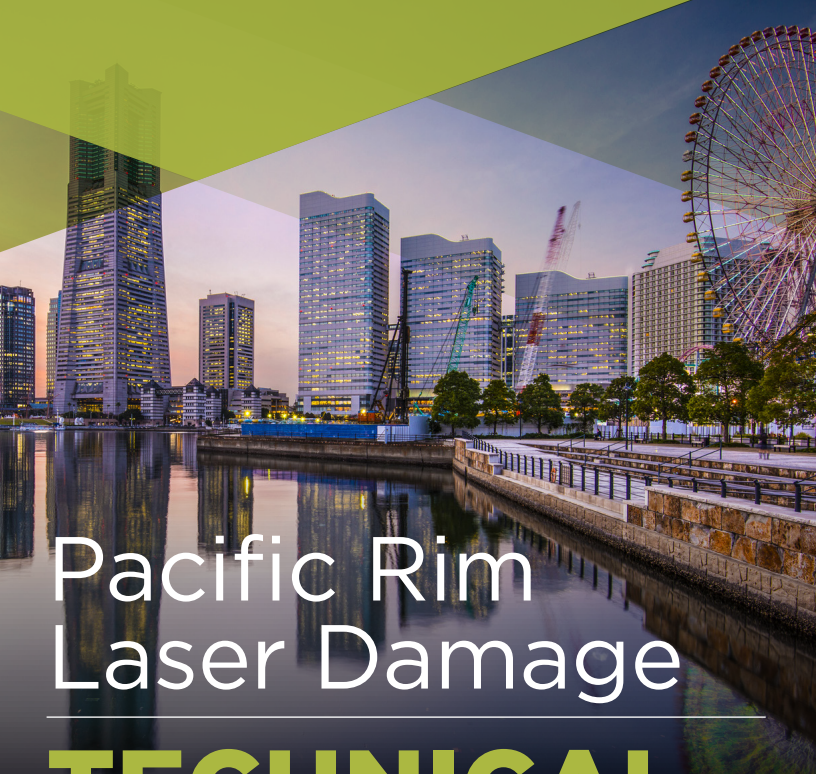

Pacific Rim Laser Damage

TECHNICAL PROGRAM

25 – 27 April 2018
Yokohama, Japan

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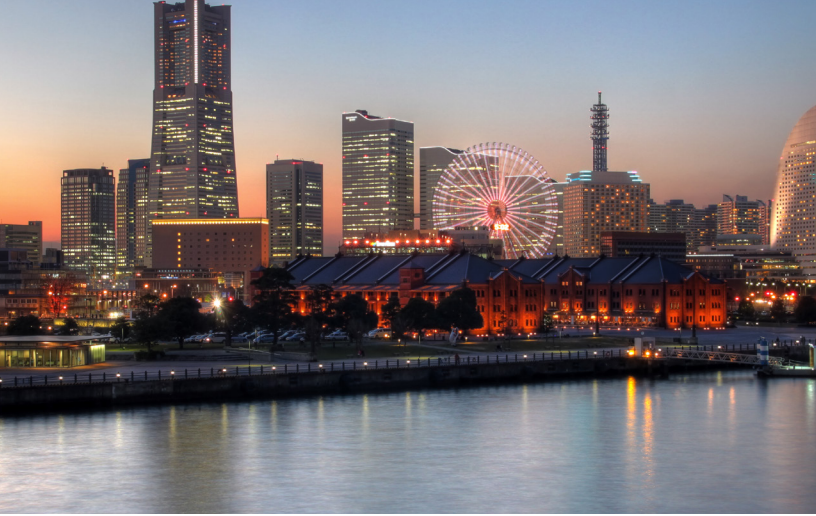

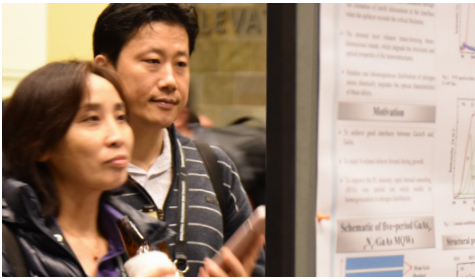
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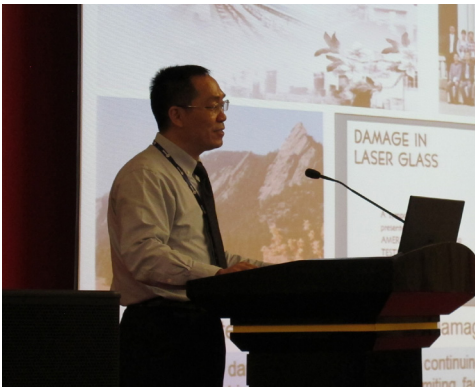
DAMAGE IN
LASER GLASS

SPIE. SIOM PACIFIC RIM LASER DAMAGE

25 – 27 April 2018 · Yokohama, Japan

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Conference 10713
Pacific Rim Laser Damage 2018: Optical Materials for High-Power Lasers

Wednesday–Friday 25–27 April 2018

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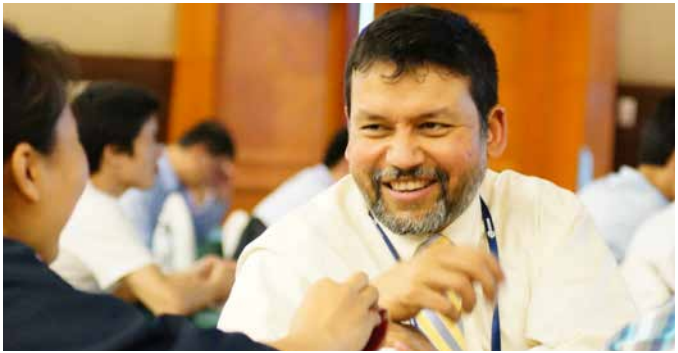

CONFERENCE SESSIONS AT A GLANCE

TECHNICAL CONFERENCE

Wednesday–Friday 25–27 April 2018

Pacific Rim Laser Damage 2018: Optical Materials for High-Power Lasers

Conference Chairs: **Takahisa Jitsuno,** Osaka Univ. (Japan); **Jianda Shao,** Shanghai Institute of Optics and Fine Mechanics (China); **Wolfgang Rudolph,** The Univ. of New Mexico (USA)

WEDNESDAY 25 APRIL

OPENING REMARKS

Location: Room 302 . . . . . 13:30 to 13:45

SESSION 1: SLPC-PLS-LIC1: JOINT SESSION I

Location: Room 302 . . . . . 13:45 to 15:15

Session Chairs: **Kunihiko Washio,** Paradigm Laser Research Ltd. (Japan); **Takahisa Jitsuno,** Osaka Univ. (Japan)

14:45: **Mechanisims of laser damage in optical components for PW-class laser systems** *(Invited Paper),* Stavros G. Demos, Alexei A. Kozlov, Kyle Kafka, James B. Oliver, Semyon Papernov, Brittany Hoffman, Terrance J. Kessler, Sheryl M. Gracewski, John C. Lambropoulos, Univ. of Rochester (USA) . . . . . [10713-1]

We investigate the mechanisms of laser-induced damage and ensuing material modifications on multilayer dielectric mirrors and gratings. Thermomechanical modeling combined with analysis of damage morphologies provides insight into the energy deposition and relaxation pathways.

Refreshment Break . . . . . 15:15 to 15:45

SESSION 2: SLPC-PLD-LIC1: JOINT SESSION II

Location: Room 302 . . . . . 15:45 to 17:15

Session Chair: **Takahisa Jitsuno,** Osaka Univ. (Japan)

15:45: UV-**induced aging leading to laser damage in the bulk of fused silica** *(Invited Paper),* Frank R. Wagner, Alexandre Beaudier, Jean-Yves Natoli, Aix Marseille Univ., CNRS, Centrale Marseille, Institut Fresnel (France). . . [10713-2]

Results on material modifications observed by photoluminescence in the bulk of fused silica during UV S-on-1 tests show modifications in the color center concentrations before the occurrence of damage and help predicting fatigue damage.

Closing Remarks . . . . . 17:15 to 17:20

THURSDAY 26 APRIL

SESSION 3: HIGH-POWER LASER DAMAGE I

Location: Room 212 . . . . . 9:00 to 10:15

Session Chair: **Takahisa Jitsuno,** Osaka Univ. (Japan)

9:00: **Toward "defect-free" optics: a pioneering comprehensive metrology method** *(Invited Paper),* Jianda Shao, Shanghai Institute of Optics and Fine Mechanics (China); Jian Chen, ZC Optoelectronic Technologies Ltd. (China); Shijie Liu, Yuan'an Zhao, Meiping Zhu, Shanghai Institute of Optics and Fine Mechanics (China); Liang Ma, Wencai Li, Ming Huang, ZC Optoelectronic Technologies Ltd. (China) . . . . . [10713-3]

The laser based inertial confinement fusion (ICF) research devices, typically represented by the National Ignition Facility (NIF) are striving to seek a new energy source for human-being. However, until now ICF systems worldwide still face several obstacles. One of them is the limitation of laser damage resistance of large optics and some optics should be regularly recycled or replaced when the damage sites on optics grow up. Various defects generated in the optics manufacturing processes are critical factors to reduce the laser damage threshold of optics. Therefore, obtaining "defect-free" optics is the ultimate dream of optical engineers, which is also a promising way to improve the laser damage resistance and to reduce the running cost of large high-power laser systems.

Precisely detecting various defects with micron or sub-micron size over the meter-size surface of optics is very important to control and eliminate the laser damage precursors. Existing metrologies of optical defects however, have not been able to directly reveal the correlation between damage and defects. Therefore it is necessary to develop defect metrology methods at the mesoscopic level, a bridge between existing microscopic and macroscopic metrology methods. In this paper, the concept of a multi-mode

metrology technology with high-speed and high-sensitivity is proposed for characterization of surface defects for large optics. The technology is a comprehensive integration of laser scattering method and highly sensitive photo thermal method. The principle, experimental setup and preliminary measurement results are presented in detail in the paper. A statistical model between the mapping results of defects and laser damages is also proposed to show the effectiveness of the comprehensive metrology method. The proposed method can detect non-destructively surface defects with high-speed and high-sensitivity at the mesoscopic level. It is a promising novel tool for mapping defects in meter size optics and hence it can provide clues to eliminate defects during the manufacturing processes and march toward "defect-free" optics.

9:30: **Study of absorption and defects properties for large aperture high-power laser optics at multiple wavelengths**, Jian Chen, Anhui Province Key Lab. of Non-Destructive Evaluation, ZC Optoelectronic Technologies Ltd (China); Zhouling Wu, Liang Ma, Xi Wang, Haifeng Zhou, Wenyang Xu, Anhui Province Key Lab. of Non-Destructive Evaluation, ZC Optoelectronic Technologies, Ltd. (China) . . . . . [10713-4]

Many precise laser systems set strict requirements on the optics, such as low absorption, high laser damage threshold, and low defect density. Photothermal absorption measurement system based on the laser induced surface thermal lensing (STL) effect has been widely used in the research on the correlation between laser damage susceptibility and properties of weak absorption defects for small optical specimens. The measurement of weak absorption properties for large aperture optics with meter-size still remains a big challenge.

In this paper, we present the progress in the study of absorption and defects properties for large aperture high-power laser optics at multiple wavelengths. An automated weak absorption measurement system for large aperture optics with a size up to 450mm is designed and built. This system can be used to investigate the absorption properties at multiple wavelengths. The system shows a measurement sensitivity of absorbance down to 50 ppb. It is fully automatic and requires little special skills from the operators and is therefore more reliable and reproducible. The specific applications of the system include weak absorption measurement, local absorption defects detection as well as laser-coating-interaction dynamics monitoring. The high sensitive automated system proposed in this work is an effective diagnostic tool for the examination of large aperture optics with desired optical properties.

9:45: **Comparison of 355-nm nanosecond and 1064-nm picosecond laser-induced damage in high-reflective coatings**, Cheng Li, Yuan'an Zhao, Yun Cui, Xiaocong Peng, Chong Shan, Meiping Zhu, Jianguo Wang, Jianda Shao, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-5]

The laser-induced damage thresholds (LIDTs) and morphologies of high-reflective coatings tested by 1064-nm picosecond pulses and 355-nm nanosecond pulses are compared.

10:00: **351nm mirrors with modified outer stack and post-treatment methods to increase the laser damage resistance,** Feng Pan, Zhichao Liu, Qian Wu, Chengdu Fine Optical Engineering Research Ctr. (China) . . . [10713-6]

The 351nm mirrors with different outer stacks were prepared by electron beam evaporation. The deposition and laser conditioning process of high refractive index layers were optimized to suppress the UV nano-absorbing precursors.

Refreshment Break . . . . . 10:15 to 10:45

SESSION 4: HIGH-POWER LASER DAMAGE II

LOCATION: ROOM 212 . . . . . 10:45 TO 12:00

Session Chair: **Shinji Motokoshi,** Institute of Laser Technology (Japan)

10:45: **Investigation on the multilayer coating with co-evaporated interface** *(Invited Paper),* Meiping Zhu, Nuo Xu, Yingjie Chai, Jian Sun, Kui Yi, Jianguo Wang, Yuan'an Zhao, Jianda Shao, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-7]

Multilayer coatings fabricated by e-beam evaporation are widely used in high power laser system. Much work has been done to investigate the laser induced damage mechanism. Previous studies demonstrated that the interface issues can lead to coating delamination, because of high interfacial absorption, inferior adhesive strength, and difference between thermal expansion coefficients of two materials. Co-evaporated interface is proposed and demonstrated to solve the interface related problems, and therefore improve the laser induced damage. Furthermore, of the interface related problems, which dominates the laser induced damage is not clear yet. In this work, co-evaporation of the interface is carried out in an oxygen-insufficient environment, to achieve co-evaporated interface with higher absorption than a normal interface. The properties of the multilayer coating with oxygen-insufficient co-evaporated interface are studied and compared with that of the conventional multilayer coating. Experimental results demonstrate that adhesive strength play a more important role in the interface-induced laser damage than interfacial absorption.

11:15: **Effect of micro-crack and reaction product on laser damage performance of optical glass during chemical etching,** Huapan Xiao, Zhi Chen, Hairong Wang, Jiuhong Wang, Na Yu, Xi'an Jiaotong Univ. (China) . . . . . [10713-8]

By simulations and experiments, the effect of micro-crack and reaction product on laser damage performance of optical glass during chemical etching is analyzed. The effect mechanism is revealed.

11:30: **Strategies for improving the laser-induced damage thresholds of dichroic coatings developed for high-transmission at 527nm and high reflection at 1054nm,** Ella S. Field, Damon Kletecka, Sandia National Labs. (USA) . . . . . [10713-9]

We report on progress for increasing the laser-induced damage threshold of dichroic beam combiner coatings for high transmission at 527 nm and high reflection at 1054 nm (22.5° angle of incidence, S-polarization). The initial coating consisted of HfO2 and SiO2 layers deposited with electron beam evaporation, and the laser-induced damage threshold was 7 J/cm2 at 532 nm with 3.5 ns pulses. Different strategies were then utilized to increase the laser damage threshold of this coating to 10 J/cm2. These strategies included the addition of alumina layers in the coating, and adjustments to coating deposition parameters such as deposition rate and oxygen content. The effectiveness of each strategy is discussed in this report.

11:45: **Investigation on water vapor transport of e-beam coatings by employing a PIAD capping layer** (Invited Paper),Tingting Zeng, Shanghai Institute of Optics and Fine Mechanics (China), Univ. of Chinese Academy of Sciences (China); Meiping Zhu, Yingjie Chai, Shanghai Institute of Optics and Fine Mechanics (China); Chaoyi Yin, Nuo Xu, Shanghai Institute of Optics and Fine Mechanics (China), Univ. of Chinese Academy of Sciences (China); Jianda Shao, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-10]

The large aperture multilayer coatings by electronic beam deposition are widely used in high power laser systems, e.g. National Ignition Facility, ShenGuang series big laser Facilities, and so on, because of high laser-resistance, surface uniformity, as well as good optical performance. The stress control of large aperture coatings, however, continues to be an essential and challenging work for decades. The mechanical property of the porous coatings can be easily influenced by environmental humidity. The capping layer employed by plasma ion assisted deposition (PIAD) may delay the water vapor transport rate of the coating. In our experiment, SiO2 mono-layer, HfO2 mono-layer and SiO2/HfO2 double layer coatings are prepared by Leybold coater, and some samples capped by extra dense encapsulation SiO2 layers deposited by PIAD to delay the water vapor transport rate. The mechanical stress evolution and optical spectrum shifts in VIS-NIR of the prepared samples are recorded and investigated in a temperature/humidity controlled clean room. Surface morphologies of prepared coatings with/without capping layer are characterized by atomic force microscope, for investigating their nanostructural information (roughness, surface porosity, and pore size distribution, etc.). Lateral water vapor transmission rate (WVTR) of prepared coatings are extracted by the Bruggeman effective medium approximation method and the WVTR on interface might be investigated by SiO2/HfO2 double layer.

Lunch Break . . . . . 12:00 to 13:00

SESSION 5: DEFECTS AND DUV

LOCATION: ROOM 212 . . . . . 13:00 TO 15:00

Session Chair: **Meiping Zhu,** Shanghai Institute of Optics and Fine Mechanics (Japan)

13:00: **UV laser-induced degradation of nonlinear optical borate crystals** *(Invited Paper),* Masashi Yoshimura, Osaka Univ. (Japan), SOSHO CHOKO Inc. (Japan); Ryota Murai, Yoshinori Takahashi, Osaka Univ. (Japan); Yusuke Mori, Osaka Univ. (Japan), SOSHO CHOKO Inc. (Japan) . . . . . [10713-11]

The present paper reviews recent progress in crystal growth technology of nonlinear optical crystal CsLiB6O10 (CLBO) and discuss 266-nm ultraviolet-induced degradation of CLBO, β-BaB2O4 (BBO), LiB3O5 (LBO), and SrB4O7 (SBO).

13:30: **Study of laser-induced damage and defect by multiple pulses irradiation for silica glasses**, Shinji Motokoshi, Institute for Laser Technology (Japan); Yuki Takemura, Haruka Ogawa, Minoru Yoshida, Kindai Univ. (Japan); Kana Fujioka, Takahisa Jitsuno, Masashi Yoshimura, ILE Osaka Univ. (Japan) . . . . . [10713-12]

The Laser-induced damage threshold (LIDT) of optics decreases with increase irradiation laser pulse number and pulse frequency. To clear the causes the LIDTs by two pulses with separated pulses time and the changes of transmittance by irradiation multiple pulses were estimated by using ArF excimer laser (193-nm wavelength and 10-ns pulse width) for synthetic silica glasses. The transmittance changes were analyzed by the model of accumulated defects. As results, the defects had two relaxation times which one was shorter than a few second and another one was longer than 1000 seconds. It could be consider that the former defects had a influence on the LIDTs by multiple pulses irradiation.

13:45: **Laser damage measurement of commercially available UV fused silica at 193nm,** Xingliang Song, Pengfei Sha, Jiang Rui, Guangyi Liu, Bin Liu, Jiangshan Zhao, Yi Zhou, Junhong Yang, Guangliang Xiong, Yu Wang, Academy of Opto-Electronics, CAS (China) . . . . . [10713-13]

Based on the LIF measurement, a real-time monitor is built for investigating the laser damage of optics at 193nm. We report the results of an accelerating damage test of several commercially available fused silica windows.

14:00: **Transmissivity testing of calcium fluoride windows under high pulse repetition rate laser radiation at 193nm,** Xingliang Song, Yuanyuan Fan, Pengfei Sha, Huiwen Zong, Hui Li, Jiangshan Zhao, Yi Zhou, Junhong Yang, Guangliang Xiong, Yu Wang, Academy of Opto-Electronics, CAS (China) 10713-14

We report a method of testing the transmissivity of three different grade CaF2 windows under high pulse repetition rate laser radiation at 193nm. The testing module distinguishes well with a repeatable precision better than 1%.

14:15: **Influence of bulk defects on bulk damage performance of fused silica optics at 355-nm pulse laser,** Jin Huang, China Academy of Engineering Physics (China) . . . . . [10713-15]

We demonstrate the effects of typical bulk defects of fused silica on bulk damage threshold under nanosecond UV pulse laser. A new test method is built to evaluate laser induced bulk damage performance more reasonably. The bulk bubble, hydroxyl, metal impurity, and weak absorption of 355 nm laser are characterized, respectively. The influences of bulk defects on bulk damage performance are analyzed statistically based on the correlation principle. Results indicate that, for synthetic fused silica, metal impurity and hydroxyl have weak correlation coefficient with bulk damage threshold, while there is strong correlation between weak UV absorption and bulk damage threshold. In addition, the influence of bulk damage threshold on surface damage performance is also analyzed and discussed.

14:30: **Interstitial O2 and Si-H stretching bond defects absorption produced in fused silica during laser-induced damage,** Chunyan Yan, Baoan Liu, Xin Ju, Univ. of Science and Technology Beijing (China) . . . . . [10713-16]

Fused silica irradiated with 6.8-ns 355-nm laser pulses is studied by micro-Raman scattering spectroscopy. Results show that, for laser fluences above the laser-induced breakdown threshold, in all the cases studied, irradiation results in the formation of four laser-induced defect-related Raman bonds centered on 1363, 1557, 1609 and 2330cm-1. Bonds centered on 1363, 1557 and 2330cm-1 are attributed to Si=O, interstitial O2 and Si-H stretching bond. However, defects giving rise to a broad bond at 1609 cm-1 are unknown. Based on these results, we discuss physical processes occurring during the laser-induced fused silica breakdown, leading to the formation of non-bridging oxygen hole center and interstitial O2 and the fracture of fused silica.

14:45: **Absorption enhancement by laser-induced defects in fused silica**, Takahisa Jitsuno, Osaka Univ. (Japan); Shinji Motokoshi, Institute for Laser Technology (Japan); Masashi Yoshimura, Osaka Univ. (Japan) . . . . . [10713-17]

Absorption enhancement phenomena by laser-induced defects have been investigated experimentally in fused silica with 157 nm F2 laser pulse. The transmittance change of single pulse was explained by laser-induced absorption in fused silica.

Refreshment Break . . . . . 15:00 to 15:30

TECHNICAL CONFERENCE

SESSION 6: LASER MATERIALS

LOCATION: ROOM 212 . . . . . 15:30 TO 17:15

Session Chair: **Takahisa Jitsuno,** Osaka Univ. (Japan)

15:30: **Highly-efficient Ho:KY(WO4)2 thin-disk lasers at 2.06 µm** *(Invited Paper),* Valentin P. Petrov, Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie (Germany); Xavier Mateos, Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie (Germany), Univ. Rovira i Virgili (Spain), LISA Laser Products OHG (Germany); Pavel Loiko, ITMO Univ. (Russian Federation); Samir Lamrini, Karsten Scholle, Peter Fuhrberg, LISA Laser Products OHG (Germany); Soile Suomalainen, Antti Härkönen, Mircea Guina, Tampere Univ. of Technology (Finland); Sergei Vatnik, Ivan Vedin, Institute of Laser Physics (Russian Federation); Magdalena Aguiló, Francesc Díaz, Univ. Rovira i Virgili (Spain); Yicheng Wang, Uwe Griebner, Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie (Germany) . . . . . [10713-18]

Highly-efficient (up to 60% slope efficiency) watt-level thin-disk lasers based on Ho:KY(WO4)2/KY(WO4)2 epitaxies with a simplified single-bounce pump geometry are demonstrated. The spectroscopy, thermo-optics, continuous-wave and Q-switched performance of the thin-disk lasers are presented.

16:00: **Functional crystal films fabricated by pulsed laser deposition** *(Invited Paper),* Jacob I. Mackenzie, Sergey V. Kurilchik, James A. Grant-Jacob, Robert W. Eason, Jake J. Prentice, Univ. of Southampton (United Kingdom) . . . . . [10713-19]

We report recent developments of our Pulsed-Laser-Deposition (PLD) system that enables routine fabrication of ~> 10-micron thick crystal layers. With these films the first PLD-grown waveguide laser with a slope efficiency of 70% and over 20W of output power was realised. The same Yb:Y3Al5O12 waveguide, used as a double-pass amplifier, produced an equivalent output power with 16dB of gain. The non-thermal-equilibrium conditions exploited in PLD, growth of refractory oxides such as sesquioxides are readily realised, which can also be doped with optically active ions to make functional films, suitable for waveguide amplifiers and lasers, and advanced composite structures.

16:30: **Third-order-nonlinear effects in ceramics,** Efim A. Khazanov, Vlad Ginzburg, Anton Kochetkov, Institute of Applied Physics of the Russian Academy of Sciences (Russian Federation) . . . . . [10713-20]

We study difference of the generation of cross-polarization, self-phase modulation and laser beam self-focusing in ceramics from these effects in single crystals. Random small-scale spatial modulation of laser beam polarization and phase has been predicted.

16:45: **Visible waveguide lasers based on femtosecond laser inscribed cladding waveguides in Pr:YLF crystal,** Hongliang Liu, Nankai Univ. (China); Minghui Hong, National Univ. of Singapore (Singapore); Feng Chen, Shandong Univ. (China) . . . . . [10713-21]

Visible lasers at wavelength of 605 nm and 720 nm are achieved in the femtosecond-laser-inscribed waveguide in Pr:YLF crystal.

17:00: **Design and fabrication of multiplexed volume Bragg gratings as angle amplifiers in high-power beam scanning system,** Peng Chen, Yunxia Jin, Hongbo He, Junming Chen, Jingyin Zhao, Jiao Xu, Yibin Zhang, Fanyu Kong, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-22]

Volume Bragg Grating (VBG) recorded in photo-thermo-refractive (PTR) glass has advantages of high diffraction efficiency, excellent wavelength selectivity and angle selectivity, high angle magnification and flexible design, and high power tolerance, making it good candidate for angle amplifier in high power beam scanning system. In this paper, matrixed-based algorithm was used for determining diffraction efficiencies of significant coupled waves in multiplexed VBG. The cross-talk problem in multiplexed VBG was analyzed, and scheme for cross-talk optimization was proposed. The design of the multiplexed VBG recording at the wavelength of 325nm for the working wavelength of 1064nm is described. Multiplexed VBGs were experimentally fabricated inside PTR glass by multiple exposures and subsequent heat treatment. The performance of multiplexed VBG such as angular magnification capacity and diffraction efficiency was tested. The differences between theoretical and experimental results were discussed.

FRIDAY 27 APRIL

SESSION 7: ETCHING AND NON-LINEAR CRYSTALS

LOCATION: ROOM 212 . . . . . 9:00 TO 10:30

Session Chair: **Tomosumi Kamimura,** Osaka Institute of Technology (Japan)

9:00: **Three-dimensional profile of laser-induced surface damage pit of fused silica and its evolution during wet chemical etching,** Taixiang Liu, Laser Fusion Research Ctr., China Academy of Engineering Physics (China) . . . . . [10713-23]

In this work, 3D profile of laser-induced surface damage pit is measured and its evolution during etching is experimentally traced.

9:15: **Combination of reaction ion etching and dynamic chemical etching for improving laser damage resistance of fused silica optical surfaces,** Laixi Sun, Jin Huang, Hongjie Liu, Xin Ye, Jingjun Wu, Xiaodong Jiang, Liming Yang, Wanguo Zheng, Weidong Wu, Laser Fusion Research Ctr., China Academy of Engineering Physics (China) . . . . . [10713-24]

An effective combined process of reaction ion etching and dynamic chemical etching is applied for significantly improving the damage resistance of fused silica optics while minimizing the removal amount.

9:30: **Inhomogeneity of material removing and its influence on surface morphology of fused silica during HF etching,** Yuan Li, Univ. of Science and Technology Beijing (China); Ke Yang, Caizhen Yao, Hongwei Yan, Xiaodong Yuan, Liming Yang, Xin Ju, Laser Fusion Research Ctr., China Academy of Engineering Physics (China) . . . . . [10713-25]

The morphology evolution of surface scratch in the HF etching of fused silica was monitored, and the inhomogeneity of material removing was observed. It is an positive effect on smoothing the surface scratches.

9:45: **High laser damage threshold of fused silica by HF etching with multifrequency ultrasonic,** Xin Ye, Hongjie Liu, Fengrui Wang, Jin Huang, Xiaodong Jiang, Wanguo Zheng, Research Ctr. of Laser Fusion, China Academy of Engineering Physics (China) . . . . . [10713-26]

The laser damage precursors in subsurface of fused silica (e.g. photosensitive impurities, scratches and redeposited silica compounds) were mitigated by mineral acid leaching and HF etching with multifrequency ultrasonic agitation, respectively. The comparison of scratches morphology after static etching and high-frequency ultrasonic agitation etching was devoted in our case. And comparison of laser induce damage resistance of scratched and non-scratched fused silica surfaces after HF etching with high-frequency ultrasonic agitation were also investigated in this study. The global laser induce damage resistance was increased significantly after the laser damage precursors were mitigated in this case. The redeposition of reaction produce was avoided by involving multi-frequency ultrasonic and chemical leaching process. These methods made the increase of laser damage threshold more stable. In addition, there is no scratch related damage initiations found on the samples which were treated by Advanced Mitigation Process.

10:00: **Surface damage of KDP crystal induced by subsurface and bulk defects under exposure to nanosecond 3ω laser,** Feng Geng, Chengdu Fine Optical Engineering Research Ctr. (China); Jin Huang, Fengrui Wang, Hongjie Liu, Xiaodong Jiang, Research Ctr. of Laser Fusion, China Academy of Engineering Physics (China) . . . . . [10713-27]

We presented laser-induced surface damage properties of a series of KDP crystals produced by different vendors. In situ microscopy system for bright-field, scattering, fluorescence imaging was integrated in our small-aperture damage test facility, which was further used to investigate defect-damage correlation in laser damage experiments. Among those KDP samples, two types of surface damage were observed with significant different damage behaviors. The surface damage with relative low damage threshold was demonstrated to be induced by subsurface fluorescent defects produced by surface fly-cutting in brittle region. As laser fluence increases, the fluorescent features detected by in situ microscopy system all converted to surface damage craters one by one. Damage fluences at defect sites are highly correlated with the peak fluorescence intensity of defects. The other type surface damage with much higher damage threshold is likely related to bulk damage precusors near the surface that can be detected by dark-field scattering. Furthermore, time-resolved shadowgraph technique was also employed to investigate the dynamic processes of laser-induced surface damage. The two type damages exhibit distinct features from damage initiation to damage evolution, which helps to confirm the speculated damage origin.

10:15: **Transient dynamics damage process and multi-physics field simulation of KDP crystal under 355-nm nanosecond laser,** Zhichao Liu, Chengdu Fine Optical Engineering Research Ctr. (China); Hao Yang, Harbin Institute of Technology (China); Feng Geng, Chengdu Fine Optical Engineering Research Ctr. (China); Yi Zheng, Novaphoton Co., Ltd. (China); Jian Cheng, Mingjun Chen, Harbin Institute of Technology (China); Jian Wang, Qiao Xu, Chengdu Fine Optical Engineering Research Ctr. (China) . . . . . [10713-28]

The TRPP (Time Resolved Pump-Probe) technique to characterize quantitatively the shockwave propagation and debris ejection phenomenon in the damage process of KDP crystal under 351nm nanosecond laser.

FRIDAY 27 APRIL

SESSION PLD8: PLD POSTER SESSION

LOCATION: POSTER AREA . . . . . FRIDAY 10:30 TO 12:00

A real-time laser conditioning technique coupled with photothermal lens probe on 1064-nm mirror, Yi Zheng, Chengdu Novaphoton Co. Ltd. China (China); Zhichao Liu, Ping Ma, Feng Pan, Feng Geng, Jian Wang, Qiao Xu, Chengdu Fine Optical Engineering Research Ctr. (China) . . . . . [10713-39]

We have presented a novel adaptive laser conditioning (ALC) concept on 1064nm mirror that uses photo-thermal lens probe (PTLP) to detect defects in-situ and then carries out adaptive control of exposure fluence. The best advantage of ALC is that during conditioning procedure, the damage risk hiding in the defective cells can be suppressed to a low level, and in the meanwhile, the LIDT income of those non-defective cells can be earned sufficiently by one exposure. Thermal conductive function of spherical particle describes the theoretical connection between absorption and damage. Experiment actualizes the close-loop operation and verifies the performance of ALC. Results show that ALC possesses prominent advantages in damage-proof and laser dose supply thanks to its particular fluence control strategy. Future work will address the efficiency promotion to fit for the application on large-aperture optics. The time consumption of PTLP signal build-up could be shortened by increasing the pumping power and modulation frequency of the chopper, and by then ALC could operate in a several ten hertz repetition frequency.

Design and fabrication of composite antireflective structure on ZnSe in mid-infrared wavelength, Cui Yun, Shanghai Institute of Optics and Fine Mechanics (China); Fei Liang, Shanghai Univ. (China); Yuan'an Zhao, Meiping Zhu, Kui Yi, Jianda Shao, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-40]

The anti-reflection properties of ZnSe substrate with subwavelength parabolic cone array micro-structure is studied. The parameters of structure that influence the anti-reflection performance, such as the height of parabolic cone array, the period and the duty factor, are analyzed by using of the finite-difference time-domain(FDTD) method. The effect of profile shape error of structure on the anti-reflective properties in actual manufacturing process is discussed. The result of the experiment shows the transmittance of ZnSe with single-sided anti-microstructure is about 10 percent higher than that of untreated ZnSe in 2-5μm. A modified layer that used low-index Al2O3 layer by ion beam sputtering is fabricated on the antireflective structure. The new structure farther increases the transmittance in 2-5μm. It provides a novel design approach for the anti-reflective surface of mid-infrared materials.

High-efficiency and low-damage lapping process optimization based on effective damage removal rate, Ci Song, Yuxuan Lin, Hao Hu, Shanyong Chen, Lin Zhou, Guipeng Tie, National Univ. of Defense Technology (China) . . . . . [10713-41]

The low-damage optics are applied widely in modern laser system, and its fabrication is always the popular issue. As one of the key points in the manufacturing process, the optimization of efficiency and damage challenges the lapping process. The lapping process not only needs to improve the efficiency to remove the grinding damage layer fastly, but also requires to reduce the damage to obtain lower material removal in polishing process. However, the traditional optimization of lapping mainly relies on the experience, the optimum balance point between efficiency and damage is difficult to obtain. This manuscript establishes the Effective Damage Removal Rate (EDRR) model to optimize the efficiency and damage quantitatively. The relationship between the EDRR and the process parameters is simulated, and the process of rough-lapping and fine-lapping is optimized. Finally, the high-efficiency and low-damage lapping process routine is established based on the simulations, and its correctness and feasibility are validated by experiments. The proposed method can realize the optimization of efficiency and damage in the lapping process, and improve the manufacturing ability of the low-damage optics.

Research on a new combined polishing technology and damage threshold improvement of KDP crystals, Hao Hu, Guipeng Tie, Ci Song, Lin Zhou, Shanyong Chen, National Univ. of Defense Technology (China) . . . . . [10713-42]

A new combined polishing technology which is consist of MRF and IBF is researched as to meet the demands of higher surface precision and LIDT for large aperture KDP components.

Characterization of multiwavelength laser-induced damage in DKDP crystals, Jinming Wu, Shanghai Univ. (China), Shanghai Institute of Optics and Fine Mechanics (China); Yuan'an Zhao, Shanghai Institute of Optics and Fine Mechanics (China); Lin Wang, Shanghai Univ. (China); Xiaocong Peng, Liujiang Yang, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-43]

Compared to the single wavelength, the multiple wavelengths remains the energy coupling efficiency in terms of fluence and delays

Nonlinear optical characteristics of ADP crystals, Yafei Lian, Xun Sun, Mingxia Xu, Lisong Zhang, Shandong Univ. (China) . . . . . [10713-44]

The third-order nonlinear optical characteristics such as β, n2 and χ(3) of ADP crystal in different directions were systematically measured by Z- scan measurements with Pico-second pulse laser irradiation at λ= 532nm, 355nm and 266nm.

Third-harmonic-generation nonlinear absorption coefficient of 70% deuterated DKDP crystal, Dongting Cai, Shandong Univ. (China); Xin Ju, Baoan Liu, Univ. of Science and Technology Beijing (China); Zhengping Wang, Xun Sun, Shandong Univ. (China) . . . . . [10713-45]

The third-order nonlinear optical characteristics such as β, n2 and χ(3) of ADP crystal in different directions were systematically measured by Z- scan measurements with Pico-second pulse laser irradiation at λ= 532nm, 355nm and 266nm.

Wide-bandgap nonlinear crystal with high damage resistance for femtosecond mid-infrared spectrometer using chirped-pulse upconversion, Yusuke Funamoto, Osaka Institute of Technology (Japan); Yoshizumi Inagaki, Hidefumi Hata, Osaka Institute of Technology (Japan), Osaka Univ. (Japan); Tomosumi Kamimura, Osaka Institute of Technology, (Japan); Nobuhiro Umemura, Chitose Institute of Science and Technology (Japan); Hamada Norio, Ryosuke Nakamura, Osaka Univ. (Japan) . . . . . [10713-46]

For biochemical processes such as photoisomerization, bond formation and dissociation, and protein folding, femtosecond time-resolved mid-infrared (MIR) spectroscopy has been a powerful tool for gaining insight. MIR probe pulses are upconverted to the visible regime via sum-frequency mixing with highly chirped pulses in a nonlinear crystal. One of the key elements determining the sensitivity, bandwidth, and spectral resolution of the upconversion system is the nonlinear crystal. In this study, we evaluated wide-bandgap nonlinear crystals and its damage threshold. For this purpose, AgGaGeS4 and LiGaS2 crystals were prepared as efficient materials for the upconversion from the MIR into the visible.

The MIR pulses were generated in a type-I AgGaS2 crystal by different frequency mixing of the signal and idler pulses from the optical parametric amplifier. The MIR pulses were upconverted into the visible using the chirped pulses at 806 nm with a FWHM of 150 ps. The LiGaS2 (thickness: 1 mm) crystal was transparent in 0.32 - 11.6 μm, and showed high efficiency below 2000 cm-1. Laser-induced damage was not observed in the crystal at a chirped-pulse energy up to 100 μJ/mm2. However, for the slightly long-term upconversion, laser damage occurred on the AR coating of the crystal surface. In contrast, AgGaGeS4 (thickness: 0.2 mm) was transparent in 0.45 -12.1 μm, and showed higher efficiency than LiGaS2 in the frequency above 1700 cm-1.. At an upconverted wavenumber of 1600 cm-1, laser damage occurred at an energy density of 280 μJ/mm2. From these results, LiGaS2 is an efficient wide-bandgap nonlinear crystal with high damage resistance.

XANES investigation on surface electronic structure of KDP crystals

irradiated with different fluences and retired components, Xiangcao Li, Xin Ju, Baoan Liu, Univ. of Science and Technology Beijing (China) . . . . [10713-47]

The electronic structure of phosphorus is essential for understand the laser-induced damage since P atom is the body-centered atom and it is fundamental to the structure of KDP crystal. The surface electronic structure of KDP crystals irradiated with different fluences and retired components are studied by XANES. The result indicates that the A/C (the peak A and C corresponding to the transition 2p→3s, 2p→3p, respectively) ratios in L2,3-edge tends to a stable value gradually for the retired samples and aren't greater than 1 under the low fluences. It ascribe to a decrease probability of probing states with few ligand p character.

Crystal growth and UV laser-induced damage resistance of a strontium tetraborate, Yasunori Tanaka, Keita Shikata, Yoshinori Takahashi, Ryota Murai, Masayuki Imanishi, Osaka Univ. (Japan); Yusuke Mori, Masashi Yoshimura, Osaka Univ. (Japan), SOSHO CHOKO Inc. (Japan) . . . . . [10713-48]

A transparent single crystal of strontium tetraborate with the dimensions of 42×8×18 (a×b×c axis) mm was grown by using Top Seeded Solution Growth method. The crystal shows higher 266-nm UV-induced damage resistance than synthetic silica.

Research of diamond transmission gratings used for high-power laser pulse compression, Shuwei Fan, Tianfei Zhu, Hongxing Wang, Xi'an Jiaotong Univ. (China) . . . . . [10713-49]

As a milestone in the development of laser technique, chirp pulse amplification (CPA) technique is widely applied to produce ultrahigh power laser. Pulse compression gratings, one of the CPA critical components, is required for high diffraction efficiency and high threshold for optical damage. The pulse compression grating currently used in the CPA system is multi-layer dielectric film grating, which has higher diffraction efficiency but low optical damage threshold. Improving anti-damage threshold of the compression gratings while maintaining high diffraction efficiency is an urgent problem to be solved. In this work we design the pulse compression diamond grating.

Diamond is the hardest material in natural materials and has many unique characteristics such as low thermal expansion coefficient, high breakdown electric field, thermal conductivity and optical transparency in a large wavelength range from ultraviolet to far infrared domain. Meantime Microwave Plasma CVD has been developed enough to deposit large area high quality diamond films. So the diamond is becoming a very promising material for optical elements working in harsh environment.

With the aid of the developed software, the diamond transmission grating is designed and optimized. The key parameters which affect diffraction efficiency of diamond grating, such as groove depth, incident angle, duty cycle and grating period are studied with the aid of the developed grating design software. The optimized grating structure parameters are obtained. The simulation results demonstrate that the highest diffraction efficiency was over 99% at wavelength 800nm. Studies show that grating structure parameters have a larger process tolerance

Carrier dynamics in dispersion compensation element induced by femtosecond laser, Xin Xing, Wei Yuan, Shanghai Institute of Optics and Fine Mechanics (China); Takayoshi Kobayashi, Bing Xue, Advanced Ultrafast Laser Research Ctr., Univ. of Electro-Communications (Japan); Juan Du, Yuxin Leng, Yuanan Zhao, Jianda Shao, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-50]

With the wildely application of high power femtosecond laser, optical thin film components are being one of the most critical components in the laser system. Compared with standard stack structure films, chirped mirrors (CMs) have a more complicated structure and electric field distribution, generating a more complex damage mechanism. Most of the studies on CMs have focused on the measurement of laser-induced damage threshold (LIDT). In this study, the femtosecond pre-breakdown dynamics of Nb2O5/SiO2 chirped mirrors induced by 35 fs laser pulses is presented, which may help to understand the origin and mechanism of laser damage and to improve the laser damage resistance in dielectric chirped mirror coatings.

In the manuscript, the relative change of the time-resolved reflectance in chirped mirror coating has been studied by pump-probe spectroscopy. Two different laser-induced reflectivity decrease bands were found at ~780nm and ~795nm. The carrier dynamics in Nb2O5 layers was interpreted as non-linear process. The decreases of reflectance with the increase of delay time have been analyzed using three possible mechanisms, while the photon absorption of the free electrons in the conduction band contributes most to the decrease. The Nb2O5 layers, where laser damage occurred firstly, are the most vulnerable parts in chirped mirror. The electronic relaxation time from different bands was measured, and explained by a theory which includes two possible mechanisms. It shows that the LIDT of the coatings is affected by the absorption cross-section of the defect state.

Non-invasive and in situ measurement of a refractive index gradient profile of one-dimensional GRIN materials, Humbat Nasibov, TÜBITAK UME (Turkey) . . . . . [10713-51]

We present a real-time noninvasive method aimed at the measurement of a Refractive Index Gradient Profile of one-dimensional GRIN materials by means of a line structured laser beam and a machine vision based system.

Q-switched composite gold nanorod and Nd:YAG ceramic planar waveguide laser, Wenda Cui, Kai Han, Chaofan Zhang, Ge Lin, Jiang Li, Weihong Hua, Hongyan Wang, Yubai Pan, Xiaojun Xu, National Univ. of Defense Technology (China) . . . . . [10713-52]

A compact Q switched waveguide laser is built, which is composed of a Nd:YAG ceramic planar waveguide and a gold nanorod film. The Nd:YAG planar waveguide is fabricated by the non-aqueous tape casting method and the Nd:YAG layer is placed between two YAG claddings. A PVA-Au nanorod film is built as the saturable absorber. Its resonant wavelength is about 1040nm with an aspect ratio about 6.5.

Experimental study on the processing effect of DUV laser radiation to CFRP, Xingliang Song, Pengfei Sha, Academy of Opto-Electronics, CAS (China); Haiyan Shi, Beihang Univ. (China); Bin Liu, Zebin Feng, Academy of Opto-Electronics, CAS (China), Univ. of Chinese Academy of Sciences (China); Jiang Rui, Yi Zhou, Academy of Opto-Electronics, CAS (China); Songmei Yuan, Beihang Univ. (China), Beihang Univ. (China); Junhong Yang, Guangliang Xiong, Yu Wang, Academy of Opto-Electronics, CAS (China) . . . . . [10713-53]

We report the experimental results of an excimer laser radiation to CFRP surface. To make clear of the relationship between laser processing parameters and treatment quality, a detailed investigation is given by orthogonal experimental design.

Dynamical behavior of laser-produced copper plasma in uniform external magnetic field, Narayan Behera, Rajesh Kumar Singh, Ajai Kumar, Institute for Plasma Research, Gandhinagar (India) . . . . . **[**10713-54]

We have experimentally observed for the first time time the diamagnetic cavity in laser-produced copper plasma in the presence of magnetic field which is related to magnetic diffusion time.

The post-processing process and mechanism of coating based on laser shock wave, Wenwen Liu, Huan Yang, Jian Zhang, Dehua Zhu, Wenzhou Univ. (China) . . . . . [10713-55]

High power laser coatings are facing a series of more serious challenges including running on higher laser induced damage threshold (LIDT), higher repetitive frequency and higher stability. It not only involves the LIDT and damage growth under single- and multi-pulse irradiation respectively, but also the laser damage affected by optical performance and surface accuracy stability of coatings. In this paper, we intend to use the laser shock wave technique as a post-processing method for coatings prepared by electron beam evaporation. By taking advantage of shock wave which can avoid thermal effect and act as mechanical behavior to improve the coating's defect characteristic, microstructure and macro-mechanical property, is expected to ensure that coating could run on higher laser fluence with long term stability. The main research aspects will include: investigations on characterization and mechanism of LIDT improvement under single-pulse irradiation, as well as the long term running stability after post-processing of laser shock wave. Based on experiments and theoretical analysis, optimized technical parameters will be verified and the dynamic coupling process will be developed finally. This method will hopefully break the limitations of the existing technology, and provide a potential option for promoting coating to the direction of a much higher degree of laser resistance, accuracy and stability development.

POSTER SESSION

Photostability study of CdTe quantum dots using laser induced fluorescence, Ahmed El-Hussein Mohamed Kamel ElNewishy, Souad Elfeky, National Institute of Laser Enhanced Sciences (Egypt) . . . . . [10713-56]

Semiconductor quantum dots (QDs) having high quantum yields and unique photostability. This research studies the optical properties of the synthesized CdTe QDs with two different sizes using Laser induced fluorescence for investigating their photostability. TEM images illustrate that the two prepared QDs sizes are 2.4 and 3.5 nm. FTIR analysis revealed that the prepared QD capped with oleic acid. LIF technique showed that there is a red shift of the fluorescence emission of the bigger size QDs compared to the smaller one. The small size QD has a lower photostability when compared to the big size 2.4 nm. This study introduces guidance adapting CdTe photophysical properties for generalized applications especially biological laser imaging and solar cell applications.

Laser decoating of TiN from TiN-coated 316L stainless steel substrates: Effects of laser parameters on the decoating performance, Jingxuan Wang, Ya Yun Ye, China Academy of Engineering Physics (China) . . . . . [10713-57]

Q-switched laser was used for decoating of TiN from stainless steel (SUS316L) substrates. Effect of laser fluence, number of pulses, scanning speed and beam overlap on the decoating performance was investigated.

Laser-induced damage of indium tin oxide films and polyimide films at 1064nm, Liping Peng, Xiaofeng Liu, Shanghai Institute of Optics and Fine Mechanics (China), Univ. of Chinese Academy of Sciences (China); Yuan'an Zhao, Shanghai Institute of Optics and Fine Mechanics (China); Yonggang Liu, Zhaoliang Cao, Changchun Institute of Optics, Fine Mechanics and Physics (China), Univ. of Chinese Academy of Sciences (China); Meiping Zhu, Jianda Shao, Shanghai Institute of Optics and Fine Mechanics (China), Univ. of Chinese Academy of Sciences (China) . . . . . [10713-58]

Laser damage performance of indium tin oxide (ITO) films and polyimide (PI) thin films were investigated. The ITO films with 25nm thickness were deposited on glass substrates by magnetic sputtering, and then PI film samples with thickness of 80nm were spin coated on the ITO. 1ω nanosecond pulsed and CW laser induced damage thresholds (LIDT) of ITO and PI with ITO were determined according to ISO21254. The typical damage morphologies were mapped by microscope and optical profiler. It is found that both the pulsed and CW LIDT of PI with ITO is about 50% higher than that of ITO samples. The temperature field analysis was performed to understand the damage mechanisms.

Study on the micro-etched morphology and electromagnetic properties of grain-oriented silicon steel by laser processing, Zhang Jian, WenZhou Univ. (China) . . . . . [10713-59]

In order to effectively reduce the iron loss of grain-oriented silicon steel. In order to optimize the electromagnetic properties of grain-oriented silicon steel.

Lunch Break . . . . . 12:00 to 13:00

FRIDAY 27 APRIL

SESSION 9: SHORT-PULSE LASERS

LOCATION: ROOM 212 . . . . . 13:00 TO 15:15

Session Chair: **Shinji Motokoshi,** Institute of Laser Technology (Japan)

13:00: **Laser damage metrology in the sub-ps range for the PETAL facility** *(Invited Paper),* Laurent Lamaignère, Commissariat à l'Énergie Atomique (France) . . . . . [10713-29]

Abstract not available

13:30: **Progress at the high-power laser system of ELI-NP facility** *(Invited Paper),* Daniel Ursescu, IFIN-HH / ELI-NP (Romania) . . . . . [10713-30]

High Power Laser System (HPLS) of ELI-NP facility aims to deliver 10PW class pulses (200J, 20fs, at 800nm) on two parallel arms, at a repetition rate of one shot per minute. HPLS is under tests at ELI-NP site and up to now no bottlenecks were identified. The latest measurements on one of the two amplification arms will be reported, together to the in-house developments towards operating as a facility.

14:00: **Generation of few-cycle millijoule pulses at 5 µm employing a ZnGeP2-based OPOCA** *(Invited Paper),* Uwe Griebner, Lorenz von Grafenstein, Martin Bock, Thomas Elsaesser, Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie (Germany) . . . . . [10713-31]

High Power Laser System (HPLS) of ELI-NP facility aims to deliver 10PW class pulses (200J, 20fs, at 800nm) on two parallel arms, at a repetition rate of one shot per minute. HPLS is under tests at ELI-NP site and up to now no bottlenecks were identified. The latest measurements on one of the two amplification arms will be reported, together to the in-house developments towards operating as a facility.

14:45: **Ultra-short pulse induced nonlinear reflection and its applications in laser processing of dielectrics,** Mingying Sun, Yajing Guo, Jianqiang Zhu, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-33]

We investigate the characteristics of transient reflectivity in ultrafast laser ablation of dielectrics with the Fresnel-Drude model. With the numerical model, we studied the temporal evolutions of free-electron density and transient reflectivity, which have different tendencies for various pulse durations with various fluences. The dependences of the transient reflectivity and the averaged reflectance on the incident angle are investigated. The secondary ablation induced by the reflected beam is analyzed, and the map of secondary ablation are obtained. The dominant mechanisms of the ultrafast reflection are revealed and its potential applications in laser micro-machining are discussed.

15:00: **Combination properties of fluorinated ethylene propylene (FEP) film which may be used as the short pulse laser debris shields,** Shufan Chen, China Academy of Engineering Physics (China) . . . . . [10713-34]

Debris mitigation is a major challenge for all high-peak-power lasers system; the impulsive debris will pollute and damage the optical element and diagnostic facility. Thus, fabrication of special polymer films to protect from target debris is significant. Fluoride polymers representative of the fluorinated ethylene propylene (FEP) have excellent ultraviolet-visible transmission, laser induced damage threshold and mechanical properties, and stand a good chance to be used as the debris shields. However, it was found in our previous research work that the light transmittance of FEP is still lower than fused silica glass, and the transmittance of FEP need to be improved before it is really used in the laser field. The difficulty is obvious for modify and anti-reflection on inactive fluoride polymers is very hard. But if the antireflection method for FEP can be exploited and applied in large acreage, it will be meaningful for saving cost and improving efficiency. In view of above reasons, we proposed a sol-gel coating method which can implement large acreage antireflection for FEP film and investigated the optical properties of antireflection FEP film. Through an oxygen gas plasma processing, the interface interaction between silica sol and the FEP film can be improved. Through regulate the structure of silica gels and coating technique, transmittance of specific and single wavelengthfull can be improved to higher than 99%. Besides the transmittance, the combination properties including the laser induced damage behaviors, the laser transmission wavefront and the mechanical properties were investigated in our research. This cladding antireflection film has considerable applications in the high-peak-power laser field.

Refreshment Break . . . . . 15:15 to 15:45

SESSION 10: DAMAGE MEASUREMENT AND DEFECTS

LOCATION: ROOM 212 . . . . . 15:45 TO 16:45

Session Chair: **Takahisa Jitsuno,** Osaka Univ. (Japan)

15:45: **Optical modified lateral shearing interferometer for on-line damage morphology measurement,** Jie Li, Rong-Sheng Ba, Xin-Da Zhou, Yinbo Zheng, Lei Ding, Bo Chen, Jing Yuan, China Academy of Engineering Physics (China) . . . . . [10713-35]

Laser-induced damage resistence of optical components is one of the critical factor in high power laser systems. Many studies devote to obtain the morphology information in order to estimate the performance of laser damage growth and optical modulation effects on the transmitted laser beam, which induce the damage of downstream components.

15:00: **The distribution, specifies, and absorption of precursors responsible for bulk damage initiation in doubler KDP crystals at different wavelengths,** Yinbo Zheng, Rong-Sheng Ba, Jie Li, Xin-Da Zhou, Lei Ding, Jing Yuan, Hong-Lei Xu, Jin Na, Ya-Jun Li , Bo Chen, China Academy of Engineering Physics (China) . . . . . [10713-36]

This work presents the characteristics of precursors responsible for bulk damage initiation in type I doubler KDP crystals under different exposure wavelengths and fluences combinations. Pinpoints densities (PPD) are extracted through light scattering pictures captured by microscope. The experimental results illustrate that the precursors could be classified as 1ω/2ω precursors and 3ω precursors according to their distribution, while it is the same precursors that differ from each other over three different wavelengths according to their geometry shape, i.e., different criteria leads to different species. We also find that the ratio of absorption efficiency factors at 1064nm to that at 532nm is associated with the polarization orientation, which manifests the existence of different dominating absorption mechanisms responsible for bulk damage initiation in doubler KDP crystals for different polarization orientations.

16:15: **Shape dependence of downstream light intensification caused by flaws,** Zhaoyang Jiao, Mingying Sun, Lei Ren, Yajing Guo, Rong Wu, Yanli Zhang, Jianqiang Zhu, Shanghai Institute of Optics and Fine Mechanics (China) . . . . . [10713-37]

In high power laser system, the upstream flaw could induce light intensification in the downstream.The defect in the real system is nonideal with different shapes. In this paper, the light intensification effect caused by defects with different shapes are compared by numerical simulation. Results show the shape dependence of downstream light intensification caused by flaws. This research can provide some reference for the beam quality control and defect management in the high power laser systems.

16:30: **Mixture modulation to incident laser by surface defect and contaminant on fused silica,** Hairong Wang, Zhi Chen, Huapan Xiao, Jiuhong Wang, Na Yu, Xi'an Jiaotong Univ. (China) . . . . . [10713-38]

The electric field intensity distribution around the radial crack with contaminant, the lateral crack with contaminant, and the cone crack with contaminant is simulated by finite-difference time-domain method. The mixture modulation mechanism is investigated.

Closing Remarks . . . . . 16:45 to 17:00

INDEX OF AUTHORS, CHAIRS, AND COMMITTEE MEMBERS

INDEX OF AUTHORS, CHAIRS, AND COMMITTEE MEMBERS