components is proposed. The optical system consists of two lenslet arrays placed after the sensor focal plane, which allow splitting each sub-frame in two images and recombining them in the detector plane. Several types of lenslet arrays have been analysed for different source orientations. It has been concluded that the proposed compensator reduces the elongation effect by factor of two; hence it can be used with multiple reference sources exhibiting some moderate elongation.

5962-84, Session 3

In situ characterization of semiconductor saturable absorber mirrors used for passive modelocking

G. Paunescu, J. Hein, R. Sauerbrey, Friedrich-Schiller-Univ. Jena (Germany)

The dynamic response of a semiconductor saturable absorber mirror (SESAM) used for passive mode-locking was measured in situ in an operating Yb:KGW mode-locked laser. The technique can be described as a pump-probe experiment in which the intracavity beam acts as a pump beam, while the output of the same laser is used as a test beam for the SESAM reflectivity. The optical path at zero delay is arranged in such a way that the probe pulse to overlap in time the next pulse generated in the cavity. For a high accuracy of this kind of measurement, it is very important that the pulse amplitude to be constant in time, without Q-switching modulations. The Yb:KGW laser used for the experiment allows the generation of a very stable pulse train. This was proofed with an oscilloscope and with a frequency spectrum analyser which shows only the cavity frequency, without sidebands.

The method can be an alternative to the standard pump-probe

measurements, in situations where the intracavity parameters such as energy fluence on the SESAM, pulse duration and wavelength can not be simultaneously achieved.

5962-23, Session 4

Developments and design of optical systems for microscopes at Carl Zeiss

K. Uhlendorf, Carl Zeiss Jena GmbH (Germany); L. Schreiber, R. Wartmann, Carl Zeiss AG (Germany); H. Gross, Carl Zeiss Jena GmbH (Germany)

Optics at Jena is strongly connected with the name of Carl Zeiss. He opened a small optical workshop more than 150 years ago , now expanded to a large company, which is mainly busied with production and development of optical systems and instrumentation . So one of the key competences of Carl Zeiss is the optical systems design, which has it roots in the work of Ernst Abbe on the theory of microscopic imaging. In this talk we want to discuss four major aspects of optical systems design at Carl Zeiss, first the classical optical design and developments in microscopy, second optical design applying non-classical solutions, third optical design and the integration of physical effects and last but not least modern aspects of combination of optical systems and digital image processing.

With the theory of microscopical imaging Ernst Abbe developed the idea of a two-staged imaging process- object - pupil - image, where the sine condition plays a main role . With this theory it was the first time possible to go away from the try and error method to a scientific production of optical systems. Microscopy always plays a central roll at Carl Zeiss. Siedentopf invented 1902 the ultra-microscopy, where by extreme dark field illumination it was possible to see ultra-microscopic structures. Further milestones were the perfection of microscopic objectives using meniscus lenses to get a plain corrected field (1938), the extension of the spectral range to UV (ca. 1970) and the correction of lateral color of the intermediate image (1978). Nowadays confocal microscopy in life science as well as in material investigation is of main interest. One example for the complexity of optical design is the confocal 3D-wafer-inspection system using a Nipkow disk. The refined design to overcome underground stray light in conjunction with a wide spectral range highly corrected PAPO-objectives allows to get the 3D-information of the object by evaluation of the chromatic features of the image point.

A challenge to optical design and fabrication is the implementation of new optical components as free form surfaces, diffraction gratings or phase shifting masks. As an example we discuss a high-aperture objective with a great working distance for mask-inspection systems , which contains a surface with a diffraction grating for chromatic correction.

The development of optical design always stand, stays and will stay in interaction with the actually investigated physical problems and the possibilities to transfer the results to the optical design software. So we can say optical systems design is the connection of ray-tracing given by the laws of geometrical optics and important / essential physical effects. For instance the optimization of optical systems by Nijboer-Zernike-coefficients, which can be fast evaluated from the geometrical aberrations, goes back to the recommendation of Pradel and Grossmann in 1960. Around 1980 the theory of partly coherent imaging helped to better understand and assess aberrations and contrast in microscopic and lithographic imaging. Recent developments implement effects of short-time laser pulses in imaging systems, structured illumination for increasing the resolution or special technics to change the focal depth. As we believe today the trends go away from the pure projection systems to sensor systems measuring optical effects and signals. The integration of these effects in the optical design process together with a digital image detection and a postprocessing by computing is the great challenge in the future.

5962-24, Session 4

Reversible lens: theoretical limit of performance and real design

A. Yabe, Consultant (Germany)

The reversible lens is the lens design problem of ILDC (International Lens Design Conference) 1985. The problem is essentially the imaging of magnification -1/2 in a symmetrical lens. From the nature of light, the perfect imaging can not be realized for this problem. Some researchers have been interested in the problem to evaluate the performance limit theoretically, and to find the real design that realizes the performance limit. In 1992 Forbes and Jones applied a global optimization to this problem and showed some solutions with different element numbers. In 1995 Forbes and Wallace predicted a performance limit by the method of the optimization of the Eikonal function. But this prediction was much better than the peformance of the ever-found solutions. In this paper I examined the prediction of Forbes and Wallace and corrected their prediction. I also designed a real lens that reaches the predicted performance limit.

5962-25, Session 4

Imaging properties of different optics for EUV radiation

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Triggered by the roadmap of the semiconductor industry, tremendous progress has been achieved in the development of Extreme Ultraviolet (EUV) sources and high-quality EUV optical coatings in recent years, opening up also new fields of applications apart from microlithography, such as metrology, high-resolution microscopy, or surface analysis. In all these research areas the quality and imaging properties of the employed optics play a crucial role. In this contribution we present a comparison of different optical setups capable of guiding and imaging EUV radiation, which were tested in combination with a miniaturized laser-produced plasma source with high pulse energy (~ 3.5 mJ \@ 13.5 nm) and a plasma size of about 300 μm.

First, a modified EUV Schwarzschild objective with a numerical aperture of 0.44 and a demagnification factor of 10 was developed within the research project “KOMPASS” funded by the German Bundesministerium für Bildung und Forschung (BMBF). The device consists of two spherical ULE substrates coated with Mo/Si multilayers, therefore exhibiting a high reflectance in a narrow wavelength range around 13.5 nm (2% band width). After adaptation to the table-top EUV source, a focus with a diameter ‹ 30 μm at energy densities of several mJ/cm(c)˜ could be produced. The setup is currently being used for comparative investigations of the interaction of EUV radiation with different materials, as e.g. the color center formation in LiF crystals. An attempt to use the Schwarzschild objective in reverse geometry as a EUV microscope will be part of future work.

Second, a Kirkpatrick-Baez arrangement was realized, using the reflections from two curved silicon wafers under grazing incidence (about 5°). The cylindrical curvature is obtained by bending the thin substrates, allowing for a continuous tuning to the desired radii. Due to an Au coating a high reflectivity (theoretically ~ 80 % per reflection) over a broad EUV spectral range can be achieved.

For reduction of aberrations the optical systems were fine-adjusted with the help of a Hartmann-Shack wavefront sensor both in the visible and in the EUV spectral range. The imaging properties in the EUV range were determined and compared to ray tracing calculations performed with ZEMAX.

5962-26, Session 4

Saddle points in the merit function landscape of lithographic objectives

O. Marinescu, F. Bociort, Technische Univ. Delft (Netherlands)

The multidimensional merit function space of complex optical systems contains a large number of local minima, that are connected via links that contain saddle points. In this work we illustrate a method to generate such saddle points with examples of deep UV objectives and extreme UV mirror systems for lithography. The central idea of our method is that, at certain positions in a local minimum with N surfaces, a thin meniscus or two mirror surfaces can be introduced to construct a saddle point with N+2 surfaces. When the optimization goes down on the two sides of the saddle point, two solutions are generated. We show that one of the two solutions can have interesting special properties, such as relaxation, and that this solution can also be reached from several other saddle points constructed in the same way. The advantage of our method is that we can produce new solutions from the existing ones in a simple, efficient and systematic manner.

5962-27, Session 4

Generating saddle points in the merit function landscape of optical systems

F. Bociort, M. van Turnhout, Technische Univ. Delft (Netherlands)

Finding multiple local minima in the merit function landscape of optical system optimization is a difficult task, especially for complex designs having a large number of variables. In this case, even local optimization is time consuming, so if new local minima are to be found, the only useful methods are those which achieve their goal by using only a small number of local optimizations. We have recently shown that saddle points of a special type are useful for global optical system optimization. These are the multi-dimensional equivalents of the two-dimensional saddle-points,

which in mathematics are known as the Morse index 1 saddle points. If such a saddle point is known, letting the optimization to roll down on both sides of the saddle leads to two different local minima. In this work we show that a local minimum with N variables can be converted into a Morse index 1 saddle point with N+2 variables by inserting in the system a thin meniscus lens (or two mirror surfaces). Depending on the position where the meniscus is inserted, different saddle points can be obtained from the same local minimum. A simple method to compute the required meniscus curvatures will be discussed. If the number of surfaces must be restored, a pair of surfaces can be removed via a systematic procedure somewhere else in each of the resulting local minima. The method is applicable for rotationally symmetric systems of arbitrary complexity and enables a rapid generation of new local minima.

5962-28, Session 4

Weight optimization in lens design

W. Besenmatter, Independent Consultant (Germany)

Weight Optimization here stands for Optic Design, i.e. the creation of a new optical system, on the assumpion that weight should be a minimum! This will be done only by means of traditional design methods, i.e. excluding the use of aspherical surfaces, the use of plastic materials, no diffractive elements, no mirrors or similar elements! This demand for the lowest possible weight is important with systems, that must be transported (e.g. into space) as well as with hand held systems, for instance binoculars, rifle-scopes, but also with photographic lenses. Up to now, no theory excists which describes how this problem can be solved. Here, the treatment starts with a fundamental relationship, after that the basic facts related to the weight of a lens are discussed, as well as some papers given in the literature. At the end, a design example will be given, which shows, that even in hopeless cases sometimes a solution can be found.

5962-30, Session 4

Aspheres for high-speed cine lenses

C. Beder, Carl Zeiss AG (Germany)

To fulfil the requirements of today's high performance cine lenses aspheres are an indispensable part of lens design. Among making them manageable in shape and size, tolerancing aspheres is an essential part of the development process. The traditional method of tolerancing individual aspherical coefficients results in unemployable theoretical figures only. In order to obtain viable parameters that can easily be dealt with in a production line, more enhanced techniques are required. In this presentation, a method of simulating characteristic manufacturing errors and deducing surface deviation and slope error tolerances will be shown.

5962-31, Session 4

System concept and optical design of miniaturized projection and imaging systems with OLED microdisplays

S. Riehemann, M. Palme, U. Lippmann, G. Notni, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)

New imaging concepts based on OLED(organic light-emitting diode)-microdisplays will be presented. Up to now mostly all projection systems are based on reflective and/or trans-missive microdisplays like digital micromirror devices (DMDs), nematic liquid crystals dis-plays (LCDs) or liquid crystal on silicon displays (LCOS). But the size of the necessary light source and of the illumination optic is a strong limitation for the miniaturization of the arrangement itself or for system integration. Here we propose to use a high-brightness OLED-microdisplay as active element for pattern generation, giving the possibility to real-ize compact projection or imaging units.

Optical parameters of the microdisplays are determined to get input data for optical sys-tem design. Based on these experimental results specially adapted optical systems are designed. First prototypes and realized systems in the fields of optical 3D-shape meas-urement and stimulation arrangements for neurophysiological investigations are pre-sented.

5962-32, Session 4

Catadioptric projection lenses for immersion lithography

H. Feldmann, A. Dodoc, A. Epple, H. Rostalski, Carl Zeiss SMT AG (Germany); D. R. Shafer, Dave Shafer Optical Design (USA); W. Ulrich, Carl Zeiss SMT AG (Germany)

Due to the advent of immersion lithography arose the demand for large field projection lenses with an NA much greater than 1. The extension of refractive concepts originally developed for dry lenses leads to exploding lens dimensions and system costs. As in many other situations, the field curvature is identified as the aberration dominating the high-NA scaling behavior.

In this situation, we suggest to use mirrors for field curvature correction. Once introduced, they open the door to the large and complex class of catadioptric design concepts.

However, mirrors also introduce vignetting problems and force the designer to either use an off-axis field or an off-axis/obscured pupil. The combined task of vignetting control and op-timal implementation of mirrors in the optical path has lead to a variety of lens configurations, ranging from one to six mirrors, some of them with additional plane folding mirrors. As the NA is increased, the arrangement of the mirrors becomes more and more critical for the system dimensions.

We present several concepts including inline and folded designs and discuss their properties and their applicability as projection lenses for immersion lithography.

5962-33, Session 4

A wide-angle catadioptric lens with the rectilinear projection

G. Kweon, S. Choi, Honam Univ. (South Korea); G. Kim, S. Yang, Korea Basic Science Institute (South Korea); Y. Lee, Hannam Univ. (South Korea)

Oftentimes, it is necessary to have an imaging system that has a wide field of view(FOV). Traditional method of obtaining a wide field of view is by employing a fisheye lens. Some fisheye lens has a FOV that exceeds 180°. However, images obtained using fisheye lens has a significant amount of visually disturbing barrel distortion. For an application which requires a FOV under 180°, then employing a rectilinear lens can be more satisfactory, because it renders a straight line as straight. However, both fisheye and rectilinear lenses are bulky, heavy and expensive. Furthermore, the FOV of rectilinear lens is no larger than 140°.

One alternative has been the rectifying mirror proposed by Hicks et al. This catadioptric lens combines a specially designed convex mirror and a refracting lens. However, the profile of the proposed rectifying mirror can only be obtained after numerically solving a non-linear differential equation. This method is neither guaranteed to yield a solution nor gives a consistent answer.

With an intention to building a wide-angle imaging system having the rectilinear projection scheme, we have derived a new integral equation that can be easily evaluated to yield the desired mirror profile. The mirror has been fabricated from Al6061-T6 using an ultra precision machining tool called Nanoform 600. A commercial CCD bullet camera has been used with a focal length of 3.6mm and the completed catadioptric imaging system has a FOV of 160°. The test result from the fabricated prototype seems encouraging.

5962-34, Session 4

Optics design key points for high-gain photovoltaic solar energy concentrators

J. L. Alvarez Rico, V. Diaz, J. Alonso, Isofoton (Spain); I. Anton, G. Sala, C. Dominguez, Univ. Politécnica de Madrid (Spain)

Last advances in optical design and manufacturing have helped to enlarge possibilities for optical solutions in any field that used optics elements. However, the useful solution is not always the best theoretical achievable one. Now, to find the right solution, the restrictions usually do not come from theoretical limits of optics, but from the feasibility of its practical implementations.

This paper analyzes a set of important figures to be considered in the design of concentration optical system for photovoltaic solar energy applications. To do it, two systems will be comparing. First one is based in a more classical optics: one aspheric lens and a DTIRC secondary[1]; second one is based in a more innovative design methods of non-imaging optics and it is called TIR-R[2]: a primary lens, working mainly by total internal reflection, plus a secondary lens, working by refraction.

In photovoltaic applications, the highest the concentration range (ratio aperture area to solar cell (exit) area), the highest the efficiency of the solar cell. The analysis begins with the theoretical limit enforced by thermodynamic second principle in the relation between concentration range and angular acceptance angle of the system. From this, in one hand, it is followed immediately the effect of the angular response of solar cell to incident radiation, and in the other hand, the effect of assembly and manufactured tolerances of the optics elements. For the high concentration range considered in this paper, other important issue is the radiation flux density inside of secondary element. Finally, focal length (compactness) has impact on assembly procedures, weight, and cost of so called "housing

materials".

[1]. X. Ning, J. O'Gallagher, R. Winston. "Optics of two-stage photovoltaic concentrators with dielectric second stages". Applied Optics, Vol. 26, No. 7, pp 1207-1212 (1987).

[2]. J.L Alvarez, M. Hernández, P. Benitez, J. C. Miñano, "TIR-R Concentrator: a new compact high-gain SMS design", Nonimaging Optics: Maximum Efficiency Light Transfer VI, Proc., pp.32-42, (2001).

5962-35, Session 4

Enhanced optical system using distortion control

S. Thibault, J. Gauvin, M. Doucet, Institut National d'Optique (Canada)

The control of optical distortion is useful for the design of a variety of optical system. The most popular is the F-theta lens used in laser scanning system to produce a constant scan velocity across the image plane. Many authors have designed during the last 20 years distortion control corrector. Today, many challenging digital imaging system can use distortion the enhanced their imaging capability. A well know example is a reversed telephoto type, if the barrel distortion is increased instead of being corrected, the result is a so-called Fish-eye lens. However, if we control the barrel distortion instead of only increasing it, the resulting system can have enhanced imaging capability. This paper will present some lens design and real system examples that clearly demonstrate how the distortion control can improve the system performances such as resolution. We present innovative optical system which increase the resolution in the field of view of interest to meet the needs of specific applications. One critical issue when we designed using distortion is the optimization management. Like most challenging lens design, the automatic optimization is less reliable. Proper management keeps the lens design within the correct range, which is critical for optimal performance (size, cost, manufacturability). Many lens design presented tailor a custom merit function and approach.

5962-36, Session 4

Design of a stationary Fourier transform spectroradiometer with accurate modeling of optical system aberrations

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Stationary Fourier transform spectrometry is a well-known concept to build reliable spectroradiometers, especially for the mid- and far- infrared. Here we investigate a Michelson interferometer that gives equal thickness fringes. The quality of the interference pattern formed on the focal plane array is crucial to obtain a good spectrum by Fourier transform. We take into account three effects, vignetting, fringe distortion, and fringe blurring.

Vignetting, if present, should be symmetrical on the two arms. It then results in a loss of signal depending on the object point.

If fringe distortion did not depend on the object point position, it could be compensated, but this is unfortunately not the case. Fringe shape variation as the object point moves in the field is the most severe constraint: fringes are blurred if this effect comes into play, with the loss of contrast depending on luminance variations in the object field.

To investigate these effects, we start from a commercial optical design software to extract optical path information from a number of rays for both interferometer arms, taking into account all aberrations. Next, with the help of a general numerical software tool, we reconstruct the wavefronts of both arms on the detector and, from there compute relevant interference pattern properties, like the fringe contrast map and the fringe distortion map. We illustrate the concepts on a six off-axis mirrors configuration that we are designing for accurate radiometric measurements in the 3μm-10μm range with 8cm^-1 spectral resolution on an 4.5°x0.6° field of view.

5962-37, Session 4

Telephoto axicon

A. Burvall, A. V. Goncharov, J. C. Dainty, National Univ. of Ireland/Galway (Ireland)

The axicon is an optical element which creates a narrow focal line along the optical axis, unlike the single focal point produced by a lens. The long and precisely defined axicon focal line is used e.g. in alignment, or to extend the depth of focus of existing methods such as optical coherence tomography or light sectioning.

Axicons are generally manufactured as refractive cones or diffractive circular gratings. They are also made as lens systems or doublet lenses, which are easier to produce. We present a design in the form of a reflective-refractive single-element device with annular aperture. This very compact system has only two surfaces, which can be spherical or aspheric depending on the required focal line precision. Both surfaces are reflection coated in annular regions. This axicon will exhibit the same properties as a telephoto lens, thus compressing any optical system where it is used. The scheme is also more flexible than the traditional axicon in terms of specifying the extent and convergence angles of the focal line.

To control both line width and on-axis intensity, the axicon must be apodized. The required apodization is often difficult to implement, but for the aspheric version of our axicon it could be realized intrinsically.

5962-38, Session 4

Reflective high-NA projection lenses

H. Mann, W. Ulrich, Carl Zeiss SMT AG (Germany)

Dioptric systems are the first choice for the design of an optical system, e.g. a projection lens or a microscope. But in some cases refractive designs suffer from serious drawbacks like chromatic aberration or material problems (cost, quality, absorption, birefringence,...). In such cases reflective lenses are an attractive alternative. Reflective lenses can be subdivided into two classes: on one hand there are systems with central pupil obscuration (e.g. reflective microscopes, telescopes in astronomy, ...), which have a large numerical aperture but only a small field , on the other hand there are non-obscured systems (e.g. reflective relay systems, EUV projection lenses), which have a large field but only a small numerical aperture.

By the combination of a non-obscured and an obscured lens one obtains systems with large field and large numerical aperture. We present old and new designs, which prove this design principle.

5962-90, Session 4

SMT LEDs in variable message signs

M. Wanninger, Osram Opto Semiconductors (Germany)

Variable Message Signs have to be readable independant from environmental issues. Therefore requirements regarding luminance, luminance ratio and beam width are very demanding.

Systems available on the market in general use Radial LEDs, mounted with through hole technique. The optical design is adapted to a relatively narrow radiation pattern of those devices. To use SMT LEDs with all it´s advantages e.g. in assembly practice, an optical system has to be designed to handle the different radiation characteristics.

This paper describes the development, simulation and optimization of an optical system for a Variable Message Sign with SMT LEDs.

5962-39, Session 5

Variable phaseplates for focus invariant optics

T. Hellmuth, A. Bich, A. Holschbach, Fachhochschule Aalen (Germany)

According to an established technique known as wavefront coding the depth of focus (DOF) can be enhanced without almost no loss of resolution by inserting a phaseplate with a cubic surface function into the exit pupil plane of an optical system. The higher the enhancement factor of DOF is the stronger must be the cubic phaseplate. Therefore the choice of the phaseplate has to be adapted to the respective situation. In photography the optimum DOF depends on the scene and the type of object and of course also on the expectations of the photographer.

We have designed and manufactured a pair of complementary phase plates which can be shifted to each other. Their surface functions are designed so that they compensate each other in zero shift position and perform like a single cubic phase plate when they are shifted relative to each other. The strength of the resulting cubic wavefront is proportional to the shift. The phaseplates are fabricated by diamond turning PMMA. Immersion liquid is filled between the phaseplates to achieve wavefront deviations from the ideal cubic shape of less than 200 nm. The optical performance of the variable phaseplate and the achieved fabrication quality will be discussed.

5962-40, Session 5

Extend focal depth of a tracking lens by phase apodizers

X. K. Cai, S. Chang, National Research Council Canada (Canada)

In a conventional particle tracking system, the depth of field is usually very small because of use of high power imaging lens. The tracking accuracy may also be affected by the smearing of spot image, caused by focal shift. Increasing the focal depth and keeping effective spot size minimum variation in the focal region is highly desirable for the tracking system. In this report, we study the design of phase filters that could be used to

increase the focal depth of a tracking lens. The design is based on the requirements by highly accurate tracking that the point-spread function (PSF) of the lens keep an even and concentrated energy distribution when the lens is defocused. To achieve this purpose, a multi-level phase-shifting apodizer is introduced on the pupil plane of the lens. The function of the apodizer is to control the energy distribution of the 3D diffraction pattern near the focal region and make the effective spot size uniform or minimum variation along optical axis. The pattern of the 3D PSF of the lens with the apodizer shapes closed to an extended cylinder. New method used to search and optimize the design of the phase apodizer that meet the requirements of a particle tracking system will be studied. Theoretical analysis and experiment verification will be given in support of the method.

5962-41, Session 5

Tolerance analysis of optical systems containing sampling devices

G. C. Curatu, C. E. Curatu, Univ. of Central Florida (USA)

A variety of optical systems use nowadays adaptive optics. These systems are equipped with wavefront sensors, which are often sampling devices measuring the slope of the wavefront at discrete points across the pupil (e.g. Shack-Hartmann sensors). The accuracy of the sampled output signal is always affected by the fabrication and alignment tolerances of the wavefront sensing optical system. Typically it is a requirement to express the measurement error in terms of input wavefront, so the optical output error has to be converted into wavefront measurement error. This conversion cannot be obtained directly from a conventional tolerance analysis because of the wavefront braking by the sampling device. The tolerancing method proposed in this paper solves the problem of converting conventional merit function into input wavefront measurement error. The proposed method consists of two parts. First, a Monte Carlo tolerance analysis based on a specific merit function is performed, and a 90% border system is chosen. Then, an optimization is applied to the 90% border system, by varying a dummy phase surface introduced at the entrance pupil of the system. A concrete example is presented.

5962-42, Session 5

Design of off-axis diffractive optical elements in the resonance domain of light diffraction

M. A. Golub, A. A. Friesem, Weizmann Institute of Science (Israel)

Kinoform blazed diffraction grating, geometrical optics and Fourier transforms based on scalar diffraction are common tools in diffractive optics design, despite of their limited applicability for small grating periods. Alternative numerical methods of rigorous diffraction theory are more powerful and general, but are more complex and loose some physical sense. We will present a new method that combines the main advantages of scalar diffraction design with rigorous diffraction design. In this method we exploit resonance domain surface relief gratings rather that the usual thin blazed gratings, for achieving very high local diffraction efficiencies. It is mainly useful for designing diffractive optical elements with high offset angles, to which a local grating model is applicable, and where 1st diffraction order is determined by geometrical optics. Our design is based on an effective grating model, which generalizes the effective medium theory to the case of resonance domain surface relief gratings by considering both first order and zero order of diffraction. Modeling the surface relief gratings as an effective Bragg grating with two diffraction orders provides closed form analytical solutions for diffraction efficiency and phase as a functions of the gratings parameters. We show that local grooves parameters (period, depth, detour and slant angle) may be chosen with simple analytical equations so as to change the local diffracted beam direction with high diffraction efficiency. Computer simulations of specific diffraction gratings and off-axis diffractive lens confirm the validity and applicability of our method.

5962-43, Session 5

High-efficiency transmission gratings for unpolarized illumination: an intelligible analysis of the diffraction process

T. Clausnitzer, E. Kley, H. Fuchs, A. Tünnermann, Friedrich-Schiller Univ. Jena (Germany); A. Tishchenko, O. Parriaux, Univ. Jean Monnet Saint-Etienne (France)

Due to the fast progress in developing high-power femtosecond laser systems for micromachining and material processing applications the design and fabrication of highly efficient diffraction gratings, which are involved in most of those setups, is currently of great interest. These gratings can be metallic or dielectric reflection as well as transmission gratings, at which the last-named, e.g. made of fused silica, apparently exhibit the highest damage resistance. Numerical calculation of these fused silica transmission gratings show that a diffraction efficiency of 98% even for unpolarized illumination can be achieved if a rectangular groove profile is assumed.

However, this numerical treatment by itself does not give much insight to the mechanisms that lead to this remarkable effect. For gaining higher design potential and to give a deeper understanding of the processes which take place in the grating, a phenomenological representation of the structure has been developed on the basis of modes which propagate vertically in the direction normal to the substrate. The explicit modal analysis discloses the explanation of the highly-efficient diffraction for both polarizations by a very simple interference mechanism. This representation teaches also that no high field concentration in the ridges is expectable, therefore the damage threshold will in principle not be decreased.

5962-44, Session 5

Use of diffractive optical elements in lithographic projection lenses

H. Rostalski, A. Epple, H. Feldmann, Carl Zeiss SMT AG (Germany)

Projection lenses for high resolution lithography have large NA and work at small wave-lengths. In the wavelength regime of VUV (e.g. 193nm), there is a very limited number of optical glasses available, namely fused silica and calcium fluoride. The latter is very expen-sive and used only sparely, leading to limited possibilities to correct color.

In addition to catadioptric approaches, another way to deal with color aberrations is the use of diffractive optical elements (DOEs). They have negative dispersion coupled with positive power and they do not contribute to the Petzval sum. Moreover, it is easy to integrate an aspherical functionality into the structure of the DOE.

The largest challenge for a real world application of DOE in projection optics is the diffrac-tion of light into unwanted diffraction orders, which never can be suppressed completely.

These unwanted orders can lead to stray light and contrast loss if not properly controlled by the designer.

Usually a DOE is placed close to the aperture stop to correct axial color. That stop of a litho-graphic projection lens often is located at the largest diameter, causing some serious fabrica-tion difficulties for the DOE. For this reason a class of lenses with intermediate image is of interest. Here, the accessible image of the aperture stop enhances the possibilities to arrange the stop and the DOE. This allows a convenient trade off between fabrication challenges and aberration correcting properties. We present different lens designs that take advantage of the named properties of DOEs at high numerical aperture.

5962-45, Session 5

Combined elements for beam shaping and polarization management

M. Cumme, P. Triebel, D. Mademann, R. Pechmann, M. Schrenk, P. Weissbrodt, JENOPTIK Laser, Optik, Systeme GmbH (Germany)

Micro and nano optics enable the control of light for producing intensity distributions with given profiles, propagation properties and polarization states. The higher the requirements on the optical function, the more complicated will be its realizing with a single element surface or a single element class. Combinations of refractive and diffractive, both diffractive or sub wavelength structures with each other give the ability to link the advantages of different element classes or different element functions for realizing the optical functionality.

In the paper we discuss different examples of combinations for DUV applications. In detail we present a diffractive - diffractive beam homogenizer with NA of 0.3 that show no zero order. A binary phase grating for polarization control combined with a beam shaping element will be presented. The polarized order of this grating shows an efficiency of about 90% with a degree of polarization better than 90%.

Wave optical and rigorous design strategies and simulations as well as the optical measurements will be discussed for the given examples.

5962-46, Session 5

Diffuser technology for illumination

H. Schimmel, LightTrans GmbH (Germany); F. Wyrowski, Friedrich-Schiller-Univ. Jena (Germany)

Diffuser technology is known in diffractive optics for several decades and

was mainly used together with coherent monochromatic light sources. In the last years diffusers play a more important role for illumination and homogenization task of partial coherent light sources - example, Excimer lasers and LED's. In difference to illumination systems using lenses and micro lens arrays diffusers can be used to freely redistribute the intensity of the light source with a high homogeneity. Using diffuser technology for partial coherent illuminations needs an understanding of the characteristics of the light sources as coherence, wavelength bandwidth, divergence, radiation characteristic/ intensity distribution. Since these characteristics are different for coherent and partial coherent light sources, these must be taken into account during the design of diffuser. This leads to new design concepts and surface structures. The authors will explain concepts of diffuser design for LED's and Excimer lasers and will show practical results

5962-47, Session 5

Design of a tessar lens including a diffractive optical element

U. G. Fotheringham, W. Pannhorst, SCHOTT AG (Germany); R. E. Fischer, OPTICS 1 Inc. (USA)

No abstract available

5962-48, Session 6

Spiral phase contrast microscopy

S. Bernet, A. Jesacher, S. Fürhapter, M. A. Ritsch-Marte, Innsbruck Medical Univ. (Austria)

We demonstrate a spatial filtering method in microscopy, which generates strong edge amplification of the images of both amplitude and phase samples. Insertion of a spiral-phase generating off-axis hologram into a Fourier plane in the beam path of a microscope produces the two-dimensional Hilbert transform of the image wave. The properties of this transformation include a strong edge contrast enhancement, the possibility to produce relief-like views of the phase topography of a sample, and allow an advantageous modification of optical interferometry.

5962-49, Session 6

Interference imaging with a spatial spiral phase filter

S. Fürhapter, A. Jesacher, S. Bernet, M. Ritsch-Marte, Innsbruck Medical Univ. (Austria)

In established central phase contrast methods in microscopy the zero-order Fourier component of an image carrying light wave is phase shifted and used as a reference wave for interferometric superposition with the remaining part of the image wave. Our setup is similar to that principle, with the difference that the phase of the remaining part of the image wave is spatially filtered in its Fourier plane with a spiral phase element. Such a spiral phase element is realized by displaying a high resolution phase hologram at a computer controlled spatial light modulator, which is used for Fourier plane filtering of an incoming object wave. The interferogram is recorded with a CCD-camera. The special shape of the interference fringes allows to reconstruct the phase profile of the sample with sub-wavelength resolution by demodulation of only one single interferogram.

5962-50, Session 6

Design of a microscopy illumination using a partial coherent light source

M. Wald, M. Burkhardt, A. Pesch, J. N. Greif-Wüstenbecker, Carl Zeiss Jena GmbH (Germany)

A homogeneous illumination of a microscope requires a homogeneous intensity distribution in the field plane and in the pupil plane. An inhomogeneity in the pupil gives rise to a distortion in the image. This distortion is more clearly seen in defocused image planes and is commonly misinterpreted as classical aberration. An inhomogeneous intensity distribution in the field plane causes for example a line thickness variation of an imaged structure.

In classical microscopy which operates with classical light sources, for example spiral-wound filaments, the task of designing a homogenised illumination can be solved using geometrical optics. The new inspection microscopes for lithography masks use excimer lasers at 193 nm for illumination. The partial coherence of this kind of light sources may lead to interferences in the pupil and in the field plane which represent the major drawback of such illumination systems.

We present simulated and experimental results concerning the homogenisation of partial coherent light sources. The lateral and temporal coherence of an excimer laser was determined experimentally. With these results simulations were done using partial coherent beams. The considered optical components include microlens arrays and diffractive optical elements. Finally we verified the simulations with experiments.

5962-51, Session 6

Mounting an EUV Schwarzschild microscope lens

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A 20x Schwarzschild microscope lens for the EUV spectral range with an numerical aperture of 0.2 was designed and fabricated. The mechanical design of the lens had to comply with the high requirements on surface figure amounting to 0.5 nm r.m.s. error for both mirrors.

In particular, gravity load, intrinsic stresses of the multiplayer reflective coating as well as mounting forces had to be considered. The diameters of the mirrors are 65 mm for the primary and 12 mm for the secondary. Because of its size the primary mirror is the most sensitive component with respect to gravity load. However, an optimized mount design based on finite-element simulations allowed us to use a classical mounting strategy based on solid-state hinges. To provide a completely hydro-carbon free design the hinges were connected to the mirror by soldering. To comply with the differences in thermal expansion between mirror (ULE) and hinge (Invar) materials a specially adapted flux-free soldering technology had to be developed. Mirror deformations due to stresses induced by the soldering process were compensated during final polishing of the mirror.

Additionally the deformations due to internal stresses of the mirror coatings were calculated. To compensate those errors the values calculated were given into the final polishing process as an offset.

The secondary mirror was clamped between three flexures which were oriented tangentially to the mirror circumference. To allow for an in-operation centering of the lens the base points of the flexures may be moved via remotely actuated micro-positioning screws.

5962-52, Session 6

Designing considerations of an afocal optical system adaptable to high-precision microscopes

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In a number of applications the high precision microscopes are indispensable and rather complex instruments, which have afocal optical systems. The magnification of afocal optical systems are independent of the object distance. Therefore we can image a real and constant image height of an object from a comparatively big object distance range. Our aim is to develop an afocal optical system with a relatively big numerical aperture that facilitates the description of the vectorial calculation of electromagnetic field propagation from the object to the image. The conditions that constitute the preconditions of these vectorial calculations will be achieved by a complex rear and a single front elements special afocal optical system, of which the following are strictly true: the object is in the front focal plane of the front element; the image is in the rear focal plane of the rear element; the aperture spot is in the rear focal plane of the front element and in the front focal plane of the rear element on the adjacent coincidental focal planes; the raytrace is strictly telecentrical in both the object and image space.

Further specifications of the above characterized special afocal optical system are: the magnification: -0,04; the numerical aperture: 0,7; the total legth of imaging: 400mm; the object distance from the last surface of the optical system: 1,25mm; the image height: 0,2mm; the wavelength range of automated correction: Delta(lambda)=612-652nm; the quality of the imaging is diffraction-limited; the maximum value of the distorsion: 1 micrometer

The presentation shows the relevant steps of the design of the afocal optical system that satisfies the above conditions and specifications.

5962-92, Poster Session

The removal speckle using a computer-generated random-phase hologram plate in green wavelength(532 nm)

S. Shin, C. Park, LG Electronics Inc. (South Korea)

The display image using green laser (532 nm)source has a speckle like hot spot noise by a spatial and temporal coherence.

Since,the computer generated hologram (CGH)is designed a random phase binary pattern image,the laser beams through the CGH plate were spatial

incoherent with different phase each other. Then,we have designed a CGH image with 1024 by 1024 pixel size. And then, we fabricated a CGH random phase plate in glass substrate.

The image by using a CGH plate in FT position can be created the removal speckle. The speckle contrast with CGH plate was obtained below 4%.

5962-93, Poster Session

Concept, design and analysis of a large format autostereoscopic display system

F. Knocke, R. de Jongh, M. Frömel, Xetos AG (Germany)

Autostereoscopic display devices with large visual field are of importance in a number of applications like computer aided design projects, technical education or military command systems. Typical requirements for such systems are, besides the large visual field, a large viewing zone, a high level of image brightness and an extended depth of field. Additional appliances such as specialised eyeglasses, head-trackers or the like are disadvantageous for the above applications.

We report on the design and prototyping of an autostereoscopic display system on the basis of projection-type one-step unidirectional holography. The prototype consists of a master holder, an illumination unit and a special direction-selective screen. Reconstruction light is provided by a 2W frequency-doubled Nd:YVO_4 laser. The production of stereoscopic master stripes on photopolymer is carried out on a specifically designed origination setup.

The prototype has a screen size of 180cm x 90cm and provides a visual field of 29° when viewed from 3.6 meters. Due to the coherent reconstruction, a depth of field of several meters is achievable. Up to 18 master stripes can be arranged on the holder to permit a rapid switch between a series of motifs or views. Both computer generated image sequences and digital camera pictures may serve as input frames.

However, a comprehensive pre-distortion needs to be performed in order to account for optical distortion, vertical displacement between master and screen, and several other geometrical factors. The corresponding computations are briefly summarized. The performance of the system is analysed, aspects of beam-shaping and mechanical design are discussed and photographs of early reconstructions are presented.

5962-94, Poster Session

CAD/CAM for lasers and optomechatronics

H. Zhou, Xiamen Univ. (China)

We focus at CAD/CAM for Lasers & optomechatronics. We have developed a kind of CAD/CAM, which is not only for mechanics but also for Lasers, optics and electronic. The software can be used for training and education. We introduce lasaer CAD,mechanical CAD, optical CAD and electrical CAD, we show how to draw a circuit diagram, mechanical diagram and luminous transmission diagram, from 2D drawing to 3D drawing. We introduce how to create 2D and 3D parts for optomechatronics, how to edit tool paths, how to select parameters for process, how to run the post processor, dynamic show the tool path and generate the CNC programming. We introduce the joint application of CAD&CAM. We aim at how to match the requirement of Lasers optical, mechanical and electronics.

5962-95, Poster Session

Optical design of infrared thermal imager

S. Cheng, Shanghai Intitute of Technical Physics (China)

This paper describes the design of the infrared thermal imager capable of offering fire warning during both the day and night. The optical system of the thermal imager is Cassigrain system with IFOV of 2.5mrad and the channels covering the wavelength range 4.0 to 4.6 microns. The system will have an F5.0, 80mm diameter primary mirror. The detector of InSb is comprised of 1000umÅ~1000um pixels with the temperature sensitivity of 1 degree.

5962-96, Poster Session

Formation of radially and azimuthally polarized Bessel light beams under the interaction with a layered periodical medium having defect inclusions

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Necessity of solving a number of practical problems (optical alignment, recording and reading information, optical nondestructive testing and control) have caused an increasing interest in diffractionless Bessel light beams (BLBs). Radially(ρ-) and azimuthally (ϕ-) polarized BLBs are promising for confinement and guiding cold atoms and microparticles and controlling their movement, at the transport of laser energy in hollow waveguides and in optical microscopy. By now, however, techniques of formation of ρ- and ϕ- polarized BLBs are not developed, which hinders their practical application in the above mentioned fields.

In the present work a method of transformation of BLB with an arbitrary cone angle into beams, having ρ- and ϕ- type of polarization, is suggested and elaborated. This method is based on usage of interaction of radiation with a periodical medium, having both optical isotropic and anisotropic defect layers. It is shown that owing to variation of parameters of defect inclusions one can realise a controlling effect on interference maximums of transmission of the periodical medium. Moreover, this permits one to change the position of existing photonic band gaps (PBGs) and to form new regions of nontransmission in given frequency region. Due to the phase difference of eigen waves of orthogonal polarization in passing every period of the medium, PBGs, corresponding to different eigen waves, are splitting and shifting with respect to each other. Such a shift can result in the overlapping of regions of significant reflection of one eigen mode with a region of high transmission of another eigen wave. This enables one to separate and consequently spatially select ρ- and ϕ- polarized Bessel light beams. A merit of the suggested method of formation of ρ- and ϕ- polarized BLBs is the possibility of its realization for any wavelength. This is easily attained by tuning the cone angle of the incident circularly polarized BLB.

5962-97, Poster Session

Design and simulation of a high-resolution superposition compound eye

H. R. Fallah, A. Karimzadeh, Univ. of Isfahan (Iran)

The interest in miniaturizing imaging systems has been increased recently.This paper discuss aberration calculation and design of a superposition compound eye. This designed system contains three micro lens arrays with aspheric surfaces. The simulation of micro-optical systems, especially those including micro lens arrays is still a challenging task. We have simulated and optimized system using geometrical and diffraction-based methods and in some parts commercial optical design software save been used. Low resolution is a disadvantage of superposition compound eye systems against their very large FOV, small size and sensitivity. By simulation and diffraction considering we optimized and increased the resolution of a typical compound eye system.

5962-98, Poster Session

Evaluation of contrast loss introduced by scattering effects at optical mounts: field dependence in the IR region

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The reduction of contrast due to scattering by optical mounts was studied, specially for the systems that must work in the infrared region. When a particular optical system is optimized up to a specified field value the scattering effects introduced by optical mounts must be taken into account. The scattering effect plays an important role in designing for the IR region where the influence of off-field effects are important.

The scattering model used is based on the classical point of view of the scattering electromagnetic radiation and it is adapted for optical evaluation using ray tracing techniques. In order to test the validity of our scattering model we have calculated the distribution of illumination produced for a laser beam in a plane-parallel plate with perfect scattering properties at the back surface. The comparison between the results obtained from our model and from the analytical models permit us to extrapolate the use of our model in systems that consist of complex geometry.

The model was applied in a selection of simple optical IR systems: a ZnSe lens and a Germanium lens, and for a more complex system: a four element objective. In all the situations the contrast as a function of field value with and without scattering effects was compared to determine the influence of the mounts. By contemplating the contrast loss, a better choice of materials and geometry for the mounts can be made possible.

5962-99, Poster Session

Schmidt-like spherical aberration corrector for large spectral region intended for the space optics

G. M. Popov, E. Popov, Crimean Astrophysical Observatory (Ukraine)

Original Schmidt-like spherical aberration corrector is designed. This

corrector is useful for the ground and Space optics. Corrector can be easily made of any transparent material - Fused Quartz, UBK7 glass, etc.. for very large spectral region - from IR to UV. These optical systems are especially recommended for Space telescopes for observation of the big fields of view in a large spectral region.

5962-100, Poster Session

DOE-generated laser beams with given orbital angular moment: application for micromanipulation

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The higher-order Bessel and Gauss-Laguerre modes contain optical vortices providing screw character and presence of orbital angular moment. A microparticle, trapped in such a beam, receives a rotary movement. The new types of laser beams having orbital angular moment, - optical vortices “imbedded” in a plane or a Gaussian beam, are considered. After passing some distance, such fields get rather stable configuration, reminding of Gauss-Laguerre modes, and are distributed under the similar law.

We discuss the generation of laser beams with given orbital angular moment using the phase diffractive optical elements (DOEs). In that case light beams can be forming as a desired superposition of the optical vortices with the complex coefficients. Several laser beams of different orbital angular momentum can be generated simultaneously using multi-order DOE. Such light field configurations can be employed to simultaneously manipulate microparticles in a variety of ways.

Spreading of a scope of laser “traps” has demanded their complication to have new additional opportunities. Such opportuities can be achieved using the laser beams of the high order Bessel, Gauss-Lauguerre modes, angular harmonics (or optical vortices) and their special superpositions. Due to remarkable properties of these beams it is possible to make various actions with microobjects, such as to operate particles stream movement, to rotate them, to trap in the several spatial locations.

In the present work experimental results on trapping and rotation of 5-10 micron-sized biological objects (yeast cells) and polystyrene beads of diameter 5 um using various laser beams are discussed.

5962-101, Poster Session

Characterization of new electrooptical PMN-PT single crystal

V. Pavlenko, B.I. Stepanov Institute of Physics (Belarus); A. Akimov, Institute of Solid State and Semiconductor Physics (Belarus); S. Kurilkina, I. Utkin, B.I. Stepanov Institute of Physics (Belarus); H. Lee, Korea Electronics Technology Institute (South Korea)

The crystallographical and optical investigation of new perspective electrooptical PMN-PT single crystal has been carried out. It has been established the opportunity of existence of this crystal in two modifications, having tetragonal unit cell (space group P4mm) and cubic perovskite one (space group Pm3m) accordingly. Their lattice parameters were found. The results of optical investigations have shown, that the crystals have high transparency in wide spectral area from the visible to near- IR range. The refractive coefficients are calculated by a Kramers-Kronig’ method for the spectral range from 4000 to 5000 cm-1 and have value 2.7 - 2.75 depending on the frequency. It has been established a thermal stability of the PMN-PT single crystals in wide temperature range (20 - 950°C). Using interferometry method, extremally large linear electro-optic coefficients r13~33 pm/V and r33~80 pm/V were characterised for the crystal, having tetragonal unit cell. The half-wave voltage is about 180-220 V. So, to reach the same index change the applied voltage on PMN-PT is much lower than that on $TaLiO_3$ or $LiNbO_3$. It has been grounded that by combining the electro- optic effect and the excellent electro- mechanical properties tunable optical devices, tunable grating, tunable Fabry- Perot interferometer may be created. It has been discussed great prospects of the material while creating variable optical attenuators, polarisation controller, variable gain filters, dynamic gain flatting filters and Q-switches, where various optical parameters, such as intensity, polarisation, phase, need to be managed precisely and reliably.

5962-102, Poster Session

Mask tilt effects counteracted by wafer tilt in an SO-based EUV lithography setup

A. Torre, S. Bollanti, P. Di Lazzaro, F. Flora, L. Mezi, D. Murra, ENEA (Italy)

The results of a numerical simulation of a conventional and a modified Schwarzschild objective are illustrated in relation with its use as imaging system in an extreme ultraviolet lithography setup. It is demonstrated that the degradation of the resolution on the wafer due to the unavoidable tilt of the mask with respect to the optical axis can fairly be vanished by a counter tilt of the wafer as well. In particular, it has been analysed the Schwarzschild objective setup under implementation at the ENEA Frascati Center within the context of the Italian FIRB project for EUV lithography.

5962-103, Poster Session

Design of diffractive optical microrelief for waveguided beam focusing

V. S. Pavelyev, Samara Institute of Image Processing Systems (Russia)

Introduction of diffractive optical elements (DOEs) opened the possibility to control field distribution in the cross-section of laser beam. In fact, by use of DOE one can focus the laser beam into predicted areas [1] as well as form the beam with pre- given behavior propagation through waveguide medium [2,3].

The diffractive micro- relief can be realized either on the separated substrate [3] or directly on the waveguide surface [4].

Some applications need the focusing of the waveguided beam into predicted area [4].

But generally, one can use diffractive micro-relief on the output of waveguide in case of excitement of selected waveguide mode only.

In the present talk it is suggested to use micro-relief on the waveguide input for selected mode excitement and micro-relief on the waveguide output for focusing of the selected mode into pre-given focal area.

The strategy of the search of waveguide mode with intensity distribution closed to the illuminating beam intensity distribution [5] is suggested to be used. Corresponding numerical procedure is described.

Different approaches for synthesis of high-effective DOEs matched with waveguide modes are discussed.

Computer simulation results as well as results of optical experiments are presented.

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5962-104, Poster Session

Technology-oriented stochastic optimization of radially symmetric DOEs

V. S. Pavelyev, Samara Institute of Image Processing Systems (Russia)

With enhanced performance of computing facilities the iterative design of phase diffractive elements (DOEs) [1-3] has become widely accepted. A great number of up-to-date technologies for DOE fabrication make use of the approximation of the commonly continous DOE phase function by a picewise continuos (quantized) function [4]. This is a reason why constructing iterative procedures for the design of quantized DOEs (DOEs with quiantized phase function) has become topical.

Designing quantized DOEs with small number of quantization levels using Fienup-type iterative algorithms (or IFTA-algorithms [2]) is hampered by the necessity to solve the diffractive theory inverse problem at every iteration. Besides, using of such algorithms cannot guarantee convergence to global optimum [3].

The use of stochastic procedures [5,6] does not make it necessary to solve the inverse problem.

Thus, the DOE phase function may be sought for directly over a set of „technologically implemented functions", allowing the quantization errors to be avoided. Such approach can be used also in the case of another restrictions (restriction on the etching depth value, etc.).

However, constructing a stochastic optimization preocedure for a real DOE calls for solving a great number of direct problems, which in general may result in an unpractical coputational efforts.

It seems worthwhile to consider how the stochastic DOE phase optimization can be used when solving the direct problem does not require great computational effort (e.g. for a radially symmetric DOE) [5].

This talk deals with application of the known genetic stochastic procedure to determine the optimum of the function of many variables to designing quantized DOEs focusing light into radially symmetric focal domains (focusing into a circle, alongated focus formation).

Computer simulation results as well as results of optical experiments are presented.

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5962-105, Poster Session

Design of a frequency stabilization system using polarization spectrum in Cr atom lithography

M. Zhao, F. Li, B. Zhang, Z. Wang, Tongji Univ. (China)

In atom lithography, deposition of an atomic beam on a given substrate is controlled by the radiation pressure of laser on the atoms or the laser pumping process, which results in specific density and space distributions of atoms on the substrates. Consequently, atom lithography can be used to fabricate nano-scale lithography samples with different patterns, such as ordered lines or dots. Because of the precise dependence of the period of lithography samples on the frequency of the light-wave, the frequency stabilization of the laser in atom lithography is very important. Various frequency stabilization methods have been developed recently. One of the important methods is polarization spectrum method, which has the advantages of high sensitivity, narrow linewidth, and Doppler free. The pumping process of the polarized pump laser changes the particle number distribution in different energy levels of atoms, as a result, the absorption of the probe laser, which has the same frequency with the pump laser, will also be changed. By measuring the frequency discrimination signal of the polarization angle change of the probe laser passing through atom vapor, the frequency shift of laser can be detected. Apparently the laser frequency could be locked to the atom's transition frequency by using this frequency discrimination signal as the source of a feed back signal.

In this paper, by using of polarization spectrum, a laser frequency stabilization system for Cr atom lithography was designed and fabricated. In order to eliminate the noise and improve the signal-to-noise ratio, an Lock-in amplifier was used. The energy sublevel distributions of Cr atom, which are important for frequency discrimination signal as the designed system would be used for Cr atom lithography, were also discussed. Calculation shows that the nuclear magnetic torque of Cr atom is zero, which in turn has no influence on the energy level of Cr atom. Several other factors, such as the isotopes and the earth magnetic field, were found having little influence on the energy level of Cr atom, indicating that they could be ignored in the current experimental setup.

5962-106, Poster Session

Optical design in CAD software

J. Venturino, OPTIS (France)

The development of optical design and analysis tools in a CAD software can help to optimise the design, size and performance of tomorrow's consumer products.

While optics was still held back by software limitations, CAD programs were moving forward in leaps and bounds, improving manufacturing technologies and making it possible to design and produce highly innovative and sophisticated products.

Optical software was limited because optics were still not connected to other areas of product design. Interactions between mechanics and optics, for instance, had never been possible in the same software. Most traditional simulation software was standalone and, although some enabled data export and import, transfer errors were a problem. More importantly, the process lacked intuitiveness. Altering something in the optics meant that the mechanics had to be re-thought from the beginning.

That is why OPTIS has created the first optical design program to be fully integrated into a CAD program. The technology is available in an integrated SOLIDWORKS or CATIA V5 version and will allow mechanical designers to work on optical systems and to share information with optical designers for the first time.

Previously not possible in a CAD program, you may now determine all the optical performances of any optical system, providing first order and third order performances, sequential and non-sequential ray-tracing, wave front, spot-diagram, using real optical surfaces and guaranteeing the mechanical precision necessary for an optical system. Optimisation process can be handled simultaneously on optical parts and mechanical parts. Designers will now have access to complex surfaces such as NURBS meaning they will now be able to define free shape progressive lenses and even improve on optical performances using fewer lenses.

This paper will present several examples where the integration of optical calculation in a CAD software gives a significant advantage to the optical designer.

5962-107, Poster Session

Zoom lens design

A. Miks, J. Novák, P. Novák, Czech Technical Univ. in Prague (Czech Republic)

Optical systems with variable optical characteristics (zoom lenses) find broader applications in practice nowadays and methods for their design are constantly developed and improved. Our work describes a methodics of design of the zoom lenses using the third aberration theory. The proposed method makes possible to determine, which elements of the optical system can be only simple lenses and which elements must have more complicated design, e.g. doublets or triplets. It is also shown the method for optical system design that permits to calculate the radii of curvature and optical glass types for individual lenses.

5962-108, Poster Session

Calculation of polychromatic aberration coefficients

A. Miks, J. Novák, P. Novak, Czech Technical Univ. in Prague (Czech Republic)

The work deals with the influence of the wavelength of light on the values of wave aberration coefficients. It is proposed a methodics for calculation of the dependence of aberration coefficients on the wavelength, their interpretation and the connection to chromatic aberrations. It is also shown the calculation of the Strehl definition using chromatic aberration coefficients and the tolerance limits are given.

5962-109, Poster Session

Formulation of wave aberration coefficients using correction zones

A. Miks, J. Novák, Czech Technical Univ. in Prague (Czech Republic)

During design process of optical systems, it is desirable to obtain residual aberrations of designed optical systems as small as possible. By analysis of the dependence of aberrations on the numerical aperture, it is possible to find such values of the numerical aperture, where the residual aberration is zero. Such values of the numerical aperture are called correction zones. The work theoretically analyses the described problem and equations are derived for expression of wave aberration coefficients using correction zones for aberrations of the third and fifth order.

5962-110, Poster Session

Fast approach for optical transfer function computation due to image motion and vibrations

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

Image motion and vibrations are often major cause of image degradation in many optical systems located on aircraft, ships, and other vehicles. This image degradation is usually much more severe than that from optics and electronics. Many authors have investigated in this image blur effects with different analytical tools such as optical transfer function (OTF) and point spread function (PSF). OTF is a more convenient tool with which to quantify the blur in spatial frequency domain due to image motion and vibrations. As a matter of fact, the formulation of image degradation into an OTF format is practical for analysis and design of imaging systems as well for image restoration.

OTF expressions due to different types of motion and vibrations are well known in literature. The most systematical method to derive analytical OTF has been introduced by Stern in terms of the statistical moment series of the motion function, suitable for image blur analysis with arbitrary motion. However, in practical the numerical computation using this proposed method does not work well for a few motion functions, with much slow converge speed.

Another new OTF approach is developed in this paper, with which the OTF can be expressed by the direct integral of motion function during the exposure. Compared with the above method, an exactly analytical OTF solution to any kinds of function can be obtained by using this sampler method, and the numerical computation with this approach is much faster and more effective. Furthermore, analytical OTF expressions are derived for linear and quadratic motion, and for sinusoidal and random vibrations in terms of their power spectrum density.

5962-112, Poster Session

Design of a lens system for microlens lithography

H. R. Fallah, A. Karimzadeh, Univ. of Isfahan (Iran)

Micro lens lithography is a new method of lithography which does not impose any limit on the mask and on the wafer area size theoretically. The details of aberration calculations and design of a lens system for micro lens lithography is discussed in this paper. This system contains three micro lens arrays. We simulate and optimize this system with geometrical and diffraction-based methods and in some parts using available commercial optical design software. The resolution of this system has been increased using aspheric surfaces.

5962-113, Poster Session

Pupil filters for wavefront coding: design for improved off axis performance

F. Gómez-Morales, R. Tudela, Univ. de Barcelona (Spain); J. Ferre-Borrull, Univ. Rovira i Virgili (Spain); S. Bosch Puig, Univ. de Barcelona (Spain); M. C. de la Fuente, Indra Sistemas S.A (Spain)

Phase filters for wavefront coding in incoherent imaging systems are usually designed by taking into account on-axis performances only. Of course, these are the most important design constrains, mainly towards attaining the invariance to defocus and/or chromatic aberration. Anyway, when large field of views are considered, the influence of off-axis aberrations can also be relevant for the assessment of the system. More precisely, the influence of the other aberrations of the optical system (astigmatism, coma,...) added to the non-circular-symmetric nature of most of the phase filters proposed for wavefront coding may lead to a loss of space invariance of the PSF.

We analyze the performances of the most known phase filter designs (with or without rotational symmetry) with respect to on- and off-axis imaging. To this end, the PSF will be calculated at different off-axis positions and the contribution of each aberration term to its spatial variation will be evaluated. The PSF will be calculated using the method recently developed by the authors consisting of an exact ray tracing from the point object to a regular mesh of points at the exit pupil plane followed by a propagation considering the Fresnel diffraction approximation. This method guarantees the accuracy of the PSFs obtained.

The study will include the subsequent digital image processing procedure as well, so that a clear idea of the overall system performance will be drawn.

5962-114, Poster Session

Implementation of a new LCD polarized stereoscopic projection system with improved light efficiency

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The majority of commercial LCD projectors have the linear polarized output with two color components of red and blue in the vertical direction and the other color of green in the horizontal direction. Therefore, in case these LCD projectors are used for polarized stereoscopic projection, the orientation of the polarizer is very important because the output of LCD projector has already been polarized. Moreover, light loss of LCD polarized stereoscopic projection highly depends on the configurations of LCD projectors for polarized stereoscopic projection. In this paper, a new LCD polarized stereoscopic projection system with improved light efficiency is proposed and implemented. In this system, two external polarizers employed in the conventional LCD polarized stereoscopic projection system for orthogonal polarization of two projected views have been excluded by effectively taking into account of inherent polarization properties of the conventional LCD projectors. That is, two beams projected from the system are polarized into the orthogonal directions without use of the external polarizers, as a result maximum light efficiency can be obtained. Firstly, the left and right video images captured by stereo camera are separated into three-color components of red, blue and green, respectively. Then, a new left image for the left projector is generated by mixing the red and blue components of the left image with the green component of the right image. At the same time, a new right image for the 90°-rotated right projector is generated by mixing the red and blue components of the right image with the green component of the left image. But, because the right projector has been initially rotated by 90° with respect to the left one in the proposed system, the right image projected from the right projector is also rotated by 90° with respective to the left one. Therefore, the new right image must be adjusted in its orientation and aspect ratio to match with those of the left one through some image processing techniques before it is loaded into the 90°-rotated right projector. These new left and right images are sent to the corresponding left and 90°-rotated right projectors and the size of the projected stereo image pair is matched on the screen by using the 3D reform function of the LCD projector. Then, by using a pair of glasses with linear polarizers oriented at the horizontal and vertical directions, the new stereoscopic images can be finally viewed. From some experimental results with the LCD projectors of NEC MT 1060R, it is found that the implemented system shows a minimum light loss in the polarization process and the resultant stereoscopic image projected from this system is 213% brighter than that projected from the conventional LCD polarized stereoscopic projection system.

5962-53, Session 7

Development of large aperture cooled telescopes for the space infrared telescope for cosmology and astrophysics (SPICA) mission

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The Space Infrared Telescope for Cosmology and Astrophysics (SPICA) mission is a Japanese astronomical infrared satellite project optimized for mid- to far-infrared observations. It will employ mechanical coolers and an efficient radiative cooling system, which allow us to have a 3.5m cooled (4.5K) telescope in space. The large aperture size for cryogenically use, however, demands a challenging development for the telescope system. We take a monolithic mirror design because of the technical feasibility and reliability. We set the optical performance requirement as being diffraction limited at 5micron at the operating temperature. The total weight allowed for the telescope system is 700kg, which requires a very light 3.5m primary mirror together with the mirror support structure. Currently we are working on two candidate materials for the SPICA mirror: silicon carbide (SiC) and carbon-fiber reinforced silicon carbide (C/SiC). This presentation reports the current design and status of the SPICA telescope system, including recent results of the development of the C/SiC material. Laboratory tests at cryogenic temperatures will be

presented by Kaneda et al. For further information on the SPICA mission, visit http://www.ir.isas.ac.jp/SPICA.

5962-54, Session 7

Wide-angle optical systems with moderate spectral resolution, for monitoring the oceans from low Earth orbit

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Monitoring of the oceans from satellite requires frequent updates - preferably with global coverage in one day, excluding effects of cloud. This demands optics covering swath widths up to about 3000km, within which, spatial resolution in the order 250m or less is desirable for observation of coastal zones. Wide field angles, typically \›90 degrees, are needed for optical systems operating from altitudes that are typical for polar orbiting satellites. At least 15 resolved spectral bands are needed in the visible and near-IR regions, requiring wide-field imaging spectrometers or designs

using multiple filters. Other constraints on optical design include requirements for radiometric calibration, precise spatial registration of spectral bands, good control on stray light, and insensitivity to polarisation. The paper describes two design forms in which a single optical channel provides the complete wide-angle field, with appropriate allowances for calibration etc. In the first design, a wide angle telescope is followed by a spectrometer and an area-array detector. The spectrometer uses refractive dispersion for stray light control, and gives good spatial and spectral registration. In the second design, spectral resolution is provided by a set of filters with linear array detectors. In-field separation of detectors is used to avoid a need for beam splitters or dispersive optics; spatial registration in this case demands exceptional distortion correction, that takes account of Earth curvature. Both designs provide an external entrance pupil for location of calibration hardware.

5962-55, Session 7

Ozone monitoring instrument in-flight performance and calibration

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The Ozone Monitoring Instrument (OMI) was successfully launched on board of the EOS AURA satellite on 15 July 2004. OMI is a hyperspectral sensor that measures in the wavelength range 264-504 nm with a spatial resolution of 13x24 km2 for wavelengths above 305 nm and 13x48 km2 below 305 nm. The 115 degrees instantaneous field of view covers about 2600 km at the equator, which enables daily global coverage of the Earth.

OMI measures the total ozone and nitrogen dioxide columns, ozone vertical profiles, cloud properties, aerosol indices and a number of trace gases that are important to ozone chemistry (HCHO, BrO, SO2, OClO). OMI continues the total column ozone record of the Total Ozone Mapping Spectrometer (TOMS), operated by NASA over the past 25 years. In order to obtain the required quality of the level-1 (calibrated radiances and irradiances) and level-2 data products it is important to calibrate the instrument accurately both pre-launch and in orbit. This contribution presents the status of the OMI in-flight performance and calibration. The radiometric calibration of both the radiance and irradiance modes, spectral calibration (accurate to about 0.01 pixel), spectral slit function calibration, viewing properties calibration and spectral stray light calibration are discussed. In addition a number of detector and electronics parameters are presented.

5962-56, Session 7

Metal mirror TMA telescopes of Jena spaceborne scanners: design and analysis

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For the increasing market of low-cost multispectral pushbroom scanners for spaceborne Earth remote sensing, Jena-Optronik GmbH have developed the JSS (Jena Spaceborne Scanners) product line. They are typically operated onboard micro-satellites with strong resources constraints. This leads to instrument designs optimised with respect to minimum size and mass, power consumption, and cost.

Three-mirror anastigmat (TMA) telescope designs have become a widespread design solution for fields of view from 2 to 12 deg. The design solution chosen by Jena-Optronik is based on all-aluminum telescopes. Novel ultra-precision milling and polishing techniques now give the opportunity to achieve the necessary optical surface quality for applications in the visible range.

The TMA telescope optics design of the JSS-56 imager will be accommodated onboard the RAPIDEYE spacecraft. This TMA with a F-number of 4.3 achieves a swath width of 78km with a ground pixel resolution of 6.5m - 6.5m. The aluminium mirrors are Ni coated to obtain a suitable surface polish quality.

This paper discusses typical requirements for the thermal design in the face of bimetallic effects of the mirrors. Analysis and experimental results will be compared. To achieve a nearly diffraction limited imaging the typical surface irregularities due to the turning process have to be addressed in the ray tracing models. Analysis and integration of real mirror data in the Zemax design software are demonstrated here and compared with build-in standard tolerance concepts.

5962-57, Session 7

Design trade-offs for MET image spaceborne imaging radiometer

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A multi-spectral imaging radiometer scanning over a very large swath is often required for globally covering earth observation missions like meteorological applications. For those applications spectral bands in all atmospheric windows from UV to TIR have to be measured. Jena-Optronik is currently establishing the conceptual design of METimage, an imaging spectro-radiometer for future European meteorology missions.

This paper presents an analysis of the requirements for instruments for meteorological applications, presents different implementation options with their prime benefits and drawbacks and discusses the optimisation space.

The different scanner options with their influence on the architecture of the optical system and the focal plane assembly are addressed. This leads to different candidate implementations. For those the optimisation space is described leading to a preferred solution in form of a rotating reflective optics, an in-field spectral separation and a matrix based focal plane assembly. The main advantages of such a system are its flexibility with respect to the possible number of spectral channels, the possible radiometric resolution, and the variability of the geometrical resolution. It is shown that results of a first design iteration demonstrate the feasibility of the chosen approach.

5962-58, Session 7

Optical design of a high-resolution imaging channel for the BepiColombo space mission

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This paper describes the optical design criteria and foreseen image quality of the High Resolution Imaging Channel (HRIC), which is part of the SIMBIO-SYS (Spectrometers and Imagers for MPO BepiColombo Integrated Observatory SYStem) integrated instrument, for imaging and spectroscopic investigation of the Mercury surface. SIMBIO-SYS has been approved as part of the scientific payload of the ESA Bepi Colombo mission to Mercury.

HRIC has the main objective of characterising Mercury surface features with a very high spatial resolution in the visible. The optical design has been optimised to achieve the stringent scientific requirement of 5 m ground pixel size at 400 km from the planet surface. The optical configuration is a catadioptric Ritchey-Chretien, with a resolution of 0.25"/pixel, and a pixel size of 10 micron. The focal ratio is F#8 in order to be diffraction limited at 400 nm and to optimise radiometric flux and overall mechanical dimensions. The optical design solution includes two hyperbolic mirrors and a dioptric camera, in order to correct the field of view of 1.47°, covered by a detector of 2k x 2k pixels. The mixed (reflective + refractive) solution guarantees a good balance of achieved optical performances and optimisation of resources (mainly volume and mass). The adopted configuration corrects and transmits well over the whole band of observation (400 - 900 nm).

5962-59, Session 7

Design and performances for the heliospheric imager of the STEREO mission

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The Heliospheric Imager (HI) is part of the SECCHI suite of instruments on-board the two STEREO spacecrafts to be launched in 2005. The two HI instruments will provide stereographic image pairs of solar coronal plasma and coronal mass ejections (CME) over a wide field of view (~90°), ranging from 13 to 330 Ro. These observations complete the 15 Ro field of view of the solar corona obtained by the other SECCHI instruments (2 coronagraphs and an EUV imager).

The HI instrument is a combination of 2 refractive optical systems with a 2-stages multi-vanes baffle system. The key challenge of the instrument design is the rejection of the solar disk light, with total straylight attenuation of the order of 10-13 to 10-15. Optical system and baffle have been particularly designed to reach the required rejection.

This paper presents the SECCHI/HI opto-mechanical design, with the expected performance. A test program is currently in progress including vacuum straylight verification test, thermo-optical performance tests and co-alignment test. The results are presented and compared with the

expected theoretical data.

5962-60, Session 7

Light weight monolithic silicon carbide telescope for space application

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Since several years, ASTRIUM has developed, with BOOSTEC, Silicon Carbide (SiC) structural pieces for space Telescope applications. This technology has appeared adequate not only for optical elements (mirrors) but also for the complete Telescope structures, due to high stiffness, low coefficient of thermal expansion and high thermal conductivity of SiC. At the time being, two space SiC Telescopes are operational in observation and scientific missions. Two other monolithic SiC Telescopes, among the largest ever built are in manufacturing progress. The latest innovations in SiC technology have been implemented in the ALADIN Telescope for the AEOLUS mission (LIDAR dedicated to wind speed measurement)

5962-61, Session 7

Suppression of sun interference in the star sensor baffling stray light by total internal reflection

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We have developed a star sensor as an experimental device onboard the SERVIS-1 satellite launched in October 2003. The in-orbit data have verified the fundamental performance as a star sensor. One of the advantages of our star sensor is the baffle realizing small size of 140 mm length, instead of 182 mm in the conventional so-called two-stage baffle design. The key concepts for light shielding are total internal reflection phenomena inside a nearly half sphere (NHS) lens and scattering light control by gloss black paint. However, undesirable background noise by the sun outside of the field of view (FOV) is observed in the corner of the FOV. Ray trace simulations reveal that slight scattering light on the baffle wall comes into the NHS lens and reaches the corner of the image sensor through the multi-reflection path inside the lens and that the stray light path can be shielded effectively if the diameter of the aperture under the NHS lens is a little smaller. We evaluate the light shielding ability of the redesigned baffle by our sun interference test facility on the ground and confirm that the stray light is reduced below the acceptable level. As a result, this is effective to realize small baffle size if we pay enough attention to the multi-reflection path. The redesigned star sensor is planned to be installed as a main attitude sensor for the SERVIS-2 satellite scheduled to be launched in February 2008.

5962-62, Session 7

Advanced multispectral focal plate assembly for commercial space-borne instruments

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During the last years the department of Optical Information Systems at the German Aerospace Center (DLR) developed a considerable number of imaging sensor systems for a wide field of applications.

Systems with a high geometric and radiometric resolution in dedicated spectral ranges of the electromagnetic spectrum were provided by developing and applying cutting edge technologies. Based on the focal plate development for the airborne digital sensor ADS40 the next generation for advanced space-borne focal plate arrays was developed. This focal plate is the heart of the Multi spectral Imager (MSI) of the Rapid Eye payload.

For the MSI development DLR OS is subcontractor of the DJO GmbH in Jena Germany. The Rapid Eye satellite constellation is given by 5 identical small satellites. These satellites are equipped each with the powerful Multi Spectral Imager to record imagery of the Earth in five spectral bands and with a GSD of 6.5 m.

The Focal Plane Assembly (FPA) of the MSI contains the five-colour 12 k CCD Assembly and the Focal Plane Electronics. This electronics receives bias and clock signals from the Front End Electronic which is equipped in a separate box. The Focal Plane Electronics includes the output buffering and the clock driver of the CCD. The amplified analogue high speed video data channel is part of the Front End Electronics.

The paper gives an overview about the technology used for high mechanical accuracy and data quality for this commercial space project as well as design-to-cost aspects will be discussed.

5962-63, Session 7

Design and fabrication of multifoil hard x-ray telescope for space observations

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The hard X-ray imaging observation by means of focusing optics and imaging detector is one of the candidate technologies for upcoming X-ray observatory missions of the next generation, such as NeXT (Japan), Constellation-X(USA), or XEUS(ESA). The imaging observations above 10 keV have great importance to explore hard X-ray universe. Investigation of non-thermal emissions from clusters of galaxies is one of the most promising prove to understand particle accelerations in the Universe. Massive black holes embedded by thick obscuring matters in galaxy's nuclei, Compton-thick AGNs, are another category of objects unexplored so far. Among various approaches to imaging telescope for hard X-rays, we adopted multi-foil conical optics with multilayer-supermirror reflecting surface. In hard X-ray region, critical angle of total external reflection by a layer of metal becomes very shallow. Design of optics under such condition is tightly restricted and less efficient. Instead of total external reflection, Bragg's reflection by periodic structure (multilayer) can be an alternative method of reflection with large incidence angles. Since photo-electric absorption becomes less significant, energy response can be widened by grading periodic length into depth direction (spuermirror). We have developed hard X-ray telescope usable up to 50 keV, while previous X-ray telescopes were used below 10 keV. The telescope consists of confocally and coaxially nested ultra-thin conical foil mirrors whose surfaces are coated with multilayer supermirror optimized for hard X-ray observation. In this paper we present design strategy, fabrication process and X-ray characterization of our hard X-ray telescope.

5962-29, Session 8

Application of high-strength RS-SiC to light-weight large optical mirror

Y. Y. Yui, T. Kimura, Y. Tange, K. Enya, Japan Aerospace Exploration Agency (Japan)

We have been proceeding with the research in applicating high-strength reaction-sintered SiC to space-borne ultra-light large telescope system. This is a new material developed by Toshiba and NEC-Toshiba Space Systems and its physical properties are highly promissing for large-scale space optics. The current status of art of the mirror using this material and the future plan of further developing assuming the application to geostationary earth observation and astronomical observation are described.

5962-64, Session 8

Comparison of microwave and light wave communication systems in space applications

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The performances of optical and radio frequency communication systems are compared for long distance applications (e.g. deep space communications), where the signal-to-noise ratio is crucial. We compare an optical system (operating at a wavelength of 0.8 μm) using intensity modulation and direct detection by an avalanche photodiode, an optical system (operating at a wavelength of 1.5 μm) using on-off keying and employing an optical preamplifier, and a radio frequency system in the X-band. Assuming currently available system parameters for the link budget analysis, we find - for distances beyond R = 10^6 km - the signal-to-noise ratio for the optical communication systems to be proportional to R^-4, and that of the radio frequency communication system to be proportional to R^-2. For distances beyond 10^7 km, the maximum data rate achievable with the RF system is higher than that with the optical system. For distances corresponding to low earth orbit links as well as for geostationary earth orbit links, the optical system with optical preamplification is preferable when the data rate is higher than several Gbit/s.

5962-65, Session 8

Optical design of the near-infrared spectrograph NIRSpec

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The James Webb Space Telescope1 (JWST), the successor of the Hubble Space Telescope, is a passively cooled, 6.5m aperture class telescope, optimized for diffraction-limited performance in the near-infrared wavelength region (1 - 5 μm). JWST will be capable of high-resolution imaging and spectroscopy and will carry a scientific payload consisting of three scientific instruments. One of the instruments - NIRSpec - is a near-infrared, multi-object, dispersive spectrograph, which is capable of measuring the near infrared spectra of at least 100 objects simultaneously applying various spectral resolutions.

The NIRSpec instrument will be provided by ESA and EADS Astrium GmbH is the prime contractor. The actual NIRSpec design has evolved during three years of studying of different spectrometer design and performance options. Basic feature of the current design is the all ceramic material concept for the instrument structure and mirror optics; both were successfully tested on component level for room-temperature and 30K. NIRspec This paper presents our NIRSpec design concept consisting of optical and mechanical design. The predicted optical performance will be shown for the imaging and spectral modes.

5962-66, Session 8

Straylight analysis and minimization strategy in Planck low-frequency instrument

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Planck is the space mission of the European Space Agency devoted to measure the cosmic microwave background (CMB), the relic radiation left by the big bang. The satellite will be launched in 2007 and it will carry state-of-the-art of microwave radiometers and bolometers arranged in two instruments: Low Frequency Instrument (LFI) and High Frequency Instrument (HFI), both coupled with a 1.5 m telescope and working in nine frequency channels between 30 and 857 GHz. From the second Lagrangian point of the Sun-Earth system, the instruments together will produce a survey that will cover the whole sky with unprecedented combination of sensitivity, angular resolution, and frequency coverage, and they will likely lead us to extract all the cosmological information encoded in the CMB temperature anisotropies. As far as possible, the development strategy of Planck and the two instruments has been to set up a mission that is inherently free of systematic effects. The optics, composed by an optimised telescope-feed array assembly, can introduce unwanted systematic effects in the measurements such as main beam distortions and straylight pick-up through sidelobes. A trade-off between angular resolution and straylight has been carried out for LFI in order to reach the best optical performaces preventing the Galactic contamination. This has been done performing robust optical simulations that are of primary importance in the understanding of the straylight rejection capability of the instrument and telescope, in particular for the far sidelobe region, where the power levels are extremely low (tipically below to -60 dB) and direct measurements become difficult and uncertain. The main product of the study presented here is the definition of the internal geometry of the Flight Model of the eleven LFI feed horns and the characterization of the overall optical response of the instrument.

5962-67, Session 8

Technological challenges in designing, manufacturing, and testing the optical subassembly of Herschel/HIFI wide-band spectrometer

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In the present paper, the design, manufacturing and testing of the optical subsystem specifically tailored for the acusto optic Wide Band Spectrometer (WBS) part of the Heterodyne Instrument for First (HIFI - Far InfraRed and Submillimeter Telescope - ESA mission for the Herschel Space Observatory) is presented.

WBS optical sub assembly is based on two (one is for redundancy) optical chains consisting of collimator, a beam splitter and a relay optics. The system operates at 785 nm achieved by a laser diode. The outgoing beam from the collimating unit is a laminar like radiation flux, 8 mm large, that is split into quadruplets beams. The quadruplets are focussed in one direction by means of a cylindrical element thus achieving a four “sticks” like focussed pattern in an intermediate focus where the acoustic channels of a Bragg cell are positioned. The relay optics propagates the imaged sticks into a four, diffraction limited point spots. The overall system has been designed to operate under paraxial working conditions.

Despite the conceptually simple optical configuration, the system has represented a technological challenge, being of the order of few millimetres the integration scale for the optics and for the tight tolerance set requested in terms of degree of collimation and for the alignment precisions and stabilities over a wide range of temperatures and other environmental conditions.

5962-68, Session 8

ALADIN transmit-receive optics (TRO): the optical interface between laser, telescope and spectrometers

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The Transmit/Receive Optics (TRO) for the future space-born ADALIN LIDAR instrument will be presented. ALADIN will monitor the 3D atmospheric wind profile up to 20 km from ground on a global scale by means of UV laser technology (Doppler LIDAR operating at 354.8 nm). The TRO forms the optical interface between laser, telescope and spectrometers. Its main function is to feed the optical signals from the laser source to the emitting/receiving telescope, and vice versa, the received back scattered signals from the telescope to the two spectrometers of ALADIN. Additionally, the TRO consists of a calibration branch bypassing the telescope (beam directly going from the laser to the spectrometers) and aims at levelling out the received signals in terms of wavelength and signal height changes due to inherent wavelength and intensity variations of the laser. A special feature of the TRO is its modular concept with optical assemblies, that can be separately aligned. Further highlights are a specially developed narrow-band interference filter with supreme performance (< 1 nm band width associated with a very high transmissity) to suppress disturbing background signals, state-of-the-art optical performance in terms of bulk transmission, wave front error and optical stability (particularly w.r.t. co-alignment between the different paths) as well as optical coatings resistant to the high laser energy. This paper presents the hardware realisation of TRO and its key optical performance data.

5962-69, Session 9

VST optics design strategy and foreseen performance from U to I bands

G. Marra, D. Mancini, Osservatorio Astronomico di Capodimonte (Italy)

This paper shows criteria and strategy followed for the optics design of VST telescope, and foreseen image quality. The optics design has been optimized in order to achieve the high required image quality on the base of main scientific requirements, mechanics constraints coming from the wide CCD mosaic camera and dimensional requirements. Manufacturing reliability, integrated operational efficiency, and costs optimization criteria have been also taken into account. The VST optics has been designed in order to have a 2.61 m Alt.az telescope operating from U to I bands with an excellent image quality (80% of Encircled Energy enclosed in less than two pixels) on a wide field of view (1° x 1°) and a very high resolution (0.21"/pixel) with a pixel size of 15 micron. The peculiarity of VST optics design is that telescope configuration is not a pure Ritchey - Chretien, but it is integrated with two different refracting correctors in order to minimize residual field aberrations. One corrector is optimized for observations at small zenith angles (U-I bands), while the other one includes an ADC providing high quality images until zenith angles of 50° (B-I bands). This corrector is a very useful and innovative integrated facility. The optics is beeing manufactured from Zeiss/LZOS. The telescope is going to be mounted in Napoli before shipment to Chile where it will be installed near the giants VLT units and will be a dedicated wide field imaging facility operating in narrow and wide visible bands.

5962-70, Session 9

VST optomechanical technical specifications versus error budget

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This paper concerns optomechanics technical specifications for VST telescope. It shows the strategy of tolerances, movement’s ranges, resolutions, and repeatability definition for optomechanics systems and subsystems mounting and positioning. These prescriptions are the baseline for development and tests of VST telescope optomechanics components. Design specification data have been compared with manufactured ones in order to verify the compliance and the foreseen

performance. The telescope is provided with an active optics control system, so some tolerances may be relaxed, respect to passive systems designs, since they can be actively compensated. Gravitational and thermal deformations have been also considered. Mounting and alignment tolerances have been evaluated within the whole telescope image quality error budget in terms of rms spot radius. The error budget strategy is described, from design to manufacturing and test. Do to its large field of view (1 degree square), the VST optical design (optomechanics tolerances included) is the first source of error if compared to a classical telescope design that has a small field of view. The overall optical quality depends also on telescope configuration (ADC and one-lens corrector or two-lens corrector configuration) and on observational zenithal angle. In addition since the telescope is seeing limited, effects of atmospheric seeing have also been considered in the error budget in terms of CIR.

5962-71, Session 9

PRIMA FSU: a fringe sensor unit for the VLTI

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The Phase Referenced Imaging and Micro-Arcsecond Astrometry (PRIMA) facility of the ESO VLT Interferometer is a system which enables simultaneous interferometric observations of two objects that are separated up to 1 arcmin, without requiring a large continuous field of view. The brighter (Primary) object, will be used as a reference star for fringe stabilisation, whilst the fainter (Secondary) one, will be the science target.

PRIMA will be the key to access higher sensitivity (limit magnitude K = 20), higher angular resolution in faint objects imaging (‹10 mas), higher precision astrometry (~10 uas over 10 as field).

Alenia Spazio, under a contract of European Southern Observatory (ESO), is building the PRIMA sub-system Fringe Sensor Unit (FSU).

The FSU is an interferometric instrument or “fringe sensor”, working in H and K bands, which combines two light beams coming from one celestial object (collected by two different telescopes), so that interference fringes form when the Group Delay between these beams is smaller than the light coherence length. It provides the measurement of the Optical Path Difference (OPD) between the two light beams, the Group Delay (GD) and the amplitude (A) of the interferometric fringe pattern. Data are delivered to the VLTI OPD controller to correct the OPD perturbations induced by atmospheric turbulence.

The GD represents in itself also a scientific output of the FSU, which is utilised for the astrometric measurements.

To perform microarcsecond astrometry, the instrument includes dedicated optical elements which operate also (or, sometimes, only) on a laser metrology sub-system.

The paper describes the concept and the implementation of the Fringe Sensor, which is currently being integrated in Alenia laboratories. The main technological issues are discussed together with their impact on instrument performances.

5962-72, Session 9

VST active optics system design

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This paper concerns VST active optics system design and specification. The VST is a modified Ritchey-Chretien wide field Alt-Az telescope with two correctors cameras (1 square degree field of view), so when all optical components are correctly aligned, only residual aberrations in whole field are present. The major amounts of these aberrations can be introduced by gravitational and thermo opto-mechanical deformations and mirror misalignments. For these reasons active controls of the primary mirror shape and secondary mirror position are required to lessen optical aberrations. The aim of active optics is to correct all optical telescope errors in order to make them small compared with external seeing. The VST is essentially compensated for static or slow frequency deformations and misalignments with a band pass from dc to 1/30 Hz, since the corresponding integration time is sufficient to integrate out the external seeing, giving a round image corresponding to the integrated external seeing quality. VST decentering, coma and defocus are corrected by mean of secondary mirror position control system (a two stage hexapode system) and spherical, astigmatism, quad-astigmatism and tri-coma are corrected by mean of M1 mirror shape deformation (axial and radial support system). For optical aberrations and guiding measurement a optical sensing arm and a guiding arm have been designed.

5962-74, Session 9

Improved grating microspectrometer

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A quasi free space grating LIGA-microspectrometer design with an improved spectral resolution and high sensitivity is described. The design of the microspectrometer consists of optical fibres, coupling light into the spectrometer through an entrance slit, a hollow waveguide guiding the light to the grating by Fresnel reflection, a curved selffocusing blazed grating and a mirror reflecting the light towards the photodiode detector array. Improvements in the sensitivity of the system have been achieved by introducing a cylindrical collimator lens with a spherical and an aspherical surface close to the entrance slit, reducing the number of reflections in the hollow waveguide. Moreover a curved outcoupling mirror was calculated to raise the amount of light hitting the detector. A process to make it possible to integrate this mechanically fabricated mirror in the LIGA-mould insert has been developed. Instead of one single 300 μm fibre, six 105 μm fibres were piled in front of the entrance slit to reduce the fraction of light being cut off the entrance slit. To achieve a higher resolution without restricting the wavelength range, the optical path length had to be enlarged. This would have lead to larger outer dimensions of the system. In order to avoid larger dimensions of the spectrometer a flat mirror is used, which allows folding the optical path twice. The enlarged optical path length also leads to a rising number of reflections in the waveguide. Raising the height of the LIGA-structured waveguide from 340 μm to 750 μm (and even 1500 μm) reduced the number of reflections and showed the possible application of such high LIGA-structures in microspectrometers.

5962-76, Session 9

Simple electronic speckle pattern shearing interferometer with a holographic grating as a shearing element

E. M. Mihaylova, I. G. Naydenova, S. Martin, V. Toal, Dublin Institute of Technology (Ireland)

An optical set-up for electronic speckle pattern shearing interferometry (ESPSI) using a photopolymer diffractive optical element as a shearing element is presented. A laser beam illuminates the object at an angle to the normal to the object surface. The holographic diffraction grating is placed in front of the object. The zero and the first order of diffraction form the image and the sheared image of the object. The images are imaged onto the CCD camera, whose optical axis coincides with the normal to the object surface. The field of view is limited only by the dimensions of the photopolymer plate. The photopolymer diffractive element is characterised by low level of light scatter and diffraction efficiency of 60%. The simplicity of the proposed new shearing interferometer is manifested by the extremely small number of components required - a coherent light source, a holographic optical element and a CCD camera.

5962-116, Session 9

Optical design and cryogenic mounting of the optics for a pyramid wavefront sensor working in the near-infrared wavelength range

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No abstract available

5962-77, Session 10

Add-on laser reading device for a camera phone

J. Mäkinen, J. K. Aikio, K. Niemelä, H. Vasama, R. Mattila, M. Aikio, VTT Elektroniikka (Finland)

A novel add-on device to a mobile camera phone has been developed. The prototype system contains both laser and LED illumination as well as imaging optics. Main idea behind the device is to have a small printable diffractive ROM (Read Only Memory) element, which can be read by illuminating it with a laser-beam and photographing the resulting pixel matrix pattern with a camera phone. The element contains information in the same manner as a traditional bar-code, but due to the 2D-pattern and diffractive nature of the tag, a much larger amount of information can be packed on a smaller area.

Optical and mechanical designs of the device were made in such a way that the system can be used in three different modes. First lens of the additional optics forms an intermediate image, which is relayed into the

camera optics by the second lens. By removing the first lens and adding an illuminating LED, a portable “microscope” can be created. The image magnification produced with the combined phone camera and double aspheric add-on macro-lens is approximately 15x if the picture is viewed with the phone’s own display and can be as large as 50x if the image is viewed with a larger display e.g. PC screen. With the first lens intact the optics functions as a telescope and it enlarges distant objects with a 2.3x magnification. The ROM reading device is created simply by adding laser illumination to the telescope optics.

5962-78, Session 10

Microlens design for CMOS image sensor

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CMOS image sensors include control transistors in the pixel itself, which generally results in a square or rectangular shape in the design of the photo sensitive surface, which is thus much smaller than the total pixel surface. The CMOS process also results in the presence of a stack of layers (dielectric and metallic) with specific optical properties, deposited above the photo sensitive area. In order to focus the maximum number of photons on the optically sensitive area of the pixel, a micro lens is fabricated on the top of the stack.

The aim of this study is to optimise the micro lens to maximise photon collection in the photodiode. Especially we have evaluated the influence of micro lens cross sectional and base shapes on the light focusing and sensitivity.

For this study we used the optical modelling software ZEMAX (ray tracing) and modelled the CMOS image sensor by a simple optical system: micro lens, media (“stack”) with particular optical properties and a photosensitive area.

Concerning the cross sectional shape, our results show that it is important to optimise the process to obtain a spherical one. Furthermore, even though the photosensitive area is rectangular, the best base shape for the micro lens is not necessarily a square: a significant portion of the photon gain due to the base shape (square or octagonal) is lost in the non-sensitive area of the pixel. Moreover, the gain in sensitivity on-axis due to the larger size of a square base is relatively small, and is offset by a significant loss in relative illumination versus incidence angle.

Our modelling results are confirmed by measurement on an optical characterization tool.

5962-79, Session 10

Micro-optical artificial compound eyes: from design to experimental verification of two different concepts

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Two different objective types on the basis of artificial compound eyes are examined. Both imaging systems are well suited for fabrication using microoptics technology due to the small required lens sags.

In the apposition optics a microlens array and a photo detector array of different pitch in its focal plane are applied. The image reconstruction is based on moiré magnification. The cluster eye approach, which is based on a mixture of superposition compound eyes and the vision system of jumping spiders, produces an overall image. Here, three microlens arrays of different pitch form arrays of Keplerian microtelescopes with tilted optical axes, including a field lens.

The two artificial compound eye concepts allow for a decoupling of magnification and system length. Consequently they deliver compact vision systems with strong magnification. An individual correction of each channel for its central viewing direction can be applied because of the image transfer through separated optical channels. Both types of objectives are analyzed with respect to theoretical limitations of resolution, spatial information capacity, sensitivity and system thickness. Explicit design rules and possibilities of simulation are introduced.

For the artificial apposition compound eye objective, several generations of demonstrators are manufactured by photo lithographic processes. This includes a system with opaque walls between adjacent channels and an objective which is directly applied onto a CMOS detector array.

For the cluster eye objective, a special paraxial matrix treatment is used to describe the complex arrangement of arrays of microtelescopes. The obtained paraxial parameters are transferred to the parameters of real microlenses in chirped lens arrays and implemented in raytracing software. Here the systems are further optimized. Microlens arrays of a demonstrator system are fabricated using microoptics technology and subsequently stacked to the overall microoptical system.

The fabricated compound eye imaging systems are experimentally characterized with respect to resolution, sensitivity and cross talk between adjacent channels. Captured images are presented.

5962-80, Session 10

Design considerations for integrated microoptical systems combining refractive and diffractive optical components

S. Sinzinger, M. Amberg, B. Mitschunas, Technische Univ. Ilmenau (Germany)

Planar integrated microoptical systems have been demonstrated for a variety of applications such as optical interconnects, sensing and security applications. Diffractive optical elements provide the necessary design freedom to optimise the optical performance of such systems along the folded optical axis. For enhanced optical efficiency it is necessary to combine diffractive and refractive elements within such systems. Hereby the refractive components provide most of the optical power while the diffractive elements are used as correction elements for optimised system performance. The integration of refractive components has significant consequences on the geometry of planar integrated optical systems as well as on the optical systems design. Based on this approach we present various designs for efficient planar-optical (phase-contrast) imaging systems. We compare various possibilities for the simulation of diffractive and holographic optical components and their integration in the design of planar microoptical systems. To this end we apply commercial design software (e.g. Zemax, ASAP) as well as self programmed tools.

5962-81, Session 10

Design and fabrication of a chirped array of refractive ellipsoidal micro-lenses for an apposition eye camera objective

F. C. Wippermann, J. W. Duparré, P. Schreiber, P. Dannberg, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)

Apposition compound eye camera objectives are one approach for a vast reduction of the optical system length of an imaging optical sensor. Despite imaging the complete field of view through one aperture like in classical lenses, these objectives split the overall field of view in separated channels which are located adjoined like in insect eyes. Due to the splitting each channel can be optimized for reduction of aberrations. A correction for astigmatism, field curvature and distortion occurring under oblique incidence can be accomplished by the use of anamorphic micro-lenses leading to an improved resolution of the camera objective. In contrast to regular arrays of equally shaped and equidistant positioned micro-lenses the parameters of the lenses like radii of curvature, center position and angular orientation are functions of the position within the array. These functions can be derived analytically leading to a complete description of the array parameters. We present design considerations for a chirped array containing 128x128 individually shaped ellipsoidal micro-lenses. Melting of photo-resist is employed as fabrication technology for achieving diffraction limited performance. Detailed considerations for the semi-automated layout generation of the photo lithographical masks as well as characterization data of first realized prototypes of the array are given.

5962-18, Session 11

Measurement of the four-dimensional Wigner distribution of paraxial light sources

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The complete knowledge and description of light sources is a fundamental base of optical design. Partially coherent, paraxial light sources of homogeneous polarisation state are very well represented by the four-dimensional Wigner distribution, which contains all information on amplitude, phase and spatial coherence. Hence, knowledge of the Wigner distribution enables the prediction of power density distributions after propagation through a wide range of optical systems by numerical simulation.

A simple optical setup consisting of a spherical lens, a cylindrical lens, and a CCD camera can be utilized to experimentally retrieve the Wigner distribution by a tomographic reconstruction scheme. Numerical simulations as well as measurements on real laser beams have demonstrated the feasibility of this method.

This presentation will briefly introduce the Wigner distribution and outline the reconstruction scheme. Measurements of the Wigner distributions of

coherent and partially coherent lasers beams will be shown including the derivation of coherence and phase distributions as well as the successful prediction of power density distributions behind some optical systems.

5962-82, Session 11

Profile homogenization and monitoring for a multiple 100 J diode-laser pumping system

M. Siebold, S. Podleska, J. Hein, R. Bödefeld, M. Hornung, M. Schnepp, R. A. Sauerbrey, Friedrich-Schiller-Univ. Jena (Germany)

Multi-pass amplification to the 10 joule level for a femto-second CPA laser system is aimed at diode-pumping an Yb3+ doped fluoride-phosphate glass disk with an energy of 240J at 940nm. Collimated pump light of 40 diode stacks with 25 laser diode bars each is focussed onto an overall area of the glass disk with a diameter of 18 mm regarding to a pump light fluence of 95Jcm^-2. A two-sided ring shaped assembly of diode stacks, directing mirrors, collimating and and focussing optics is a feasible optimum in terms of the parameters packaging density, acceptance angle and path length. 40 pump light spots have to be spread in even balance over the required area. In a quasi-3-level system like Yb3+ where re-absorption processes occur due to pump rates below zero-gain threshold the pump profile requires a homogeneous spatial gain profile. We developed a computer aided optimization routine for positioning single pump foci to achieve a smooth homogeneously distributed top-hat shaped overall pump profile. The algorithm belongs to the class of local search tools. In order to sensitize the positioning routine the blue visible parasitic up-conversion light as a nonlinear process recorded with a CCD is analyzed. For monitoring purpose the optical pulse power of each diode stack is measured by a solar panel with size of the beam placed behind the reflecting mirror using the transmittance of 1%. Additional optical damping of 20dB is required to drive the solar panel below the saturation intensity.

5962-83, Session 11

Ultra-short pulse laser safety: a challenge to materials science

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In this paper, safety-related experiments with ultra-short laser pulses (down to 30 fs) on various components (goggles, curtains, metal parts) for laser protection are presented. The damage and failure behaviour of protective devices has been investigated dependent on pulse duration and beam geometry. The effects of laser-irradiation on materials can be roughly divided into temporal ones like laser-induced transmission (LIT) and permanent damages like the formation of colour centres and laser damage by ablation. The former effects are particularly important for transparent devices like laser goggles. It is known that in some materials LIT does not occur at pulse durations lower than 1 ps. Therefore, the following indicators for failure of protection devices are the most important: normal linear transmission, surface or bulk laser damage, including ablation and melting, frequency generation (e.g. white light continuum) within the filter material. To obtain a complete overview on laser safety issues and the prevention of failure there are two important fields of investigation: the effects of laser radiation on human eyes and skin and to the possible protection materials. Both fields have been addressed during the German project SAFEST (safety aspects in femtosecond technology). The amount of safety data available in the ultrashort pulse region has been increased remarkably. This allows for a re-evaluation of known laser protection materials for this region of pulse durations. Furthermore, a new design for laser safety goggles has been proposed and patented which can lead to lower-weight protection eye-wear. This aims at the important problem of ergonomic and therefore better accepted protection devices.

5962-85, Session 11

Alignment of a multigrating mosaic compressor in a PW-class CPA-laser

R. Bödefeld, M. Hornung, M. Siebold, J. Hein, R. Sauerbrey, Friedrich-Schiller-Univ. Jena (Germany)

The coherent adding (tiling) of gratings is a promising alternative to large single gratings for highest-power CPA laser compressors. This article aims at a thorough description of an alignment procedure, which uses both spatial and temporal properties of the laser beam to detect grating misalignments. The main emphasis lies within the analysis of the k-space, which becomes accessible by focussing the compressed laser-pulse or an additional monochromatic alignment laser, respectively. We present the effect of grating misalignments on both near and far field by propagating continuous-wave, monochromatic laser light through a misaligned tiled grating compressor. A numerical simulation of the wave propagation within the compressor indicates that misalignment in all rotational degrees of freedom (tilt, tip, twist) is amplified by a factor of three to four with respect to the direction of the wave vectors stemming from reference and misaligned grating, respectively. In order to avoid a spatial separation of the main focus image the accuracy of grating alignment has to be better than 1/3 to 1/4 of the diffraction limited angular resolution of the focal imaging. In this case the optical retardation is less than one wavelength, leading to an inhomogeneous temporal broadening of less than 2% of the pulse width. Thus the spatial broadening of the focus image due to misalignment defines the necessary minimum alignment accuracy.

5962-86, Session 11

Characterization of a general astigmatic laser beam by measuring its ten second order moments

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The well tested and accepted ISO standard 11146 provides the measurement procedures to characterize the propagation properties of stigmatic and simple astigmatic laser beams which are intrinsically symmetric. The beam diameters are defined by the second order moments of the power density distribution which can be measured e.g. with a CCD-camera. In this standard the second order moments are used since the knowledge of these second order moments allows the calculation of the beam properties behind aberration-free optical systems with the well known ABCD-matrices. The new ISO/FDIS 11146-2 provides a new measurement procedure to characterize general astigmatic beams which are characterized by ten independent second order moments of their Wigner distribution. We present experimental results of the characterization of a general astigmatic beam and compare this results with theoretically calculated values. In this experiment a well characterized simple astigmatic beam is propagated through a cylindrical lens which is tilted with respect to the symmetry axis of the beam so that the simple astigmatic beam is transformed into a general astigmatic beam. This general astigmatic beam is characterized according to the new ISO standard. The experimental results are in good agreement to the theoretically calculated beam properties.

5962-87, Session 11

Optics for focusing of ultrashort laser pulses

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For many ultra-short pulse applications, such as micro-structuring of various materials, it becomes more and more important to have suitable and well defined laser pulses. Hence the manipulation of the propagation behaviour of ultra-short pulses requires for specially designed optics. We have developed a tool for the simulation of ultra-short laser pulse propagation through complex real optical systems based on a combination of ray-tracing and wave optical propagation methods. In addition it can also be used as a design tool. The focussing properties of different lenses will be analysed and the results are demonstrated. A design for a special focussing optic will be presented. Its focussing properties are compared to a commonly used microscope objective in theory and experimentally. Latter one is done by taking advantage of permanent material modifications in BK7 caused by focussed laser pulses with either one of the optics.

5962-88, Session 11

Design and construction of diffractive gratings for multipetawatt laser compressors

N. Bonod, J. Néauport, Commissariat à l'Energie Atomique (France)

We study gratings used in the chirped pulse amplification technic for multipetawatt lasers. We design profiles in order to obtain performant gratings presenting a laser damage threshold higher than 3 J/cm2 in right section. Moreover, in view to reduce the mechanical constraints inside the stack, a thin metallic layer is inserted between the substrate and the dielectric mirror to reduce the number of dielectric pair of layers while preserving the reflectivity of the mirror.

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5962-89, Session 11

On-line characterization of Nd:YAG laser beams by means of modal decomposition using diffractive optical correlation filters

M. R. Duparré, B. Lüdge, Friedrich-Schiller-Univ. Jena (Germany); S. Schröter, Institut für Physikalische Hochtechnologie e.V. (Germany)

Earlier we presented an alternative approach for laser beam characterization, based on the decomposition of the field distribution at certain cross section of the laser beam into a system of orthogonal functions. As such orthogonal function systems we selected “natural” laser eigenmodes of either GL or GH type. The looked for strength of the individual modal components then can easily be achieved by measuring the output signal (“correlograms”) of multi-channel correlation filters placed in a Fourier set-up, whereas the correlation filters themselves have been realized as DOEs by laser lithography.

Meanwhile different systems of such GL and GH correlation filters have been designed, manufactured and experimentally tested with miscellaneous laser beams. Achieved results demonstrated a very good conformity between optical experiment and computer simulation. Attempts to compare results of our method with results of “standard” beam characterization methods (new ISO11146) indicated principal conformity, but illustrated the continuing demand for a sophisticated adjustment procedure for the filter during application.

In the meantime such a sophisticated adjustment algorithm has been developed, implemented and applied to latest measured correlograms. This gives us the capability to evaluate with high accuracy even very complex correlograms, resulting from superposition of miscellaneous transversal modes.

Exploiting a “tuneable” Nd:YAG laser as mode generator for supply of pure or mixed GH modes, and evaluating the quality of the same laser beam twice, in one branch by our decomposition method and at the same time in the second branch by Second Order Moments method (new ISO 11146), demonstrates the strong potential of the decomposition method.

5962-91, Session 11

Multifunctional laser devices for new technologies in oncology

V. N. Svirin, POLYUS Research & Development Institute (Russia)

Laser systems and devices for therapy and diagnosis of various pathologies are widely used in different areas of medicine especially in oncology. The designing of the multifunctional laser devices (MLD) for the new technologies in oncology is considered in this paper. It is shown that MLD allow to realize the combined method of photodynamic therapy (PDT) with laser induced thermotherapy (LITT) which was proved to be more efficient due to mutual influence of two effects. It is emphasized that intratreatment diagnosis based on laser spectrophotometry for monitoring of treatment dynamic and control of therapy procedure make treatment more short and resultative.

MLD technical and user specifications including digital control of output power dependently on biological tissue temperature are presented in the paper. The ways of optimization of hardware, software and algorithms are discussed.

The fields of medicine are shown where MLD can be used to the best advantages.

5962-115, Session 11

Characterization and control of beam propagation parameters and spatial coherence properties using Hartmann-Shack wavefront sensors

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The integration of spatially resolved far-field measurements into a Hartmann-Shack wavefront sensor system using a single detector is described. The technique is not only suited for characterization of wavefront and power density distribution, it also accomplishes real-time determination of important beam parameters such as beam width, divergence, propagation ratio M(c)˜ and spatial coherence of virtually all relevant laser beams, including partially coherent sources. The device is fast and manages without moveable parts, permitting a very compact design.

Combination of the Hartmann-Shack sensor with adaptive optical elements, such as spatial light modulators or piezo-driven deformable mirrors, enables closed-loop control of the wavefront distribution, and thus active stabilization of the relevant beam parameters. As examples, the correction of “low-order” aberrations of femto-second laser beams as well as shaping and control of Nd:YAG lasers with the help of spatial light modulators are addressed.

5962-118, Session 11

Laser beam diagnostics according to ISO and their impact on practical application

R. Kramer, H. Schwede, V. Brandl, PRIMES GmbH (Germany)

No abstract available

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5963-01, Session 1

Milestones in optical coating technology-from A. Smakula/ John Strong until today

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The first optical interference coatings were produced about 70 years ago.

Since then, the optical coating industry has grown to serve a $ 2.1 billion market worldwide.

There are three requirements to produce good multilayer optical interference coatings: 1. a good theoretical design, 2. at least two reliable coating materials, and 3. production processes which allow the deposition of these materials.

A chart of historic milestones in the development of theoretical design techniques was published before. In this paper we make an attempt to develop a chart of historic milestones in the development of better coating materials (harder, more stable and moisture resistant) and better production processes (more reliable, more precisely monitored, and allowing large area/high volume deposition).

5963-02, Session 1

History of optical coatings in Jena

H. Bernitzki, JENOPTIK Laser, Optik, Systeme GmbH (Germany); E. J. Hacker, High Tech Private Equity GmbH (Germany); N. Kaiser, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); H. Lauth, JENOPTIK Laser, Optik, Systeme GmbH (Germany)

Not many places have a history as rich as Jena in the field of modern optics, especially regarding the field of optical coating technology. The era of modern optical thin film coatings started with the patents “Additive process of low index interference layers on high index glass components” by Alexander Smakula from Carl Zeiss Jena in 1935 and “Fabry-Perot interference system by means of thin film structures” by Walther Geffken from Glasswerk Schott & Genossen Jena in 1939. Since then, Jena is associated with the latest developments in optical coating technology, covering applications from the FIR to the XUV.

Today, Jena and the surrounding region is the home to a large variety of companies and institutes developing and producing optical coatings. Key competence regarding coatings for the IR, for the DUV/VUV/XUV, for fs-Lasers, for plastic optics and all related metrology and analytic services can be found in Jena.

5963-03, Session 1

Antireflection coatings: key optical components

J. A. Dobrowolski, National Research Council Canada (Canada)

Antireflection (AR) coatings are one of the first applications of optical interference coatings. Because of their many technological applications, it is not surprising that they have been the subjects of a large number of scientific investigations. AR coatings have been routinely produced in the past for spectral regions extending from the ultraviolet into the mid-infrared, and they have been applied to glasses, crystals, organic, inorganic and semiconductor materials. They can be composed of homogeneous or inhomogeneous layers, porous and structured materials and can be designed for one or more wavelengths or to act over broad spectral regions. The optical properties of AR coatings must often be combined with other physical properties. For example, AR coatings may also have to protect soft substrate materials from abrasion, or hydroscopic substrates from the effects of humidity and water. They might be required to have a finite conductivity to prevent dust build-up. In some systems, such as high power lasers or very demanding telecom applications, AR coatings are required that have extremely low losses. A special challenge is to produce AR coatings that are at the same time effective over a broad range of wavelengths and a wide range of angles of incidence. A special form of AR coatings is applied to metallic surfaces in order to absorb all the incident radiation. An attempt will be made in this talk to review these various types of AR coatings.

5963-04, Session 2

New optimization algorithm for the synthesis of rugate optical coatings

A. V. Tikhonravov, M. K. Trubetskov, T. V. Amotchkina, M. A. Kokarev, M.V. Lomonosov Moscow State Univ. (Russia); N. Kaiser, O. Stenzel, S. Wilbrandt, D. Gaebler, Fraunhofer-Institut für Optik und Feinmechanik (Germany)

Successful manufacturing of various types of rugate coatings demonstrates their high stability to manufacturing errors. This fact is probably the main stimulus for the development of new algorithms for the synthesis of rugate optical coatings and for the attempts to find new applications for these coatings. A new algorithm presented here is close to the Fourier-transform algorithms in considering a wide class of rugate refractive index profiles not limited to combinations or modifications of sine profiles. At the same time it differs from the Fourier transform approach in two important aspects. First, this algorithm is based on the exact analytical expressions connecting coating spectral characteristics with coating refractive index profile and not on approximate expressions for the so-called Q-functions which are cores of all Fourier-transform algorithms. Second, in contrast with the Fourier transform technique the upper and lower limits for the refractive index profile are incorporated in the design algorithm from the very beginning of the synthesis procedure. The new algorithm is based on a special model of a rugate coating which is connected with the manufacturing process used by Leybold Syrus Pro 1100 deposition system. Several examples will demonstrate possible applications of the proposed algorithm.

5963-05, Session 2

Colorimetry in optical coating

C. Oleari, Univ. degli Studi di Parma (Italy)

In nature, generally, the colour of the non-luminous objects is due to absorption, diffusion, fluorescence and refraction of light. The colour of the optical coatings, as that of some kind of bird feathers, of the soap bobbles, butterfly wings, some insects, etc. is due to interference and therefore is named interference colour. Generally, the industrial colorimetry does not deal with interference colour and the usual colorimetric instruments are inadequate to measure it. Only recently, with the new mice-pigment coatings, colorimetry is considering the measurement of the interference colour.

This communication is mainly an introduction to the ground of colorimetry and, only at the end, deals with interference colours.

A short overview is given of the Physiological Optics and of the colorimetric standards of the “commission International de l’éclairage” (CIE): particularly, the Psychophysical Colorimetry, the Psychometrical Colorimetry and the Measurement Geometries are summarised.

Related to the interference colour, basic elements on multi-layer films are given. Then the interface between isotropic non-absorbing media in considered. Finally, the following three system are analysed: thin mono-layer, thin multi-layer and thin film on metallic surface.

5963-06, Session 2

Fourier transform estimation of optical thin film thickness

P. G. Verly, National Research Council Canada (Canada)

Even if it has tough competition from more recent thin film synthesis techniques, the Fourier transform (FT) method has unique features that sometimes have been hardly explored. A parallel was recently established between results derived from the FT theory and an empirical procedure for the estimation of reflecting thin film thickness. Two different avenues were identified. One was by integrating the refractive index profile n(x) - where x is a thickness coordinate - of a known, but not necessarily realistic solution of the problem. The other was by integrating the square of Q(T)/Sigma, where Q(T) is the modulus of a complex function of the transmittance T and Sigma is the inverse wavelength. This approach has the advantage that the (usually unknown) phase of the complex Q-function does not matter. However it has of some limitations because (i) there is no exact analytical form of Q(T) in the literature, and the accuracy of the existing forms deteriorates as the reflectance increases; (ii) the reflectance of the filter outside the spectral region of interest, for example in ripples or harmonics, can affect the results. These limitations are discussed in the present paper

and simple corrective measures are proposed. It is shown that good results are possible even with complex reflectance targets.

5963-07, Session 2

Thin-film coatings and transmission-polarization-devices: negative system

A. R. M. Zaghloul, M. Elshazly-Zaghloul, Georgia Institute of Technology (USA) and ITR Technologies, Inc (USA)

In this communication, we discuss the behavior of the negative transparent-film transparent-substrate film-substrate system as a transmission-polarization-device. A transmission-polarization-device is defined as a device that produces pre-specified polarization changes of the electromagnetic wave upon transmission through the device. A comprehensive account of all devices is presented through the analysis of the transmission ellipsometric function of the film-substrate system. We present device-specific closed-form design formulae for each and every device. We also present a general-device design-formula to design any and all transmission-polarization-devices. Polarization characteristics, of the relative amplitude-attenuation and relative phase-shift, for all devices are presented and analyzed. In this communication, thin-film coatings are treated as polarization devices.

5963-08, Session 3

Laser trimming of thin-film filters

M. Lequime, Institut Fresnel (France)

The use of a photosensitive material for manufacturing the spacer of bandpass thin-film filters is a very attractive way for enabling the post-processing of such devices with the help of a light beam, either to correct with a high accuracy the consequences of some deposition errors on the filter properties (central wavelength out of specifications, inadequate spatial uniformity) or to create entirely new filtering devices with controlled spatial properties (for instance, variable filters with arbitrary profile). A theoretical presentation of the main problems arisen by such a laser trimming will be done, first for bandpass thin-film filters but also for multiple-cavity Solid Spaced Etalons (SSE). This presentation will especially include an analysis of the effect of the refractive index modulation induced in the spacer thickness by the illumination process, as well as a description of the method that we have developed to design a stair-case variable filter through a 2-cavity SSE Filter. After a comprehensive analysis of the possible materials which can be selected for such an application, we will conclude our talk by the description of the first experimental results obtained by our team in this new field, including a rapid presentation of the dedicated control means needed by this spatially localized approach of a filtering device.

5963-09, Session 3

Optical coatings for artwork preservation and enhanced viewing

A. M. Piegari, ENEA (Italy)

Science and technology play a continuously increasing role in art conservation because of the worldwide interest in the preservation of works of art but also owing to the development of new technologies that can be successfully applied to such a field. Optical methods are mainly used for diagnostic and data acquisition but also laser-based techniques and optoelectronic sensors are assuming great importance in art restoration and conservation. A possible application of optical coatings is considered here and, in particular, the use of properly coated glass is proposed as a method to protect the artwork against damage induced by illumination. Both natural and artificial illumination sources have a radiation spectrum (280-2500nm) much larger than what is necessary for vision. Radiation arriving on the artwork causes color fading and other damage, thus it is important to eliminate all radiation not perceived by the human eye, that means out of the range 410-680nm. Some glazing products able to cut the ultraviolet radiation (below 380nm), can be found on the market, but they do not eliminate radiation in the range 380-410nm and do not attenuate infrared (above 680nm). The purpose of the proposed coating is to leave only the radiations from 410 to 680nm pass through the glass pane. This requirement can be combined with the reduction of the reflected light coming from uncoated glass, to enhance the viewing. These two effects, together with the optimization of color rendering, are obtained with a few-layer optical coating, by combining optical interference and intrinsic properties of thin film materials.

5963-10, Session 3

Steep-edge filter designs with equivalent layers

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Thin-film edge filters as long-wave passes or short-wave passes are essential optical elements of fluorescence microscopy. State-of-the-art fluorescence detection requires steep edges filters with spectral slopes of only few nanometers for the transition from blocking values less than 0.001 % transmission to the passband with nearly 100 % transmission. Based on a new definition of the edge region of a multilayer involving a periodical layer sequence, an algorithm to design steep edge filters using the theory of equivalent layers is presented. Some features are discussed that are needed to modify the known theory to meet the topical filter requirements. The extended theory is compared to design approaches using rugate and bandpass filters. Some examples are theoretically outlined and the spectral performances of some manufactured filters are shown.

5963-11, Session 3

Manufacturing of linear variable filters with straight iso-thickness lines

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Linear variable filters are multilayer band-pass coatings manufactured with the help of masks to obtain a thickness gradient. This results in a continuous shift of the centering wavelength of the filter along the gradient direction. Associated with an array detector, such components are of great interest to design small, light and compact spectrometers. However, if such a filter is associated with a 2D detector, typically a CCD matrix, care must be brought not only to the thickness gradient, but also to the shape of iso-thickness lines that should be as straight as possible.

We present in this paper the work we have done to solve this difficulty for the manufacturing of linear variable filters by Dual Ion Beam Sputtering. The solution we developed consists to combine, by the mean of a came, both a rotation and a translation movements of the mask during the deposition of the layers. By this way, iso-thickness lines are almost straight as expected, while the came profile permits to achieve the required thickness gradient.

The characterization of the first prototypes, performed on a dedicated spectrometer we developed for this purpose, showed a thickness uniformity better than 99.6 % along the direction that is perpendicular to the thickness gradient.

5963-12, Session 3

Studies on superprism effects in multilayer thin film stacks

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The concept of “Superprism” which is used in photonic crystal will be introduced in thin film coatings, due to the fact that periodic multilayer thin films coatings are one kinds of 1D photonic crystal.

In this paper, The “superprism” effect of multilayer thin film coatings will be presented, which will make thin film filter acts as “thin film grating”. Firstly a review of period thin film photonic band theory based on Bloch wave will be introduced, and the analysis of the superprism effects in regular 1D periodic structures and non-periodic structures will be discussed on considering the relation between spatial dispersion and temporal dispersion.

Two kinds of “thin film gratings” based on the improved double-chirped thin film structures are presented. One is constructed by repeating several times of both Bragg mirror and the basic double-chirped structures, which can increase the spatial linear shift and the beam shifting with different incident wavelength; the other is constructed by repeating the Bragg layers and the basic double-chirped structures for different times according to different demands to obtain the step-like spatial shifts with the incident wavelengths, which can overcome the limits of linear spatial shift and allow some drifts in the central wavelength of the output channel. A new design of thin film interleaver grating, which is based on improved Fabry-Perot structure and works at obliquely incident will also be presented. The novel thin film grating can directly demultiplex different wavelength channels from space synchronously and does not need the posterior filters for serial processing.

The experimental results of the super-prism effect in thin film gratings show that the maximum shift by spatial dispersion can achieve 65 at the peak transmittance wavelength for a 41 layers F-P filter, which corresponding to a spatial dispersion nearly 3.4°/ in the around wavelength 782nm. The spatial dispersion curve measured in the experiment exhibits a good accord with the theoretical calculation.

5963-13, Session 4

Substantial progress in optical monitoring by intermittent measurement technique

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The production capabilities for optical multilayer coatings were improved significantly in the last decade. So called “shift free” coatings have become a standard in the coating production. The paper will briefly review the evolution of optical monitoring which is closely linked to research and production of optical coatings.

Direct optical monitoring plays a key role to improve the layer thickness accuracy and takes advantage of error compensation effects. For the production of DWDM filters direct monitoring was introduced in the last decade. Continuous measurement is applied on relatively small substrate areas (ø < 200 mm). For coating systems with a large area substrate holder (ø \> 250 mm) the monitoring spot should be close to the location of the substrates which is normally far out of center. In this case intermittent monitoring on a substrate or a witness is an adequate solution. This technique enables rapid prototyping with tight specifications and high yields in large area batch coaters. Application results of challenging optical multilayer systems are demonstrating clearly the potential of this powerful monitoring technique.

5963-14, Session 4

Use of real-time lateral optical monitoring for the fabrication of complex multilayer stacks

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In this paper, we present a direct optical monitoring system that alows to prevent in-situ evolution of parameters during process. In particular, we show how real-time optical monitoring on one or several lateral samples located on the same circumference of final components overcomes the problem of uniformity time dependence for long process and allows the fabrication of complex optical functions. Real time signal processing on transmittance versus wavelength is used to determine in-situ refractive index of deposited material for each layer in the multilayer stack. It is shown how this method can be applied to the realization of quarter-wave and non quarter-wave stacks and the repetability of an automatized process is demonstrated for different components such as narrow band filters, polarizers or edge filters. Numerous experimental results from different deposition techniques are presented here.

5963-15, Session 4

Re-engineering of inhomogeneous coatings based on in-situ optical broadband monitoring data

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Inhomogeneous layers, such as so-called gradient index layers and rugate filters represent new and prospective thin film designs. Manufacturing such systems in practice requires calculation, deposition, monitoring and characterization of optical coatings with a well-defined continuous refractive index profile along an axis that is perpendicular to the film surface. Those coatings may be manufactured in the Leybold Syrus Pro 1100 deposition system by co-evaporation of SiO_2 and Nb_2O_5 as a sequence of several refractive index gradients. During these experiments our in-situ broadband monitoring system was utilized to measure the transmittance of the growing film directly at the rotating substrate. This additional information on the intermediate stages of the not yet completed film are extremely helpful in reverse engineering tasks, and clearly superior to the extent of information that may be drawn from the spectra of the completed film only. For characterization of these coatings a new model was developed, which significantly reduces the number of parameters. To generate a feasible parameter set, deposition rates for both materials recorded with quartz crystals monitor during deposition were used. This approach achieves a better accordance between in-situ measured transmittance and modeled transmittance than the intended design. In the optimisation process, a local minimization algorithm was used to refine the refractive index profile of the whole coating and film thickness at the intermediate stages.

5963-16, Session 4

Plasma monitoring of the RLVIP-process with a Langmuir probe

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The aim of this investigation was to find out the characteristics of a low-voltage high-current ion plating plasma and to correlate the observed plasma data with the properties of films obtained under such conditions. A Langmuir probe system (Smart Probe - Scientific Systems) was inserted into a Balzers BAP800 ion plating plant between evaporation source (e-gun) and insulated substrate holder. In this position plasma potential, floating potential, self-bias voltage, ion current density and particle number density were measured and calculated respectively. All measurements were performed in dependence of arc current (20-80A) and oxygen partial pressure (2-30 x 10-4mbar). With rising arc current the number of charged particles, the self-bias voltage and the energy of the condensing and bombarding species are increased. These data explain the observed increase in density, refractive index and mechanical stress of RLVIP deposited metal oxide layers, e.g. Ta_2O_5 and Nb_2O_5. An increase of gas pressure reduces the energy of the particles and decreases slightly film density and refractive index. However, it improves chemistry and decreases unwanted residual optical absorption and decreases also compressive mechanical stress.

5963-17, Session 4

Ion-source characterization based on an array of retarding field analyzers

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During the last decade the ever increasing demand for both high-quality optical coatings and virtually deterministic deposition processes has led to a large number of ion sources available for deposition purposes. For a successful implementation of an ion source the prime economic objectives process stability and production yield have to be considered. Thereby the economic efficiency is strongly dependent on the temporal stability and spatial distribution of the ion current density and ion energy spectrum.

Retarding Field Analyzers have demonstrated their potential as a tool for the analysis of ion sources. Deliberate evaluation of the measurements, however, is required especially at a non-zero angle of incidence occurring during the examination of three dimensional ion emission profiles.

The present study discusses the influence of different geometric Faraday-Cup designs on the resulting data as well as erroneous conclusions potentially drawn from measurements. Futhermore first results of the ion energy density distribution characteristics of different ion sources, evaluated on the basis of data taken by a multicup array are presented. Finally an optimized alignment of the ion source is discussed by means of single layers showing an increased radial homogeneity of the refractive index over the extent of the calotte.

5963-18, Session 5

IBS deposition of dense fluoride coatings for the vacuum ultraviolet free electron laser

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Fluoride materials like Magnesium Fluoride and Lanthanum Fluoride exhibit unique properties for applications in mirror and anti reflecting coatings in the VUV spectral range (120- 230 nm). These large band gap materials provide low absorption and material pairs with usable refractive index contrast. Common deposition methods are thermal evaporation and electron beam evaporation. A columnar microcrystalline structure with a significant porosity is observed for such coatings. Furthermore, a high sensitivity for contamination processes resulting in an increasing absorption is often perceived. Investigations on mirror systems exposed to a harsh environment like the storage ring free electron laser at ELETTRA show a rapid degradation in respect to a reduced reflectivity, an increased hydro carbon contamination, and a formation of colour centres.

An improved performance of the fluoride coatings is expected for films which do not show the polycrystalline columnar structure. Ion beam sputtering deposition of fluoride materials demonstrated its applicability to deposit dense amorphous fluoride coatings down to 193 nm [1,2]. The optimisation of Magnesium and Lanthanum Fluoride layer deposition of single layers and multilayer structures is reported. An IBS deposition plant with a Kaufman ion source using a reactive fluorine environment is used to grow fluoride layers with comparably low absorption values. Single and multilayer coatings were optically characterised after deposition, exposed to Synchrotron radiation at ELETTRA, and characterized again after irradiation.

[1] J. Kolbe, H. Schink “ Optical Losses of Dielectric VUV Mirrors Deposited by Conventional Evaporation, IAD, and IBS “ , Proc. SPIE 1782 , 433 - 446 (1993)

[2] J. Dijon, E. Quesnel, B. Rolland, P. Garrec, C. Pellé, J. Hue “ High damage threshold fluoride UV mirrors made by Ion beam sputtering “ , Proc. SPIE 3244 , 406 - 418 (1998)

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5963-19, Session 5

Performance data of a variable transmission phase shifting mask blank for 193nm lithography enhanced by inspection contrast tuning

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Schott's already commercially available two layer Ta/SiO2 phase shift system can be tuned from 6% up to 30% transmission for 157, 193 and 248 nm lithography wavelengths. Thus one film patterning process provides a wide product range. Attenuated phase shift masks for 6%, 20% and 30% transmission at 193nm were produced. Tests for laser stability and chemical durability show excellent performance. The phase shifting film achieves a high etch selectivity to the substrate. Results of defect density and phase and transmission uniformity are included.

Our newest development enhances the layer system and provides a better contrast for inspection in reflection mode. Transmission of our standard two layer Ta/SiO2 PSM system is below the required 20% at inspection wavelengths. The reflectivity of 30% to 40% can be lowered by insertion of an additional contrast layer. The thickness of this contrast layer is adjusted to achieve the required reflection at inspection wavelengths, while the other film thicknesses are tuned to preserve the desired transmission and 180° phase shift at the design wavelength. As first examples 6% and 20% transmission PSM for 193 nm were tested. Reflection at 257 nm and 365 nm inspection wavelengths can be lowered from initial 30% to 40% down to about 10%.

5963-20, Session 5

Influence of the amorphous character of Al2O3 layers on their use in the deep UV spectral range

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Amorphous layers of metal-oxides deposited by Plasma Ion Assisted Deposition (PIAD) are widely used in the field of optical coatings due to their salient properties which enable the deposition of complex multilayer stacks. However their use in the Deep UV spectral range is limited as the range of transparency is limited by the absorption due to the first electronic band transition. The only oxide suitable for applications at e.g. 193 nm seems to be Al2O3 for which a band gap energy of 8.7 eV (143 nm) is reported for the crystalline state. Yet for thin layers of Al2O3 no work reports the making of absorption free layers at 193 nm. In this study we investigate how the amorphous structure of PIAD deposited Al2O3 thin films influences the electronic structure and as a consequence of that the absorption behaviour for wavelengths close to the absorption edge. The electronic structure is worked out by a theoretical approach where in a first step the geometric structure is simulated using a Monte Carlo approach. Using this geometric structure the electronic structure is calculated by the tight-binding method in a second step. With these data absorption spectra are calculated and compared to experimental data measured on PIAD Al2O3 layers. The experimental data for the start of the absorption lie on the longer wavelength side of the limit set by the amorphous structure a fact that encourages further work on the optimization of deposition parameters.

5963-21, Session 5

Oxide and fluoride coatings for the excimer wavelength 193nm

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The requirements to produce high performance coatings increase dramatically when moving from 248 nm to 193 nm. The quality of DUV thin film components is mainly determined by the optical properties of the applied layer materials. The reduction of losses due to scattering and absorption of dielectric materials is essential for excellent properties of the coating results. The most common fluoride and oxide materials SiO2, Al2O3, MgF2 and LaF3 have been investigated and optimized.

Plasma ion assisted deposition was applied for the deposition of the oxide materials, using improved coating equipment such as the APS (advanced plasma source). The paper reports the results of UV coatings using plasma ion assisted deposition for the oxide materials. Single layers of silica and alumina and multilayer systems with both materials were investigated. In addition, MgF2 and LaF3, conventionally coated at very high temperatures, have been performed to demonstrate the improved capabilities of the optimized SYRUSpro for DUV applications with all the new features. The coatings were characterized mainly by R and T measurements.

5963-22, Session 5

Aluminium-enhanced optical coatings for the VUV spectral range

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Aluminium is the only metal that has high reflectance in the VUV spectrum region till 100 nm. However as classically observed, aluminium oxide is quickly formed on the fresh surface of deposited aluminium, and reflectance decreases due to the absorption of aluminium oxide in the VUV region.

In this paper, thin highly reflecting VUV aluminium reflectors are presented. Very thin single fluoride and oxides layer, homogeneous multilayer and hybrid multilayer solutions are put forward. Single fluoride and oxides materials achieve reflectance above 90% at 193 nm. Multilayer capping can provide reflectance of 93.4% at 193 nm, and hybrid multilayer of fluoride and oxide can obtain reflectance above 90% down to 160 nm.

However, measurements on the samples, which have been stored in air, show that aluminium with single protection layer of fluoride material is sensitive to environment. Reflectance of these kind of mirrors will decrease in the VUV spectral range. Hybrid protection layers are employed here to enhance the reflectance by interference effect, and to enhance the environmental stability. Experimental outcome shows that hybrid multilayer of fluoride and oxide can preserve the high reflectance with a higher environmental resistance, while the reflectance from fluoride capping layers will decrease 2-4% in 4-week exposure in air.

With fluoride capping materials, high reflectance can be reached till 115 nm. Reflectance of 85% at 120 nm is realized. Further research will focus on aluminium-enhanced coating for wavelength below 100 nm.

5963-23, Session 6

Lanthanide tri-fluorides: a survey of the optical, mechanical and structural properties of thin films with emphasis of their use in the DUV- VUV-spectral range

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While LaF3 is the best known high index thin film material for use in interference layer stacks at excimer laser wavelengths below 248nm, little is known about the properties and the advantages or disadvantages of the other members of the lanthanide tri-fluoride family with regards of their use in DUV- and VUV - optical stacks. Therefore, a survey was performed in order to determine the optical, mechanical and structural properties of evaporated thin films of selected lanthanide tri-fluorides (LaF3, PrF3, NdF3, GdF3, DyF3, ErF3). Brief supplementary work was also done on CeF3,YbF3, and SmF3.

The samples were deposited by a low-loss evaporation technology in a BAK 640 coating plant applying various deposition conditions.

Besides results on single layer evaluation, HR multi-layer stacks made of LaF3, GdF3 and DyF3 in combination with various low index fluorides were deposited and investigated.

5963-24, Session 6

Optical, structural, and mechanical properties of gadolinium tri-fluoride thin films grown on amorphous substrates

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Since excimer laser applications extend to deep and vacuum UV wavelengths at 248 nm, 193 nm and 157 nm, renewed research interest has recently arisen on fluoride thin films due to their unrivaled position as wide-band-gap material for the vacuum UV (VUV). Among these materials, only a very limited number can act as the high refractive index component in multiplayer interference stacks. Besides LaF3, gadolinium tri-fluoride is a potential candidate especially for wavelengths at about and below 200nm. We report on the evaluation of the structural properties, the optical properties with emphasis to the DUV - spectral range, and the mechanical properties of GdF3 single layer by means of XRD, GIXR, AFM measurements, spectral photometry and by ex - situ mechanical stress analysis using the laser beam deflection method to measure the substrate deformation.

The samples were deposited onto fused silica and silicon substrates by a low-loss evaporation technology in a BAK 640 coating plant applying various deposition conditions.

5963-25, Session 6

Absorption and fluorescence measurements of DUV/VUV coatings

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The performance of optical coatings for high power DUV/VUV laser applications depends amongst others on residual absorption in the thin film layers due to impurities or defects.

Using pulsed F2 laser induced fluorescence measurements (LIF), characteristic non-intrinsic emission bands are identified for several high reflecting AlF3/LaF3 based mirrors. The investigation of the single AlF3 and LaF3 layers indicates that the emission bands result from certain impurities within the LaF3 material.

The influence of different LaF3 raw material on the absorption properties of high reflecting mirrors is measured upon ArF laser irradiation using the laser induced deflection technique (LID). The absorption of the coatings varies by more than a factor of 2 which is correlated to the appearance of selected impurity emissions in the LIF spectra.

5963-26, Session 6

Lessons learned from 157 nm

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Big effort has been made to develop coating technologies which meet the semiconductor roadmap for 157 nm lithography. Now the roadmap has switched to 193 nm immersion lithography and the 157 nm related technologies are checked concerning their contribution to 193 nm and other VUV/DUV applications. The main manufacturing related processes (polishing, plasma- and UV cleaning, used coating materials and deposition technologies as thermal evaporation, e-beam evaporation and plasma assisted technologies) will be discussed. Reasons for laser damage and lifetime limitation as contamination processes, coating defect generation will be treated and highlights of optical thin film elements for Excimer laser applications meeting highest demands will be shown.

5963-27, Session 6

Nanostructure and optical properties of fluoride films for high-quality DUV/VUV optical components

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The persistent utilization of optical lithography at the DUV and VUV excimer laser wavelengths leads to extraordinary demands on the optical components involved (high throughput, low scattering, high mechanical stability, ...). Fluorides are the main or even the only candidates for film materials in these spectral regions because of their low absorption indices.

There are several high index and low index fluoride materials. These materials, however, may significantly differ in their nanostructural properties which have a non-negligible influence on the properties of the layer system.

To find optimal material combinations, coatings were fabricated of different fluoride film materials. For comprehensive characterization several methods were used: optical spectroscopy, stress measurements, atomic force microscopy, light scattering modeling and measurement.

5963-28, Session 7

Multilayers for the EUV and soft x-ray region

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The present status of studies on EUV, soft x-ray and x-ray multilayers in the Institute of Precision Optical Engineering (IPOE), Tongji University, is briefly reviewed. The design, fabrication, characterization and application of semitransparent multilayer beam splitters working at 13.9nm are described. The beam splitter which is Mo/Si multilayers on 10mmÅ~10mm area Si3N4 membrane is fabricated using the magnetron sputtering. The figure error of the beam splitter has reached the deep nanometer magnitude by using optical profiler and the product of reflectivity and transmission of the beam splitter measured by synchrotron radiation is about 4%. The broad angular multilayer analyzer in the range between 12.4nm and 20nm is designed, and made which can deviate the Quasi-Brewster's angle several degree and show very high polarization. The main feature of our design approach is the use of an analytical solution as a starting point for direct computer search, and the desired results can be given in a reasonable time. The method can be applied in different spectral range for suitable material combination. Supermirrors with broad angular band working at different wavelength such as Cu K _ line and Al K _ line are designed, manufactured and measured. The results show that the performance of the supermirrors agrees with designed.

5963-29, Session 7

Laterally graded EUV multilayers

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According to the optics requirements of an EUVL tool, the accurate deposition of high reflective and laterally graded multilayers on ultraprecise polished substrates can be regarded as one of the major challenges of EUV lithography development today. To meet these requirements, a new dc magnetron sputtering system NESSY and technologies to coat laterally graded EUV multilayers were developed. The major characteristics of the deposition tool and results of sputtered multilayer optics are presented in this paper.

The sputtering system is equipped with four rectangular magnetrons, 600 mm x 125 mm each and the maximum substrate diameter is 600 mm. Two Ø 450 mm substrates or three Ø 300 mm substrates can be coated simultaneously. The target-substrate-distance is variable and allows the installation of moving shutters to realize lateral thickness gradients of the sputtered multilayer. Special effort was made to construct the cathodes. Different configurations of the magnets were successfully realized in order to assure highest flexibility for different coating materials in terms of homogeneity requirements and target utilization. The lateral layer thickness distribution was optimized with specially formed shadowing masks fixed close to the cathodes. A homogeneity of +/- 0.1 % on 150 mm and +/- 0.2 % on 300 mm and a reflectivity of R \› 68.5 % \@ 13.5 nm is routinely achieved with Mo/Si multilayers on both flat and curved substrates.

Different deposition technologies were developed to coat laterally graded multilayers on curved substrates. Large area EUV condensers as well as collector and imaging optics for various applications in the EUV spectral range were successfully realized and will be presented.

5963-30, Session 7

Interface-engineered multilayer mirrors

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Most applications of Mo/Si multilayer optics in EUVL require a high normal incidence reflectivity. Using dc magnetron sputtering we achieved R = 68.8 % \@ l = 13.5 nm. Different interface-engineered Mo/X/Si/X multilayers with maximum reflectivity of 69.6 % at 13.5 nm were developed. These new multilayer mirrors consist of molybdenum and silicon layers separated by different interdiffusion barriers (X). Microstructure and optical properties of the multilayers have been investigated by small and large angle Cu-Ka scattering, HRTEM and characterized by EUV reflectometry. A concept for material selection, thickness optimization of interdiffusion barriers and perspectives for their wide application in imaging EUVL optics is discussed.

Some applications of multilayer mirrors in EUVL require not only the highest possible normal incidence reflectivity but also a long-term and thermal stability at the operating temperatures. This requirement is most important in the case of the first mirror (C1) of the illumination system close to the EUV source where a short-time decrease of reflectivity is most likely. A serious problem of Mo/Si multilayers is the instability of reflectivity and peak wavelength under high heat and radiation loads. The instability of Mo/Si multilayers becomes especially critical at elevated temperatures of more than 200 oC, thus limiting the application possibilities of Mo/Si multilayers for coating of the condenser optics for EUVL. Investigations on new high temperature multilayers were focused on new interface-engineered Mo/X/Si/X systems. The multilayer designs as well as the deposition parameters of the systems were optimized in terms of high peak reflectivity at a wavelength near 13.5 nm (Rp (c)¯ 60.0 %) and broad operated temperature range (T = 20 - 5000C). Annealing in vacuum was carried out at elevated temperatures up to 500 °C for up to 100 hours. The major results of the comparative study will be presented in this paper.

The combination of good optical properties and high thermal stability of interface-engineered Mo/X/Si/X multilayer mirrors underlines their potential for their use in coating of EUVL optics.

5963-31, Session 7

Improved nanometer multilayers for x-ray fluorescence analysis

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The principle of wavelength-dispersive X-ray fluorescence (WDXRF) analysis is based on the excitation of characteristic radiation of the chemical elements contained in the specimen under investigation. In order to separate the emission lines of the different elements, monochromators like crystals or multilayers are used. In this paper we will focus on the development and improvement of multilayer monochromators for the detection of light elements of the periodic table (Be - S).

The photon wavelengths of the characteristic radiation of light elements are in the range of 0.7-11.4 nm. Correspondingly, the period thickness of the multilayers has to be in the same order. However with smaller period thicknesses the requirements for the interfaces between adjacent layers within the multilayer significantly increase. It has to be ensured that both interface roughness and interface diffusion has to be minimized at the same time. Additionally the stability of the deposition process must be extremely high since the multilayers consist of up to 1200 single layers. In this paper we will report about the improvement of different multilayer coatings (e.g. W/Si, W/B4C, Mo/B4C) in the period thickness range from 1.2-4.0 nm. We will present the improvement that was obtained and characterized by Cu-Ka reflectometry. Finally, we will show the performance of the multilayers at the working wavelengths using synchrotron radiation.

5963-32, Session 7

X-UV chirped mirror fabrication for phase control of attosecond pulses

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Recent calculations have demonstrated that multilayer XUV chirped mirrors can be numerically optimized and designed to compensate for the intrinsic chirp which is responsible for a temporal broadening of attosecond pulses generated with high order harmonic sources. . In the present communication, we design and manufacture aperiodic multilayer mirrors with the aim to obtain sub-100 attosecond pulses in the 12-20 nm spectral range.

Mo/Si multilayer structures were deposited in a high vacuum ion beam sputtering chamber described elsewhere . Calibrations of Mo and Si thickness for the deposition process were deduced from the structural parameters obtained from Grazing incidence x-ray reflectometry analysis of layer thickness of periodic Mo/Si multilayers. The thickness accuracy for each individual layer of the periodic and aperiodic multilayer mirrors is better than 0.1 nm and interfacial roughness is estimated to be of the order of 0.5 nm. The substrates for the chirped mirrors were 2 in. diameter spherical mirrors of pure silica with a maximum surface roughness (RMS) of 0.3 nm.

Grazing incidence X-ray reflectivity at wavelength 0.154 nm was measured and the resulting curves were compared to simulations done by using the IMD code. The X-UV reflectivity of the aperiodic multilayer mirrors was measured using a plasma X-ray source and compared with the calculated one.

Experiments performed by using the chirped mirrors mounted on a high order harmonics source for the generation of attosecond pulses in the X-UV spectral range are under consideration.

5963-33, Session 7

Performances and stability of Sc/Si multilayers with barrier layers for wavelengths around 46 nm

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The high reflectivity of Sc/Si multilayers in the range 40-50 nm [1,2] makes this coating interesting for many applications as X-ray laser [3], high harmonic generation sources and spatial application [4]. However problems concerning aging and thermal stability of Sc/Si multilayers has been reported [1,2], mainly due to the interaction between Si and Sc.

We present an experimental study of aging and thermal stability of Sc/Si multilayers deposited by magnetron sputtering. These multilayers have been characterized by using hard X-ray grazing incidence reflectometry at 0.154 nm and synchrotron radiation reflectometry at near normal incidence. The composition of silicon and scandium thin films have been measured by Rutherford back scattering. Sc/Si multilayers for different thickness ratio have been measured. The experimental results are compared from simulation using scandium optical constant measured recently by Uspenskii et al. [5]. The reflectivity was found to be stable after one year. A maximum reflectivity of 45% has been measured at 46 nm. However a 20% relative decrease of the reflectivity have been observed after one hour thermal annealing at 200°C.

In order to improve thermal stabilty, we studied three different barriers layers (B4C, Si3N4 and ScN). We compare the decrease of peak reflectivity and its wavelength shift after one hour annealing at 200°C under vacuum atmosphere. The best result was observed with the design using 0.3 nm B4C barrier layers. A relative decrease of 2% of the reflectivity peak has been observed with this design as compared to a 20% decrease without barrier layers.

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5963-92, Session 7

Study of potential quantization effects in designs for 12.4 nm mirrors, R. R. Willey, Willey Optical (USA)

Mirrors at normal incidence have been successfully made for the 12.4 nm spectral region using molybdenum (Mo), silicon (Si), and other materials. At these wavelengths, a typical layer is of the order of 3 nm in physical thickness, and the atomic diameters of the materials are of the order of 0.3 nm. The implication is that the layers are of the order of 10 atomic layers thick. If the deposition of such films were done by atomic layer epitaxy (ALE) or other atomic layer deposition (ALD) techniques, the spectral results would fall in discrete patterns that could limit the potential design choices. The problem would be even more severe at shorter wavelengths. This work reports on the study of some of those possibilities and limitations.

5963-53, Poster Session

Comparison optical resistance of ion-assisted deposition and standard electron-beam deposition methods for high-reflectance dielectric coatings

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The ion assisted thin film deposition (IAD) method has been used extensively for more than two decades, but questions about possibility of improving of the laser-induced damage threshold by this method compared with the conventional electron-beam evaporation (non-IAD) method are still not fully answered. A more complete understanding of different factors that can influence laser-induced damage threshold is necessary for continued development of multilayer dielectric coatings optimized for high-power laser applications. To clarify these factors we performed comparison of LIDT for IAD and non-IAD coatings in nanosecond and femtosecond pulse ranges. High reflectance mirrors at 800 nm and 1064 nm were tested. Mirror coatings were made of ZrO2 and SiO2. Automated LIDT measurements were performed according to the requirements of current ISO 11254-2 standard. Two lasers were used for the measurements: Nd:YAG (l = 1064 nm, t = 5 ns) and Ti:Sapphire (l = 800 nm, t = 130 fs). Measurements at 800 nm and 1064 nm were performed at 1-kHz and 10 Hz pulse repetition rate respectively (S-on-1 test). The damage morphology and structure of coatings were characterized by an atomic force microscopy (AFM), Nomarski microscopy and X-ray diffraction (XRD), and relation of LIDT with coating parameters was analyzed. In addition total scattering loses of the samples where evaluated.

5963-54, Poster Session

Multiple pulse laser-induced damage of AR-coated lithium borate

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An investigation of laser-induced damage thresholds (LIDT) of AR coated lithium borates (LBO) used for second and third harmonic generation were performed at 1064, 532, and 355 nm wavelengths for 5 ns pulses. Two types of coatings where tested; a dual peak anti-reflection at 1064 nm and

532 nm, three peak anti-reflection at 1064 nm, 532 nm, and 355 nm. Ion beam sputtering and magnetron sputtering technologies where used for coatings deposition. Automated LIDT measurements were performed according to the requirements of current ISO 11254-2 standard. The obtained LIDT were in range of 3-15 J/cm2. Conclusions where drawn about the preferred method of deposition for increased LIDT.

5963-55, Poster Session

Investigation to planar optical waveguides based on oxidised porous silicon/PMMA by dark mode spectroscopy method

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The abstract submitted (Number: EOD05-OSD02-3) was revised:

The open porous structure and the very large specific surface area of porous silicon (PS) are strong motivations for trying to introduce different kinds of materials inside the pores. The resulting composite structures can open the door to new developments mostly in the field of light emitting devices, waveguide devices and sensors based on silicon. This paper reports the fabrication of planar optical waveguides formed by penetrating polymer into the oxidised PS film and optical parameters of waveguides characterized by the dark mode spectroscopy method. About 15μm thick PS layer with 76% porosity on silicon substrate was obtained by anodization process followed by fully oxidation step. After oxidation ,the residual porosity is 53%. The core (waveguide) layer was formed by impregnated polymethylmetacrylate (PMMA) into pores of oxidised PS by method of immersion sample into PMMA/toluene solution. The thickness of core was controlled within 5μm by choice suitable immersion time. The waveguides consisted of a higher index core oxidized PS/ PMMA layer and a lower index buffer oxidsed PS layer separating the core from a high index silicon substrate. Both the refractive index and thickness of oxidised PS/PMMA film are obtained simultaneously and with good accuracy by measuring the coupling angles at the prism at a wavelength of 633 nm and fitting them by a theoretical dispersion curve. The measured effective index values of the guided modes have been used to investigate the optical properties of the core layers of the waveguides.

5963-56, Poster Session

Optical sensitivity of thin films to hydrocarbons and ozone

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ZnO, $BaTiO_3$, SnO_2, WO_3 and TiO_2 films were deposited by PLD or sputtering on transparent substrates to obtain planar optical waveguides sensitive to various gases. The optical and morphological properties of these thin films were investigated using the m-line technique and Atomic Force Microscopy. The variation of the optical properties was studied under butane and ozone exposure. A variation of the refractive index of several 10-4 under butane exposure was observed for ZnO, $BaTiO_3$ and SnO_2 with good reproducibility at room temperature whereas no response was found for WO_3 and TiO_2 at room temperature. There was no response of any film to 3 ppm of ozone at room temperature. The concept of optical sensitivity and more precisely the refractive index variation and the mechanisms involved in the interaction between the gas and the sensitive material will be discussed. The integration into a sensor head of the sensitive film in waveguide configuration by means of a coupling grating will be presented.

5963-57, Poster Session

Growth and thermal stability of interfaces in ion beam sputtered Mo/Si mirrors

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In the field of microelectronics, the Extreme Ultraviolet (EUV) lithography operating at _ =13,5 nm, appears, today, as the most promising future technology. The viability of this next generation technology has, however, to face several technical issues. Among them, the realisation of highly reflective EUV mirrors is one of the key issues and concerns the mirrors for light transport as well as the lithography masks. In this last case, the mirrors which consist in a periodic Mo/Si multi-layer coating deposited by ion beam sputtering, suffer from reflectance limitations and thermal instabilities.

In this paper, an experimental investigation on IBS deposited Mo/Si multi-layers is presented. The study is mainly focused on the formation of Mo/Si interfaces and their evolution with thermal annealing up to 600°C. Detailed investigations by high-resolution transmission electron microscopy (HRTEM) and energy filtering TEM have been performed in association with differential scanning calorimetric (DSC) analyses. For the purpose, dedicated samples were prepared enabling the identification of phase transformations occurring during thermal annealing. The characterisation results are presented and discussed. It will be shown, in particular, how this coupled characterisation approach (TEM+DSC) can help understanding the interface growth in such metal/silicon systems.

5963-58, Poster Session

Zr-silicate thin films

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The Zr-silicate is a candidate for the high permittivity gate dielectric application. The mixing thermodynamics of the ZrO_2 - SiO_2 system was analysed. Thin films of Zr-silicate were deposited on silicon and quartz substrates by EB coevaporation. Chemical bonding in Zr -silicates has been studied by Fourier-transform infrared spectroscopy. The structural and optical properties and the surface morphology were investigated.

5963-59, Poster Session

Properties of chirped mirrors manufactured by plasma-assisted electron-beam evaporation

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Nowadays chirped dielectric mirrors for ultrafast optics and laser applications are usually manufactured by sputtering techniques. The suitability of Advanced Plasma Source (APS) assisted electron beam evaporation in respect to such coatings is still under investigation. The purpose of this presentation is to show our first results of the deposition of chirped layers produced by plasma assisted electron beam evaporation and their properties.

The aim was to design and prepare a NIR-mirror for the 700nm - 900nm spectral range. It has been attempted to find a design that is robust with respect to errors of thickness and refractive index. The mirror consists of more than 30 layers composed of alternating high- (Nb_2O_5) and low-refractive index (SiO_2) layer materials.

The deposited coatings have been tested in terms of their group delay dispersion (GDD) and their reflectivity. It is shown, that in the wavelength range between 720nm and 890nm the GDD exhibits a value of about -50fs2, whereas the reflectivity is above 99%. However, the subsequent reverse engineering operations show a relative large thickness error of more than 1% - 2% with regard to the particular layers. Nevertheless the effect on the GDD and the reflectivity is tolerable.

Furthermore the first experiments are presented of controlling the third order dispersion (TOD). There it is essential to keep the deviations of the layer thicknesses in comparison with the target value below 1%.

5963-60, Poster Session

Comparison of gradient index and classical designs of a narrow notch filter

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Rugate structures, as well as gradient refractive index films in general, attract a lot of interest, although their manufacture is more challenging than that of classical high-low stacks. The reason is that gradient index systems may provide advantages in both the optical performance and mechanical properties of the optical coatings. A lot of theoretical work on design of rugate filters has been done in the last decades. However, only few of the designs could be deposited, which is often caused by practical problems to prepare materials with the desired refractive index values. Rugate structures are particularly prospective for notch i.e. bandstop filters, especially when a narrow rejection band is required. Classical designs are limited here by the choice of materials having proper refractive indices and good optical and mechanical properties at the same time. This is not the case for a gradient index approach because any value of index within a given range can be chosen. In this paper two gradient index designs of a narrow bandstop filter for a wavelength of 532nm are presented. Both of them take into account the constraints posed by

limitations of the real deposition systems. One of the designs is synthesised as an apodized sinusoidal structure that is approximated by homogeneous sublayers. The other one is based on an apodized sinusoidal structure as well, but it is approximated by a hybrid structure, i.e. a combination of linear gradient index ramps between the lowest and the highest refractive index used and homogeneous layers of this extreme index values. The presented graded index designs are compared to a classical high-low stack and the advantages and drawbacks of each approach are commented.

5963-62, Poster Session

Synthesis and manufacturing the mirrors for ultrafast optics

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We discuss properties of 2 types of chirped mirrors manufactured with Helios Leybold system (magnetron sputtering with plasma/ion assisted technology). The first type includes complementary multilayer dielectric mirrors providing a certain negative group delay dispersion (GDD) and high reflectance in the wavelength range 600-1050 nm. We use such mirrors in broadband Ti:Sa oscillators for producing short phase-stabilized pulses. The second type of mirrors has extremely low both GDD oscillations and losses in the range 700-900 nm. Such mirrors are of interest to long-cavity high-energy Ti:Sa oscillators and so-called external cavities for storing energy from femtosecond oscillators. The achieved GDD fluctuations for this type of mirrors are 5 fs^2. Different coating materials: Nb2O5, TiO2, Ta2O5 together with SiO2 will be compared. We present the results of reproducibility of such mirrors and their characterization in terms of reflectivity, losses, surface quality and GDD. The comparison of the designed and manufactured mirrors will be also done.

5963-63, Poster Session

Optical thin films deposition by MDECR-PECVD

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The optical coatings fabrication technology evolves with 3 main objectives - deposition with higher rate, on larger areas and with more accurate control. We report on application of high-density plasma PECVD for the multilayer and gradient structures deposition. We designed and built Matrix Distributed ECR (MDECR) PECVD reactor dedicated for dielectric filters deposition and equipped it with multiple sensors for process control. Planar matrix geometry of plasma source is based on electron cyclotron resonance effect at 2.45 GHz microwave frequency and provides scalability of the deposition on large area substrates. High (up to 5 nm/sec) deposition rate obtained due to high dissociation efficiency and careful design of the gas injection system. Optical emission spectroscopy, quadrupole mass-spectrometry and spectroscopic and multi-channel kinetic ellipsometry are used for in-situ studies and control of the film deposition. We performed in-depth studies of the nature of high-density plasma discharge in silane, oxygen and nitrogen mixture and correlated its properties with optical and physical properties of deposited materials. To demonstrate the capabilities, a wide band multilayer and gradient index antireflection coatings were realized by deposition of SiOxNy alloy thin films. The predefined variation of an index in a profile for each design is obtained by changing the flows of precursors. Real-time control is performed with multi-channel kinetic ellipsometry.

5963-64, Poster Session

Ageing of optical components under laser irradiation at 532nm

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The pulsed Laser Induced Damage Threshold (LIDT) of optical components usually reaches several hundreds of MW/cm(c)$^{-}$. When exposed to laser power several order of magnitude below their LIDT, the lifetime is by default considered infinite.

The accumulation of laser pulses may lead to a contamination of the surface and a degradation of its optical properties and LIDT. In the first order, these phenomena depend on the experimental conditions such as the irradiation time, the laser power, and the environment.

In order to better understand the physics ruling this degradation, we developped an experimental cell with an in-situ spectroscopic ellipsometry diagnostic. The dry-pumped cell shelting the sample is associated with a mass spectrometer that enables us to follow the environmental conditions in which we experiment the ageing. Anti-reflection coatings on fused silica were tested under 10kHz-532nm laser ageing. We present first results of degradation obtained in these conditions.

5963-65, Poster Session

Determination of complex optical indices in the 80-140nm VUV wavelength region from reflectivity measurements under normal incidence: application to ZnSe

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The 80-140 nm VUV domain is peculiar in that numerous materials display a very high absorption coefficient. As a result, the values of the real (n) and imaginary (k) parts of the refraction index in this spectral range published in the literature are few. Compiled tables of Windt [1], HOC [2] and B4C values given by Larruquert [3] are often used.

It is shown here that from the reflectivity measurements at normal incidence performed with different thicknesses of a capper layer on Al, complex indices of this top layer material in the VUV wavelength region can be extracted.

We report the results obtained with a capper layer of ZnSe on Al. The layer appears able to provide a good barrier against oxidisation, which is a necessary condition to carry out this method. The optical indices found for ZnSe in the 80 -140 nm spectral range are drastically different from the only data available in literature (Palik in HOC).

1. http:/cletus.phys.columbia.edu/~windt/

2. HOC: Handbook of Optical Constants , E.D. Palik, G. Ghosh, Academic Press, 1999 (CD Rom).

3. J. I. Larruquet, R. A. M. Keski-Kuha, Optical properties of hot-pressed B4C in the extreme ultraviolet., Applied Optics, 39 (2000), N°10, pp1537-1540.

5963-66, Poster Session

High-performance Cr/Sc multilayers for the soft x-ray range

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The development and production of high performance multilayer mirrors for the "water window" region of soft X - rays is a challenge of modern technology because multilayers for normal incidence optics have single layer thicknesses in the atomic range of about one nanometer. Cr/Sc is the most promising material combination for application in the "water window" due to its predicted high reflectivity and the good growth properties of this couple. A serious problem of the development of multilayers for this region is the strong effect of interface quality on the optical performance. This problem of short-period Cr/Sc multilayer mirrors will be discussed.

Cr/Sc multilayer mirrors were designed for grazing (30o, 60o and 85o) incidence at l = 3.12 nm and l = 4.47 nm. The multilayer coatings have been grown on Si-substrates using ion-assisted magnetron sputtering. X-ray scattering of CuKa radiation, transmission electron microscopy, atomic force microscopy and mechanical stress measurements were used for the characterization of the multilayer structure. It is shown that the interface performance of such structures can be considerably improved by the application of negative substrate BIAS voltage during the film growth. The reflective properties of the Cr/Sc multilayers were measured with synchrotron radiation. Maximum normal incidence reflectivities of 17.3 % \@ 3.12 nm and 7 % \@ 4.47 nm were achieved and additional ways for the reflectivity improvement will be suggested and discussed. These very promising and still not limited results indicate a large potential for future applications of Cr/Si as high reflective coatings for Schwarzschild objectives for application in and just outside the "water window".

The application of Cr/Sc multilayer mirrors for polarization analysis of synchrotron radiation and diagnostics of high-temperature plasmas requires not only a high reflectivity but also a long lifetime under heat load. The annealing effect in short-period Cr/Sc multilayers was studied in the temperature range of 100 - 500oC by X-ray scattering and transmission electron microscopy. Structural and phase transformations and the corresponding changes of the optical properties are presented and discussed.

5963-67, Poster Session

Ion-assisted deposition of SiO2 film from silicon

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Silicon dioxide, SiO2, is one of the preferred low index materials for optical thin film technology. It is often deposited by electron beam evaporation source with less porosity and scattering, relatively durable and can have a good laser damage threshold. Beside these advantages the deposition of critical optical thin film stacks with silicon dioxide from an E-gun was severely limited by the stability of the evaporation pattern or angular distribution of the material. The even surface of SiO2 granules in crucible will tend to develop into groove and become deeper with the evaporation process. As the results, angular distribution of the evaporation vapor changes in non-predicted manner.

This report presents our experiments to apply Ion Assisted Deposition process to evaporate silicon in a molten liquid form. By choosing appropriate process parameters we can get SiO2 film with as good and stable property as one obtained by traditional E-gun evaporation.

5963-68, Poster Session

B4C/Mo/Si multilayers for 20-40 nm wavelengths: application to broadband mirrors

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The wavelength region ranging from 20 nm to 40 nm is of particular importance for EUV astrophysics, high harmonic generation sources, x-ray laser sources and others applications. For wavelengths higher than 30 nm, the classical Mo/Si multilayers are not really efficient. In order to improve the reflectivity of multilayer mirrors in the 30 nm range, we have studied a new periodic multilayer structure with 3 components instead of 2. Simulations show that multilayers made of B4C, Mo and Si materials present higher reflectivity than 2 component multilayers (B4C/Si and Mo/Si) if they are deposited in optimal order : B4C over Mo over Si. B4C/Mo/Si structures present a theoretical reflectance of 42 % at 32 nm which represents a great increase as compared with B4C/Si or Mo/Si multilayers. [1]

Optimized B4C/Mo/Si and B4C/Si multilayers have been deposited by magnetron sputtering and ion beam sputtering. The composition of Si, Mo and B4C thin films have been measured by Rutherford Backscattering and Nuclear Reaction analyses. The multilayers have been characterized by x-ray grazing reflectometry (l = 0.154 nm) and synchrotron radiation measurements at near normal incidence. The experimental reflectivity for B4C/Si is 25% at 32 nm. For B4C/Mo/Si multilayers, we obtained an experimental reflectivity of 34 % at 32 nm.

We have used B4C/Mo/Si multilayers in a non periodical structure in order to produce brandband mirror. Preliminary experimental results demonstrate the interest of such structure : a broadband spectrum centered at 32 nm with peak reflectivity of 22% and FWHM larger than 9 nm has been measured. Design and chacarcterisation of these broadband mirrors will be presented and compared with simulation.

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5963-69, Poster Session

Spectral properties of the new emulsion nanocomposite material based on silicon

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The optical properties of emulsive nanocomposite materials based on silicon are studied. The method for production a new type of UV protecting cream and control the spectral structure of transmitted electromagnetic radiation is reported. Two series of silicon nanocrystals, incapsulated in SiOx (type 1) and SiOx+SiNx (type 2) were synthesized in high frequency inductive plasma. The results of FTIR-spectroscopy of silicon - based nanocrystals indicates the formation of SiO2 and SiOx phases on the surface layer of the type 1 sample and forming a nitride phase on the sample type 2 surface layer. The Raman spectra investigation of two series of samples allowed the determination of the nanoparticles mean size and phase structure in silicon based nanocrystals. The Raman spectra of samples type 1 and type 2 at the region of 500-600 ñì-1demonstrated that UV active part of the material is nanocrystalline silicon with average kernel dimension of d=10±2 nm for type 1 and d=13±2 nm for type 2. Emulsion composite samples with nanocrystalline silicon have been prepared and tested. The spectra of optical density as well as the transmission- and diffusive reflection into integrative sphere spectra were measured for both types of samples. It was shown that the type 2 samples have advantages as main protective ingredients of UV sunscreens.

5963-70, Poster Session

Dichroic beam splitter with two silver layers for visible transmission and infrared reflection

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Optical characteristics of Ag films were investigated. The Ag films were deposited on JGS-1 quartz glass, ZnS film, and Al2O3 film in vacuum.

The deposition rate and temperature influence the n & k of Ag layers. Optical constants of Ag layers were reported from 0.4 to 15.0μm. Using AFM (atomic force microscopy) and TEM (transmission electron microscopy), the surface and transect morphology of Ag layers has been observed.

Using the structure of dielectric/ Ag/dielectric/Ag/dielectric, we have gotten induced-transmission filters. The filters have good reflectance in infrared range and satisfied transmittance in visible and near-infrared.The average transmittance in visible (400 to 900nm) reach 80%, and the average reflectance reach 75% in short infrared (1.5 to 3.0μm), 85% in middle-long infrared (3.0 to 15.0μm). Between 900nm and 1.5μm, the reflectance and transmittance change rapidly. Fixed slantingly on 45(or other) degree in optical system, the filters can be used as dichroic beam splittter. And some spectrum resource in short infrared (1.0 to 3.0μm) can been also used.

Taking opportune measure while and after depositing, the splitter can endure 24h in water, and in RH95% humidity at 48 Celsius centigrated. The layers have good adhesive intensity with substrate, and can endure rapid pull by standard adhesive tape.

5963-71, Poster Session

Deposition of innovative optical coatings by reactive magnetron sputtering methods

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We present an innovative sputter deposition concept which allow the deposition of high quality optical interference coatings on areas up to 40 cm diameter by reactive pulsed magnetron sputtering at high rates. A linear ion source is implemented to improve the film properties. The deposition concept is based on rotation like motions of the substrate combined with optical insitu monitoring. Different single films and coatings (stacks and rugate filters) were deposited by mid-frequency as well as by radio-frequency magnetron sputtering. The film properties are characterized with different optical and non-optical methods.

5963-72, Poster Session

Optical monitoring of rugate filters

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Rugate filters have a high potential for solving specific design problems in many applications of modern optics and lighting technology. However, the exact manufacture of these gradual layer systems is still a challenge which could not be solved completely until today. One of the prominent approaches for the production of rugate filters is based on independent quartz crystal devices measuring the rate of the different coating materials. As an alternative, optical broadband monitoring has been already qualified for controlling the deposition of complicated non quarterwave stacks. In the present study, promising results of this deposition control concept as a direct monitoring of rugate filters will be presented. In a first attempt, the continuous change of refractive indices in the graded layers was transformed to a set of discrete homogeneous sub-layers with thicknesses of around 5 nm. These discrete layers are realised by defined mixtures of two materials. A data base for the dispersion behavior was created for the different mixing ratios and is employed for the production of such quasi-rugate filters. The optical monitor is operated in the usual mode determining the switching points of the layers. Selected examples will be presented for quasi rugate coatings produced by ion beam sputtering from a movable zone target. Different designs will be discussed in comparison to classical interference systems considering production problems as well the optical properties and stability.

5963-73, Poster Session

Effective medium models for metal-dielectric composites: an analysis based on the spectral density theory

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Metal-dielectric mixtures consisting of metallic aggregates in an insulating matrix present a peculiar optical behaviour that allows their use in different applications, both in linear and non-linear optics (selective light absorbers, surface enhanced Raman spectroscopy, second harmonic generation). The optical properties of these composites are mainly dominated by the surface plasmon resonance of the free electrons of the aggregates and the effects of the percolation among aggregates. Thus, the optical behaviour of these mixtures may depend on a large number of parameters, like the size, shape and distribution of the metallic aggregates, the interaction among them and the nature of the dielectric matrix. A widely used approach for modelling the optical properties consists of using effective optical constants for the composite, calculated in terms of the optical constants of the mixing materials (effective medium approximations). Nevertheless, most of these theories are restricted to certain conditions and may not be appropriate to account for the influence of some of the above mentioned parameters.

According to the work of D. Bergman (Physics Reports C, 43, p. 377, 1978) any effective medium theory for a two-phase mixture has an integral representation in terms of a positive function defined as the spectral density. This function is completely determined by the geometry of the two-phase mixture. In this work we present a numerical study of the influence of several parameters in the spectral density function, like the multipolar interaction between aggregates or their size distribution. The results are compared with the spectral density of classic and recently developed effective medium theories. Such comparison allows establishing the intrinsic limitations of the analyzed effective medium theories regarding the studied parameters.

5963-74, Poster Session

Design elements of porous silicon omnidirectional mirrors

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The electrochemical etching of silicon under some well-defined conditions can lead to the formation of a thin film of porous silicon atop of a Si bulk substrate. The thickness and porosity (and consequently, the refractive index) of the film can be controlled by means of the etching conditions. The technology for making porous Si allows producing different layers with different thicknesses and porosities giving rise to multilayer interference filters.

One interesting application of porous silicon is the omnidirectional mirrors: multilayer mirrors showing a high reflectivity for all angles of incidence over a wide spectral range. Such mirrors are of interest in optoelectronics as boundaries for high-performance waveguides.

The omnidirectional reflectivity properties of these mirrors are better understood when they are considered as 1-D photonic crystals. Within such framework, the high-reflectivity region corresponds to the photonic band gap of the multilayer.

In this work we will carry out numerical studies to understand the influence of the different design parameters on the bandwidth of the photonic band gap. First, the influence of the optical thickness ratio between the high and the low refractive index layers will be analyzed. One interesting fact that can be demonstrated is that the optical thickness ratio leading to a widest omnidirectional band gap does not correspond to the classical quarterwave structure. On the other hand, the second part will be devoted to the study of the influence of the ratio of high-to-low refractive indices. One of the most interesting properties of porous silicon is that there is the possibility of selecting the refractive index by controlling the porosity, which makes the refractive index an adjustable parameter on the design process.

5963-75, Poster Session

VUV optical coatings for the next-generation micro-mechanical mirrors

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The synergistic combination of micro-electro-mechanical systems technologies and opto-electronics has evolved into a class of integrated micro systems with brand new application domains and huge expectation of opportunities for the near future. Presently, the research activities focused on coating development for micro structured mirrors concentrate on high reflecting designs for the realisation of defect free actuated micro mirror coatings. Since micro-mirrors arrays are inherently 2-dimensional at nanometre scale, requirements are different to those for optical systems for the VUV spectral range, which challenges therefore the optics development towards smart compatible solutions with minimized coatings stress and optimised optical performances. Micro structured mirrors must operate in MOEMS environment with high requirements concerning optical and mechanical properties, clean atmosphere and cohabitation with the electronic structure; the coatings on these micro structured mirrors must be designed for a compatibility with CMOS technology.

High reflecting low-stress optical coatings for the next-generation of micro mechanical mirrors have been developed. The presented metal systems are applicable from VUV and DUV up to the UV and VIS spectral region and can be integrated in the technology of MOEMS, such as spatial light modulators (SLM) and micro scanning mirrors. These optimised metal designs enable to reconcile high optical performances with adequate mechanical properties and convenient CMOS compatibility. Currently, micro-mirror arrays with enhanced highly reflective coatings for DUV (l = 193 nm) and VUV (l = 157 nm) exist as prototypes.

5963-76, Poster Session

Resonance effects on quasi dense thin aluminum metal films

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We present numerical findings based on rigorous coupled wave analysis (RCWA) and finite difference time domain algorithm (FDTD) and measurements of resonance effects on quasi dense surface layers based on fused silica substrates. These layers are 30nm to 40nm thick. Thereby aluminum films consist of periodically arranged 3 to 8nm small aluminum oxide stripes. In spite of the small gaps between the aluminum structures the resonance effect can be observed. These structures were produced with a special micro structuring process and coating regime. Depending on the feature sizes of the desired structures polarized and none polarized resonance effects are occurred. Numerical modeling show that light can pass through that layers for a characteristic resonance wavelength. These resonance is based on the stimulation of film plasmons. Theoretical and experimental results were compared for aluminum - aluminum oxide gratings with varying periods in wavelength range between 400nm and 1700nm. The results show a good agreement between numerical findings and experimental results.

5963-77, Poster Session

High-resolution video-based inspection method for LIDT investigations of thin-disc laser crystals

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During the last two decades, high power NIR-laser systems could be developed to versatile tools in the industrial production and fundamental research. Especially innovative cutting and welding applications in automotive industry, imposes ever increasing demands on the development of highest power systems with improved beam quality. In this context, disc laser systems, which deliver output powers of several kilowatts in continuous wave operation in combination with exceptional beam quality, are considered as a laser concept with high potential. Also, these systems offer various advantages for the amplification of pulsed laser irradiation, which is of current interest in advanced material processing. In both applications, the power handling capability of the disc laser crystal is considered as a limiting factor, which has to be investigated especially in view of the high field strength in the laser systems. It is assumed that the damage can be traced back to the defects on the crystal surface or in the optical coatings. The expected size of the defects initiating laser damage ranges in the micrometer scale. In the present study, LIDT experiments are focused on the verification of this assumption and are intended to assist in the optimisation of the manufacturing process. For a detection of the defects, an online defect inspection system was extended by a high resolving imaging technique. The LIDT measurement was performed on the basis of the Son1 protocol according to ISO 11254-2 at an effective pulse duration of about 11ns and a repetition rate of a few Hz at a wavelength 1.064nm.

5963-78, Poster Session

Surface roughness of Mo and Si thin films and Mo/Si multilayers

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Mo and Si thin films are grown by ion beam sputter deposition technique using Ar as sputter gas. 2'' silicon wafers are used as substrates. The surface roughness of the single layers are measured by AFM in dependence of the layer thickness. The roughness of the Mo is nearly constant up to a thickness of 15 nm but increases markedly above this value. In contrast to that the roughness of the silicon does not increase with the thickness. It remains at the value of the substrate.

From the silicon layer it is known that it is amorphous whereas the Mo grows polycrystalline on silicon. To clarify the structural influences on the development of the surface roughness the texture of two Mo single layers on silicon substrate of 10 nm and 120 nm thickness is investigated by X-ray diffraction. The preferential orientation of the Mo crystallites is the [110] direction. The 10 nm thin Mo layer exclusively shows this orientation. But for the 120 nm layer, one can find additional orientations as [200] and [211]. Thus, the increasing of surface roughness with the increasing layer thickness can be explained by the occurrence of grains of different orientations.

In the case of multilayer growth, the Mo thickness is in the range of 3 nm and consequently below the critical thickness of about 15 nm. This means, the multilayer roughness will not increase with the number of layers. But the initial surface roughness of the substrate will influence the final roughness after multilayer deposition.

5963-79, Poster Session

Laser ablation of SiOx thin films for direct mask writing

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The present study of silica thin films illustrates a new way of direct writing of diffractive phase elements by means of UV-laser ablation.

The strong UV-absorption of silica, tailored with an appropriate oxygen deficiency, serves the basis for an efficient laser ablation process of silica coatings. Therefore, direct patterning of silica layers can be achieved. After an additional annealing process, the silica coating becomes highly UV-transparent and the rapid manufacturing of diffractive phase elements becomes possible.

As an example, a pixel pattern generated by an appropriate optical design algorithm is transferred into a phase delay pattern in the form of a silica surface relief, which results in a diffractive shaping of a beam transmitted (or reflected) by this structured layer.

5963-80, Poster Session

Deposition of broadband antireflection coatings on plastic substrates by evaporation and reactive pulse magnetron sputtering

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There is a growing interest in broadband, colour neutral antireflection coatings on plastic substrates in display, art and ophthalmic lens applications. The design AR Hard(r) combines a large bandwidth of the AR coating with a scratch resistant SiO2 coating of 1...4 μm thickness. In the paper the deposition of these coatings on polycarbonate substrates by evaporation and by reactive pulse magnetron sputtering is presented. The influence of deposition process and plasma pretreatment on reflectance spectrum, absorption, adhesion and climatic stability is discussed.

5963-81, Poster Session

New advances in improving low-temperature performance of infrared thin-film interference filters

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When temperature varies, the performance variations of an optical thin-film interference filter, such as the shift of center wavelength and the deterioration of peak transmission, are not acceptable. In particular, It becomes difficult to sustain the functional performance of non-dispersive narrow-bandpass interference filters for precision spectroradiometric measurements from space. In our previous work, an attempt has been done to fabricate a simple narrow-bandpass filter, in which Pbo.94Geo.06Te was substituted for PbTe. It was found that the low-temperature stability is obviously improved: in the temperature range of 80-300 K, the shift of center wavelength with temperature is reduced from 0.48 nm.K-1 to 0.23 nm K-1; furthermore, the peak transmittance of filter fabricated with Pbo.94Geo.06Te is ~3 % over that fabricated with PbTe. In this paper, we report a progress in improving low-temperature performance of infrared thin-film interference filters: the shift of center wavelength of 0.1 nm K-1 has been achieved.

5963-82, Poster Session

Optical characterization of nonuniform thin films using imaging spectrophotometry

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In this contribution an imaging spectrophotometer enabling us to characterize thin films exhibiting non-uniformity in the optical parameters, i.e. non-uniformity in thickness and optical constants, along the substrate surfaces will be described. This spectrophotometer is the two-channel one. It operates within spectral region 230-1000 nm.As a detector of this imaging spectrophotometer a CCD camera is used. Thus the spectral reflectances and transmittances can be measured in the points of a matrix taking place along the substrate surfaces corresponding to the pixels of this CCD camera. These spectral reflectances or transmittances can then be treated independently so that one can obtain the local values of thicknesses and optical constants, i.e. refractive index and extinction coefficient, corresponding to the individual points of the matrix on the substrate surfaces. Thus one can obtain the distribution of thickness values and spectral dependences of both the refractive index and extinction coefficient of the films studied along the substrate surfaces. In this way the complete optical characterization of the non-uniform thin films is performed. In this contribution the imaging spectrophotometer described is used to characterize non-uniform carbon thin films and thin films of the mixture of SiOx and CNy. Both the films were prepared by plasma chemical methods onto substrates formed by silicon single crystal wafers. This means that the reflection mode of the imaging spectrophotometer is employed for their characterization, i.e. the local spectral reflectances are utilized for this purpose.

5963-83, Poster Session

Deposition of robust multilayer mirror coatings for storage ring FEL lasing at 176nm

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Progresses in the development of multilayer mirrors used in storage ring Free Electron Lasers (FEL) operating in the vacuum ultraviolet spectral range were achieved in the last year. On the basis of dense oxide coatings deposited by Ion Beam Sputtering, a stable lasing at 190 nm was demonstrated. The extension towards shorter wavelengths had to overcome severe problems connected to the radiation resistance and the necessary reflectivity of the resonator mirrors. In this context, radiation resistance can be regarded as the ability of the mirror materials to withstand the high power laser radiation and the intense energetic background radiation generated in the synchrotron source. The bombardment with high energetic photons leads to irreversible changes and a coloration on the specimen. Reflectivity requirements can be evaluated from the tolerable losses of FEL systems. At ELETTRA FEL the resonator mirror reflectivity must be above 97 %. Evaporated fluoride multilayer mirrors provide sufficient reflectivity, but they do not exhibit an adequate radiation resistance. Pure oxide multilayers show a sufficient radiation resistance, but they can not reach the necessary reflectivity below 190 nm. A successful approach is the combination of an evaporated fluoride multilayer stack with a dense protection layer of silicon dioxide deposited by Ion Beam Sputtering. Such mirror systems were produced by an advanced deposition process combining a pure fluoride stack with a 200 nm thick silicon dioxide IBS protection layer resulting in a reflectivity of approximately 99 % at 180 nm. Lasing in the storage ring FEL at ELETTRA was realised in the range between 176 - 179 nm. The mirror reflectivity shows only a slight degradation after lasing which could be fully restored after the lasing experiment. Details of the deposition processes, and characterisation of the mirror system before and after lasing will be displayed.

5963-85, Poster Session

Spatial beam switching using the superprism effect in nonlinear thin-film stacks

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Thin-film stacks exhibiting a high spatial dispersion similar to the photonic crystal superprism effect can be employed to multiplex or demultiplex

several wavelength channels using a single thin-film stack. The phase properties of these stacks are designed such that a small change in the wavelength results in a large change of the effective group propagation angle and therefore of the beam exit position for light beams of oblique incidence angle. Here we demonstrate that such a structure also exhibits a large change in the exit position for a fixed incident wavelength due to a small refractive index variation. We investigate the introduction of optically nonlinear polymer layers into multilayer thin-film structures for electro-optic switching of the refractive index. Polymers offer a number of advantages as nonlinear materials - they are simple to process, they show high, non-resonant nonlinear coefficients and they posses low refractive indices. A dispersive thin-film stack containing tunable polymer layers is therefore promising as a 1:N spatial beam switch with switching times in the nanosecond range. We developed different designs for dispersive thin-film stacks consisting of dielectric and polymer layers. The approaches range from Bragg stacks with two alternating materials, one of them the active polymer, over cavities that contain the active material to coupled resonators where the active layer works as coupling element. Initial experiments with guest-host polymer systems were carried out. The material's optical and nonlinear properties have been determined and these results were integrated into our calculations.

5963-86, Poster Session

Preparation and characterization of multilayers for EUV applications

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In this paper we will give an overview of the preparation and characterization of Mo/Si multilayer coatings prepared by magnetron sputter deposition (MSD). As one result, high normal incidence EUV reflectance of \>70% has been achieved. Other important issues of multilayer optical systems, like thermal and long-term stability and internal stress have been investigated and the results are reported.

Besides the preparation of homogeneous multilayers, the deposition of laterally graded multilayers will be discussed. Some examples of laterally graded multilayers with rotational symmetry and linear graded multilayers are shown. The graded multilayers are controlled and measured by using a stand-alone laboratory EUV reflectometer.

5963-87, Poster Session

Generation of coherence and elliptically and circularly polarized infrared waves by incidence of randomly polarized light through a-quartz

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In the absorptive frequency region of a-quartz, there exist several sharp transmission windows in the infrared range. By incidence of randomly polarized light, the transmitted waves from the transmission windows were found to vibrate in two eigenpolarization directions through a-quartz, corresponding to the ordinary and extraordinary waves, respectively. There was a phase shift of ~$\pi/2$ between them after passing through the crystal, producing the elliptically polarized waves and even circularly polarized waves at some frequencies. The coherent states of polarization and partial correlation of the extraordinary and the ordinary waves are result from the interaction between them. Differing from propagation of light through the quarter-wave plate, the generation of coherence and elliptically and circularly polarized infrared waves through a-quartz was independent of the thickness of a-quartz plate, and irrespective of the state of polarization of the incident light.

5963-88, Poster Session

Genetic algorithm design of reflection thin-film coatings and polarization-devices

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In this communication, the design of reflection thin-film coatings and polarization-devices is achieved by the use of a recently developed fast genetic algorithm (GA). The reflection thin-film coatings, and polarization-devices, are both treated as a film-substrate system. With the required polarization-characteristics of the device as an input, the GA provides the film thickness and angle of incidence at which the coating, or device, behaves as prescribed for the chosen materials of the film and substrate, at the wavelength of operation. The GA is real fast. It is modified to provide the required design parameters within a few cycles, literally in no time. The accuracy of the GA is high, and the GA itself is robust and consistent.

5963-89, Poster Session

High reflectivity measurement with cavity ring-down technique

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Abstract: Cavity Ring-Down Spectroscopy (CRDS) is a highly sensitive loss measurement technique. It was used for quantitative diagnostics of molecular species. In our experiment CRDS has been applied for measuring the reflectivities of optical mirrors. An experimental system has been established. The reflectivities of a pair of cavity mirrors and of a 22.5° optical mirror have been measured. The reflectivities of the cavity mirrors are(99.925±0.001)% and that of the 22.5° mirror is (99.992±0.003)%. The measurement error was as low as 0.001%.

5963-90, Poster Session

Thin film optical fiters design by search and optimization methods

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The design of thin film optical devices has been the subject of many books in the last century, and is going to be a basic tool in the continuously developing field of nanotechnology. However the basic principle of the major interferometers is well known and commonly applied to explain the performance of multilayer coatings and interferometric filters, the inverse approach of how to design the device in order to fulfil given requirements and optimize the performance of the device is not fully understood. In this paper we would like to provide a theoretical approach based on the recognition of the critical parameters and the use of different search and optimization methods for their evaluation, both deterministic (conjugate gradient method) and not (Genetic Algorithms). Finally we provide several examples of design and realization of Photonic Band Gap structures and other multilayer coatings.

5963-91, Poster Session

Characterization of optical thin films exhibiting defects

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In this contribution the results of the complete optical characterization of ZrO_2, TiO_2 and As-S chalcogenide thin films deposited onto planparallel glass plates will be presented. The ZrO_2 and TiO_2 films were prepared by magnetron sputtering and the As-S films were prepared using vacuum evaporation. For the

characterization of these films the combination of variable angle spectroscopic ellipsometry (VASE), near-normal spectroscopic reflectometry (NNSR) and spectroscopic transmittometry (ST) is used. The ZrO_2 and TiO_2 films exhibited roughness of their upper boundaries. The As-S chalcogenide films exhibited the optical inhomogeneity consisting in the profile of the refractive index and extinction coefficient across these films. For including the boundary roughness of the ZrO_2 and TiO_2 films into the formulae expressing the ellipsometric quantities, reflectance and transmittance of these films the Rayleigh-Rice theory is used. Spectral dependences of the optical constants of the ZrO_2 and TiO_2 films are expressed using the dispersion model based on parameterization of the joint density of electronic states. For the As-S films the dispersion model of amorphous solids based on parameterization of the density of electronic states is utilized. It is also shown how to exclude the systematic errors connected with measuring the transmittance and reflectance of the films studied caused by the reflection of the convergent light beam on the back sides of the glass substrates. Using the analytical method presented the values of thickness, spectral dependences of the optical constants and the values of the parameters characterizing the defects can be determined simultaneously.

5963-34, Session 8

Engineering meter-scale laser resistant coatings for the near IR

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Laser resistant coatings are needed for beam steering (mirrors), pulse switching (polarizers), or high transport efficiency (windows) on large laser systems. A range of defects limit the exposure fluence of these coatings. By understanding the origin and damage mechanisms for these defects, the deposition process can be optimized to realize coatings with greater laser resistance. A variety of characterization tools such as Photothermal

Microscopy, Damage Testers, Laser Conditioners, Interferometers, Photometers / Reflectometers, Scanning Electron Microscopes, and Focused Ion Beam Microscopes can be used to improve thin film quality. Electric field modeling can provide insight into which defects are most problematic. Laser damage growth studies and propagation modeling are useful for determining a functional laser damage criteria. Finally selection of the proper coating materials and deposition parameters can lead to high fluence operations.

5963-35, Session 8

Comparative study of IR and UV laser damage resistance of silica thin films deposited by EBD, IP, DIBS and IAD

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The laser damage resistance of optical coatings is a critical point for a large number of applications. However improving this resistance is often hard to obtain because of the large number of parameters in the deposition processes than can modify the laser damage threshold and the lack of detailed and exploitable studies published on this subject. Then, the aim of this work is to test and analyze the laser damage resistance of a usual material for high power applications (silica) deposited in various conditions. The thin films of different thicknesses were specially deposited using classical techniques: Dual Ion Beam Sputtering, Electron Beam Deposition, Ion Assisted Deposition and Ion Plating. The laser-induced damage thresholds of these coatings were determined at 1064nm and 355nm using nanosecond pulsed YAG lasers, with a 1-on-1 test procedure. Other diagnostic tools were used to complete the study and make potential correlations with laser damage: photothermal techniques, fluorescence measurements, profilometer, spectrometer, dark field and Nomarski microscopy, atomic force microscopy. The comparative study of these results highlight different laser damage behaviors of the silica coatings that are correlated to the optical and structural properties, the density and the nature of the defects, the absorption...

5963-36, Session 8

Sol-gel protective coating for high-power laser amplifier silvered reflectors

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Today, a large majority of high power laser is including cavity in which amplifier medium is pumped using flashlamps. Because of its high reflectance properties, silvered reflectors are often used to back-reflect flashlamp light towards amplifier media in order to increase pumping efficiency during laser pulse magnifying step. Due to safety and economical reasons, it is preferable to decrease laser cavity temperature using air flow. Consequently, silvered reflectors need to be protective coated to avoid fast tarnishing and oxidation damage induced by gas impurities (H2S, COS,...) and by ozone generation under oxygen and UV-light conditions. Beside the silver oxidation resistance improvement, the protective coating has to be as transparent as possible in the wavelength range of interest to maintain silver reflectance performance and should also resist to mechanical and chemical procedure during mounting and replacing steps of the laser maintenance. To fulfill all these requirements, a silica-based hybrid material has been developed. After silver electrodeposited steel substrate surface cleaning, the hybrid material is applied by dip-coating and gives a dense and protective layer after 30 minutes infrared curing at 200°C under air flow. The film thickness (around 150 nm) allows to maintain a high reflectance value up to 93% above 500 nm wavelength and to ensure mechanical properties (in compliance with 10-010 NFS test) and good chemical resistance. The hybrid coating protection effect has been characterized : no damage is observed after 45 minutes exposure in UV/ozone chamber and the reflectance losses are maintained under 2 % after 10,000 flashlamp discharge tests.

5963-37, Session 8

LIDT improvement of multilayer coatings by accurate analysis of fabrication steps

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We present Laser Induced Damage Threshold (LIDT) results on multilayer components with different optical functions for near infrared applications. In this paper, we investigate the different fabrication steps of such functions. In particular, we show experimental results on surfaces preparation (polishing, cleaning,...) and on deposition techniques (evaporation, ion beam assisted process,...) related to the materials involved in coatings. Laser damage tests are performed at 1064-nm with a 5-ns pulse Nd:Yag laser and experiments are made at surfaces of optical components using a 12μm diameter focused beam. Accurate probability curves are plotted due to a reliable statistical measurement of laser damage. Use of a statistic model permits to deduce densities of laser damage precursors. Additional characterizations are performed to have information about absorption and roughness. Analysis of all the steps involved in fabrication allows then to build multilayer components with high laser induced damage threshold.

5963-38, Session 8

Laser-thin films with very-high damage threshold

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New developments of laser thin films for high power laser systems were reviewed. Special attention was paid to several key coatings which bottlenecked the higher power laser system, such as pick-off mirrors, large aperture polarizer and YAG harmonic wavelength splitter, as well as AR coatings.

Defects were deemed to be the initial and essential source of laser-induced damage. The investigation of the original control of defects was focused on the deposition process control, such as substrate cleaning, purity of deposition materials, deposition temperature, oxygen pressure in vacuum chamber and so on. Several methods of evaluation of laser damage were employed, which included Laser Induced Damage Threshold (LIDT) determination and absorption detection based on Surface Thermal Lensing (STL) technique, as well as Total Integrated Scattering (TIS) measurement.

The LIDT of pick-off mirrors reached to 20J/cm2 (1064nm, 1ns), meanwhile the LIDT of the ultraviolet coatings did to 8J/cm2 (355nm, 1ns) because of its comprehensive mechanism. The LIDT of third harmonic mirror could be improved effectively with post-treatment methods, such as laser conditioning and oxygen-plasma post-treatment.

Actually the situation of the laser thin films with very high damage threshold was complicated due to their uniformity of optical properties and stress induced surface deformation in the large aperture.

5963-39, Session 9

Ion beam sputter coatings for laser technology

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The initial motivation for the development of Ion Beam Sputtering (IBS) processes was the need for optical coatings with extremely low optical scatter losses for laser gyros. Especially backscattering of the gyro-mirrors, which had a direct contact to the discharge in the HeNe-laser gyros of the early generations, couples the directional modes in the ring resonator leading to the lock in effect, which limits the sensitivity of the gyro. Accordingly, the first patent on IBS was approved for an aircraft company (Litton) in 1978. In the course of the rapid development of the IBS-concept during the last two decades, an extremely high optical quality could be achieved for laser coatings in the VIS- and NIR-spectral region. For example, high reflecting coatings with total optical losses below 1 ppm were demonstrated for specific precision measurement applications with the Nd:YAG-laser operating at 1.064 μm. Even though the high quality level of IBS-coatings had been confirmed in many applications, the process has not found its way into the production environment of most optical companies. Major restrictions are the relatively low rate of the deposition process and the lateral homogeneity of the coatings, which are related to the output characteristics of the currently available ion sources. In the present contribution, the basic principles of IBS will be discussed in the context of the demands of modern laser technology. Besides selected examples for special applications of IBS, aspects will be presented for approaches towards rapid prototyping of coatings and the production of rugate filters on the basis of IBS-techniques.

5963-40, Session 9

Highly reflective thin-film coatings for high-power applications of micromechanical scanning mirrors in the NIR-VIS spectral region

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This paper addresses different highly reflective optical coatings on micro scanning mirrors (MSM) for applications in the NIR-VIS-spectral region to enable new applications like laser marking at high optical power density. In the common case of MSM with an unprotected Al coating, the absorption

limits the maximal power density because of induced heating. In contrast to macroscopic NIR optics HR-micro-mirror coatings have to guarantee, beside high reflectivity, additional demands like (a) low-stress to enable the required flatness of the fragile mirror mirrors and (b) the integration of NIR-coating deposition into the fabrication process of MSM.

To overcome the mentioned problems, highly reflective low-stress optical coatings for the next-generation of micro mechanical mirrors have been developed enabling novel MOEMS applications in the VIS-NIR spectral region. Stable highly reflective NIR coatings were investigated according to a dual strategy of (a) broadband metallic reflectors and (b) dielectric multilayers. Enhanced metallic broadband reflectors reach a reflectivity of 98.7% at 1064nm and enable an excellent mirror planarity of a total deformation below 10 nm, i.e. smaller than l/100, whereas narrow-band dielectric multilayer coatings reach a reflectivity of 99.7% at 1064nm. The improved laser damage threshold and long term stability of HR-NIR coatings have been verified by a harsh short pulse irradiation tests at 1064 nm, whereas no degradation of the reflectance occurs. Currently, Au and Ag based metallic NIR coatings for 1064nm and broadband HR-NIR applications exist as prototypes enabling new MSM applications like laser marking at higher laser power density and broadband NIR spectrometry.

5963-41, Session 9

Investigation of the temperature stability of optical thin films

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Multilayer optical thin films on incandescent lamps are used to improve the efficiency of the lamps. For ultra high performance lamps, new materials with improved temperature stability are required. Therefore, different mixed oxide films, especially with high refractive index, were deposited on quarz glass by reactive pulsed magnetron sputtering. The temperature stability was investigated with optical and other methods for up to 1000 deg C. It was found out the crystallization can be significantly influenced by mixing different materials.

5963-42, Session 9

High-performance cold light mirror production with plasma ion assisted deposition (PIAD)

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Since many years the production of Cold Light Mirrors (CLM) for illumination and projection application is well known. In Batch Coaters hot conventional deposition processes are the state of the art.

In the last years a new domain for CLM is rising up rapidly. This application for projection TV forces the quality of the reflectors to a new level. High reflectivity, low scattering, colour balance, long term and high temperature stability as well as high productivity are the requirements for these new products. Because of miniaturization of the light engines for projection TV the temperature load to the reflectors and coatings starts rising and exceeds the limit of 500°C.

With Plasma Ion Assisted Deposition using a Leybold Advanced Plasma Source (APS) it is possible to provide these high performance CLM. Because of the plasma treatment the scattering is reduced and the reflectivity rises up. The pre heating and the hot processes at 300°C are no longer necessary. The post baking is also skipped because of the well done oxidation during the coating. Both will save production and handling time.

Using the appropriate material combination these CLM's can withstand up to 700°C. A superb feature of the reliable production coater is the high flexible planet drive for the substrate movement. With this equipment it is easy to adjust the layer uniformity and adapt the machine for different reflector types.

5963-43, Session 10

Correlation between the optical performance of TiO2-Ag-TiO2 multilayers and the interface roughness between the layers

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Ag-dielectric multilayers are widely used in the production of heat reflecting filters, induced transmission filters, beam splitters, etc. The performance of such coatings in the visble part of the spectrum is sometimes strongly influenced by a plasmon absorption in the Ag-layer or a surface plasmon absorption in the Ag-dielectric interfaces. The strength of the plasmon absorption is very sensitive to the layer structure, the light polarisation and the angle of incidence. As a result, the target specifications for reflection an transmission are not reached in many cases. We investigate PVD-deposited TiO2-Ag-TiO2 multilayers by means of optical reflection and transmission and Grazing Incidence X-ray Reflectometry (GIXR). The GIXR-method yields the individual layers thickness and the interface roughness. Some of the coatings have a broad absorption peak between 500 and 400nm, that can not be modelled using the bulk dielectric function of Ag. The magnitude of the absorption peaks is correlated with the measured roughness of the TiO2-Ag interfaces. The analysis of the results shows the critical parameters for the deposition process.

5963-44, Session 10

High-rate deposition of optical coatings by closed-field magnetron sputtering

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"Closed field" magnetron (CFM) sputtering offers a flexible and high throughput deposition process for optical coatings and thin films required in a wide range of applications such as durable Anti-Reflection (AR) coatings for ophthalmic lenses and display windows and coatings for digital imaging, projection and displays. CFM sputtering uses two or more different metal targets to deposit multilayers comprising a wide range of dielectrics, metals and transparent conductive oxides. Moreover, CFM provides a room temperature deposition process with high ion current density, low bias voltage and reactive oxidation in the entire volume around the rotating substrate drum carrier, thereby producing low stress films over a large surface area at high deposition rate with excellent and reproducible optical properties. There is no need for ancilliary plasma/ ion sources to assist the oxidation and film densification process, as each magnetron is designed to provide necessary plasma with ion assist energies typically in the range 20 to 30eV, producing spectrally stable, amorphous and dense microstructure. Machines based on the Closed Field are scaleable to meet a range of batch and in-line size requirements. This paper describes optical and durability properties of a range of coating types which have been CFM sputtered onto both plastic and glass substrate materials.

5963-45, Session 10

Innovative production of thin film laser components

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Future production of high quality laser components asks for both, the precise preparation of low loss multilayer stacks and a clean room compatible innovative deposition process. In addition a cost-effective thin film filter production is required in order to transfer new developments like ultra fast pulse laser technique from research to economical products and applications.

One of the most promising candidates is magnetron sputtering due to the potential of excellent film properties, a fully automatic clean room compatible manufacturing process and a high productivity. Similar film qualities as with ion beam sputtering are realised but with a more than 10 times higher productivity. The reproducible production of multilayer broad band mirrors with controlled group delay dispersion and low losses is still a big challenge. Promising results were achieved on the basis of silica and niobia and will be presented.

5963-46, Session 10

Thorium-free interference coatings for infrared applications

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Recent developments in defence, security or space applications have increased the demands on optical properties and environmental stability of IR optical components. This contribution shows improvements in manufacturing technology for components with very different functions. By means of examples for AR coatings, filters, mirrors and beam splitters on Ge, Si, ZnS and CaF2 and Aluminium substrates the influence of the applied coating technology on resulting transmittance, reflectance and operational stability will be discussed. All optical functions in a wide range of spectral regions are realised without using radioactive materials such as thorium fluoride.

5963-47, Session 10

Precision optical and antireflection multilayer and gradient coatings containing reactively sputtered oxides, nitrides and fluorides

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Optical coatings have been deposited by pulse magnetron sputtering of the target materials silicon and aluminium using the reactive gases oxygen, nitrogen and fluorine. Examples presented in the paper include multilayer of silicon oxide and nitride used in antireflective coatings for optophalmic lenses and in filters consisting of up to 150 quarter wave layers. These films were produced at one stationary coating station without interruption of film deposition by changing the reactive gas during the plasma process. This process was also used for the deposition of rugate filters with apodization function by continuous variation of the reactive gas composition during the deposition. Furthermore in the paper optical properties of the sputter deposited AlF3 layers will be presented.

5963-48, Session 11

Organically modified SiO2 coatings on polycarbonate

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Transparent plastics are widely used today for optical components. They are coated to improve their mechanical durability and to provide a desired optical functionality, e.g. antireflection.

Antireflective coatings consist of high and low-index layers, which can be deposited by plasma ion-assisted deposition. SiO2 is the classical low-index material for antireflective coatings and additional it features an advantageous scratch resistance . The contrary properties of the organic substrate and the inorganic coating - such as thermal expansion - may result in a limited environmental stability of the coated plastic optical components. Improved environmental durability of these coatings is required with simultaneous consideration of premium optical and mechanical properties.

It is proposed to modify SiO2 coatings by adding hexamethyldisiloxane (HMDSO) into the deposition process with the objective of creating a smooth transition between the typical organic and inorganic properties of substrate and coating, respectively.

Single layers of organically modified SiO2 have been deposited on polycarbonate by electron beam evaporation in a Plasma-IAD process with additional input of gaseous hexamethyldisiloxane (HMDSO) under various evaporation and plasma parameters.

The paper will present the comparison of these coatings in terms of their chemical composition, coating adhesion, environmental stability and mechanical properties in dependency on the process parameters. Further investigations focus on the involvement of organically modified SiO2 layers into antireflective coating systems with enhanced environmental stability.

5963-49, Session 11

Design and fabrication of hybrid coatings composed of homogeneous layers and linear refractive index gradients

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Inhomogeneous coatings are promising for superior optical properties, e.g. broadband antireflection, in comparison to conventional HL-stack designs. Although a lot of excellent theoretical work on optical behavior of rugates and gradient index films has been done during the last decades, there is no real breakthrough in industrial fabrication. The realization of such coatings leads to an extensive and time-consuming computer-aided process control, because of complicated layer designs with continuously changing refractive index gradients.

We describe the design, realization and optical behavior of an omnidirectional antireflection coating that essentially represents a hybrid coating composed from homogeneous layers and linear refractive index gradient layers. The preparation was performed by a plasma-assisted coevaporation of niobium pentoxide as high index material and silica as low index one on a Leybold Syrus Pro deposition system.

5963-50, Session 11

Gravure printing of transparent conducting ITO coatings for display applications

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Modern display technologies have generated an increasing demand for tailored transparent conducting oxide coatings (TCO) on thin glass and plastic foil substrates. At present, TCO materials such as indium tin oxide (ITO, In2O3:Sn), however, are mostly deposited by PVD techniques and hence are largely limited to flat substrates. A wet chemical deposition of such materials would be of considerable advantage for some forthcoming display applications because of their lower deposition cost and the higher deposition flexibility.

This contribution presents a gravure printing technique for UV-curable ITO nanoparticle coatings on thin glass and PET (polyethyleneterephtalate) foils for use in OLED displays. This most versatile printing approach to TCO coatings allows the deposition of both homogeneous large-area coatings and patterned structures and can also be used in a web coating process. Depending on the ITO solid content and the rheology of the coating paste, homogeneous coatings with a thickness ranging from less than 100 nm up to 1 μm can be realized with a sheet resistance down to a few kohm/sq. The presented research work is part of a EC-funded project on the roll-to-roll manufacturing of OLED displays on flexible PET films ('ROLLED'), in which the ITO is acting as the hole-injection layer (anode) with a target sheet resistance of 500 ohm/sq. The fundamental advantages and drawbacks of the ITO nanocomposite coatings compared to sputtered ITO and conducting polymers like PEDOT will be addressed.

5963-51, Session 11

Optical and mechanical properties of RLVIP Nb2O5-films

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Nb2O5-films were deposited on unheated glass, fused silica and silicon substrates by reactive low-voltage ion plating RLVIP.

Optical as well as mechanical data and environmental stability of the films are influenced remarkably by deposition parameters as e.g. arc current, deposition rate, gas composition and total gas pressure.

It was found out that arc currents around 40A, gas mixtures with high amount of oxygen and deposition rates between 0,1 and 0,7 nm/s yielded the best results. Refractive index was calculated from spectrophotometric intensity measurements of the constrained amorphous and homogeneous films. Residual optical absorption k in the films high transmittance range was determined by photo-thermal deflection spectrometry. Mechanical stress, for dense films always compressive, was measured by deformation of coated thin silicon discs.

Typical values obtained are n550 = 2,39-2,40, k515 = 2,5 x 10-4, σ = -30MPa. Detailed information will be presented in tables and diagrams.

5963-52, Session 11

Chemical vapour deposition of optical coatings onto small scale complex optical components

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Chemical vapour deposition (CVD) offers a non-line of sight deposition method well suited to economical coating of 3D micro-optical components. In CVD a thin solid film on a surface is synthesised from the gaseous phase as a result of chemical reactions occurring at the gas/surface interface. It is this reactive process which distinguishes CVD from line-of-sight physical vapour deposition (PVD) processes. The prime benefit of CVD arises from the fact that the deposition process occurs by a molecular reaction on the substrate surface and consequently is non line-of-sight which means that it is possible to coat intricate solid shapes, such as spherical and cylindrical lenses, with layers that are of uniform thickness and composition. Moreover, non line-of-sight deposition also enables simultaneous coating of opposite substrate surfaces thereby providing no stress induced distortion of substrate optical form. It also allows enhancement of product throughput. All this is in contrast with PVD processes where the deposition is line-of-sight, which precludes the possibility of coating 3-D objects uniformly without complex movement of either the substrate and/or the deposition source. Furthermore, in a CVD reactor the environment is generally cleaner with less contamination by dust than in a PVD reactor, since precursors are in the vapour phase in the reactor as opposed to nano-particulates from solid material evaporation sources, and this allows better control of product cosmetic quality. Results are presented of CVD application to high cosmetic quality, anti-reflection coatings, blocking filters and deep-UV coatings, deposited onto a range of small scale optical components.

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5964-01, Session 1

2.5Gbit/s fiber receiver with integrated PIN photodiode in low-cost 0.6μm BiCMOS

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In resent publications we presented PIN photodiodes with a bandwidth of 600MHz implemented in low-cost 0.6μm BiCMOS technology. A new method to increase the response time of these PIN photodiodes is proposed here. This method was applied to design an optical fiber receiver with a maximum possible data rate of 2.5Gbit/s. In addition to the PIN photodiode attached to a transimpedance amplifier it also includes a decision circuit and a 50Ω output driver. The measured bandwidth of the receiver of 1.90GHz is sufficient for 2.5Gbit/s. At an optical wavelength of 660nm, a sensitivity of -17.0dBm was measured. At a supply voltage of 5V, the power consumption of the complete receiver is 171mW, from which the output driver requires 128mW. The overall chip size is 1154μm times 727μm.

5964-02, Session 1

Status of AlGaN based focal plane arrays for UV solar blind detection

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The fast development of nitrides has given the opportunity to investigate AlGaN as a material for ultraviolet solar blind detection. These detectors present both an intrinsic spectral selectivity and an extremely low dark current at room temperature in contrast to technologies based on photocathodes, MCP intensifiers, back thinned CCD or hybrid CMOS focal plane arrays. This spectral properties are analysed in regards to the sharp cut off required for solar blind detection around 290nm, and we will quantify how the stringent difficulties to achieve solar blind filters can be reduced. The alloy fluctuations are the only limitation to the sharpness of band edge cut off. Rejection of visible light is limited by internal photoemission in Schottky contact and can reach more than six decades. We also investigated the electrical capabilities of Schottky diodes or Metal-Semiconductor-Metal (MSM) technologies to detect extremely low UV signal. The large responsivity of Schottky or p-i-n diodes at zero bias is an advantage for re-use of standard infrared readout circuits, but their capacitance (200fF for 30μm pitch) is a drawback for extremely low flux. On the contrary, MSMs present a lower capacitance and are adapted to Capacitive Discharge Mode already used for astronomy applications. This readout design will be compared to Capacitive Trans Impedance Amplifier approach. Among focal plane arrays achieved, we will especially present results from a linear array based on a CCD readout multiplexor providing built-in integration, multiplexing and delayed read out capabilities.

5964-03, Session 1

Fast-operating focal plane array of a 128x128 elements format on the basis of InSb with the frame-accurate accumulation and function of a range finder

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Infrared imaging systems of a second generation on the basis of two dimensional arrays (TDA) have the best dimensional parameters and smaller power consumption first of all due to the absence of a optical scanning system. Besides they have very high spatial resolution and good threshold performances due to integration of a photocurrent. On a spectral range 3-5 μm both monolithic focal plane arrays (FPA) on the basis of PtSi TDA and hybrid one on the basis of indium antimonide and CMT, semiconductors with intrinsic photoconductivity, were developed. PtSi TDA have low quantum efficiency that does not allow to achieve high sensitivity and high frame frequency simultaneously. The hybrid FPA consisting of a TDA from InSb or CMT photodiodes and Si readout and integrated circuit (ROIC), jointed more often by means of indium microbumps have high quantum efficiency and an acceptable level of background currents that allows to have simultaneously high frame frequency and high sensitivity. However, the realization of hybrid version requires the solution of some the complex technological problems, basic of which are: development of a photodiodes TDA having high quantum efficiency under backside illumination and maximum compensation of thermomechanical stresses originating because thermal expansion coefficient difference of TDA and ROIC; development of technology of indium microbumps and hybridization of TDA and ROIC; development of ROIC with the broad functional capabilities.

We developed the version of TDA with the thin basic area which largely removes influence of thermomechanical stresses on indium microbumps. Developed TDA contains supporting a silicon substrate with 3÷5 μm AR coating on which by means of cryogenic adhesive layer the TDA of photodiodes with the thin n-type base is fixed. Reversed I-V characteristics of TDA photodiodes were investigated on connected by indium microbumps TDA and ROIC with pixel size 30x30 μm2 .It was found that the bigger the number of diode from the TDA center the greater dark current, but for TDA with thick base region this dependence is weaker. As a rule, TDA's with thin base region have greater dark currents. The existence of thermomechanical stresses in TDA may be one of reasons of such I-V characteristics.

The ROIC of format 128x128 elements with pixels size 35μm using 1.2μm CMOS rules were fabricated and investigated. The method of direct current injection was used as simplest in realization. requirement. It was been found that over the currents range I = (10-12ë10-8) A the incremental resistance of input transistor channel Rch and current I are connected by ratio Rch= mkT _ I-1 (m=1,2ë2), that ensures injection ratio h\@1 at a background currents of diode Id\@(2ë5) _10-9 A under an incremental resistance of TDA photodiodes Rd\@109 Ohm. The digital part of ROIC consists of the horizontal register and the vertical register and provides continuous reading signals from accumulation capacities (a thermovision mode) and a mode of a range finder, when reading is manufactured from a central zone of a format 4Hx2V. For a maximum frequency of frames as in a thermovision mode, and a range finder, information is readouting on four outs at a maximum clock frequency not less than 4 MHz. Power supply voltage of ROIC equally 5V and power dissipation less then 30mW. ROIC contains metallized areas for formation of indium microbumps.

The FPA performance were measured at operating temperature 80 K and background flux restricted by cool diaphragm with aperture 2q=40°.Micro cryogenic system based on the gas cryogenic machine was used for cooling. The output signals were measured by quick-operating 10 MHz 14-bit AD converter with own noise less than 10-4 V. The noise voltage was calculated using not less than 32 samples.

It was found that averaged voltage sensitivity Svl linearly depends on integrating timeTi for 4 _10-4 s‹Ti‹1.4 _10-3 s and it maximum was Svl.=6*10 VW- The dispersion of voltage sensitivity was not more sv‹15% The averaged value of background current was Ib=2.5 _10-9 A.

The measured total voltage noise by the factor 1.5 was larger than the background limited one. Meas Minimum value of noise equivalent power was (5 ë7) _10-13 W/ pixel at Ti=1.4 _10-3 s. ured voltage noise dispersion was sn‹25 %.

Minimum value of noise equivalent power was (5 ë7) _10-13 W/pixel at Ti=1.4 _10-3 s.

5964-04, Session 1

Zinc diffusion process investigation of undoped InP

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InP/InGaAs-based devices are key in space qualified near-infrared detectors.The difficulty in InP based optoelectronic fabrication technology is concluded in the change of InP properties because of the defects as a result of phosphorus atoms evaporation from InP. This bring about surface degradation, deterioration in electrophysical parameters and reliability of devices.At the same time,the widely-used ion implantation technique appears to be not effective in fabrication InP/InGaAs-based devices that require deep junctions and very low leakage current. So Zn diffusion by sealed ampoule is a good choice for InP/InGaAs-based devices. But its reproducibility is decided by severel reasons ,such as the diffusion temperature and the quantity of the diffusant .In this paper, Zn or Zn3P2 is used as diffusant for undoped InP material.The effect of the quantity of the diffusant on the junction depth with diffusion time and the volume of the quartz ampoule kept constant has been studied.The experiment shows that there exists a certain value of the quantity.When the quantity of the diffusant is more than this value, the junction depth is independent of the

quantity.But when the quantity is less than the value, the depth decreases greatly. Moreover, the certain value increases with temperature increased. After diffusion, secondary ion mass spectrometry (SIMS) and electrochemical capacitance-voltage were used to examine the zinc diffusion profiles and the hole concentration profiles.The diffusion coefficients of zinc at different temperature are obtained. At last,the diffusion mechanism is also explained.

5964-05, Session 1

Comparative analysis of low-doped bulk, MBE and LPE grown n-HgCdTe material and photoconductors based on it

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Low-doped n-Hg1-xCdxTe (0.18 ≥ x ≥ 0.35) thin layers (3-10 μm) with electrons concentration n(77K) ≈(1-10)x1014 cm-3 are widely used for manufacturing of high performance both small-pitched and large active area photoconductors covering spectral range from 3 to 20 μm and designated for thermal imagery and spectroscopy applications. Low-doped layers of n-Hg1-xCdxTe (0.20 ≥ x ≥ 0.65) with electron concentration n(77K) ≈ (0.5-5.0)x1014 cm-3 are called for manufacturing of advanced PV arrays with p-on-n photodiodes and two/three colors PV arrays based on multilayer epitaxial structures covering spectral range from 1.5 to 15 μm. Evidently high-purity low-doped n-Hg1-xCdxTe material grown by advanced bulk crystallization can be considered as reference for other growing techniques like as LPE or MBE because its electro-physical and photoelectrical properties responds theoretically predicted and uniform level of electrons concentration n(77K) ≈(1-3)x1014 cm-3 is reached easily. Comparative analysis of electro-physical and photoelectrical properties of high-purity low-doped n-Hg1-xCdxTe material grown by advanced bulk crystallization, LPE and MBE is presented. Capacitance-voltage (CV)-technique applied to array of MIS structures formed on examined surface of the layer was used for determination of conductivity type, total concentration of ionized impurities and level of compensation. Typical doping concentration profiles in innovative Hg1-xCdxTe epitaxial material were examined and presented. Electro-optical measurements on fabricated photoconductors showed significant improvement in responsivity and low-frequency noise spectrum on photoconductors made of epitaxial material in comparison with bulk devices. Physical aspects of low-level doping by donors are discussed.

5964-06, Session 2

The third generation cooled IR detector approach in France

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InfraRed (IR) detectors are produced at mass level for second and second and half generations systems. Reliability and cost issues are more and more of first interest and to answer these needs SOFRADIR is offering new products with an increase in reliability and a decrease in cost. These new products are based on new technological steps developed for preparing the third generation IR detectors. As a matter of fact, SOFRADIR is working with CEA-LETI/LIR in the frame of DEFIR (Design Excellence For InfraRed), on the third generation R&D mainly based on HgCdTe material growth by MBE. This process on alternative materials like Germanium, are in position to replace CZT homo-substrates and to compete with other material candidates. This enables very larger wafer size (4" and more) with a well-mastered thickness of the sensitive thin film deposition leading to very low cost 2D MCT arrays. In addition multi spectral arrays including advanced photodiode technologies are developed thanks to the MBE process.

5964-07, Session 2

Low-energy inductively coupled plasma etching of HgCdTe

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The high-density inductively coupled plasma etching technique has been applied to HgCdTe, while using the RF-powered wafer electrode to provide low plasma energy. By using a CH4/H2/N2/Ar chemistry the HgCdTe etch profiles were studied as a function of mask selectivity, chamber pressure, gas ratio and ICP power. The etch rate was found to decrease as etch depth increasing. The LBIC and I-V measurement were used to investigate the electrical damage of HgCdTe material caused by plasma bombardment .

5964-08, Session 2

Short wavelength Hg1-xCdxTe infrared detectors prepared by loophole technique

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Short wavelength Hg1-xCdxTe infrared detectors were novelly fabricated by loophole technique basing on the Liquid Phase Epitaxial material, rather than the conventional ion implantation technology. The substrate material is p type doped by the Hg vacancy. The formed sensitive area is an annulus centered on the circular junction. The dimension of the annulus depends on the diffusion lengths of minority carriers in both the “p”and “n” regions. Laser Beam Induced Current (LBIC) signals by the Scan Laser Microscope measurement were used to determine the key parameters such as the minority diffusion length, the size of both the n type and p type regions as well as the information of uniformities of the arrays. Good uniformities were observed for the 4Å~4 HgCdTe photovoltaic arrays from the LBIC signals, furthermore, the exponential decays in LBIC signals showed the average minority carrier diffusion length in p type substrate was around 9 micron, and the average diameter of the n type annulus was 17 micron. The I-V measurement for the arrays showed the average Ro was around 1.2E9Ω, then the zero bias dynamic resistance junction area product RoA can be calculated to be average 6.4E3Ωcm2 for the measured 4Å~4 arrays. Further investigations have been made for the Electro-optical characteristics. Infrared response spectrum measurement results showed the peak wavelength lay around 2.2 micron and cutoff wavelength about 3.5 micron under temperature 77K, the average black detectivity D* was 4.44Å~1010cm Hz1/2W-1. It can be expected better performances by optimizing the loophole technique and choosing the suitable parameters of materials.

5964-09, Session 2

MWIR and LWIR detectors based on HgCdTe/CdZnTe/GaAs heterostructures

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In our report we present a review of the investigations of MWIR and LWIR focal plane arrays (FPA) operating in photoconductor (PC) and photodiode (PD) modes on the basis of novel HgCdTe (MCT) heterostructures (HS) grown by molecular beam epitaxy (MBE) on GaAs.

The linear MWIR and LWIR photoconductors (PC) have been fabricated using specific n-type MCT HS with the widegap graded layers at boundaries of an active layer. PC detectors of a different format (2´16, 2´32, 1´128) and pixel sizes were fabricated by laboratory and FGUP “Alpha” enterprise technologies. The parameters of LWIR PC (50´50 mm) are compared with the best ones over the world: 100 - 300 W impedance per square (variation of the active layer thickness in range of 4 - 11 mm); up to 2´105 V/W (7´105 V/W in peak of Rv); D* near the background level; very low frequency of 1/f noise level. The Rv of MWIR PC is reached up to record value of 3´104 V/W.

P-type MCT HS with have been used for fabricating different format MWIR and LWIR PD FPA’s (128Å~128, 320Å~240, 320Å~256, 1Å~576 and 4Å~288) on the basis of planar low temperature technology combined with B+ ion implantation. Our calculations and experimental results showed that the presence of widegap graded layers at boundaries of active layer improved the parameters of n+-p junction (sharply decreases the surface recombination of photogenerated carriers and surface leakage current). An additional narrow gap layer at the interface sharply decreased the series resistance that is needed for fabricating large format FPA’s and heterodyne type detectors.

The requirements to parameters and architectures of MCT HS’s for improved IR detectors have been met by numerical physical-chemical scientific and industrial investigations at developing MBE growth of MCT on “alternative” substrate.

5964-51, Session 2

High-resolution FPAs on MBE-grown HgCdTe/CdTe/Ge

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Owing to its bandgap tunability and superior performance in high-end applications, HgCdTe (MCT) is now the material of choice for infrared detection both in the middle wave infrared (MWIR) and the long wave (LWIR) atmospheric windows. MCT grown by molecular beam epitaxy (MBE) is set to become increasingly important for advanced single and dual-band detection for a variety of commercial and military uses. In view of the challenges posed by commercialization, it is imperative to increase both the growth and device fabrication yield, in order to reduce costs. The trend is therefore to increase substrate areas, as well as to improve on the current device fabrication methods. In the past years, our laboratories have been pursuing both objectives. Here, we report on the progress achieved in the MBE growth of 3" and 4" MCT on CdTe(211)B/Ge composite substrates,

and the subsequent fabrication of high performance FPAs.

Device-quality 3" MCT layers are grown routinely on a Riber 32P reactor, equipped with custom made effusion cells that ensure an excellent compositional uniformity and run-to-run reproducibility. This chamber runs now in a semi-production mode. In addition to this, we have recently acquired a commercial 5" MBE machine, equipped with a spectroscopic ellipsometer (SE), and retrofitted with a custom-made manipulator which allows an excellent control of the growth temperature. The growth of CdTe on 4" Ge(211) follows a standard recipe, whereby a thin layer of Zn is laid between the substrate and the epilayer to preserve the orientation. The layers are then characterized ex-situ, and subsequently reintroduced into the growth chamber for MCT deposition. After oxide stripping, MCT is grown using a standard set of effusion cells, while the composition is monitored by SE. We believe the temperature to be reproducible run-to-run within better than ±2ºC. We will report on the quality of both the CdTe and the MCT layers that we fabricate in the two reactors. This will include a discussion of X-ray diffraction results, and ex-situ and in-situ ellipsometry data. In particular, we will see that all CdTe layers are characterized by an excellent crystalline perfection, yet their surface morphology varies from run to run. The reason for this is still being debated. We will also focus on the importance of in-situ SE, the one tool that is capable of picking up all of the mentioned characteristics correctly.

The LETI has recently presented results on a 128x128 dual-band MWIR FPA based on MBE-grown MCT/CdTe/Ge. Such results showed that CdTe/Ge is a viable alternative to lattive-matched substrates, in spite of the obvious shortcomings of the former in terms of dislocation density. On the other hand, the development of large-area 1024x1024 MWIR FPAs was demonstrated only using LPE-grown material on lattice-matched CdZnTe. It has now been possible to realize both a 1024x1024 and a 1280x1024 MWIR FPA prototype on 3" CdTe/Ge, the latter in collaboration with Sofradir SA. Their characteristics will be examined in detail in light of the most recent advancements in the field. These breakthrough results paves the way to further investments in the MBE growth of MCT on CdTe/Ge composite substrates.

5964-53, Session 2

Four-band infrared detector for FY-2C application

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Four band HgCdTe infrared(IR) detector is developed for the first operational Chinese geostationary meteorological satellite FY-2C lounched on October 19, 2004. As the Visible Infrared Spin-Scan Radiometer (VISSR) is the primary payload on FY-2C, the IR detector is one of the most important modules for such an imaging instrument. Compared with its predecessors FY-2A and FY-2B(experimental models, lounched in June 1997 and June 2000), the detector used in FY-2C is quite different in band selection and detector package. The four band IR detector for FY-2C application consists of four photoconductive(PC) detector chips made of Hg1-xCdxTe with different compositions x , corresponding to the wavelengths of 3.5 to 4.0μm, 6.3 to 7.6μm, 10.3 to 11.3μm and 11.5 to 12.5μm respectively. Four cooled IR filters are included in one detector package, which enables us to simplify the system without any IR beam splitters and IR filters outside the detector for defining separate bands. The IR detector operates at radiative cooler temperature ranging from 92 to 102K. This paper reviews the specification process, design, testing, and packaging for the four band IR detector used in FY-2C satellite. The performances and related aspects of this detector are also presented.

5964-10, Session 3

Far-infrared and submillimeter photosensitive devices based on Pb1-xSnxTe‹In\› films: results and perspectives

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Deep cooled high detectivity far IR (red cut off about 20-25 micrometers) multielement PbSnTe (LTT) photosensitive devices (PD) use the unique properties of LTT (x=0.24-0.28) doped with In up to 1-3 at. % [1]. The first of them is extremely low conductivity in darkness which is close to intrinsic one down to T=20 K and lower. The second is a very high lifetime of photoexcited charge carriers - up to seconds, minutes and even hours. This allowed us to fabricate PD with NEP‹2.10^(-18)

W/Hz^(-0.5) (T = 7 K).

Nevertheless, the nature of unique properties of the narrow gap LTT mentioned above is not still clear till now. For the first time we present the detailed analysis of the well known LTT‹In\› characteristics and of several late experimental results based on a concept of a narrow gap semiconductor LTT like an isolator. The roles of injection current and space charge in the presence of traps are analyzed in darkness as well as under illumination. The model described explains well photocurrent “switch off” by shot impulse of strong electrical field.

Ferroelectrical properties of LTT are taken into account to describe temperature dependences of darkness conductivity and photoconductivity. Both the experimental results on photodielectric effect (dependence of low frequency permittivity on illumination) [2] and presented model allowed us to explain the submillimeter sensitivity of LTT [3, 4] as “photoinjection currents”, i.e. as a consequence of dependence of injection current on permittivity and permittivity - on submillimeter illumination.

The experimental results on PD operating at T»30 K are given including PD on LTT/Si. Perspectives of multielemental LTT/Si arrays for the far IR and submillimeter optical regions are analyzed.

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5964-11, Session 3

A parallel analogue-digital photodiode array processor chip with hard-wired morphologic algorithms

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We present a chip, which is suited for applications in data-communication areas as well as in image-processing applications.

Through the combination of parallel signal gathering and processing, we save components and we can increase the processing rate.

We think thereby on problems like the so-called “interconnection crisis”.

On the other hand we direct our attention to data-parallel applications which are characterised by high bandwidth requirements.

To ful-fil these requirements we transfer binary data matrices of optical signals with a fibre array.

Our prototype chip receives an optical matrix of size 6´6. The chip has a structure as follows.

Every processor element contains an optical detector, a transimpedance amplifier and a comparator. A digital logic is directly connected to these components. This logic realizes the programmable processing of the signals.

This structure is also called Smart Pixel. Every processor element communicates to their neighbours over a NEWS-network, i.e. each processor element is connected to its four direct orthogonal neighbours within the processor array.

The digital parts consist of a special processor. It realises simple hard-wired image algorithms. As an example for cooperation of the analogue and digital part we have implemented some morphologic operations.

Because of its structure it is indicated as a so-called SIMD-Architecture. Over a VHDL description we have synthesized an area-saving logic of only 120x120 μm(c)˜.

It consists of only 19 logical cells including storage.

It was placed beside each analogue part. Our receiver consists of a 8´8 photodiode array. A data rate of 625 Mbit/s for an average op-tical power in the range of 25 μW to 500 μW is possible for a bit-error-rate of 10-9 per channel.

Signal processing limits the frequency to 200 MHz for a processor element according to simulations. Using an image with a size of 6*6 according to parallel data transfer a data throughput of 7.2 GHz results.

5964-12, Session 3

Restitution of technological parameters on a 320-240 MCT LWIR focal plane array by optical technique

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Evaluation of technological parameters is important to check the fabrication process and to optimize the optical and electronics characteristics of detectors. By measuring the spectral response of detectors with a high resolution, it is possible to display small optical effects. With radiometric models of detectors we can understand their physical origins and determinate certain technological parameters.

Recently we have developed a new test bench which provide spectral response of mono, linear and array infrared detectors by a Fourier transform spectrometer. We will present it and so the treatments of data. Experimental results will be presented on a special 320´240 MCT LWIR focal plane arrays (FPAs) and its associated radiometric model.

5964-13, Session 3

Uncooled microbolometer detector: recent development at Ulis

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This paper reviews ULIS'progress, on 35μm pitch, in amorphous silicon uncooled microbolometer focal plane (UFPA) technology and product development over the last year. ULIS FPA products are largely described, including product capabilities and above all complete EO performances. At a 60Hz frame rate, focal planes with a 40mK (f/1) NETD are now achieved in production with a spatial fixed patter noise lower than 25mK after sensor level gain and offset compensation. Key improvements, compared to 45μm pitch technology, have been the achievement of microbolometer resistance uniformity better than 0.15% (standard deviation) on the IRFPA die for the different formats. Thanks to a new pixel design, a high fill factor has been kept, a not too high thermal time constant (7ms) has been obtained to make

35 μm components a prime candidate for high FLIR applications

5964-14, Session 4

Improvement of the dynamics of the bolometric detector working with high sensitivity

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The dynamics of the bolometric detector is constantly being improved, which is a direct result of the technological development of microbolometers elements production. It takes place through the reduction of surface covered by a single pixel. In this article, however, alternative techniques of compensating the irregularity of the FPA have been presented. They make it possible to improve the dynamics of the detector, and - in a more advanced version - to implement the initial NUC inside the detector in the read-out circuit. The article presents one of the possible ways of its realization; namely by means of modifying the read-out circuit of the detector. A considerable attention has been paid to the detector operating in applications requiring high sensitivity, where the compensation gives the best results. In such cases, an improvement of the dynamics up to 40% of the measurement range is assumed. The article contains results of measurements of the detector system after modification, simulated on data coming from real detectors with the resolution 320 x 240 and pixel size 45 um x 45 um (ULIS company).

5964-16, Session 4

PIN-photodiode based pixel architecture for high-speed optical distance measurement systems

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Contact-less optical distance measurement systems are necessary to obtain 3D-information of an entire scene. To be able to determine depth information of the scene by a sensor without moving parts e.g. scanner, it is necessary to measure the distance from the camera to an object in every single pixel. A new pixel for such a 3D-camera is presented. The operating principle is based on the Time-of-Flight (TOF) of laser light from a modulated light source to a diffuse reflecting object and back to the receiver IC. The receiver is implemented as an opto-electronic integrated circuit (OEIC). It consists of a fast, effective PIN-photodiode having a 3dB bandwidth of about 1.35 GHz, a single-stage transimpedance amplifier and an electronic mixer on a single silicon chip. By correlating the received optical signal and the original electronic modulation signal, the phase-shift between sent and received signal can be determined. By performing correlation with a delayed modulation signal it is possible to eliminate the influence of object reflectivity and background illumination. The measurement time for a single distance measurement is only 500μs for a range up to 3.5m. The standard deviation at 3.5m is better than 3cm for a transmitted optical power of 1.5mW at a wavelength of 650nm. The OEIC was fabricated in a slightly modified BiCMOS 0.6μm process. The diameter of the photosensitive area of the integrated PIN-photodiode is 100μm. The effective pixel size is about 220x400μm(c)˜. Therefore a fill factor of ~9% is reached.

5964-17, Session 4

Signal processing for a single detector MOEMS based NIR microspectrometer

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The examination of spectra in the NIR range is needed for applications like process control, element analysis or medical. Typical integrated NIR spectrometer are based on optical setups with diffraction grating and detector arrays. The main disadvantage is price and availability of NIR array detectors.

The implementation of a scanning grating chip realized in a MOEMS technology which integrates the diffractive element makes it possible to detect spectra with single detectors time resolved. Either simple InGaAs photodiodes or cooled detectors may be used.

The setup is a shrinked Czerny-Turner spectrometer. The light is coupled in by an optical fibre. After focussing the light passes the scanning grating moving at 500 Hz in a sinusoidal way. There it is split off in the different wavelength, the monochrome intensity is caught by a second mirror and led to the detector.

The detector signal is amplified by a transimpedance stage and converted to digital with 12 bit resolution. The main part of the signal processing is done by a digital signal processor which is used to unfold the sinusoidal position and calulate the final spectra. The data rate is 3 MHz, a spectrum is acquired every 2ms.

Using the DSP, the spectrometer can operate autarc without any PC. Then the spectrum is display on a 160 x 80 pixel graphic LCD. A keypad is used to control the functions. For communication a USB port is included, additional interfaces canbe realized by a 15 pin port which is freely programmable by the system firmware.

5964-18, Session 5

An intelligent error correction method applied on an active pixel sensor based star tracker

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Star trackers are opto-electronic sensors used on-board of satellites for the autonomous inertial attitude determination. During the last years star trackers became more and more important in the field of the attitude and orbit control system (AOCS) sensors. High performance star trackers are based up today on charge coupled device (CCD) optical camera heads. The active pixel sensor (APS) technology, introduced in the early 90-ties, allows now the beneficial replacement of CCD detectors by APS detectors with respect to performance, reliability, power, mass and cost.The company's heritage in star tracker design started in the early 80-ties with the launch of the worldwide first fully autonomous star tracker system ASTRO1 to the Russian MIR space station. Jena-Optronik currently develops an APS based autonomous star tracker "ASTRO APS" as successor of the CCD based star tracker product series ASTRO1, ASTRO5, ASTRO10 and ASTRO15. The key features of the APS detector technology are a true xy-address random access, the multiple windowing read out and the on-chip signal processing including the analogue to digital conversion. These features can be used for high accurate star tracking at high slew rates and under worse conditions like stray light and solar flare induced single event upsets. Special algorithms have been developed to manage the typical APS detector error contributors like fixed pattern noise, dark signal non-uniformity (DSNU) and white spots. These algorithms work fully autonomous and adapt to e.g. increasing DSNU and up-coming white spots automatically without ground maintenance (re-calibration). In contrast to conventional correction methods the described algorithm does not need calibration data memory like full image sized calibration data sets. The usage of the presented algorithms to manage the typical APS detector error contributors is a key element for the design of star trackers for long term satellite application like geo-telecom.

5964-19, Session 5

An analytical method to find the optimal parameters for gas detectors based on correlation spectroscopy using a Fabry-Perot interferometer

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Several designs of infrared absorption based gas detector use a Fabry-Perot Interferometer (FPI) to modulate the incident light. In these systems, generally the FPI's fringes are matched with very well defined rotational absorption lines of a target molecule such as CO_2, CO, N_2O, CH_4, etc. In order to obtain modulation the cavity length of the FPI is scanned over one

half of the reference wavelength. In this work, we present a simple analytical method based on the Fourier Transform that describes the performance of these systems. Using this method the optimal reflectivity and optical spacing of the FPI can be determined. Furthermore, the modulated signal generated by the system as a function of the cavity length scan can be calculated by applying the inverse Fourier Transform. Finally, this method describes the underlying reasons why for some filters the background amplitude is severe, and gives guidance on the choice of optimised filters. Our method evaluates the optimal FPI parameters and the modulated signal much faster than the direct numerical computation which is used currently. Simulation results for different molecules in combination with diverse filters shapes are presented, with a comparison to directly computed results, as well as some experimental data.

5964-20, Session 5

Bessel beam based optical profilometry

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We present new schemes for nondestructive optical profilometry of cylindrically and conically shaped surfaces by using spatially matched Bessel light beams.

The detailed analysis of the refractive axicon, a basic optical element of two types of profilometers (based on Mach-Zehnder and Mickelson interferometer), has been carried out.

The principal source of distortion of the output field of the profilometer has been detected by numerical simulation and also experimentally. It originates from the diffraction of the input beam in a region close to the vertex of the axicon. For elimination of the indicated distortion of the output field an approach has been proposed based on the illumination of the axicon by the ring beam instead of the Gaussian one. The required ring-shaped (Laguerre -Gaussian) field has been obtained using the astigmatic mode converter. The designed scheme for the beam shaping and forming the ring field proved its efficiency and can be used in various profilometers. The important feature of the profilometers proposed, in contrast to known ones, is the possibility to control their sensitivity and resolution. For this purpose the scheme of tuning the cone angle of the Bessel beam over a wide range is proposed. The advantage of the operation regime of the profilometer characterized by nonzero spatial frequency of output signal is specified. It consists in the possibility to apply a relatively simple and effective algorithm for the interpretation the output signal. This algorithm implies the calculation of the azimuth spectrum, which characterizes the deviation of tested profiles from the circular ones.

5964-22, Session 6

Diffuse optical tomography with an amplified ultrafast laser and a single-shot streak camera: application to real-time in-vivo songbird neuro-imaging

H. Guillet de Chatellus, Univ. Jean Monnet Saint-Etienne (France); C. Vignal, Univ. Jean Monnet Saint-Etienne (France) and Univ. Paris XI (France); S. Ramstein, S. Mottin, Univ. Jean Monnet Saint-Etienne (France); N. Mathevon, Univ. Jean Monnet Saint-Etienne (France) and Univ. Paris XI (France)

Imaging in diffuse and absorbing media (brain tissues in particular) requires the implementation of original optical techniques (micro-endoscopy, confocal microscopy, Optical Coherent Tomography, Diffuse Optical Tomography (DOT)). The latter is currently the only way of reaching few millimeters depths below the surface. Taking into account both temporal and spatial aspects of reflectance lead us to implement what we believe to be the first in vivo time-and space-resolved real time DOT set-up where the absorption and diffusion coefficients of the probed medium are deduced from the measurement of the transient response to a local and temporal “Dirac” excitation light pulse. An ultrafast white light continuum generated by a chirped pulse amplified Ti :Sa system (830 nm, 1 kHz, 300 mW, 150 fs; Thalès) is sent on the surface of the medium by a fiber. An imaging set-up conjugates a 5 mm long and 70 mm wide segment on the surface of the medium located 5 mm apart from the source fiber, with the entrance slit of a single-shot streak camera (Streakscope, Hamamatsu). An interference filter (centered at 700 nm, 10 nm FWHM) is used to select the spectral window of analysis. The picosecond dynamics of the photons time of flight is monitored at a video rate.

Non-invasive in vivo measurements were performed on five anaesthetized male songbirds (Zebra Finch) to probe an auditory brain region (Caudomedial Nidopallium). The blood oximetry linked to the cerebral activity is deduced from the monitoring of diffusion and absorption parameters through the intact skull and skin, under various stimulations (hypercapnia, acoustic stimulation).

5964-23, Session 6

Technical challenges for the construction of a medical IR digital image database

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Infrared thermal imaging was first made available to medicine in the early 1960’s. Despite a large number of research publications on the clinical application of the technique, the images have been largely qualitative. This is in part due to the imaging technology itself, and the problem of data exchange between different medical users, with different hardware. An Anglo Polish collaborative study was set up in 2001 to identify and resolve the sources of error and problems in medical thermal imaging. Stardardisation of the patient preparation, imaging hardware, image capture and analysis has been studied and developed by the group. A network of specialist centers in Europe is planned to work to establish the first digital reference atlas of quantifyable images of the normal healthy human body.Further processing techniques can then be used to classify abnormalities found in disease states. The follow up of drug treatment has been successfully monitored in clinical trials with quantitative thermal imaging. The collection of normal reference images is in progress. This paper will specify the areas found to be the source of unwanted variables, and how the project is able to develop protocols to overcome them.

5964-25, Session 6

Improvement of EVS II versus EVSI

E. Grimberg, Opgal Optronic Industries Ltd. (Israel)

No abstract available

5964-41, Session 6

In-vivo optical tomography of corneal tissue based on the SHG and the multiphoton autofluorescence imaging excited by near-infrared femtosecond laser pulses

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In-vivo optical tomography of corneal tissue based on the SHG and the multiphoton autofluorescence imaging excited by near-infrared femtosecond laser pulses

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Abstract

The intratissue multiphoton autofluorescence imaging (MAI) and second harmonic generation (SHG) based on nonlinear absorption of femtosecond nanojoule laser pulses at wave length of 750-850 nm emitted from solid-state Titanium: Sapphire FemtoCut system have been used as a highly precise non-invasive tool to realize the in-vivo differentiation of the five layers of cornea according to the conventional histology with the help of the intratissue optical tomography and to visualize the keratocyte structure and collagen fibers with an order of sub-μm and μm resolution. Imaging based on multiphoton-excited autofluorescence and SHG formation of collage fibers come into being at GW/cm2 photon intensity in a sub-femtoliter intrastromal volume obtained by diffraction-limited focussing with a 40x objective (N.A.1.3 oil). This technology acting as a novel diagnostic system proved to be an essential tool to determine the interest of region before intrastromal nanosurgery, visualize and verify the outcomes immediately after the laser surgery performed with higher power of the same laser system. Additionally, we have observed the activated keratocytes in-vivo 48 hours after laser operation with this system.

5964-48, Session 6

Optoelectronic system for NO2 detection

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This paper presents the application of Cavity Ring Down Spectroscopy(CRDS) and Cavity Enhanced Spectroscopic (CES) techniques with blue laser diodes-based system for nitrogen dioxide (NO_2) detection. CRDS is a sensitive laser absorption technique, which basically consists of measurement of the decay time of a light pulse trapped in an optical resonator formed by two highly reflective mirrors. A short pulse, injected into the cavity reflects between the mirrors. After each roundtrip, the light transmitted through the output mirror is detected by photo receiver and monitored on digital oscilloscope. This allows the determination of the decay time. When

the cavity is filled with an absorber, the decay time is shorter in respect to the case when the cavity is empty. In this way, the absorption coefficient can be found. CES technique bases on integration of the light leaving theresonator. Since the integrated intensity is proportional to the decay time, the experimental signal can be related to the absorption. The minimum detectable concentration of absorber for a specific transition is inversely proportional to the effective sample-path length, and directly proportional to the minimum intensity fluctuation detected by a receiving system.:In presented system, the blue laser diode was mounted in a temperature-controlled housing. The temperature of the laser diode was controlled by a Peltier element. A mechanical chopper was used to modulate the beam. Modulated light transmitted through the cavity was focused onto a photomultiplier,H5783-03. The detector signal was then fed into a lock-in amplifier and a computer with a 16-bit data acquisition board.

5964-27, Session 7

Eye speed 300 system

T. Avigdor, Opgal Optronic Industries Ltd. (Israel)

No abstract available

5964-28, Session 7

Dual-band infrared camera

H. Vogel, H. Schlemmer, Carl Zeiss Optronics GmbH (Germany)

Every year numerous accidents happen on European roads due to bad visibility (fog, night, heavy rain). Similarly, the dramatic aviation accidents of year 2001, in Milan and Zurich, have reminded us that aviation safety is equally affected by reduced visibility.

Therefore Carl Zeiss Optronics GmbH developed a dual-band thermal imager to raise human situation awareness in conditions of reduced visibility especially in the automotive and the aeronautical context. In such a system cameras operating in spectral bands less obscured by reduced visibility condition (fog, night, haze) than the visible band produce an image which is then presented to the driver or the pilot.

Here the LWIR (Long Wave InfraRed, 7 to 12 μm) and the SWIR (Short Wave InfraRed, 0.8 to 2 μm or 1.3 to 2 μm) bands are used. These two bands are used because they often contain complementary information of the scene and are effected by different visibility limitations.

Because two images of the same scene are captured, before displaying to the driver or pilot the images are fused by using pyramidal fusion. This process is used to integrate complementary and redundant information from multiple images into a fused image that shows more and better information of the scene.

In the following example the LWIR image shows clearly the bending of the road, the exit to the large building on the left and more buildings ahead of the road but all sign posts, traffic signs and traffic lights are only to be seen in the SWIR image.

5964-29, Session 7

Aspects of paper characterization from on-line optical measurements

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A new framework is proposed for the analysis, detection, and classification of various imprints (variations) in paper, hidden in a real time series recorded on-line in a paper machine. These variations originate from parts in the paper machine such as the headbox, rollers, machine clothing and resonances in the machine foundation. Therefore it is important for the paper manufacturer to have tools and methods that can detect abnormalities in order to attain the desired quality of paper. The data acquisition is performed by scanning the paper web surface using different optical sensors, such as reflection, transmission and fluorescence sensors. The framework is based on a combination of the wavelet transform, principal component analysis (PCA) and a set of kernel based novelty detectors. Since the imprints are known to exist in different frequency regions the wavelet transform is used to decompose a time series into different time-frequency levels. The description dimensionality at each decomposition level is reduced by applying PCA. To decide whether a preprocessed data block is novel or not a committee of kernel based novelty detectors, exploiting signals from different sensors and different resolutions is used. The proposed framework has successfully been implemented for the detection of calendar barring in a paper machine.

5964-30, Session 7

Remote online processing of multispectral image data

C. Groh, H. Rothe, Univ. der Bundeswehr Hamburg (Germany)

Technological advances in digital imaging and liquid crystal tunable filters allow for a design of a both compact and cost effective multispectral camera system. Despite of their limited functionality (e.g. regarding calibration) in comparison with commercial systems such as AVIRIS the use of these upcoming compact multispectral camera systems can be advantageous in many applications.

Additional benefit can be derived adding online data processing. In order to maintain the systems low weight and price this work proposes to transmit pre-processed camera data online to a stationary high performance computer for further interpretation. The necessary data transmission has to be optimised because of bandwidth limitations.

All the mentioned considerations hold especially for applications involving mini-unmanned-aerial-vehicles (mini-UAVs). Due to their limited internal payload the use of a lightweight, compact camera system is of particular importance.

This work addresses the optimal software interface in between pre-processed data (from the camera system), transmitted data (regarding small bandwidth) and post-processed data (based on high performance computer). Discussed parameters are pre-processing algorithms, channel bandwidth, data latency and resulting accuracy in the classification of multispectral image data.

The benchmarked pre-processing algorithms include diagnostic statistics, test of internal determination coefficients as well as loss-free and lossy data compression methods. The resulting classification precision is computed in comparison to a classification performed with the original image data set.

5964-33, Session 8

Microbolometer-based infrared camera for the 3-5 μm spectral range

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Microbolometer cameras have yet been operated only in the long-wave infrared range (LWIR). Since microbolometers are now available with broadband windows and show acceptable absorption in the mid-wave infrared range (MWIR), they are becoming more and more interest for the MWIR range. Primarily for industrial applications, this wavelength range offers many advantages, e.g., for the measuring of glass temperatures or for fire room supervision.

The newly developed camera system is based on a LWIR microbolometer camera system with 320 x 240 pixels. The optical channel had to be adapted to the microbolometer. In addition, special correction and calibrating procedures were added for the MWIR.

The camera system is suitable for stationary use in harsh industrial environments. The robust housing may be completed by integrated water-cooling and air purge for the lens system. The camera is equipped with two trigger inputs for the synchronization with the process to be measured.

To achieve a sufficiently high measuring accuracy, such crucial MWIR peculiarities like carbon dioxide absorption lines and sunlight reflections must be known. Such problems can be avoided by usage of narrowband filters. Usually, they have to be adjusted to the particular measurement task. First results by the use of the MWIR cameras will be presented.

5964-34, Session 8

Uncooled camera application

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No abstract available

5964-35, Session 8

Hardware-software complex for chlorophyll estimation in phytocenoses under field conditions

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Vegetation is a sensitive indicator suitable for testing of ecological stresses and natural anomalies of the technogenic character. First, it is determined by the prompt response of photosynthetic apparatus to changes of environmental conditions, mainly by change of green pigment (chlorophyll) content in leaves. Second, the specific kind of a reflectance spectrum of leaves is due to chlorophyll presence in them, and the area in the range of 500-80nm is extremely sensitive to variations of pigment content. Thirdly, there are interesting results now concerning spectral properties of leaves and canopies obtaining with high-resolution spectroscopy. The data are high informative in relation to content of chlorophyll and some other biochemical constituents of a cell. The high resistance to various types of noises is inherent to methods developed on the basis of such spectral data.

We have developed a method for chlorophyll estimation using the 1-st derivative plots of reflectance spectral curves. The method gives good results for plant-soil systems with both 100% and incomplete projective covering as our simulation models show. Field measurements of chlorophyll content in closed and open canopies confirm the results.

A hardware-software complex has been produced by us for chlorophyll determining under field conditions. It consists of spectral and computing blocks. First of them is a two-beam spectrometer of high resolution supplied by a system to visualize of measured object. The irradiance and temperature sensors are included to the spectral block as well as GPS-receiver. The following technical characteristics are inherent to the block: spectral range 500-800 nm, band-pass 1.5 nm, field of view 16x160, scanning time 0.1-1.0 s, dynamic range of signal 1:1024 (10 bit), signal/noise ratio 400, amount of pixels in image 1240, range of estimated chlorophyll concentrations 1.5-8.0 mg/dm2, supply voltage 12 V, weight 8 kg.

Computing block is intended for spectral date processing to obtain chlorophyll estimations using our algorithm. The block is supplied by our original software WINCHL, which includes spectrum and algorithm libraries and various mathematical tools. Accumulation of reflectance spectra of various plants together with data of environmental conditions at measurements gives a good possibility to use all of them for future scientific researches and developing other important parameters of canopy status.

5964-37, Poster Session

Effects of surface processing on the surface properties of p-type Hg1-xCdxTe grown by LPE

Y. Shi, Y. Yao, J. Zhuang, Y. Cai, Kunming Institute of Physics (China)

Experiments were designed for analyzing the effects of the surface processing on the surface properties of p type Hg1-xCdxTe Liquid Phase Epitaxy films. Owing to the special surface characteristic of p type Hg1-xCdxTe material, it is easy to make conductivity conversion by surface processing such as the abrading, polish etc. Samples have prepared according to different surface processing conditions. Variable magnetic-field Hall measurement has been used to investigate the transport properties in the temperature range from 1.5 to 200 K. The experimental date were analyzed by using a hybrid approach composing of the mobility Spectrum(MS) technique followed by a Multi-Carrier Fitting(MCF) procedure. Fundamental properties such as surface charge density, bulk carrier density, surface mobility and bulk mobility were extracted from the calculated results. Apparently surface electrons existed for the all test samples judging by the temperature characteristic of surface electrons. Besides, surface electron density decreases for the passivated samples following by anneal processing comparing with the samples without anneal. In addition to this, the C-V measurement of MIS devices combining with different surface processing conditions was also used to analyze the effects. In the C-V measurement the applied bias to the annealing samples which samples can bear is larger than the unannealing samples, at the same time, the fix charge density in passivation layer of the annealing samples is smaller than that of the unannealing ones. The above results implied the surface charge density is reduced by the anneal treatment. It can be explained that anneal improve the surface status of Hg1-xCdxTe.

5964-38, Poster Session

The response time of GaN photoconductive detector under various ultraviolet-radiation intensities

J. Xu, Y. Tang, X. Li, H. Gong, Shanghai Institute of Technical Physics (China)

The persistent photoconductivity (PPC) effect was generally observed in many III-V compound semiconductors and it was always related to yellow luminescence. In this paper, the PPC effect in unintentionally doped GaN was investigated. The GaN photoconductive detector response time measured by changing the chopper frequency of modulator was studied under various ultraviolet-radiation intensities. The maximum value of UV intensities used in test was approximately 0.35W/m2. Experimental results show that the response time of unintentionally doped GaN PC detector is independent of the wavelength of the ultraviolet radiation, and it decreases with the increasing of UV radiation intensity. The longest response time getting in experiments was 7.64ms and the shortest 2.89ms. Fourier transformation and lock-in amplifier was used to reduce the noise at AC frequency of 50Hz and the results show that Fourier transformation was more effective to eliminate the low frequency noise. The experimental data fit the theoretical curve very well, better than the results reported previously. Finally, these phenomena were tried to be explained using a mechanism that minor carriers were captured by deep acceptors. The deep acceptors were deduced to be V_{Ga}^{---}-related complexes. In strong UV radiation, the photogenerated holes (minor carriers) were no longer captured by deep acceptors and the recombination opportunities with majority carriers were increased. Consequently the response time was reduced. The other possible reason was that there were metastable states which were related to Ga vacancy.

5964-39, Poster Session

Homogeneity of composition in evaporated Pb1-xGexTe thin films

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PbTe based semiconductors are well-known narrow gap IV-VI compounds, which are of interest due to potential application in the fabrication of photo-detectors in the mid- and far infrared spectral range. Among them, Pb1-xGexTe is known to have wider band gap than PbTe, which has been used to fabricate photo-detectors with shorter wavelength (λ<6.7 μm). However, the homogeneity of composition in Pb1-xGexTe thin films has not been investigated. In the paper, we report the result that the element profiles as a function of depth in evaporated Pb1-xGexTe layers measured with Auger electron spectroscopy in combination with argon ion sputtering.

5964-40, Poster Session

Design of MCT1024x1 short wave infrared thermal camera

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it is reported that the design of short wave infrared thermal camera based on MCT1024x1 . The optical system of this imaging system was briefly introduced By making use of three-transmission optical system ,the image quality was improved and the aberration is reduced, and by use of silicon and germanium material to avoid chromatism.In signal processing ,the Nonuniformity Correction (NUC) of IRFPA,examination and repairation of invalidation member, image enhancement,contrast improvement and realtime display IR were discussed. we developed a IR instrument .the main technic target is followed: optics calibre:90 mm, focus:270.6 mm, identifiaction ratio :170 urad, wave band:2-2.5um, the half period :5 second, NEΔP : 0.8%. while the design of the electrical system and the crux of the technique were described in detail .

5964-42, Poster Session

The research of microsized bionic insect vision exploration technology

P. Feng, S. Chen, Huazhong Univ. of Science and Technology (China)

The research of bionic insect vision has a feature of crossover of many subjects. It involves some rising subjects, such as biology, bionics, micro-optics, microelectronics, micro-machine, nervous network signal disposal, intelligent controlling, and so on.

The text represents the design, manufacture and integration technology research of every part of bionic vision sensor, investigates the main component of bionic vision system: micro-lens array, design and manufacture approach of crystalline cone, plan to utilize micro-optics technology and MEMS technology integrating the micro-lens array, crystalline cone array and photodiode array.

It represents internal and external developments first ,and then represents three steps of micro-lens' manufacture: photolithography, heat melt and etch, manufacture of crystalline cone by theory and experiment. Finally it presents the experiment result.

5964-43, Poster Session

Simple-laser microinterferometer for spaceborne measurements

G. M. Popov, E. Popov, Crimean Astrophysical Observatory (Ukraine)

Laser microinterferometer consists of laser, semitransparent mirror-microlens forming aberration-gree beam of light (reference beam), and analyzer beam , reflecting by mirror system to be tested. The analyzer beam is directed to viewing screen, or CCD, and it is recombined with the reference beam to produce a system of Twyman-Green fringes. Microinterferometer is very small, simple and lightweight, that is why it it is especially recommended for testing optics of the space telescopes in the Space.

5964-45, Poster Session

A demo-imaging system based on GaN UV detectors

Y. Huang, X. Li, H. Gong, Shanghai Institute of Technical Physics (China)

Gallium Nitride (GaN) UV detectors have become one of the most important UV detectors for much more compact, more robust, higher quantum efficiency and good stability in higher temperature environment than the traditional detectors. We can evaluate the quality of the detectors by detectivity, responsivity, Signal-to-Noise (the detector with read-out circuit), etc. Although these methods can analyze performance quantificationally, they are partial and indirect. The demo imaging system described in this paper provided a simple and more direct way as an assistant method. We can easily assess the performance of the detectors in actual application by the images obtained by the imaging systems and compare the uniformities of these detectors.

The system is mainly designed for 64x1 linear UV detectors (the band is 330nm ~ 365nm). It is composed of a precise scanner platform to provide 1-D wide field scan (it can be extended to 2-D if needed), UV telephoto optical system, signal transfers and processing system and the software. The detail design of these components is introduced. The images obtained by the system are also given at the end of the paper.

5964-46, Poster Session

Failure analysis of PC MCT caused by current

D. Liu, H. Gong, Shanghai Institute of Technical Physics (China)

Photoconductive Hg1-xCdxTe (MCT) detectors and arrays have been the workhorse for high volume production of first generation thermal imaging and sensor systems in both long- and mid-wavelength infrared bands of the electromagnetic spectrum regions for nearly three decades. For high quality MCT material and state-of-the-art device fabrication technology, MTBF of the detector even reaches higher than 10 years. So both obtaining failure data and getting the reliability of detector are very difficult, if not impossible, to obtain under normal operating conditions.

In order to accelerate their failures, a large constant bias current is applied to detectors. Our detector is biased by applying a constant current less than 10mA under normal conditions. To accelerate the failures in the experiment we apply 40mA and 100mA constant current to two group of detectors, respectively. Parts of the detectors responsivity and minority carrier lifetime decreases obviously.

The relationship between detector conduction and temperature shows the conduction of failed detector increase more quickly, which may caused by lower electron mobility. Low frequency noises of the detectors before and after failure were measured. The experimental results show that g-r noise of failed detector increased evidently. Response spectra have no obvious change between good and failed detectors. These points show that the failure mechanism is that current introduce defects in the interface regions of the detector, leading to a reduction in the minority carrier lifetime and the increase of g-r noise.

5964-47, Poster Session

Comparative analysis of 4x288 readouts and FPAs

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Comparative analysis of four 4x288 different designed readouts is presented. All the readouts have the direct injection input circuit with incorporated cells allowing testing without photodiodes. TDI registers have three delay elements between neighbor inputs.

2-phase and 4-phase CCD readouts (2.5 micron technology) have different channel types (surface, buried and semi-buried), which include 10 bit TDI registers in each channel, and 18 channel multiplexing to 16 outputs. Two polysilicon, one metal level and 400 A dielectric layers were used. The readouts characteristics: charge handling capacity, transfer characteristics, output nonlinearity characteristics, bias dispersion, etc. are presented. CCD technology used for data multiplication results in crosstalk increase, because of the presence of rather considerable transfer inefficiency at cryogenic temperatures. Inefficiency temperature dependences and the ways to decrease it are discussed.

Using 2.5 micron CCD technology and 2.0 CMOS technology the readouts, which include the digital interface for dead pixels deselection, preliminary amplification circuits, 36 channel multiplication by CCD registers and 2 beat multiplication by analogue switches to 4 output amplifiers, were manufactured. One pocket CMOS technology with two polysilicon, two metal levels and 250 A dielectric layers were used. To increase the linearity of transfer characteristics and noise level decrease at the output of CCD the circuits of charge-voltage conversion on the base of operational amplifiers were used. This allows getting circuits with parameters close to those obtained by 0.8 - 1.0 micron CMOS technology.

Also some characteristics of 4x288 readouts designed by 1.2 micron CMOS technology are discussed (two polysilicon and two metal levels). This one includes the circuits of auxiliary electronics.

Comparative analysis shows that the readouts mentioned are different in numbers of outputs, external service but have rather similar parameters. The properties and characteristics of FPAs with 4x288 readouts are presented.

5964-50, Poster Session

Excess power penalty to compensate modal noise in fiber-optics communication

C. M. Jadhao, G.S.College of Khamgaon (India) and Amravati Univ. (India)

This paper presents a theoretical analysis of the modal noise in optical fiber communication system.The analysis and Experimental results are carried out to show that to maintain BER,Excess power is required to overcome modal noise due to the splice loss in the single mode optical fibers.The result is useful in design of long distance fiber optics communication system.

5964-52, Poster Session

A mixed process with differential amplification and multiple sampling behind infrared FPA

Y. Fu, X. Niu, Q. Zheng, Shanghai Institute of Technical Physics (China)

An infrared FPA is used in push-broom scanner. The output of the FPA includes both signal from the object of the scanner and that from the system background radiation. Special process of the signal must be taken in the electrical circuit to obtain the target information.

An analogue method to deal with the background signal is using a differential amplifier to subtract the uneven background signal. One source of this differential amplifier is the output of the FPA, and the other that from a Digital Analogue converter circuit. What is important in this method is obtaining the background data in site.

A digital method is using a high accurate ADC to digitalize the signal including the object information and background information. The background information can be subtracted in the image rebuilding circuit or rebuilding software.

Because the background signal takes up a great part of the output range of the FPA, the integrating time is limited to less than 100mm, and the SNR is also limited. Beside the special optical and mechanical techniques to reduce the background radiation, a digital process of multiple fast sampling and adding is adopted to improve the SNR.

A 320´256 MCT infrared PFA is used in this project. Using the mixed signal process introduced in this paper, we rebuild the image with little influence of the background radiation and improve the uniformity. Such a processing is effective both in mid-wave infrared systems and long-wave infrared systems.

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5965-01, Session 1

Micro-optics: manufacturing and characterization

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Micro-optics plays a significant role in various application areas and markets today. The constraints imposed on the micro-optics can be extremely demanding, especially for telecom, metrology and beam homogenizing applications. Very precise control of lens profiles, etch depth, lateral position, overall optical performance, array uniformity, etc. is required. We will discuss manufacturing and characterization of high-quality micro-optics in detail.

5965-02, Session 1

Replication and surface enhancement of microstructured optical components

H. Bitzer, J. Zosel, M. Gebhardt, Reflexite Corp. (USA)

This paper will present recent developments in the field of microstructured plastic optics. Throughout the industry there is a steady push for improved precision and increased component efficiency as well as complexity. Discussed are different replication techniques and product enhancement capabilities, in particular coatings and nanostructures, such as top surface features of polymer optical components.

Processes which will be discussed include compression molding, injection molding, casting and coatings. In the area of coatings we explore chemical deposition processes (scratch coating) and physical deposition methods (BBAR, HR). As a method to improve the management of light for polymer optical components we discuss the use of nanostructures to provide AR-capabilities on polymer surfaces. A special plasma based method to generate random AR-structures on polymer surfaces is discussed and results are demonstrated. We compare the process called PlasmARTM to traditional physical vapour deposition methods as well as to the periodic Moth-eye Antireflective MicrostructureTM technology.

5965-03, Session 1

Design and fabrication of refractive and diffractive micro-optical elements, used in holographic recording setups

T. Kaempfe, E. Kley, A. Tuennermann, Friedrich-Schiller-Univ. Jena (Germany)

The uniform illumination of holographic screens during their recording process is commonly realized by using only the quasi-constant, inner part of the gaussian intensity profile of a very strongly expanded laser beam. This technique is characterized by a very low efficiency (about 5%, depending on the required uniformity). We present a method, which uses refractive, micro optical beamshaping elements in order to create a rectangular, extraordinarily uniform, flat-top intensity profile with minimal phase aberrations. This allows the use of about 80%-90% of the provided optical power for the illumination of the holographic screen.

To ensure the required quality of the illumination wave, a spatial frequency filtering has to be applied. Conventional pinholes are either too thin or too sensitive to handle a combination of high beam-divergence and high optical power, which is necessary for some specific holographic applications. To solve this problem, we present a new concept of dielectric pinholes, based on diffractive microstructures.

The combination of beamshaping elements and dielectric pinholes allowed us to significantly extend the available parameter range during the recording of holograms. The efficiency of the process was greatly increased and it became possible to work with a very high beam divergence for the illumination.

5965-04, Session 1

Novel fabrication technique of continuous profiles for micro-optics and integrated optics

T. Käsebier, H. Hartung, E. Kley, A. Tünnermann, Friedrich-Schiller-Univ. Jena (Germany)

We developed a fabrication process for microoptical elements with continuous profiles. In contrast to gray tone lithography with the cost intensive HEBS-glass or direct writing by laser or electron beam and the closely connected expensive equipment, the presented technique allows a low budget fabrication of continuous profiles with smooth surfaces. We use conventional binary photolithography with universalized DNQ-Novolak based photoresist, simple smoothing techniques and proportional transfer by dry etching. All variations of the procedure are based on the local depth control with the local filling factor of a periodic pattern in a binary photomask. The filling factor of the mask defines the resist volume, which corresponds to an effective layer thickness. With the aid of smoothing techniques after developing, the effective resist layer thickness is transformed to the real local profile thickness. Thus continuous change of the filling factor in the periodic mask pattern results in a smooth height profile.

Furthermore it is possible to fabricate continuous height profiles with just one lithographic step, if the mask pattern can not be resolved by the exposure-system. This can be achieved by the use of smaller periods or by increasing the gap between mask and substrate. The need of further surface smoothing depends on the smoothness demands.

With the help of continuous resist profiles, fabricated by smoothing of binary resist patterns and also by using non-resolvable masks, combined with further binary structuring after the proportional transfer, three dimensional waveguide taper for low loss fibre-waveguide coupling via mode matching were successfully manufactured.

5965-05, Session 1

Near-field holography with a two-dimensional phase mask for fabrication of two-dimensional structures in a single exposure step

H. Hartung, T. Clausnitzer, E. Kley, A. Tuennermann, Friedrich-Schiller-Univ. Jena (Germany)

We present a technique for fabrication of small period structures using a near field holography setup. By the use of a two dimensionally structured phase mask we are able to create two dimensional hole or dot arrays with one single exposure. Rectangular or hexagonal hole arrays can be created by using three or four beam interference. Therefor the grating periodes and the incident angle were changed. To get a high contrast interference pattern the mask parameters were optimized by a rigorous calculation to achieve equal transmission efficiency in the different diffraction orders. The mask generation was done by electron beam lithography and etching. We have made exposures with two different setups. The first setup is an exposure with perpendicular incidence where we use the interference of the four first diffraction orders. The second setup uses the zeroth and first diffraction order interference of a conical incident beam.

5965-06, Session 2

Characterization of resonance domain diffractive optical elements

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Resonance domain surface relief diffraction gratings that are holographically recorded are useful for a variety of laser beam manipulations, such as coupling, deflection, shaping, light-guiding and aberration correction. For the visible spectrum, the grating period is below half micron, groove depth about one or few microns and diffraction depends both on material and the shape of the grating grooves. We present a model for calculating the diffraction efficiency a function of various grating parameters of such resonant gratings. It is based on rigorous coupled wave analysis and newly developed effective grating theory. We present experimental data on characterization of surface relief gratings holographically recorded with different recording parameters so as to obtain differing groove shapes, different modulation depths, and various groove slant angles. The grating groove profiles were measured with scanning electron microscope, AFM and diffraction measurements. In diffraction measurements, grating parameters were estimated by fitting of experimental and theoretical curves for diffraction efficiency as a function of incidence angle. Our results reveal that Bragg type diffraction, with efficiencies above 90% can be achieved for resonance domain surface relief gratings.

5965-07, Session 2

A multisensor metrology tool for nanometer to meter measurements

T. Fries, FRT GmbH (Germany)

One of the actual challenges in optics is the fabrication of micro lenses as a part of MEMS or even integrated in macroscopic systems. This task needs a completely new category of metrology devices. To fill the gap in dimensions occuring with this technologies between the milli-/micrometer technology and the nano-/subnanometer technology, it is now possible for the surface measuring instrument MicroGlider(r) from FRT GmbH to be optionally equipped with up to 17 different sensors, most of which are optical sensors. Various optical principles are under use, to meet the different needs of devices under investigation, depending on material, surface character or necessary resolution. In addition an Atomic Force Microscope (AFM) may also be added. The AFM is fixed to the instrument additionally to the standard optical topography sensor. If necessary, a spot will be selected into the available overview measurement to determine the measuring range of the AFM. The AFM is able to investigate structures down to the atomic range. The measuring instrument enables the combination of measuring ranges from 100 mm, 350 mm or 600 mm with resolutions down to the sub-nanometer range in one single instrument.

5965-08, Session 2

Critical dimension metrology using optical diffraction microscopy

P. Hansen, N. Agersnap, LuKa Optoscope (Denmark); J. C. Petersen, J. Garnaes, Danish Fundamental Metrology (Denmark); N. Destouches, O. M. Parriaux, Univ. Jean Monnet Saint-Etienne (France)

We present an innovative method for the simultaneous measurement of specular and non specular diffraction patterns of submicron periodic structures called Optical Diffraction Microscope (ODM). The sample is illuminated with broadband light at selected angle of incidences. The entire diffraction pattern is collected using a pair of ellipsoidal mirrors, optical fibers and a spectrometer. This new method allows for fast measurements and makes used of the Rigorous Coupled Wave (RCW) algorithm for data analysis. In the present work the method has been applied to binary and multilayer submicron gratings. A series of binary gratings with period from 318 nm to 360 nm with different exposure level of the photoresist were investigated. On one sample a sinus shaped profile was identified; on another sample thin and separate round lines were identified showing that all photoresist was removed between the rounded lines. Such measurements serve very well to determine the exposure energy for photoresist grating. The ODM determination may thus be used online as a feedback to adjust the exposure energy in the process line as well as specifying the exposure window for the production. The homogeneity of a multilayer grating has been investigated. The measurements shows height and duty cycle variation from 50 nm to 55 nm and from 0.25 to 0.97. AFM measurements for the gratings show very good agreement with the results and demonstrate that the ODM can be used to determine the topology of the samples and the exposure energy for photoresist gratings.

5965-09, Session 2

Nanopositioning and nanomeasuring machine for high accuracy measuring procedures of small features in large areas

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The enormous progress of nanotechnologies demands new requirements on metrology tools.

High accuracy measuring procedures are necessary for ever-smaller features and in the same time in large areas and volumes. State-of-the-art scanning probe microscopes on the one hand and conventional coordinate measuring machines on the other hand can not full-fill this requirements.

With the development of a Nanopositioning and Nanomeasuring machine (NPM machine) at the Technische Universität Ilmenau we achieved subnanometer resolution and nanometer uncertainty in a measuring range of 25x25x5 mm3. The high accuracy can be achieved by compliance with the Abbe comparator principle in all measurement axes.

For high speed scanning in a range of 25x25 mm2 a high precision focus probe was developed and integrated in the NPM machine. The lateral resolution is about 0.8 μm. This is 30% better than conventional autofocus systems. The achievable scanning speed is of special interest with regard to large area scans. Scans with a velocity up to 5 mm/s have been carried out, without an observable increase of the measuring uncertainty, which was about 0.8 nm.

To improve the lateral resolution we equipped the focus probe with a Si cantilever to act as a scanning force sensor. Due to an integrated piezotranslator measurements in tapping mode as well as in contact mode are possible. We achieved an extended uncertainty of 0.4 nm (k=2) at a 780 nm step height standard. The scanning speed in tapping mode was 10 μm/s. Navigation on samples is very comfortable by an integrated CCD-camera microscope. Therefore on larger samples different small measuring regions of interest can be measured in one time. Due to the capability of the NPM machine the distance between this regions can be measured with high accuracy and the regions can be retrieved very easily.

Nevertheless, further improvements on new effective measurement strategies for high resolution measurements in large areas are necessary as well as advance in scanning speed of SPM techniques.

5965-10, Session 2

Scanning force microscopy for optical surface metrology

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Surface structures with lateral dimensions in the nm-range (‹~ 100 nm) have a significant impact on the optical and functional surface properties.

Scanning Force Microscopy (SFM) has been increasingly used to investigate the nanotopography of substrates and thin films. SFM data evaluation is nevertheless so far mainly restricted to qualitative image information or single roughness parameters. Appropriate description of statistical surface roughness needs, however advanced quantitative data analysis. This can be accomplished by Power Spectral Density (PSD) functions.

If the structure size is in the nm-range, conclusions about the information content and comparability of measurement results are difficult and only possible in a qualified manner. The results can be strongly influenced by the geometry of the probe whose lateral dimension is in the nm-range too.

Based on experimental/empirical work we estimated probe size effects on the PSDs of smooth optical substrates and thin films.

Especially the SFM measurement of super smooth samples (e.g. substrates for EUV coatings) can also be affected by inherent noise of the system. We therefore also present and discuss methods of noise analysis.

5965-11, Session 3

Subaperture metrology technologies extend capabilities in optics manufacturing

M. Tricard, G. W. Forbes, P. E. Murphy, QED Technologies Inc. (USA)

Subaperture polishing technologies have radically changed the landscape of precision optics manufacturing and enabled the production of higher precision optics with increasingly difficult figure requirements. However, metrology is a critical piece of the optics fabrication process, and the dependence on interferometry is especially acute for computer-controlled, deterministic finishing. Without accurate full-aperture metrology, figure correction using subaperture polishing technologies would not be possible.

QED Technologies(r) has developed the Subaperture Stitching Interferometer (SSI(r)) that extends the effective aperture and dynamic range of a phase measuring interferometer. The SSI's novel developments in software and hardware improve the capacity and accuracy of traditional interferometers, overcoming many of the limitations previously faced.

The SSI performs high-accuracy automated measurements of spheres, flats, and mild aspheres up to 200 mm in diameter by stitching subaperture data. The system combines a six-axis precision workstation, a commercial Fizeau interferometer of 4" or 6" aperture, and dedicated software. QED's software automates the measurement design, data acquisition, and mathematical reconstruction of the full-aperture phase map. The stitching algorithm incorporates a general framework for compensating several types of errors introduced by the interferometer and stage mechanics. These include positioning errors, viewing system distortion, the system reference wave error, etc. The SSI has been proven to deliver the accurate and flexible metrology that is vital to precision optics fabrication.

This paper will briefly review the capabilities of the SSI as a production-ready, metrology system that enables cost-effective manufacturing of precision optical surfaces.

5965-12, Session 3

Standardization in dimensional nanometrology: development of a calibration guideline for scanning probe microscopy

T. Dziomba, L. Koenders, G. Wilkening, Physikalisch-Technische Bundesanstalt (Germany)

Nanotechnology plays an ever-growing role in many different industries. Already now, nanotechnological processes are largely applied e. g. in the optics' industry, as nanoscale features often determine the optical properties. Quality control in the nanometre range involving quantitative dimensional measurements is therefore of paramount importance in the fabrication of optical components as well as for other nanotechnological applications.

Consequently, Scanning Probe Microscopy (SPM) is increasingly used for quantitative measurements in nano- and micro-technology, but except for a few specially designed set-ups mainly at national metrology institutes, measurements made with these instruments usually lack traceability to the metre definition. Especially when used in industrial inspection processes, however, great importance is attached to standardised calibration routines ensuring traceability similar to those already established for instruments used at larger scales. Thus, both a generally accepted guideline for SPM calibration and appropriate transfer standards are required. While a number of standards suitable for SPM calibration are already available commercially, there is - up to now - no generally accepted guideline on how to perform SPM calibrations. Such a scheme is therefore currently being worked out on international (ISO-TC) and national levels (VDI/VDE-GMA in Germany) with PTB as National Metrology Institute participating resp. chairing the working groups. After a brief general overview of standards and methods already established in micro- and nanometrology, this paper introduces the traceability chain for SPM and presents the status-quo of the development of the SPM calibration guideline. This draft will be illustrated by some practical examples of SPM calibrations. Finally, it aims to stimulate discussions of the draft.

5965-13, Session 3

Modern topics in standardized laser-induced damage threshold measurements

K. Starke, H. Blaschke, M. Jupé, D. Ristau, Laser Zentrum Hannover e.V. (Germany)

Although the measurement of the laser-induced damage threshold is a field of permanent research effort since the late 1960s, the optimization of the damage handling capability is still a key issue for the development of high performance laser systems. In conjunction with the ever increasing demand in lasers with high average power, energy, extreme wavelengths or short pulses, the resistance to laser damage has to be optimized with special regard to the different damage mechanisms. Therefore, a report of the current status of the laser-induced damage threshold is given for the most interesting components and laser systems applied in science and industry. Further, several results of recently performed damage investigations in the UV and NIR spectral range and for ultra short pulses are presented in this paper.

The reliability of damage threshold measurements are crucially depending on the chosen test parameters. The importance of the different parameter values were investigated during several Round-Robin experiments. These investigations can be regarded as the basis of the standardization process leading to the International Standard ISO 11254. In this paper, selected results of the comparative campaigns in damage testing are described, especially in the field of ns and fs pulses.

5965-14, Session 3

Digital signal processing in AFM topography and recognition imaging

S. Adamsmair, A. Ebner, P. Hinterdorfer, B. G. Zagar, Johannes Kepler Univ. Linz (Austria)

Operating an AFM equipped with analog driving hardware frequently shows hard to control drift and noise problems. In this proposed paper we address these problems by introducing advanced digital signal processing algorithms able to accurately stabilize MAC mode AFM for characterizing biological structures. In MAC mode a magnetically coated cantilever is driven by an oscillating magnetic field close to its resonant frequency. The signal is picked up by a photodiode. By using an antibody tethered to the AFM tip binding to antigens on the surface, concurrent topography and recognition imaging is possible. Information regarding topography is obtained by tracking minima deflections of the tip, whereas recognition (highly specific antibody-antigen recognition reaction) is obtained from tracking maxima deflections. The sought information is conveyed by slight variations of the minima and maxima amplitudes. These variations are very small as compared to the maximum possible DC deflection. Furthermore, the DC offset exhibits a rather large drift mostly attributed to temperature changes.

To obtain reliable tracking results the oscillating photodiode-signal needs to be nonlinearily filtered and efficiently separated into four major components: the maxima, the minima, the spatial average of the maxima, and the spatial average of the minima. The recognition image then is obtained by a non-linear combination of these four components evaluated at spatial locations derived from the zero-crossings of the differentiated signal resulting from a modified differentiator FIR filter. Furthermore, to reliably estimate the DC drift an exponential tracking of the extrema by a first-order IIR filter is performed.

The applicability of the proposed algorithms will be demonstrated for biotin and avidin.

5965-15, Session 3

Transmission measurements for the optical characterization of 2D-photonic crystals

M. Gerken, R. Boschert, U. Lemmer, Univ. Karlsruhe (Germany)

The successful realization of devices based on two-dimensional (2D) photonic crystal structures relies on an accurate characterization of the properties of the fabricated nanostructured surface. Scanning electron microscope (SEM) images allow the verification of geometric parameters of fabricated 2D-photonic crystal structures such as the periodicity or the hole diameter. In order to investigate the optical properties of 2D-photonic crystals we realized an experimental setup for spectrally and spatially resolved transmission measurements at normal incidence. These measurements reveal the allowed states of the photonic crystal at the Gamma-point. In contrast to transmission measurements in the plane of the photonic crystal, these measurements are independent of the lateral termination of the structure, since only the area of the photonic crystal is probed. The experimental setup allows for the characterization of microscopic structures of dimensions down to 50 micrometers in diameter. The setup can furthermore be utilized to characterize the spatial homogeneity of larger nanostructured surfaces. We present experimental results and compare them to photonic band structure calculations.

5965-16, Session 3

Classification of optical surface properties and material recognition using mutlispectral BRDF data measured with a semihemispherical spectro-radiometer in VIS and NIR

C. F. Hahlweg, H. Rothe, Univ. of the Federal Armed Forces (Germany)

A characterization of optical surface properties, especially in terms of the human visual perception, demands the use of BRDF data over a wide spectral range, at least over VIS. Further it could be interesting to perform a fast optical material recognition industrial metrology.

For the fast acquisition of large amounts of BRDF data over wavelength a small, fast and rugged spectro-radiometer without moving parts for angular resolution was developed.

The system, as described in earlier papers, consists of an elliptical mirror mapping a semi-hemisphere onto a CMOS-detector with a dynamic range of 140dB. The detector has 32887 pixels and works with a maximum frame rate of 30 fps, giving about 1 million solid angles per wavelength and second. The incoherent illumination is provided by a set of assorted LEDs. A radiometric measurement is possible over a wide spectral range from VIS to NIR over 7 deacades (1e-5 W/m^2 to 100 W/m^2).

Fast property characterization or material recognition from multivariate data in industrial applications demand appropriate analysis methods.

Various analysis methods such as linear discriminant analysis and PCA are applied to the data over wavelength and angles.

In the paper measurement results of the spectral signatures of various materials and test surfaces will be presented. Classification results and performances will be compared and discussed.

5965-17, Session 4

Manufacturing and testing of precision optical components: from substrate to coating and assembling

R. P. Netterfield, Commonwealth Scientific & Industrial Research Organisation (Australia)

There is significant sophistication in the individual fields of fabrication,

coating, and metrology. Uncoated optics are characterized accurately by a wide array of techniques, as are optical coatings. However, often the coating process can change the intrinsic properties of the polished substrate such as figure, microroughness, defect density and so scattering properties. Optical components can often be distorted out of specification during assembly by contacting or cementing, and during mounting. This presentation will give examples of the interplay of all processes from fabrication, cleaning, coating, assembling and mounting on the measured performance of some precision optical components and assemblies.

5965-18, Session 4

Aspher05: rapid fabrication of precise aspheres

R. Boerret, Univ. of Applied Science Aalen (Germany); H. Wang, Carl Zeiss AG (Germany); V. Giggel, Carl Zeiss Jena GmbH (Germany)

Today's optical system in the field of projection and display systems, life science and auto-motive applications as well as industrial monitoring and safety are facing an ever-increasing demand on aspheric or complex optical surfaces. The optical designers are asking for fast prototypes to prove the optimum performance of their new approaches. In addition the fast changes in the market result in decreasing production quantities per system. Therefore a rapid fabrication process required, which allows a fast, flexible and cost effective production of high end aspheres for production lots smaller than 10000 pieces. Carl Zeiss with the subsidiaries in Jena and Oberkochen and the University of Applied Science in Aalen have started together with other industrial and academic partners (project prime: Schneider Optic Machines) the project Aspher05, with the goal to improve the productivity of asphere fabrication at least by a factor of 5. Based on the long-term experience of the partners new approaches for the fabrication are chosen during the concept phase. First results of the project Aspher05 which is to be funded by the Federal Ministry of Education and Research (BMBF) will be reported and compared to the state of the art technology.

5965-19, Session 4

Optical design, manufacturing and tests of the MUSE image slicer

F. Laurent, R. Bacon, J. Dubois, F. Hénault, E. Renault, D. Robert, Observatoire de Lyon (France)

MUSE (Multi Unit Spectroscopic Explorer) is a second generation integral field spectrograph proposed to the European Southern Observatory (ESO) for the VLT. MUSE combines a 1' x 1' field of view with a spectral resolution going to 3000 and a spatial resolution of 0.2" provided by the GALACSI adaptive optics system. MUSE is operating in the visible and near IR wavelength range (0.465-0.93 μm). It is composed of 24 identical integral field units; each one incorporates an advanced image slicer made of a combination of mirrors and mini-lenses arrays. During the feasibility study, a slicer prototype has been designed, manufactured and tested. This paper firstly describes an original approach for the slicer optical design and manufacturing. Then, we will focus on the optical tests of the prototype. These tests included the control of the angular errors and assembling method of the slicer, the measurements of the position, size and shape of the pseudo-slits, the measurements of the Point-Spread Function (PSF) for the slice-slit imagery on the whole Field of View (FoV) and an estimation of the size of the global exit pupil. We finally conclude on the feasability of MUSE image slicer and its possible improvement for the next design phase.

5965-20, Session 4

Design considerations for computer-generated holograms as supplement to Fizeau interferometers

R. Schreiner, JENOPTIK Laser, Optik, Systeme GmbH (Germany)

Computer generated holograms (CGH) are widely used in combination with standard Fizeau interferometers. The test of plane and spherical specimen is extended to the test of aspherical surfaces. The wave from a transmission flat or a transmission sphere is formed by the CGH to fit the surface of an asphere or a cylinder. There are some considerations for an advantageous design of this additional optical element in the beam path. The availability of a suitably designed CGH is often the limitation for the manufacturing of precision aspheres. JENOPTIK Laser, Optik, Systeme GmbH can provide a custom made CGH within a short time. We will show the design principles and the layout of the CGHs. The optical properties and the known limitations will be presented based on measurements of aspherical surfaces.

5965-21, Session 4

Recent advances in subaperture finishing

M. Tricard, A. B. Shorey, P. Dumas, QED Technologies Inc. (USA)

Subaperture polishing technologies have radically changed the landscape of precision optics manufacturing and enabled the production of components with higher accuracies and increasingly difficult figure requirements. Magnetorheological Finishing (MRF(r)), for example, is a production-proven, deterministic, subaperture finishing technology that has excelled at overcoming the limitations of traditional polishing. Several recent MRF developments will be presented, including complementing Single Point Diamond Turning (SPDT) technology, transmitted wavefront correction, and finishing of increasingly large apertures.

We will also discuss the high precision finishing of challenging optics using a newly developed jet-based technology. A series of examples spanning a wide range of materials, geometries and specifications will be presented. Specific areas to be discussed include micro-optics (i.e., optics less than 5 mm in size), which typically require a very labor-intensive, iterative process to finish, and steeply concave optics, such as domes, which are typically not well suited for sub-aperture polishing processes.

5965-22, Session 4

Synthesis of diamond diffractive optical elements for IR laser beam focusing

V. S. Pavelyev, V. A. Soifer, N. L. Kazansky, A. V. Volkov, G. F. Kostyuk, Samara Institute of Image Processing Systems (Russia); V. V. Kononenko, V. I. Konov, S. M. Pimenov, General Physics Institute (Russia); M. R. Duparre, B. Luedge, Friedrich-Schiller-Univ. Jena (Germany)

The application of diamond-based optical elements for high-power CO_2 lasers is of particular interest because of the low optical absorption coefficient of this material in combination with it's very high thermal conductivity and the weak temperature dependence of refractive index. Recent advances in gas-phase synthesis have made it possible to fabricate polycrystalline CVD diamond films whose optical and thermal properties are close to those of single crystal diamond material, whereas they are far cheaper. As a result, these sophisticated materials are applied more and more to tasks dominated till now by other materials. Such examples for this are windows for high-power CO_2 lasers in the 5 - 20 kW domain and beam-splitters.

Recently new techniques have been proposed for generation of phase microrelief to manufacture diamond diffractive optical elements (DOE) for the far IR range. In1,2 the realisation of DOE by UV-laser ablation has been considered. Using of plasmochemical-etching3,4 is considered later.

The present paper is devoted to further development of approaches2,3.

The realization of diamond diffractive optical elements (DOEs) is considered, able to focus an incoming CO_2 laser beam into certain pregiven focal domains. The realization of antireflective structures (ARS) on the diamond surfaces is also considered.

Results of experimental investigation of designed DOEs and ARS are presented and discussed.

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5965-23, Session 5

Megajoule laser project and polishing process for high laser induced damage threshold at 351 nm

J. Néauport, Commissariat à l'Energie Atomique (France)

No abstract available

5965-24, Session 5

The challenges of large laser optics manufacturing for laser fusion

R. Geyl, J. Bernier, F. Houbre, SAGEM SA (France)

France has launched his ambitious project MEGAJOULE dedicated to the simulation of the most dense plasma by focusing 2 MJ of light delivered by 240 large aperture laser beams on the target. SAGEM-REOSC is involved in the production of the most difficult optical components of this project and has delivered many components for the 8 beam lines of the Ligne d'Integration Laser, a development tool set up by the French Atomic Research Center. This allowed us to validate the technological choices and the production capability for the 240 beam lines to come. Some statistics of achieved performances and main lessons learned during this preliminary phase to the project will be presented and discussed.

5965-25, Session 5

From VLT to GTC and towards the ELT

R. Geyl, M. Tarreau, E. Ruch, M. Cayrel, SAGEM SA (France)

SAGEM-REOSC produced in the 90's the 4 VLT and 2 Gemini 8-m giant monolithic mirrors. However this huge size is surely the ultimate limit of large monolithic optics. As astronomy is seeking larger and larger aperture optics for improving its exoplanet detection capability, segmented optics is the only way to go and new methodologies for optical manufacturing must be used.

Presently SAGEM-REOSC is manufacturing the 36 segments of the Gran Telescopio Canarias with completely new approach. 24 segments have been delivered so far with outstanding performance results. These results will be presented and the trend to the 30-m or 100-m Extremely Large Telescopes discussed.

5965-26, Session 5

Design philosophy for the Cranfield ultraprecision big OptiX system

P. R. Shore, P. M. Morantz, Cranfield Univ. (United Kingdom); R. F. Read, Cranfield Precision (United Kingdom)

There is an emerging need for a more effective production route for ultra-precise large optics, primarily mirrors. Many hundreds of mirror segments of 1 - 2 metre size range will be needed to realise the next generation of ground based extra large telescopes (ELT). These segments demand form accuracy of less than 25 nm RMS and roughness of 1 nm RMS. They represent one of the most challenging high precision manufacturing demands in the world today. Their relative form accuracy to size approaches 1 part in 10 to the 8 whilst the high numbers required, demand serial production consideration for form grinding and subsequent figuring / finishing and testing.

This paper introduces the design philosophy behind a new ultra- precise large optics grinding system, the Cranfield Big OptiX system or "BOX". This machine has been conceived to enable ultra precise large optics to be ground within a serial production environment. It forms part of a major UK research initiative that aims to develop a new more effective process chain for the serial production of ultra precise large optics.

Important drivers for the design of the Cranfield "BOX" include:

- rapid fixed abrasive grinding of glasses and ceramics
- minimal sub-surface damage (readily removable by subsequent "finishing")
- large size capacity including design scale-up potential
- high level of form accuracy (1 um / metre)
- serial production capability

In describing the design philosophy of "BOX" the paper reviews the design process which has ensured the correct "trade offs" between: the classic principles of precision machine design, the necessary "low damage" grinding demands and necessary requirements for an effective serial production system.

The paper reviews machine dynamic analyses, both FEA and modal testing which has had a significant impact on the selected machine configuration. An overview and justification of the "BOX" machine design and its targeted performance level is described.

5965-27, Session 5

CCPM (computer controlled polishing machine): combined fine grinding and polishing innovative tool for optics manufacturing

D. Mancini, ATEC Robotics (Italy) and Osservatorio Astronomico di Capodimonte (Italy)

This paper describes a flexible customized machine studied and designed for precision optical manufacturing. The machine presented (CCPM3000) is capable of working mirrors up to 3 meters of diameter. It is a innovative tool dedicated to laboratory activities and production. Due to its flexibility it is a part of an array of similar tools for the production of aspherical segmented mirrors for extralarge telescopes. The tool has been developed for polishing and control of form on flat, spherical and aspheric surfaces.

5965-28, Session 6

Recent advances in the control of form and texture on free-form surfaces

D. D. Walker, Univ. College London (United Kingdom) and Zeeko Ltd (United Kingdom); R. Morton, A. T. Beaucamp, Zeeko Ltd. (United Kingdom); G. McCavana, Zeeko Ltd (United Kingdom); V. Doubrovski, X. Wei, Zeeko Ltd. (United Kingdom); C. R. Dunn, Univ. College London (United Kingdom); R. R. Freeman, Zeeko Ltd. (United Kingdom)

The recent upsurge in the demand for off-axis and complex "freeform" optical surfaces is driving the development of novel processes for their fabrication. This paper focuses on recent developments of the Precessions CNC polishing process for freeform surfaces, including off-axis as a special case. First, the surface-prescription and metrology-data, and their relation to the data-input for the polishing machines, are considered. The relevance of consistent coordinate frames is emphasised. This leads to a description of how the process can 'polish' a ground freeform part (improve the texture), and then 'figure' the part (reduce the form errors). Specific experimental case-studies are then presented, in which the end-to-end process is captured through a history of the input-quality, intermediate stages and final results.

Recent work is also described in which the process-speed has been moderated in order to remove tens of nanometres of stock material, rather then the more usual hundreds of nanometres to tens of microns as in the standard Precessions process. The relevance of this to improving the ultimate surface-precision that should be achievable by this method is described. As a final illustration, the potential of the process to the rapid fabrication of the hundreds to thousands of 1-2 metre class mirror segments required for extremely large telescopes is considered.

5965-29, Session 6

Machining and measuring of an off-axis paraboloid

U. P. Birnbaum, R. Schreiner, JENOPTIK Laser, Optik, Systeme GmbH (Germany)

Off-axis paraboloids provide sophisticated challenges in both machining and measuring. There are 2 accepted approaches for manufacturing off-axis paraboloids. In method one a rotational symmetrical part is figured and polished with subsequent separating the off-axis elements from the block. On the other hand you can machine the single parts right from the start. In this case the surface is kind of freeform.

In this paper we will report on the manufacturing of mirrors for a beam expander using the latter method. Attention is paid to machining and measuring. The fabrication process consists of iteration steps. The systems wavefront error is measured and corrected on one mirror surface.

5965-30, Session 6

Stitching interferometry and absolute metrology: an overview

M. Bray, MB Optique SARL (France)

Stitching interferometry has s recently emerged as a valid alternative for the accurate metrology of large optics.

However, this technique is still not as widespread as was foreseen in the last years.

The reason, the author believes, is that the method is not as simple as it seems at first sight. Also, many difficulties arise, making users think that the technique generates new forms of error.

In reality, these « new » errors have always been present, but simply not visible and therefore not a problem ...

Apart from the practical difficulty in obtaining comparison measurements on large components, calibration of the interferometer is critical : Overlapped sub-apertures show the slightest calibration error, down to the nanometre level. Standard single-aperture measurements just can't show this type of error, which is nonetheless present.

Over the past years, the author has addressed the various perturbations affecting Stitching Interferometry measurements including, more recently, Absolute Calibration.

The reasoning is, if you can see an error, you might be able to correct it. We showed how Stitching Interferometry hardware and modified software can produce an Absolute Calibration system, requiring no handling of components whatsoever (viz., unlike the « Three Flat Method »). At the time, we could only show theoretical simulation - albeit, most promising.

In this paper, we briefly review the method, and show experimental results obtained from « real » measurements using standard set-up procedures and environment : The results are very good, and should convince anyone that the method does offer many advantages for both the laboratory and the industrial environment.

5965-31, Session 6

Stitching oil-on interferometry of large fused silica blanks

D. Schönfeld, R. Takke, S. Thomas, Heraeus Quarzglas GmbH and Co (Germany)

Ongoing laser fusion experiments like the "Laser MegaJoule Project" and the "National Ignition Facility" have created a strong demand for large optical lenses of special grade fused silica. The required lens dimension poses several challenges to the manufacturing process. One of the key issues is to provide a suitable measuring technique, which is capable to fulfill the extreme demands on characterizing the optical homogeneity of those large fused silica blanks.

We report on our first results achieved with a interferometer system that was installed to explore the potential and feasibility of stitching interferometry. Although the principle of stitching is well known, it had to be adapted to the special "oil-on measurement technique" that is necessary to characterize lens blank's without expensive surface polishing.

5965-32, Session 6

Dynamic holography for the space qualification of large reflectors

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The next generation of infrared - sub mm space telescopes requires reflectors with large dimensions, high quality and, according to weight issues, are based on composite materials technology. The challenging tasks of on-ground testing are to achieve the required accuracy in the measurement of these reflectors shape and antenna structures and to verify their performance under simulated space conditions (vacuum, low temperatures).

A holographic interferometry method for the verification and validation of this type of reflector in a space environment is presented. It is based on a dynamic holographic camera observing a diffuser illuminated by the object beam coming from the reflecting surface. In addition to an increase of the measuring range, the main advantage of this method, with respect to optical interferometry techniques, is that an optical system to adapt the wavefront (corrector or null lens) to the reflector being measured is not necessary. Therefore, it offers an improved flexibility that is of major importance for reflectors with exotic shapes (aspheric reflectors).

Since the holographic method is very sensitive (20 nm resolution), the holographic recording process is perturbed by movements (mechanical or thermal) of the object or the set-up with time constants smaller than the holographic recording time. This requires care on the thermo-mechanical set-up design.

The system has been made compatible with the vacuum conditions. Some elements of the holographic camera (camera lenses, CCD, crystal, optical fiber) have been adapted and tested under vacuum.

The metrological certification of the whole system was realized by the measurement of a parabolic CFRP reflector with a 1.1 meter diameter. The results are compared to the one achieved with an IR interferometer on the same antenna in laboratory conditions and under thermal vacuum conditions. This later test consisted in measuring the deformations of the reflector between an initial state at ambient temperature and a final state at a temperature of 100 K.

5965-33, Session 7

Wavefront measurement of space infrared telescopes at cryogenic temperature

H. Kaneda, Japan Aerospace Exploration Agency (Japan); T. Onaka, The Univ. of Tokyo (Japan); T. Nakagawa, K. Enya, H. Murakami, Japan Aerospace Exploration Agency (Japan); R. Yamashiro, Y. Numao, Y. Sugiyama, Nikon Corp. (Japan)

Optical performance of the 70-cm lightweight telescope on board the Japanese infrared astronomical satellite, ASTRO-F, has been evaluated at cryogenic temperatures. The mirrors of the ASTRO-F telescope are made of sandwich-type silicon carbide (SiC) material, comprising porous core and CVD coat of SiC on the surface. The total wavefront errors of the telescope were measured

with an interferometer from outside a liquid-helium chamber; a 75-cm reflecting flat mirror was used for auto-collimating the light from the interferometer. The cryogenic deformation of the flat mirror was derived independently by shifting it in the chamber and its contribution to the wavefront error was removed. The gravitational deformation of the primary and the secondary mirrors was evaluated by model calculation and its contribution was also removed. As a result, we have found that the imaging performance of the ASTRO-F telescope is diffraction-limited at 6 microns which is a little worse than our original goal of diffraction-limited performance at 5 microns.

In addition to the ASTRO-F telescope, we are currently developing a 3.5-m telescope system for SPICA, the next Japanese infrared astronomical satellite project. Details of our methodology for the ASTRO-F telescope, together with our optical test plan for the SPICA telescope, are reported.

5965-34, Session 7

Measuring wavefront tilt using shearing interferometry

H. Schreiber, Corning Tropel Corp. (USA)

Shearing interferometry is a well-established technique for high accuracy optical testing. Usually piston and tilt in the wavefront are neglected because the focus is on higher order surface or wavefront aberrations. However looking for absolute testing of elements or systems and for testing of field curvature of lens systems or similar tasks, the evaluation of the tilt in the wavefront between measurements is important. Because shearing interferometry only measures a wavefront difference, wavefront tilt does not usually show up as fringes, only as a bias to the fringe position.

We discuss the problems associated with measuring tilt accurately using standard shearing interferometry and describe a technique using a variable shear, which allows making wavefront tilt visible to the operator in form of fringes. Measurement examples are presented as well.

5965-35, Session 7

Limitations of iterative least square methods in phase shifting interferometry in presence of vibrations

J. Schmit, Veeco Instruments Inc. (USA)

Vibrations are the most difficult source of error to overcome in phase shifting interferometry (PSI) method for surface profiling. PSI algorithms can be designed to reduce the influence of vibrations of a single frequency. However, vibrations in a system may have a wide spectrum of vibrational frequencies, which introduce a random error in phase shift between frames. Longer integration times of the detector when vibration is present can additionally introduce a random change in fringe amplitude from frame to frame. These random errors introduce artifacts in the PSI measured object profile. The artifacts take the form of ripples that typically follow the fringes at twice the frequency of the interference fringes. Several algorithms based on iterative least square methods were developed to minimize measurement error caused by unequal phase shifts and have been proven to work on simulated data. We test the limits of these methods by applying them to simulated and real data. Specifically, we estimate how well the changes in phase shift and fringe amplitude need to be known in order to produce a profile error of a given value.

5965-36, Session 7

Contact-free on-axis metrology for the fabrication and testing of complex optical systems

A. Courteville, R. C. Wilhelm, Fogale nanotech (France)

This paper presents a fibre-optics low coherence interferometric sensor developed by FOGALE nanotech. Based on the proven principle of partial

coherence interferometry the sensor works as a comparator of optical path lengths. The optical path length along the optical axis in the measurement interferometer arm containing a target object (e.g. a lens system) is compared with the optical path length in an internal delay line. Multiple, partially reflecting surfaces of the target can be detected during a single scan of the delay line.

Measurement ranges are between a few mm up to 500 mm. The measurement zone can be placed at a working distance of up to several meters away from the instrument's exit. The sensor reaches an absolute accuracy down to +/-0.1 μm over the full measurement range. The system has been successfully applied in industry (glass and optical) and in research environments, e.g. for the dimensional metrology of large optical telescopes. This paper focuses on innovative applications of the sensor in the optics manufacturing industry.

The paper starts with a description of the measurement technique, the detection scheme and the signal processing. We present a modeling-based approach for the dimensional metrology of optical components (e.g. single lenses, windows, prisms) or complete lenses where the positions of all individual elements can be detected. A comprehensive propagation model including dispersion and phase effects is used to extract the distances from the optical path differences. Prior to a measurement, the optimum tailoring of the measurement beam is obtained by a simulation of the beam propagation through the target optical system. This ensures that each surface to be measured delivers a sufficiently strong signal. To illustrate our approach we present its application in the fabrication process of complex optical systems where a global metrology of complete systems can be performed with very high accuracy in a short time.

5965-37, Session 7

Nondestructive testing using real time opto-digital holographic interferometry

L. L. Bouamama, Univ. Ferhat Abbas de Sétif (Algeria); S. Krüger, H. Gruber, G. K. Wernicke, Humboldt-Univ. zu Berlin (Germany)

During the last several years, the orientation to numerical and digital techniques is quietly enlarged because the easy handling of the information and mainly, its quick processing and transfer.

Digital holography is one of those techniques who after becoming a reality, gets a high evolution in parallel with that of the imaging technology. Knowing that on one hand, digital holographic recording is based on CCD (charge coupled device) sensors and on the other hand, optical reconstruction is based on LCD (liquid crystal displays) and DMD (digital mirror displays) devices; it is then extremely important that these elements must be in close fitting of the ideal conditions as largely as possible. The important disadvantage of these elements was their pixel size which was relatively high comparatively to the classical photoplate's grains size. It was not possible to get holograms of large objects and the resolution was relatively low. The actual evolution of these elements permits to find on the market such devices with relatively low pixel size (nearly 4 μm for CCD and 7 μm for LCD). It is then possible to increase the volume of objects and the quality of holograms. We show in this work that it is possible to record and reconstruct in real time holograms of objects having several cms square.

Since all the process is controlled numerically, it is possible to follow in real time using the holographic interferometry technique any changes in the object under study. This can be done by subtracting a reference image by suitable software directly on the CCD camera. We show the first results and the ability of the technique to study in real time all evolutional phenomena.

5965-38, Session 7

The quadri-wave lateral shearing interferometer dedicated to wavefront metrology

S. Velghe, J. Primot, N. Guérineau, ONERA (France); M. Cohen, B. Wattellier, École Polytechnique (France)

Based on lateral shearing interferometry, a powerful technique, called the Quadri-Wave Lateral Shearing Interferometer (QWLSI) [1,2], is used to evaluate the wavefront with a high transverse resolution and a tunable sensitivity. Our device can be used for the characterization of complex and very aberrant optical devices, the control of optical components and also for laser beam evaluation.

The QWLSI is constituted with a 2D diffraction grating generating four replicas of the analyzed wave. These four beams are propagating in noncollinear directions and therefore are shearing each from the other along the propagation. Due to the particular diffraction geometry of the QWLSI, the interference pattern is simply made of sinusoidal fringes on a square grid. Moreover, when the incident wavefront is aberrated, this interferogram undergoes deformations directly proportional to the shear distance between each replica and to the wavefront derivatives.

In this communication, we will show that the particular design of the QWLSI provides interesting properties for metrology: (a) the sinusoidal profile of the fringes allows an optimal sampling and so a very high resolution. (b) The distance between the grating and the observation plane can be adapted to the sensitivity and the dynamic range required by the measurement. (c) Our technique is not only sensitive to the derivatives along the two common orthogonal directions but also along the two cross directions. A new wavefront reconstruction process using these extra-measurements is then proposed in order to improve the quality of the measurement [3]. (d) Finally, we show that this new wavefront reconstruction process provides an intrinsic evaluation of the noise on the reconstructed wavefront.

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5965-60, Poster Session

Optical study on GaN epilayer by infrared spectroscopic ellipsometry

J. Wang, X. Li, Shanghai Institute of Technical Physics (China); J. Liu, Shandong Univ. (China)

Infrared Spectroscopic Ellipsometry (IRSE) is known as a nondestructive technique for the accurate determination of the complex dielectric functions of materials, as well as the optical constants. For GaN epi-layers on sapphire, the substrate displays several phonon bands in the GaN phonon region. This makes it difficult to obtain reliable information on the GaN films without precise simulation so there was few reports about the IRSE measurement applied to the GaN films on sapphire. Kasic et al. reported the excellent fitting with the data from IRSE. But they didn't give the anisotropic refractive index dispersion spectra in the infrared range. In this letter Infrared spectroscopic ellipsometry (IRSE) in the wavelength range of 9.0-12.6 mm was used to study the unintentionally doped GaN film on sapphire. The parameters of the lattice vibration oscillators and of the plasmon were obtained by fitting with the experimental data. The carrier concentration and the electron mobility were derived from the plasmon frequency, as well as the damping constant. The results were compared with those of the Hall measurement. The two values of the carrier concentration had the same magnitude. The mobility derived from IRSE was only about half of that from Hall measurement. In the end the anisotropic refractive index and extinction coefficient dispersion relationships were obtained in the measured wavelength band.

5965-61, Poster Session

Self-organized antireflective nanostructures on PMMA by ion etching

A. Kaless, U. Schulz, N. Kaiser, Fraunhofer-Institut für Optik und Feinmechanik (Germany)

Transparent thermoplastic polymers hold an important position as materials for optics and optoelectronics nowadays, and glass is gradually being replaced with plastics.

Highly transparent polymethylmethacrylate (PMMA) is one of the most convenient and frequently used polymers in precision optics. PMMA is a positive resist material and its surface properties can be modified by vacuum UV and ion irradiation in a wide range. The Advanced Plasma Source (APS) of a Leybold coating plant has been used to perform an etching step that leads to self-organized nanostructures on acrylic surfaces. Optimal antireflective (AR) properties on PMMA surfaces are produced by a treatment time of several hundred seconds under chosen plasma conditions concerning gas composition, pressure and ion energy. This work is focused on the characterization of the growing structure depending on the process parameters as well as the analysis of the chemical surface modification. The paper presents topographical investigations of the produced AR-structure and analyses the different states of structure growth. From a first very fine-grained structure, larger agglomerates are formed with increasing treatment time. Finally the features are almost uniform in size but stochastically distributed over the surface and give rise to minor scatter losses. Therefore PMMA surfaces with high transmittance at normal and oblique incidence of light can be obtained.

5965-62, Poster Session

Optical properties of stochastic subwavelength surface structures

R. Leitel, A. Kaless, J. Petschulat, U. Schulz, O. Stenzel, N. Kaiser, Fraunhofer-Institut für Optik und Feinmechanik (Germany)

High transparent thermoplastics have the capability to put glass out of business, especially in everyday life's optics. Their diverse nature gives rise to different antireflection principles. The reduction of surface reflection losses in polymethylmethacrylate (PMMA) is demonstrated by means of plasma treatment. The etching process creates a self-organized stochastic subwavelength structure in the substrate itself. The decrease in reflection is described by effective medium theory (EMT), converting the surface topology into a depth-dependent filling factor profile. Since the presented antireflection occurs in a wide spectral range, the technique can be applied for omnidirectional devices or curved substrates.

In a second step this nano-scaled structure is used as the initial point for a broadband absorber by deposing it with a nontransparent metal layer. An efficient absorber can be obtained, if the metal acts as backside coating of the double-sided plasma-treated substrate and the smooth transitions between the materials eliminate the Fresnel reflections. The magnitude of absorption depends on depth of structure as well as on the complex refractive index of the metal.

5965-63, Poster Session

In-situ real-time characterization of the roughness of a growing film by x-ray scattering technique

I. V. Kozhevnikov, A.V. Shubnikov Institute of Crystallography (Russia); L. Peverini, E. Ziegler, European Synchrotron Radiation Facility (France)

The spatial and temporal developments of a growing thin-film are studied in-situ and in real-time via a novel x-ray scattering technique. The evolution of roughness, described in terms of its power spectral density, is derived from scattering measurements performed using a monochromatic synchrotron X-ray beam set to the energy of 17.5 keV.

The data are analyzed in the frame of the first order perturbation theory, which does not require any model of film growth or of correlation function. This approach permits to describe quantitatively the evolution of the micro-topography of a thin-film in the [0.3 μm-1, 50 μm-1] range of spatial frequency and of the degree of conformity between film and substrate roughness. In addition, the re-scaling of the various PSD functions into a single master curve gives the possibility to identify uniquely the dynamics of the growth process.

5965-64, Poster Session

Theoretical and experimental investigation of optical fiber coatings removal by laser irradiation

C. Zhou, D. Jiang, R. Peng, Wuhan Univ. of Technology (China)

The laser removal coating of fiber optic to improve the processing efficiency and quality is a promising technique in the field of producing telecommunications and sensor element based on optical fiber. A theoretical and experimental synergic analysis of the removal of optical fiber coating can give a more detailed description of the process mechanism. In this work, successful coating removal from a single-mode silica fiber has been achieved using both pulsed excimer and CO2 lasers. The effective absorption characteristic of coating, optics and scanning electron microscopic characterization of the coating removed fiber, and the compare of removal quality by UV and IR laser are described. A theoretical model to study the power of laser and removal deepness has been used. Theoretical results are approximately matched to experimental results.

5965-65, Poster Session

Texture analysis of ultraprecision optical surfaces

J. Ratteit, S. Schröder, S. Gliech, Fraunhofer-Institut für Optik und Feinmechanik (Germany)

To meet the ever increasing requirements for high quality optical surfaces, components and systems, high sensitive and flexible analysis of optical losses, nano-roughness and defects is necessary. For thorough texture analysis we use a set of optical and non-optical investigation techniques: i.e. atomic force microscope, white light interferometer and set-ups for measuring total and angle resolved light scattering. We present results for ultra-precision optical surfaces ranging from superpolished substrates to diamond-turned mirrors.

5965-67, Poster Session

Off axis microspectrophotometer for optical coating characterization on complex surfaces

H. R. Niederwald, L. Deisenroth, S. Nunnendorf, Carl Zeiss AG (Germany)

Optical thin films, especially reflection reducing coatings, are often applied to complex surfaces, e.g. small and strongly curved optical elements that are built into optical devices like objectives for microscopes. The performance of the device depends very much on the optical quality throughout the entire surface of the optical element.

In order to measure optical parameters in defined positions of a given optical surface, a fully automated microspectrophotometer for in line quality control was developed.

The microspectrophotometer consists of a Zeiss MCS 501 diode array spectrometer that is capable of fast and simultanous data acquisition over the desired spectrum between NUV and NIR, connected via light waveguide to a Zeiss Axiostar Microscope, which is operated in the reflected-light-brightfield mode, and a sample handling system that can be programmed to measure any spot on the individual surface of the optical element under examination.

The size of the measured spot is in the order of about ten micrometers in diameter, allowing also characterization of defects and microscopic deviations from the desired thin film coating or optical surface.

The principle and the assembly of the microspectrophotometer are presented as well as measurements of uniformity distributions of antireflection coatings on small semispheres achieved by different coating processes.

5965-68, Poster Session

Azimuthal ellipsometry of subsurface layer stresses of metal mirror

L. V. Poperenko, M. V. Ozerov, Kiev Natl Taras Shevchenko Univ (Ukraine)

The surface stresses of subsurface layer of metal mirror may be effectively monitored by azimuthal ellipsometry. Such ellipsometry is offered as a method of estimation of the subsurface stress homogeneity degree. Having determined the deviations of ellipsometrical parameters for light reflected from the metal surface in dependence on its orientation in the own plane, the level of deformational strains changes in the subsurface layer may be tested.

As metal mirrors the amorphous Ni- and Fe-based alloy ribbons polished were probed using sample rotation. Each sample was manufactured by rapidly melt quenched method. But structural modification in as-casted material must be taken into account due to the existence of an elastic-stressed state within subsurface layer.

Optical measurements were carried out at 12 orientations of the ribbon longitudinal axis relatively to the plane of light incidence. For any fixed orientation the angular dependence of the phase shift D(j) (j is angle of light incidence) was obtained and appropriate principal angle jo was determined. Then, rotating a ribbon around a normal to its surface within 3600 one can acquire the polar diagrams as a result of such orientational measurements.

The characteristic directions of optical anisotropy (for minimal and maximal values of jo) of subsurface layer at two appropriate azimuthal angles q were registered. The appearance of noncircular form of polar diagram indicates orientational effect testing due to polar dependence jo(q) strong sensitivity to internal stress variations.

Thus, the fulfilled ellipsometric measurements are evidenced that after manufacturing ribbons' surface is characterized by stressed state and the level of strains may be estimated by parameters of polar diagram of the principal angle of incidence.

5965-69, Poster Session

Spectral characterisation of scattering losses in sputtered oxide coatings

F. Menchini, A. Krasilnikova, A. M. Piegari, ENEA (Italy)

Multilayer optical devices generally suffer from two main losses sources: absorption of the materials and scattering losses, due both to volume and surface effects. The exact estimation of this latter contribution is of extreme importance for the final assessment and optimization of efficient devices. In particular, when intrinsic absorption of the materials cannot be further reduced, scattering measurements may provide useful information for improving optical device performance.

In this work we investigate single SiO2 and HfO2 layers deposited by r.f. sputtering under different deposition conditions. These materials are being

studied for implementation in multilayer dichroic mirrors for laser applications in the range from 260 to 350 nm. To avoid radiation damage, such devices need to be loss-free in the pumping and lasing region; hence, an insightful knowledge of all losses sources is fundamental.

We measured the samples with two different set-ups based on a Coblentz sphere imaging the scattered light into the backward or forward hemisphere. In the first case, two custom attachments for a commercial UV-VIS-NIR spectrophotometer (Perkin-Elmer) were used, which allow spectral total-scattering (TS) measurements in a wide wavelength range and in the angle range from 5 to 85deg. The other instrument allows monochromatic TS measurements at different laser wavelengths in the angle range from 2 to 85deg. The results are compared and discussed.

5965-70, Poster Session

Spatially resolved spectroscopy for nonuniform thin film coatings: comparison of two dedicated set-ups

A. Krasilnikova, A. M. Piegari, ENEA (Italy); M. Dami, Galileo Avionica (Italy); F. Lemarquis, M. Lequime, L. Abel-Tiberini, Institut Fresnel (France)

For characterisation of non-uniform thin film coatings optical measurements should be performed with spatial resolution often much higher than that of conventional spectrophotometers. Here we present two different instruments constructed for transmittance and reflectance measurement of spatially non-uniform coatings. One of the setups is based on the localized light distribution with a help of an optical fibre, while the other setup acquires the sample map 'at-once' with a CCD camera. The spatial resolution ranges from 100 μm up to 2 mm for the first instrument, and is 30 μm for the second one. The spectral resolution of the first setup is about 0.5 nm in the range from 400 nm to 1700 nm, while for the second instruments it is 0.1 nm in the range 400-1000 nm. The largest measurement area is represented, respectively, by a circle with the diameter of 2 mm, and a square with the sides of 1cm.

Besides the real optical performance of an optical device in terms of its spatially variable transmission and reflection, a 'mapping' of the thickness and refractive index of a single layer coating can be obtained. Comparison of the results obtained with these two instruments is given for several examples of coatings. The proposed instruments are useful tools for characterisation of both intended and unwanted non-uniformity of optical coatings.

5965-71, Poster Session

Developments of a nanoscale linewidth-standard for high-resolution optical microscopy

U. Huebner, W. Morgenroth, R. Boucher, Institut für Physikalische Hochtechnologie e.V. (Germany); W. Mirandé, E. Buhr, Physikalisch-Technische Bundesanstalt (Germany); T. Fries, N. Schwarz, FRT GmbH (Germany); G. Kunath-Fandrei, Carl Zeiss Jena GmbH (Germany); R. Hild, Hochschule für Technik, Wirtschaft und Kultur Leipzig (Germany)

As metrology reduces to the nanoscale, accurate and traceable measurements of structure widths in the submicron- and sub-100 nm-scale is becoming more and more important. Consequently, we are going to develop new linewidth standard on the nanometre scale for use in recently introduced new high-resolution optical microscopy techniques like deep ultraviolet microscopy (UVM) and confocal laser scanning microscopy (CLSM).

The high-resolution pattern for use in UVM or CLSM consists of different grating structures on a quartz substrate. For the grating material we used sputtered thin films of Niobium, Titanium, and also Silicon, with a thickness of 30 to 50 nm. The material choice was influenced by our fabrication technology and by the behaviour of the reflectance and transmittance in the UV-wavelength range. The types of grating are 1-dim (for both x and y), 2-dim (cross grating) and circular. An isolated single structure for CD determination (CD ... critical dimension) is added on one side of the 1-dim grating. The smallest structure size should equal the resolution limit of the optical microscopy method or be smaller. Currently, the lateral resolution of 248 nm-UV-microscopy is around 120 to 160 nm, and the resolution limit for CLSM (at 405 nm) is about 250 nm. At the present time the pitch of our fabricated gratings varies from 160 nm to 4 μm, i.e. the structure widths are between 80 nm and 2 μm.

Different prototypes containing very high-resolution patterns have been fabricated and initially evaluated using state-of-the-art UVM, CLSM, REM and AFM equipment.

5965-72, Poster Session

Investigations on process parameters influencing the quality of optical lenses formed by non-isothermal embossing of inorganic glasses

M. Hug, D. Rieser, P. Manns, G. Kleer, Fraunhofer-Institute Werkstoffmechanik (Germany)

Fundamental investigations on an advanced replication method for optical components in inorganic glasses have been carried out aiming at the development of a process with short cycle time and thus reduced costs. The process features a strongly non-isothermal embossing step where the glass is heated well above the temperature of the moulds. Benefitting from the low viscosity of the glass the forming process can be accomplished in less than one minute. Under non-isothermal conditions the physical properties of the glasses show a complex temperature and cooling-rate dependent behaviour. This results not only in the need for accurate adjustment of the relevant parameters but also for a detailed understanding of the thermal and mechanical processes during the forming step. In the paper is shown how the process is implemented in a self-developed automated embossing machine suitable for small series production of mini- and micro-optical components as well as for fundamental investigations on process parameters of the forming process. In order to achieve good optical surface quality and tight tolerances the influence of temperatures, forces and process timing was studied. As a result of these investigations the dominating physical properties for controlling the thickness, contour and surface quality of the lenses have been identified. Further studies aim at the description of the time-dependent thermo-mechanical conditions in the glass while in contact with the moulds. This will allow further optimizations concerning process time and quality of the replicated glass lenses as well as it provides input data for the numerical simulation of the forming step.

5965-73, Poster Session

Surface microroughness characterisation of amorphous metallic ribbons during their relief modification

K. Vinnichenko, L. V. Poperenko, Kiev Natl Taras Shevchenko Univ (Ukraine); S. I. Lysenko, Institute of Semiconductor Physics (Ukraine)

To obtain a full set of microrelief parameters for rough surface during modification of its subsurface layer it is necessary to fulfil both local (nanoscale) and low spatial frequency (microscale) topological analyses by AFM and light scattering methods respectively. As testing surfaces two sides namely contact and noncontact ones of amorphous metallic ribbons were characterized. The modification of the microrelief and the structure of ribbons' surface layers of amorphous metal alloy (AMA) $Co_{59}Fe_5Ni_{10}Si_{11}B_{15}$ after thermal treatment during 10 minutes at elevated (T=350-475 oC) and cryogenic (T=78 K) temperatures and under the action of an external magnetic field (B ~ 30 mT) is studied.

The experimental light scattering data for surface with small roughness can be used to calculate the power spectral density functions for the surface roughness. The detailed results were also obtained by AFM.

It was shown that thermal annealing of amorphous alloy leads to monotonous rise of the roughness parameters for noncontact ribbon surface. The microrelief evolution for such surface at thermal annealing and the dependence of roughness parameters on annealing temperature point out the onset of the crystallization of such AMA because its crystallization temperature is equal to 492 oC. It is beyond doubt that monotonous rise of the roughness parameters for noncontact surface at enhancement of annealing temperature occurs during structural relaxation within 350-475 oC for this AMA. It is important to emphasize that microrelief evolution obtained during precrystallization annealing for such alloy just corresponds to the onset of the crystallization of ribbon from its surface.

5965-74, Poster Session

A new optical metrology tool for measuring aspheres

T. Fries, M. Meyer, G. Jakob, FRT GmbH (Germany)

One of the most actual needs in metrology is the possibility to investigate aspheres. With many optical metrology tools this is just not possible in a direct way. This task needs a completely new category of metrology tools. A new approach for this application is presented. The measuring machine allows for high resolution, fast and non contact measurement of lens profiles. The geometry of the lens might be spherical or aspherical. The maximum profile length 180 degree, maximum lens height is 100 mm. The alignment of the centre of the lens is done automatically. As an option the system may be extended into a fully 3D metrology tool.

5965-75, Poster Session

Active shape adjustable polishing tools

V. Herold, S. Eckner, Friedrich-Schiller-Univ. Jena (Germany); C. Weber, J. Weiser, IGAM Ingenieurgesellschaft für angewandte Mechanik mbH (Germany); C. Weber, Carl Zeiss Jena GmbH (Germany)

SynchroSpeed-Polishing Technology is a widespread application for optical surface polish. The polished workpiece shape is the result of local material removal, which depends on the relative movement of workpiece and polish tool and the pressure distribution between both. Shape errors of the polished workpiece result from conditioning shape errors, wear of the polishing pad and from elastic and thermic deformations of the workpiece, the polishing tool and of components of the polishing machine. It is well known, that because of the complexity of the influencing factors sometimes the polishing process is more a craftmanship than a well controllable manufacturing process. Especially in case of high precision polishing one method to control shape accuracy of the workpiece in practice consists in variation of the slurry temperature. Because variations of the temperature can´t be restricted to shape variations of the polishing tool process control leads to different success. In this paper a polishing tool with a membranelike surface is presentet. The shape of the surface can be deformed pneumatically. To reach retention of spherical shape of the tool the design was optimized by FEM. Special hinges have been chosen to avoid hysteresis and friction forces. A pressure sensor is integrated into the polishing tool for indirect control of the tool radius. By precise process intermittend adjustment of the polishing tool inaccuracies because of tool wear and influenced by temperature variations can be corrected. The function of the polishing tool is demonstrated on the basis of experimental results, which are obtained under production similar conditions.

5965-76, Poster Session

Synchrotron radiation mirror prototype made of monocrystalline tungsten

V. Herold, R. Schwennicke, Friedrich-Schiller-Univ. Jena (Germany); H. Lammert, F. Siewert, BESSY GmbH (Germany); A. Schindler, Institut fuer Oberflaechen- modifizierung IOM (Germany)

Synchrotron Radiation mirrors are ultraprecision optical parts with very high requirements to shape accuracy and smoothness. Depending on the function there are the following demands on the materials for such mirrors:

· good thermal conductivity

· low coefficient of thermal expansion

· long-term stability (shape accuracy)

· vacuum suitability

· reasonable machinability to obtain the high requirements to shape accuracy and smothness.

Commonly such mirrors are made of single crystal silicon, Zerodur(r), ULE(r)-glass and in rare cases of silicon carbide, special steel or Glidcop(r). Some considerations lead to the result that also tungsten is an interesting alternative material for SR-mirrors. But tungsten is commonly produced by sintering processes, probably almost with some defects, which are foreclosing very smooth surfaces. Some preliminary tests have shown, that with both ,sintered / forged tungsten and also electron beam melted tungsten, the achievement of very smooth surfaces without defects is apparently not possible. On the other hand experiments with monocrystalline tungsten resulted in very smooth surfaces in the low sub-nanometer range by chemo-mechanical polishing. With availability of tungsten single crystals in mind subsequent a special design of a tungsten mirror was conceived, consisting of a basic structure of polycrystalline tungsten and a cover plate of monocrystalline tungsten, which is forming the optical surface. The components were cut by EDM and joined by diffusion welding. The paper presents the design, some results of the ultraprecision machining and some functional parameters of the SR-mirror prototype.

5965-77, Poster Session

Light scattering techniques for measurement of precision laser optical surfaces and high-reflective mirrors

V. V. Azarova, Y. D. Golyaev, G. Y. Kolodnyi, POLYUS Research & Development Institute (Russia)

Angle-resolved light scattering (ARS) has been used for several decades to probe heterogeneities in optical multilayers and substrates. We present a summary of results reached in laser metrology techniques.

OCIS Codes: (120.0120)Instrumentation, measurement, metrology (120.5820) Scattering (240.0240)Optics at surfaces (240.5770) roughness Elaboration of the optical surface finish technology requires non-destructive sensitive measurement methods subsequent development. Need optical surfaces for precision quantum electronics devices are usually composed of irregularities smaller than 1 nm “high” with “slope” of low gradient of perhaps 0,001 rad relative to the mean surface and destructive layer thickness about tens of nanometers. There are described application of ARS method and automatically device, based on this method for testing optically transparent surfaces by scattering indicatrix analysing. Investigated are the suitability of scattered light measurements, atomic force microscopy (AFM) and so named X-ray scattering as techniques for determining surface state. There are shown that scattering indicatrix includes information about surface roughness and near surface destructive layer and that is why it’s need to measure the whole indicatrix of scattering and not enough to measure differential scattering under two angles. In this case express method can give only upper limit of roughness surface parameters. It is concluded that in the process of surface finish not only “high” and “slopes” change but character of mathematical statistic described optically polished samples may be complete and changes in process of polishing. Using two control ARS , AFM and X-ray scattering methods together it may be adequately represented polishing surface by statistical parameters root mean square surface roughness, root mean square microfacet pitch and thickness of destructive layer. The testing surfaces could be controlled with help of scattering maps in particular back scattering.

5965-78, Poster Session

Optical surfacing of reflecting SiC mirrors of 520mm R-C system

L. Yuan, B. Wang, Nanjing Institute of Astronomical Optics & Technology (China)

In the area of astronomy and space camera, the using of silicon carbide (SiC) will have a good future for its specific stiffness and quickly thermal diffusion. However, the SiC as a new material of optical mirror is difficult to process efficiently because of its specific characteristics such as stiffness and material structure. To manufacture the aspheric SiC mirrors of a R-C system with aperture 520mm in diameter, we starts to research on optical surfacing of SiC. The research on the optical surfacing of some small different apertures flats SiC takes first for finding a technology to improve the surface roughness of SiC. The testing result shows that the surface roughness (RMS) of the best plat of these plats is better than 1.0nm. Finally, the surfacing results of the ellipsoid primary mirror with aperture 520mm in diameter and the hyperboloid secondary mirror with aperture 114mm in diameter of the R-C system is measured. The surface error (RMS) of them is less than 15nm, while the surface roughness of them is better than 1.8nm. The results reach the standard of optical mirrors.

5965-80, Poster Session

Optical system alignment via optical state estimation using wavefront measurements

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That Optical State Estimation provides a framework for separating errors in the test optics from the target system was presented in “Optical state estimation using wavefront data”, Proc. of SPIE Vol. 5523, pg.212. As stated, the estimated optical states obtained via interferometric wavefront measurements can be confused by state errors providing similar wavefront measurements. Extending the alignment procedure to a multi-field interferometric wavefront measurements approach, i.e. increase information content about the system, indicated to improve Optical State Estimation and thereby improving robustness of the control process and offering a better optical alignment with good optical performance across the field of view for all JWST science instruments. Our simulation results are based on the ground testing configuration of the Optical Telescope Element of NASA’s James Webb Space Telescope.

5965-81, Poster Session

Development of a CCD analyzer for the comprehensive characterization of the roughness of an optical surface

M. Zerrad, C. Deumié-Raviol, M. Lequime, Institut Fresnel (France)

The recording of the Bi-directional Reflectance Distribution Function (BRDF) is widely used to quantify with a high sensitivity the roughness properties of an optical surface. This measurement requires illuminating the sample

with a laser beam under a fixed incidence and recording with a detector mounted on a rotating arm the angular distribution of the light scattered by this surface. If this recording is performed for a single point of the sample, the corresponding roughness information can be not representative of the mean properties of the item (due to localized contamination, presence of dusts ...). As a consequence, the fine and comprehensive characterization of the actual properties of a sample needs to use a small-size spot beam for the illumination (to achieve a good spatial resolution) and three mechanical scan axis (one for the angle resolved measurements and the two others for the sweep of the whole surface), which leads obviously to very long acquisition time.

To overcome this difficulty, we propose a entirely new scheme, in which the detection system is a low-light-level CCD (as used for astronomy or live-cell microscopy) located in front of the sample at a fixed position near the zero-incidence, the surface of the sample being imaged on the CCD plane through a low-numerical-aperture telecentric objective and illuminated by an angle scanned collimated light beam.

We will provide in our talk a detailed description of this new set-up as well as a presentation of the first promising results obtained with it on standard optical windows.

5965-82, Poster Session

Large, efficient, high damage threshold gratings for laser pulse compression

J. Flamand, G. de Villele, A. Cotel, B. M. Touzet, HORIBA Jobin Yvon SAS (France); S. Kane, HORIBA Jobin Yvon Inc. (USA)

The use of the chirped pulse amplification (CPA) technique is widely employed to produce high-energy laser pulses in the femtosecond and picosecond regimes.

The compressor stage is based on a pair of reflection diffraction gratings; associated with the need to have large gratings with high efficiency, laser-induced damage threshold remains the main limiting factor towards generating higher-energy compressed pulses (terawatt and petawatt).

HORIBA Jobin Yvon has first developed the manufacturing of large gratings coated with a gold layer which present reflectivity in the range 90 to 93% in two wavelength range domains : 700-900nm and around 1.053μm.

The damage threshold is then reached when the gold is damaged.

So, in order to enhance the damage threshold of its gratings for pulse compression, HORIBA Jobin Yvon has started developing diffraction gratings engraved into the upper layer of a high-damage-threshold multilayer dielectric (MLD) coating for working at 1.053μm. The damage threshold test of a first batch of small MLD gratings exhibit damage thresholds approximately 2 to 3 times higher than classical gold coated gratings, depending on the pulse duration and beam size.

In addition, the efficiency of these MLD grating samples is quite high : 92 to 96% and so very interesting for use in laser pulse compressor.

Today, HORIBA Jobin Yvon has launched the production of large MLD gratings up to half a meter size to complement the manufacturing of large gold coated gratings.

We will present this new MLD technology with possibilities and limitations in groove density and wavelength ranges; then we will review the results of measured characteristics (efficiency, damage threshold, diffracted wavefront flatness) of the MLD gratings and compare them with the performances of gold coated gratings.

5965-83, Poster Session

New measurement tool to measure scattering of materials for 2D/3D scattered light measurements and BRDF/BTDF measurements cd

A. Le Lay, Light Tec (France)

No abstract available

5965-84, Poster Session

Comparison of different MR polishing fluids, M. Schinhaerl, E. G. Pitschke, R. Rascher, P. Sperber, Fachhochschule Deggendorf (Germany)

In a magnetorheological finishing process, a magnetorheological fluid is used as the polishing tool. The University of Applied Sciences Deggendorf has analysed different magnetorheological polishing fluids. Scanning electron microscope analysis as well as spectrum analysis show the different compositions of the particular fluids. The removal characteristics of the fluids on different materials are shown. Finally the conditions of the different fluids during polishing is presented. For this purpose fluid parameters like fluid flow rate and fluid viscosity have been analysed.

5965-39, Session 8

Wavefront sensing with varying transmission filters: past, present and future

F. Hénault, Observatoire de Lyon (France)

The use of Wavefront Sensors (WFS) is nowadays fundamental in the field of instrumental optics. This paper discusses the principle of an original and recently proposed new family of WFS. Their principle consists in evaluating the slopes of the wavefront errors by means of varying density filters placed into the image plane of the tested optical system. The device, sometimes called “optical differentiation WFS”, is completed by a digital data-processing system reconstructing the wavefront from the obtained slopes. Various luminous sources of different sizes, wavelengths and spectral widths can be employed. The capacities of the method are discussed from the geometrical and Fourier optics points of view, then by means of numerical simulations showing the ultimate accuracy of the measurement principle. Two practical examples of measurement configurations are also described and commented.

5965-40, Session 8

Interferometric asphere testing in a spherical test setup

T. Blümel, M. Bosse, FISBA OPTIK GmbH (Germany)

The non-contacting testing in reflection of aspherical samples is of increasing interest. Conventionally this is done by using an interferometer. For beam shaping, CGHs or null lenses must be placed in the test beam. These optics introduce additional errors which cannot be calibrated, unless you have a master sample. A further disadvantage of the traditional setup is that each asphere requires a unique beam shaping optic. That is the reason why interferometric asphere testing with CGHs is only profitable, if large numbers of identical samples can be tested. So during development aspheres are still often measured with profilometers.

To overcome these problems we have developed an analysis method that allows you to measure aspheres in a spherical or plan test setup, i.e. without any special expensive beam shaping optics. The method eliminates the test setup error in the primary measurement data that obscures the primary sample deviation you are interested in. It is applicable to all aspheres where deviations from a sphere or a flat do not get too large. The method will be demonstrated with example measurements.

As an option the new method also allows the user to make a so-called base radius fit. In this case the base radius of the corresponding asphere description is modified automatically by the software so that the detected aberrations become minimal. This is comparable to a procedure often applied by analyzing data from a profilometer.

The results of both analysis methods are compared with results from a profilometer.

5965-42, Session 8

Characterisation of complex optical systems based on wavefront retrieval from point spread function

B. Moeller, H. Gross, Carl Zeiss Jena GmbH (Germany)

The measurement of aberrations is essential to qualify and improve optical system performance. Interferometry and Shack-Hartmann test are well known methods, which usually characterize only a component of the system. In addition they usually neglect the field dependence of aberrations.

For the characterization of the Hubble Space Telescope as an entire system Fienup suggested an iterative wavefront retrieval from point spread images in 1993 at first. Dirksen and Braat suggested the analytical recalculation using the extended Nijbor-Zernike approach in 2001.

We evaluated the iterative approach based on the Gerchberg Saxon Algorithm and optimised its accuracy for experimental data. The aberrations are recalculated from an image stack formed by a point source with varying focus position. In addition to calculating the aberrations also apodisation can be taken into account. The numerical accuracy of the technique is up to one thousandth of wavelength (Fringe Zernike) for ideal noiseless detection. For experimental data it is shown that the main uncertainty is caused by model assumptions as the precise numerical aperture, magnification or step size in defocus. The match between retrieval and direct wavefront measurement is less than 1/25 of wavelength. Furthermore the adjustment of an objective lens is tracked with respect to lateral movement of lens elements. The influence of components of the optical system may be separated by measuring it with exchanged components.

5965-43, Session 8

Traceable measurement of wavefront sensors

S. D. Knox, S. R. Hall, R. F. Stevens, National Physical Lab. (United Kingdom)

Wavefront sensors, particularly those of the Shack-Hartmann type, have found increasing use in optical metrology and are now available in commercial form from several manufacturers. Compared to phase-shifting interferometery, Shack-Hartmann devices have enhanced dynamic range and less sensitivity to vibration.

While some users only require a high sensitivity to changes in wavefront shape, many applications demand absolute measurements. For consistent measurements over a range of instruments and measurement situations traceability of measurement is essential. This is also required to ensure interoperability of the constituent components of adaptive optic systems.

We have investigated the use of simple artefacts to generate prescribed values of optical aberration and act as calibration references. Measurement points are verified by comparison with values that are derived from calculation and measurements using the National Physical Laboratory, primary Fizeau interferometer.

5965-44, Session 8

Colorimetric method for phase evaluation in optical testing

A. Miks, J. Novák, P. Novak, Czech Technical Univ. in Prague (Czech Republic)

Measurements of very small phase changes in optics are usually performed by interferometric methods on the basis of evaluation of interference patterns that corresponds to a specific phase change of the investigated wave field. Our work presents a simple method for evaluation of small phase variations that uses the interference of polychromatic light. The phase change has effect on the color of the interference pattern, and every color of the interference pattern represents a specific phase change that can be evaluated using colorimetric methods. We describe the analysis of the proposed method in detail. The proposed method offers accurate results and it is suitable for practical utilization in optical testing.

5965-45, Session 9

Dos and don'ts in characterizing and cleaning optical surfaces

J. M. Bennett, Consultant (USA)

Depending on the application, different characterization techniques are appropriate for uncoated and coated optics. For extremely high performance, low scatter optics, a small fractional coverage of dust will produce more scattering than the rest of the surface microroughness. It is essential that substrates to be coated with thin films be dust free and do not contain surface films that interfere with the adhesion of the coatings. Surface inspection is essential before cleaning any uncoated or coated substrate and also after cleaning the optic. Some optical surfaces, especially metal-coated surfaces, cannot be cleaned. It is much preferable to keep a surface clean rather than having to clean it later.

5965-46, Session 9

Design of a full-hemispherical spectro-radiometer with high-dynamic range for characterization of surface properties using multispectral BRDF data from VIS to NIR

C. F. Hahlweg, H. Rothe, Univ. of the Federal Armed Forces (Germany) and Univ. der Bundeswehr Hamburg (Germany)

Multi- und hyperspectral image data are collected with a variety of rather complex instruments. Normally, BRDFs are measured with a goniometer. Because of the necessary mechanical movements the acquisition of a hemispherical BRDF for some specified wavelengths may take hours. In further development of an existing semi-hemispherical spectro-radiometer without moving parts for angular resolution based on an elliptical mirror, a full-hemispherical device was

designed.

For the purpose of cost reduction and reproducibility it was decided to switch from the formerly used log-polar sensor to a commercially available cartesian CMOS camera with a dynamic range of 112dB. The sensor consists of 322096 pixels, producing an equivalent angle resolution. The system can take up to 53 full-hemispherical BRDFs per second.

Illumination is provided by an incoherent white light source with eiter a filter wheel or a liquid crystal tunable emission filter or by assorted LEDs. Also a combination of white light illumination and an LCTF in front of the sensor is discussed.

A radiometric measurement over a wide spectral range from VIS to NIR requires a pixelwise calibration taking into account the spectral characteristics of the light source, filters, elliptical mirror and the CMOS-detector itself. However, the most important problems during calibration are the spectral response of the CMOS-detector, as well as its sensitivity as a function of the angle of the incident light.

Also the elliptical mirror has a reflectivity which is a function of the incident angle, the wavelength and polarization of the collected light. All these influences have to be taken into account, if a proper radiometric measurement shall be conducted.

The paper deals with the instrument design, the calibration procedures and gives some measurement results.

5965-47, Session 9

Angle resolved scatter measurements on optical components

P. Kadkhoda, H. Madebach, D. Ristau, Laser Zentrum Hannover e.V. (Germany)

For the precise angle resolved scatter (ARS) investigations on optical components, a scatterometer has been developed, which allows three dimensional scanning of the scattered radiation from the test specimen. By combining the set-up with different radiation sources, measurements in the spectral region from the DUV- to the NIR-spectral range can be performed. The optical properties of the components, reflection, transmittance, and the scatter behavior can be determined in the same run. The measured data are absolutely calibrated to the incident power.

In this paper, we report about ARS-measurements on different samples such as holographic gratings, bare and anti reflective coated substrates. Additionally, results of scatter measurements on high reflective mirrors for 633nm with different numbers of layers will be presented. The comparison of the ARS-data and the results of Total Scattering (according to ISO 13696) on the same samples will be discussed.

5965-48, Session 9

Sensitive and flexible light scatter techniques from the VUV to IR regions

S. Schröder, S. Gliech, A. Duparré, Fraunhofer-Institut für Optik und Feinmechanik (Germany)

Driven by the increasing requirements for optical surfaces, components and systems, scattering techniques for the analysis of optical losses, roughness and defects face novel challenges for high sensitivity and flexibility. The field of application of such measurement techniques extends from photolithography, communication technology, nanostructured surfaces, camera systems etc. to rough non-optical engineering surfaces.

We report on the development of measurement systems for total and angle resolved light scattering (TS, ARS, respectively) at several laser wavelengths from the VUV (Vacuum Ultra Violet) to the IR spectral region. Extremely high sensitivities down to 0.05 ppm have been achieved for TS measurements and a dynamic range of 12 orders of magnitude for ARS. Fully automatic operation enables rapid and robust investigation of extended sample areas. TS measurements are carried out according to the new international standard ISO 13696.

Besides the measurement techniques, software tools were developed on the basis of scattering theories, which enable a sophisticated evaluation of the measured data for both uncoated and coated surfaces.

5965-49, Session 9

Ellipsometry of scattering patterns from optical inhomogeneities

C. Deumié-Raviol, G. Georges, O. Gilbert, C. Amra, Institut Fresnel (France)

Far field light scattering from rough surfaces and inhomogeneous bulks has extensively been studied these last decades, with a major application in random media characterization.

However most of these studies do not allow reconstruction of topography or surface profile, because they are limited to intensity data that only give access to the statistical moments of microstructure. Therefore the motivation of this work is to extend scattering data to angular phase measurements, in order to address this problem. Interferences between the two polarizations of the scattered waves are used, that is, Ellipsometry of Angle-Resolved Scattering (EARS).

In a recent work limited to slightly inhomogeneous samples, we

demonstrated the validity of the E.A.R.S. technique and recorded accurate measurements of polarimetric phase difference, thanks to rotating analyzer and polarizer introduced in a well known scatterometer. The results were applied to the separation of surface and bulk effects in low-loss samples, because first-order scattering only depends on the origin of scattering, not on the topography or microstructure. Therefore the separation method for low-scattering samples is valid whatever their structural parameters, which provides an efficient characterization tool.

Now the major point that we address in this paper is the generalization of the separation technique (surface or bulk) to arbitrary heterogeneous samples with high level diffuse reflectance. The problem is strongly different since phase data from these samples depend on microstructure, not only on the physical origin of scattering. Moreover, cross-polarization effects play a key role and must be carefully considered.

5965-50, Session 10

Tailored properties of optical glasses

R. Jedamzik, B. Hladik, P. Hartmann, SCHOTT AG (Germany)

Today's driving markets for the development of new optical glasses with improved properties are multimedia applications like digital projection, digital camcorders and DVD players, and the digital photography market with DSC, DSLR and Camera phones. With tendencies of further component miniaturization with increasing light efficiency at the same time and the use of environmental friendly components in big amounts these markets generate high demands of optical glasses with tailored properties. These demands lead to improvements and developments of e.g. high refractive index glass types with at the same time a high transmission in the blue region, glasses with low dispersion characteristics, glasses with anomalous partial dispersion and glasses with low stress optical constants. Improvements in melting technologies and glass composition make it possible to produce even difficult glasses in economical ways. Preforms with excellent surface quality from glasses with low glass temperature (Tg) are suitable for the mass production of aspherical lenses by precision molding processes. This presentation will give an overview on the new developments in the field of optical glasses at SCHOTT.

5965-51, Session 10

Implementing a prototyping network for injection moulded imaging lenses in Finland

K. Keränen, J. Mäkinen, VTT Elektroniikka (Finland); E. Pääkkönen, Perlos Corp. (Finland); M. Karttunen, VTT Elektroniikka (Finland); H. Heino, Helsinki Univ. of Technology (Finland); J. A. Hiltunen, P. Karioja, VTT Elektroniikka (Finland)

A network for prototyping imaging lenses using injection moulding was practised in Finland. The network consists of several academic and industrial partners capable of designing, processing and characterising imaging lenses produced by injection moulding technology.

In order to verify the operation of the network a pilot lens realisation was performed. The work tasks included in the process were lens specification, designing and modelling, material selection, mould tooling, moulding process simulation, injection moulding and characterisation. A magnifying imaging singlet lens to be used as an add-on in a camera phone was selected as a pilot. The original requirement specification of the lens was targeted not to weaken the resolution of the camera phone optics. The optics field-of-view and aperture were also taken into account. Specifications were, however, altered during the optical design task in order to fulfil most of the requirements set for the component. The design of the add-on lens proved to be somewhat challenging, but a double aspheric singlet lens design fulfilling nearly the requirement specification was produced. In the material selection task the overall characteristics profile of a PMMA material was seen to be the most fitting to the pilot case. It is a low cost material with good optical and mechanical properties, and its moulding profile is well-known. Lens mould design was modelled using I-DEAS and tested by using MoldFlow 3D injection moulding simulation software. The simulations predicted the achievable lens quality in the processing, when using a two-cavity mould design. First cavity was engraved into the mould plate and the second cavity was made by tooling separate insert pieces for the mould. Mould material was steel and the inserts were made of copper alloy. Parts were machined by high speed milling machines. Insert pieces were hand polished after tooling. Prototype lenses were injection moulded using Engel ES 200/70H machine and two PMMA materials, namely Plexiglas 6N and 7N. Different process parameters were also experimented in the injection moulding test runs to study the effect of manufacturing process. Prototypes were characterised by measuring mechanical dimensions, surface profile, roughness and MTF of the lenses. Characterisations showed that the lens surface RMS roughness was 30-50 nm and the profile deviated 5 μm compared to the design at a distance of 0.3 mm from the lens vertex. These manufacturing defects caused that the measured MTF values were lower than designed. The lens overall quality, however, was adequate to demonstrate the concept successfully. Through the implementation of the pilot lens we could test effectively different stages of the manufacturing process and get information about process component weight and risk factors and see the overall performance of the network.

5965-52, Session 10

SiC-Be-Zerodur: material comparison on some real lightweight mirror cases

R. Geyl, M. Cayrel, E. Ruch, SAGEM SA (France)

In the continuous race toward large, low weight and high performance optics the 3 most considered candidate materials are Zerodur (and its equivalents near zero thermal expansion glass or glass ceramics), Beryllium and Silicon Carbides. These material have all outstanding characteristics and can be processed to complex low weight shapes. In this paper SAGEM will express his optical manufacturer point of view and discuss about their relative merits based on his wide experience in opto-mechanical design, substrate manufacturing or procurement and optical processing. More precisely reference will be made on 3 major projects presently running in parallel at SAGEM-REOSC. These are:

The GEMINI 1.1-m secondary mirror made in ultra lightweight Zerodur

The GRANTECAN 1.2-m secondary mirror made from lightweight Beryllium

The GAIA 1.5 x 0.6 m demonstrator made from Silicon Carbide

5965-54, Session 10

Angular dependent specular reflectance in UV/Vis/NIR

I. Stemmler, PerkinElmer, Inc. (Germany)

There are well known methods and equipments for measuring the specular (/directed) reflectance of a sample. There are quite different sample types such as laser mirrors or anti-reflectance material.

Most of the common set-ups are not very flexible (e.g. only one angle ore only one wavelength), critical in accuracy, extremely expensive ore difficult to use.

A new development from PerkinElmer tries to combine

- high flexibility
- high precision
- easy to use
- comparably low cost.

The system is able to measure all type of samples from HR to AR. It covers a large wavelength range of 185...3100 nm. It is able to measure fully automated a couple of self defined angles (8...68°) in s and p polarisation. No alignment is necessary in the daily use. The system works with an absolute measurement mode and therefore does not need any calibrated standard mirrors.

The intent of this contribution is to introduce this new technology in comparison to traditional measurements.

5965-55, Session 11

DUV-microscope objectives: technology driver forcing production to switch from micro- to nanometer scale

T. Sure, Leica Microsystems Wetzlar GmbH (Germany)

Cemented doublets and triplets cannot be used for objectives working at wavelengths of 248 nm and shorter, because the optical cement cannot withstand the high photon energies. It will be shown that high NA deep UV objectives can be designed and built successfully with the help of air spaced doublets. Assuring Strehl ratios above 95% enforces very tight tolerances. For example, the distance error of the lens vertex to its mount has to be less than 1 μm. This calls for a new manufacturing precision never realized before in series production. It will be shown how white light Mirau interferometer can be used to measure lens vertex positions with an accuracy of 200 nm. Also the optimization of the fine-tuning process by using a "simulated star test", where the point-spread function is calculated in real time with a FFT-algorithm from measured optical path difference data, are demonstrated. To realize the required precision, today various

measurement techniques and production processes are used. Picking up the subgroups on different machining tools and measurement systems will loosen the accuracy. The concept and the layout of a new manufacturing tool where we implemented the different measurement techniques in one CNC machining center will be presented. This tool is able to 1) adjust automatically the optical axis of the subgroups related to the machining axis better than 0.5 μm with the help of the stick-slip effect, 2) measure the lens vertex relative to the shoulder of the mount with an accuracy of ±200 nm and 3) do all steps which are necessary to process the lens mount within the accuracies described above.

5965-56, Session 11

A novel instrument for measurement of low-level scattering of optical components in the UV region

A. Krasilnikova, ENEA (Italy); J. Bulir, Institute of Physics (Czech Republic)

The quality improvement of optical components for UV application demands increasing sensitivity of the instruments for optical losses measurement. In the optical region between 150 and 350 nm dedicated set-ups are normally needed to measure low-level scattering. Such instruments typically perform single-wavelength measurements, corresponding to that of the laser used. Another draw-back of such sophisticated tools is their elevated costs and the necessity of the staff specially prepared to handle with. Here we proposed a novel instrument for measurement of spectral scattering from the high quality optical components in both UV and visible range. It permits spectral data acquisition being positioned as an attachment to a commercial spectrophotometer, and the wavelength range is limited mostly by the spectrophotometer characteristics. The advantage of low costs of a set-up constructed in the base of widely diffused commercial spectrophotometers is combined with the simplicity of its implementation. Moreover, the proposed instrument can be a base for the measurement of scattered light in a dedicated experimental set-up having the light source and the detectors different from those of a commercial spectrophotometer. Some examples of such ad-hoc set-ups are discussed here as well.

5965-57, Session 11

Application of the laser-induced deflection (LID) technique for low absorption measurements in bulk materials and coatings

W. Triebel, C. Mühlig, S. Kufert, Institut für Physikalische Hochtechnologie e.V. (Germany)

Precise absorption measurements of bulk materials and coatings upon pulsed laser irradiation are presented using a compact experimental setup based on the laser induced deflection technique (LID).

For bulk absorption measurements of fused silica and CaF2 the influence of surface absorption on the probe beam deflection is analyzed in detail. Based on a combination of surface and bulk absorption calibrations an experimental procedure is proposed to obtain surface and bulk absorption separately by investigating only one sample. This is advantageous compared to calorimetric setups where typically a set of at least three samples with different thickness is used.

Using only the surface absorption calibration the LID setup is applied to measure the absorption of highly reflecting mirrors on CaF2 substrates. In order to investigate a larger variety of coatings modifications of the LID setup are discussed which allow the absorption measurement of sample surfaces free from influences of the bulk absorption.

5965-58, Session 11

Nondestructive optical characterization of KDP crystals inhomogeneities and adapted excimer laser conditioning procedure

M. Pommies, D. Damiani, H. Piombini, H. Mathis, Commissariat à l'Energie Atomique (France)

The high-power Laser MegaJoule (LMJ) for inertial confinement fusion experiments that is currently under construction at CEA-CESTA will require thousands of large aperture Pockels cells and frequency converters made of potassium dihydrogen phosphate (KDP) and DKDP (Deuterated KDP). These optical components will be operated at fluences close to their Laser Induced Damage Threshold (LIDT) which may reduce significantly their lifetime and increase substantially the maintenance costs of the LMJ. In a global effort to reduce these costs we designed the SOCRATE system as a complete set-up for both optics conditioning and characterization. SOCRATE is made up of an excimer laser (XeF, 351nm), beam shaping optics and several characterization tools were implemented to collect the luminescence and scattering signals. A spectrometer and a time-resolved intensified CCD camera allow to study the luminescence and Raman spectra during both conditioning and degradation. A photothermal probe was also added so as to detect any absorption inhomogeneity in the samples. The system is automated and allows to scan up to 150*150mm(c)˜ samples.

In this work, we will stress the existence of inhomogeneities in large KDP crystals with strong differences in linear absorption coefficients from a region to another. We will then report how the Raman spectra in these regions are affected by a close-to-LIDT excimer illumination and we will discuss the origin of the failure in the different areas. We will finally report how to manage these inhomogeneous regions varying the excimer conditioning parameters as a function of the absorption level.

5965-59, Session 11

VUV spectrophotometry for photomasks characterization at 193 nm

M. Yang, J. Leiterer, A. Gatto, N. Kaiser, Fraunhofer-Institut für Optik und Feinmechanik (Germany); I. Höllein, S. Teuber, K. Bubke, Advanced Mask Technology Ctr. (Germany)

To improve the resolution of an optical lithography system, several resolution enhancement technology have been proposed, phase shifting mask and off-axis illumination are the common approaches. In both case, monitor and control of the TE-polarized (or s-polarized) and TM-polarized (or p-polarized) light in the Zeroth-order, first order and second order diffractive direction are of great importance to the resolution enhancement. From the viewpoint of photomask design, characterization of the masks different incident state (on-axis, off-axis), polarization state (s-polarized, p-polarized and unpolarized), incident angle (0°, 10°, 20°) can discover the correlations of mask properties (mask type, materials, structure, structure size).

The DUV/VUV characterization setup at Fraunhofer IOF allows angle-resolved reflection and transmission measurement down to 115 nm together with an in-situ sample irradiation and -cleaning by a F2-excimer laser.

In this paper, we present the possibility to characterize photomasks for 193 nm lithography applications with VUV spectrophotometry. The configured system is completely computer controlled, including automatic procedures for the photomultiplier (PM) positioning during the transmission measurements. According to the photomask characterization requirements, the modified sample holder includes a goniometric bench, which enables a free angle spectrum measurement. This angle resolved measurements at the fixed wavelength (193 nm) can be employed to collect and describe the photomask diffractive energy intensities at different diffraction order from 0° to 85° (0.2° angle resolution). By using a Rochon prism of MgF2 as a UV- polarizer, diffractive curves under different polarization states can also be characterized.

We have configured the measurement system and evaluated the optical diffractive responses of photomasks at different incidence angle with different polarization light source at 193 nm wavelength, which are effective references for further photomask designs and optimisations.

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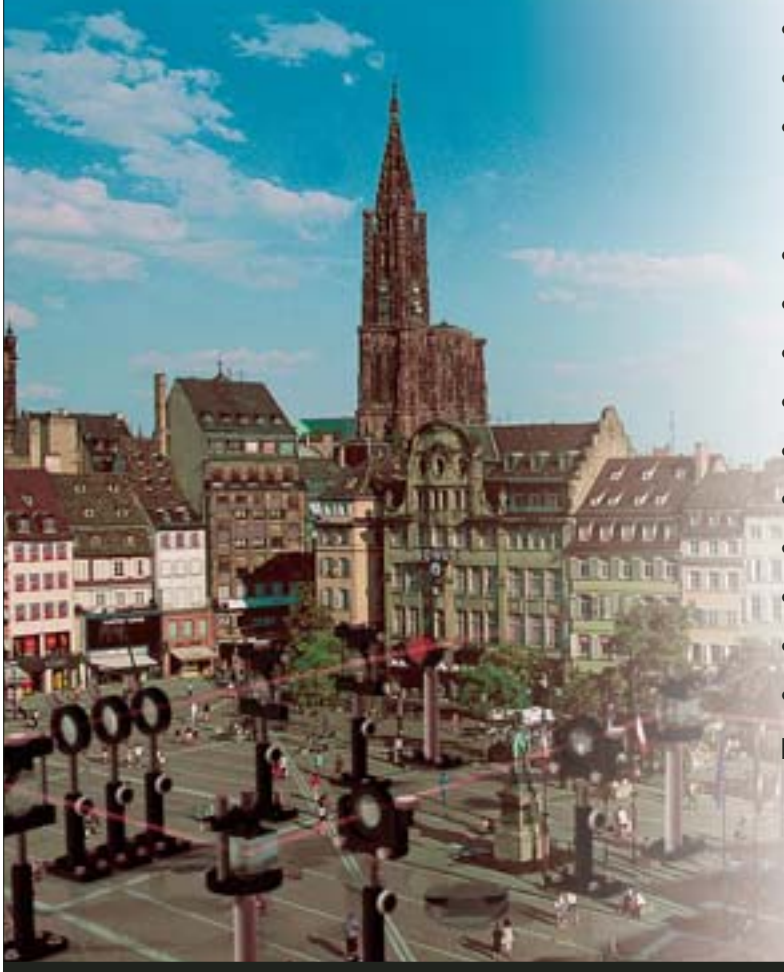

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