K 8: Laseranwendungen und Lasermaterialbearbeitung II

Zeit: Donnerstag 14:00–16:00 Raum: HS 4

K 8.1 Do 14:00 HS 4

Laser induced periodic surface structures in thin metal foils — •Hamza Messaoudi, Susanta Kumar Das, Alexander Andreev, Matthias Schnuerer, and Ruediger Grunwald — Max Born Institute for Nonlinear Optics and Short-Pulse Spectroscopy, Max-Born-Str 2a, D-12489 Berlin, Germany

Femtosecond-laser induced periodic nanostructures were generated at the surface of extremely thin metal foils with the moving substrate method [1] in air. 5 micron thick Cu and Ti specimen were translated through a linear or point-like focus of a linearly polarized and frequency-converted femtosecond laser (pulse duration 120 fs, center wavelength 400 nm). It was found that two different types of ripple structures with high and low spatial frequencies corresponding to periods in the range of 70 nm and 300 nm, respectively, can be formed. The ripple type can be adjusted by confining the number and energy of the pulses and the scanning velocity. Between the distinct parameter fields of stable formation, a transition range with partially changing ripple size and orientation appears. The nanostructured foils are of interest for laser ion acceleration in transmission mode [2]. Because of enabling an easy conversion to metal oxides and favoring material-saving approaches, these structured foils are also promising candidates for flexible solar cells and innovative approaches of photocatalysts.

References:

1. S. K. Das, et al., Nanotechnology 21, 155302 (2010).
2. A. Andreev, et al., Physics of Plasmas 18, 103103 (2011).

K 8.2 Do 14:15 HS 4

Application of fs-laser Generated Nanogratings for Arbitrary Polarization Control — •Christian Vetter, Sören Richter, Felix Zimmermann, Matthias Heinrich, Felix Dreisow, and Stefan Nolte — Institute of Applied Physics, Friedrich-Schiller-Universität Jena

We report on the generation of fs-laser induced nanogratings in fused silica and their intrinsic form-birefringent behavior. Based on that birefringence, it is shown, that nanogratings allow for the fabrication of intricately shaped and locally varying wave plates. More sophisticated structures may be used for optical mode conversion and other promising applications.

Nanogratings are permanent refractive index modifications based on emerging sub-wavelength cavities inside the bulk material. The grating period scales with the employed laser wavelength and number of applied pulses. Moreover, the orientation of the grating planes is perpendicular to the electric field direction. Since the typical grating period is smaller than the wavelengths of the visible spectral range, nanogratings act as an effective medium with anisotropic optical properties. That allows the fabrication of three-dimensional birefringent components with locally varying optical properties. The resulting spatially variable states of polarization are of great practical importance for optical mode conversion, beam shaping, improved material processing and other fields of application.

K 8.3 Do 14:30 HS 4

Formation of femtosecond laser-induced nanogratings — •Felix Zimmermann[1], Sören Richter[1], Christian Vetter[1], Andreas Tünnermann[1,2], and Stefan Nolte[1,2] — [1]Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Straße 7, 07745 Jena, Germany

We investigated the formation of femtosecond pulse-induced subwavelength structures, also known as nanogratings, in the volume of transparent materials. These self-organized patterns appear after several ultrashort laser pulses undergoing three evolutional stages from randomly distributed nanopores to a homogeneous formed grating. We analyzed the scaling behavior as well as structural properties of the nanogratings by varying typical laser pulse parameters. In order to use the inherent form-birefringence of nanogratings for optical devices, we measured the retardance as well as the polarization contrast intensity after several annealing steps. We found outstanding temperature resistibility against temperatures up to 850° C, allowing the application in even harsh conditions. Moreover, the feedback process providing the cumulative action of subsequent laser pulses can be attributed to dangling bond type defects.

K 8.4 Do 14:45 HS 4

Inscription of tailored fiber Bragg gratings with a deformed wave-front — •Christian Voigtländer[1], Ria Krämer[1], Jens Thomas[1], Daniel Richter[1], and Stefan Nolte[1,2] — [1]Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Fraunhofer Institute for Applied Optics and Precision Engineering, Alber-Einstein-Straße 7, 07745 Jena, Germany

Within the last years the interest in fiber Bragg gratings (FBGs) has ceaselessly grown, as they are excellent components for all-integrated fiber lasers. The fabrication with ultrashort laser pulses makes possible to directly induce them in active doped fibers. Thus, splicing within the laser cavity is not necessary anymore.

A common inscription technique for FBGs is the phase mask method, where an interference pattern is generated by overlapping the first diffraction orders behind the mask. This pattern is focused by a cylindrical lens into the core of the fiber. However, the grating period is predetermined by the phase mask, and another period usually requires another phase mask.

This drawback can be overcome by deforming the wave-front of the inscription beam before the phase mask. The aberrations lead to a tuned period of the interference pattern. A defocused beam can shift the period, while a coma induces a chirp of the grating period. Thus, the phase mask technique becomes more flexible.

K 8.5 Do 15:00 HS 4

Characteristics of femtosecond laser pulse written Volume-Bragg-Gratings — •Daniel Richter[1], Christian Voigtländer[1], Ria G. Krämer[1], Jens U. Thomas[1], Andreas Tünnermann[1,2], and Stefan Nolte[1,2] — [1]Institut für Angewandte Physik, Abbe Center of Photonics, Friedrich-Schiller-University Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Fraunhofer Institut for Applied Optics and Precision Engineering, Albert-Einstein-Str. 7, 07745 Jena, Germany

Applying ultrashort laser pulses for the inscription of Volume-Bragg-Gratings (VBGs) opens a large door into the field of integrated and monolithic solutions for light control. One significant advantage compared to other techniques is that a wide variety of transparent materials - which are most likely non-photosensitive - can be modified and enable therefore the possibility for monolithic solutions. We will show the basic characteristics of the written gratings like grating structure, reflection bandwidth or (tunable) diffraction efficiency. Additionally we will use a VBG to measure the Gouy shift like it is predicted in Gaussian optics and we will show a first realization of a multiwavelength beam combiner with a single element.

K 8.6 Do 15:15 HS 4

Strukturierung von Volumenbeugungsgittern in transparenten Dielektrika mittels Interferenz von Femtosekunden-Laserstrahlung — •Sebastian Nippgen[1] und Dagmar Schaefer[1,2] — [1]Lehrstuhl für Lasertechnik LLT, RWTH Aachen University, Steinbachstraße 15, 52074 Aachen, Deutschland — [2]Fraunhofer-Institut für Lasertechnik ILT, Steinbachstraße 15, 52074 Aachen, Deutschland

Volumenbeugungsgitter (VBG) können vielseitig als spektral- oder winkelselektive Filter eingesetzt werden. Viele Anwendungen erfordern zeitlich und thermisch stabile Gitter oder eine Integration der VBG in bereits bestehende Optiken. Bei der konventionellen Herstellung von VBG werden Teilstrahlen von UV-Laserstrahlquellen in photosensitiven Dielektrika überlagert. Mittels Vor- oder Nachbehandlung wird das Abbild des Interferenzmusters als Brechungsindexmodulation mit einer maximalen Amplitude der Größenordnung $\Delta n \approx 10^{-4}$ in das Dielektrika übertragen. Durch Zweistrahlinterferenz von Femtosekunden-Laserstrahlung können VBG hingegen in einem Prozessschritt in das Volumen von transparenten Dielektrika wie z.B. Quarzglas geschrieben werden. Die dabei erreichten Brechungsindexmodifikationen haben eine Größenordnung von $\Delta n \approx 10^{-3}$. Im Vortrag wird neben der Funktionsweise der VBG eine Gegenüberstellung der konventionellen Herstellung mit der Herstellung mittels Femtosekunden-Laserstrahlung vorgestellt sowie erste Ergebnisse der Gitterstrukturierung in Quarzglas präsentiert.

K 8.7 Do 15:30 HS 4

3D-Mikrostrukturierung von Quarzglas mittels Femtosekundenlaserstrahlung unterschiedlicher Wellenlängen — Andy Engel, •Manuel Pfeiffer und Steffen Weissmantel — Hochschule Mittweida, University of Applied Sciences, Technikumplatz 17, 09648 Mittweida, Germany

Es werden Ergebnisse der Untersuchungen zur Mikrostrukturierung von hochreinem Quarzglas durch Bestrahlung mittels Ultrakurzpuls-Laserstrahlung unterschiedlicher Wellenlängen präsentiert. Für die Untersuchungen wurde eine Femtosekundenlaseranlage mit einem integrierten Clark-MXR CPA 2010 (Lasersystem: Wellenlänge 775 nm, 387 nm bzw. 258 nm, Repetitionsrate 1 kHz, Pulsdauer < 200 fs) genutzt. Ziel der durchgeführten Untersuchungen war die Bestimmung der erzielbaren Qualität (z.B. Oberflächenrauheit) der eingebrachten Mikrostrukturen in Abhängigkeit von den applizierten Laserstrahl- und Prozessparametern (Wellenlänge, Fluenz, Pulsüberlappungsgrad usw.). Auf Grundlage der durchgeführten Abtragsuntersuchungen erfolgten die Optimierung der Strukturierungsparameter und die Erstellung von 3D-Demostratorstrukturen zur Verdeutlichung der erzielbaren Qualität der Mikrostrukturen. Als Demonstratorstrukturen wurden Pyramiden, Halbkugeln, Kegel und Zylindergeometrien ausgewählt. Die Entfernung des, prozessbedingt auf der Materialoberfläche verbleibenden, Debris erfolgte durch eine nasschemische Nachbehandlung der laserstrukturierten Proben.

K 8.8 Do 15:45 HS 4

Ultrashort high repetition rate exposure of dielectric materials: laser bonding of glasses — •Sören Richter[1], Sven Döring[1], Felix Zimmermann[1], Andreas Tünnermann[1,2], and Stefan Nolte[1,2] — [1]Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Fraunhofer Institute of Applied Optics and Precision Engineering, Albert-Einstein-Straße 7, 07745 Jena, Germany

The realization of stable bonds between different glasses has attracted a lot interest in recent years. However, conventional bonding techniques are often problematic due to required thermal annealing steps which may lead to induced stress, whereas glue and other adhesives tend to degrade over time. These problems can be overcome by using ultrashort laser pulses. When focussed at the interface, the laser energy is deposited locally in the focal volume due to nonlinear absorption processes. While even single pulses can lead to the formation of bonds between transparent glass substrates, the application of high repetition rates offers an additional degree of freedom. If the time between two pulses is shorter than the time required for heat diffusion out of the focal volume, heat accumulation of successive pulses leads to localized melting at the interface. The subsequent resolidification finally yields strong and robust bonds. Using optimized processing parameters, we achieved a breaking strength up 95% of the pristine bulk material. In this presentation, we will detail the experimental background and the influence of the laser parameters on the achievable breaking strength.