Short Time-scale Physics Division
Fachverband Kurzzeitphysik (K)

Andreas Görtler
LSH Kempfenhausen
Münchner Straße 49 - 63
82335 Berg
AGoertler@gmx.de

Overview of Invited Talks and Sessions

(Lecture room: SPA SR203)

Invited Talks

K 1.1	Mon	14:00–14:30	SPA SR203	**Wie kurz kann Zeit sein ?** — •Rudolf Germer
K 2.1	Mon	16:30–17:00	SPA SR203	**Elektronenstrahlgezündete Hochfrequenzentladung in Edelgasen bei hoher Pulsleistung** — •Thomas Dandl, Hermann Hagn, Sebastian Jarosch, Robert Mühling, Jochen Wieser, Andreas Ulrich

Invited talks of the joint symposium SYOT

See SYOT for the full program of the symposium.

SYOT 2.1	Tue	10:40–11:20	SPA Kapelle	**Plasma und optische Technologien: PluTO** — •Ralf Peter Brinkmann
SYOT 2.2	Tue	11:20–11:50	SPA Kapelle	**Charakterisierung von Prozessen zur plasma-ionengestützten Schichtabscheidung** — •Jens Harhausen, Rüdiger Foest, Detlef Loffhagen, Andreas Ohl
SYOT 2.3	Tue	11:50–12:20	SPA Kapelle	**Plasma-ionengestützte Abscheidung von Hafnium- und Tantaloxidschichten unter Nutzung von Xenon und Argon als Arbeitsgas** — •Olaf Stenzel, Steffen Wilbrandt, Ralph Schlegel, Norbert Kaiser
SYOT 2.4	Tue	12:20–12:50	SPA Kapelle	**IBS: Praxis und Modellierung** — •Henrik Ehlers
SYOT 3.1	Tue	14:00–14:30	SPA Kapelle	**Plasmaabscheidung nanostrukturierter Barriereschichten auf Kunststoffen - Bedeutung grenzflächenchemischer Aspekte** — Berkem Ozkaya, •Guido Grundmeier
SYOT 3.2	Tue	14:30–15:00	SPA Kapelle	**From target to substrate in high power pulsed magnetron plasmas** — •Achim von Keudell
SYOT 3.3	Tue	15:00–15:30	SPA Kapelle	**Planare Optronische Systeme - Konzept, Umsetzung und erste Ergebnisse** — •Ludger Overmeyer
SYOT 3.4	Tue	15:30–16:00	SPA Kapelle	**SFB TR 123 Planare optronische Systeme (PlanOS)** — •Hans Zappe
SYOT 3.5	Tue	16:00–16:30	SPA Kapelle	**Influence of the oxygen plasma parameters on the atomic layer deposition of titanium oxide** — •Adriana Szeghalmi, Stephan Ratzsch, Ernst Bernhard Kley

Invited talks of the joint symposium SYPP

See SYPP for the full program of the symposium.

SYPP 1.1	Wed	13:45–14:15	SPA Kapelle	**An All-Solid-State Inductive Voltage Adder For Industrial Applications** — •Werner Hartmann, Martin Hergt, Robert Fleck
SYPP 1.2	Wed	14:15–14:45	SPA Kapelle	**Behandlung von Mikroalgenbiomasse mit gepulsten elektrischen Feldern zur Wertstoffextraktion** — •Wolfgang Frey

SYPP 1.3	Wed	14:45–15:15	SPA Kapelle	**Ultrashort High Voltage Pulses for Biomedical Applications** — •Juergen F. Kolb, Anna Steuer, Jie Zhuang, Thomas von Woedtke
SYPP 1.4	Wed	15:15–15:45	SPA Kapelle	**Anwendungen der Leistungsimpulstechnik bei FAIR** — •Isfried Petzenhauser, Shekhar Mohite, Klaus Knie, Udo Blell

Sessions

K 1.1–1.6	Mon	14:00–15:45	SPA SR203	**Optische Methoden und Verfahren**
K 2.1–2.6	Mon	16:30–18:15	SPA SR203	**Strahlungsquellen und deren Anwendungen - Attosekundenexperimente**
K 3.1–3.1	Tue	11:00–11:15	SPA SR203	**Lasersysteme**
K 4.1–4.4	Tue	11:15–12:15	SPA SR203	**Laser-Materie-Wechselwirkung und Laseranwendungen I**
K 5.1–5.7	Tue	14:00–15:45	SPA SR203	**Laser-Materie-Wechselwirkung und Laseranwendungen II**
K 6.1–6.3	Tue	16:30–17:15	SPA SR203	**Laser-Materie-Wechselwirkung und Laseranwendungen III**
K 7.1–7.5	Wed	16:30–18:30	SPA Foyer	**Poster**

Annual General Meeting of the Short Time-scale Physics Division

Dienstag 12:20–12:40 SPA SR203

- Bericht
- Wahl
- Verschiedenes

K 1: Optische Methoden und Verfahren

Time: Monday 14:00–15:45 Location: SPA SR203

Invited Talk K 1.1 Mon 14:00 SPA SR203

Wie kurz kann Zeit sein ? — •Rudolf Germer — ITPeV — TU-Berlin

Mit der Größe "Zeit" wird einerseits das Sortieren in "vorher" und "nachher" ermöglicht, andererseits können zeitliche Längen (z.B. Perioden- und Lebensdauern) verglichen werden. Am Beispiel unterschiedlicher physikalischer Messungen kann man Eigenschaften der Zeit erfassen. Daraus folgen der Zusammenhang zwischen Genauigkeit und Energieaufwand, die Antwort auf die Frage, wann Zeit überhaupt sinnvoll definiert ist und wie lange Zeit dauern kann. Eine ablaufende Zeit t (die Uhrzeit) zeigt sich erst durch einen Austausch von Energie. Beim harmonischen Oszillator ist sie nur innerhalb einer Periodendauer T sinnvoll definiert und nur mit einer Genauigkeit, die von seiner Energie abhängt. Eine ablaufende Zeit t länger als die Periodendauer T ergibt sich erst durch externe Beobachtung, Zählen oder Interferenz mit anderen Systemen. Eine Richtung der aktuellen Zeit t folgt aus der Systemdynamik, u.a. für gedämpfte Oszillatoren, die bekannte thermodynamische Anschaulichkeit ist nicht zwingend. Man kann nun verstehen, wie beim Mischen zweier elektromagnetischer Signale eine genaue Zeitstruktur der beiden hochfrequenten Komponenten im niederfrequenten Mischprodukt erhalten bleiben kann.

K 1.2 Mon 14:30 SPA SR203

Analysis of Laser-Induced Plasma by Time-Resolved In-Line Holography — •Neeke Rothe, Christoph Merschjann, Conrad Schuster, Thomas Fennel, and Stefan Lochbrunner — Institut für Physik, Universität Rostock, D-18051 Rostock, Germany

Dense laser-induced plasmas attract strong scientific interest. They are crucial in understanding the interaction between condensed matter and intense laser radiation as well as for the processes relevant to laser machining. Furthermore they provide an elegant and powerful approach to study warm dense matter.
Here we describe a technique to investigate the evolution of a laser plasma with spatial and high temporal resolution. To this end the pump-probe technique utilizing ultrashort pulses is combined with the evaluation of diffraction patterns. A dense laser plasma is generated by exciting a 30 nm thick gold foil with tightly focused femtosecond pulses at 800 nm. The plasma evolution is probed by delayed 400 nm pulses in transmission and the resulting diffraction pattern of the probe is recorded by a CCD-camera. The optical properties of the plasma can be deduced from the diffraction pattern by an iterative algorithm which is based on the angular spectrum method and the concept of in-line holography. First numerical results with computer-generated test objects are shown and discussed with respect to the experimental data.

K 1.3 Mon 14:45 SPA SR203

Shaping nondiffracting few-cycle pulses with MEMS — •Alexander Treffer[1], Jens Brunne[2], Martin Bock[1], Christian Patzek[1], Ulrike Wallrabe[2], and Ruediger Grunwald[1] — [1]Max Born Institute for Nonlinear Optics and Short-Pulse Spectroscopy, Max-Born-Strasse 2a, 12489 Berlin — [2]University of Freiburg, Department of Microsystem Engineering, Laboratory for Microactuators, Georges-Köhler-Allee 102, 79110 Freiburg

Novel types of reflective micro-electro-mechanical systems (MEMS) for shaping pseudo-nondiffracting beams from ultrashort-pulsed lasers are presented. The phase profiles of these components are controlled by varying either voltage or temperature. In particular, two compact MEMS structures circular axicons [1], linear axicons [2], and spiral phase plates [3] with piezoelectric or thermally induced expansion were designed. Their purely reflective mode of operation enables for working even at high power densities and extremely short pulse durations down to the few-cycle range. The switching performance of the elements, the beam propagation characteristics and specific applications were studied. Recent results of multichannel nanostructuring of surfaces, few-cycle vortex pulse generation with tunable topological charge [3] and non-collinear phase shift autocorrelation of sub-3-cycle pulses are presented. References: 1. J. Brunne and U. Wallrabe, Optics Letters 38, 1939-1941 (2013). 2. J. Brunne, M. Wapler, R. Grunwald, and U. Wallrabe, J. Micromech. Microeng. 23, 115002 (2013). 3. M. Bock, J. Brunne, A. Treffer, S. König, U. Wallrabe, and R. Grunwald, Opt. Lett. 38, 3642-3645 (2013).

K 1.4 Mon 15:00 SPA SR203

Protonenmikroskopie als Diagnostik für stark gekoppelte Plasmen — •Philipp-M. Lang[1], Sergey Efimov[2], Michael Endres[1], Dieter H. H. Hoffmann[1], Bogdan Ionita[3], Alexey Kantsyrev[4], Yakov Krasik[2], Maria Rodionova[3], Lev Shestov[3], Serban Udrea[1], Dmitry Varentsov[3] und Karin Weyrich[3] — [1]TU Darmstadt, Darmstadt, Deutschland — [2]Technion, Haifa, Israel — [3]GSI Helmholtzzentrum, Darmstadt, Deutschland — [4]ITEP, Moskau, Russland

Mit dem Protonenmikroskop PRIOR sollen in naher Zukunft erste Experimente am GSI Helmholtzzentrum für Schwerionenforschung durchgeführt werden. Es wurde in erster Linie zur Untersuchung von Materie bei hoher Energiedichte entwickelt, bietet aber auch umfangreiche Anwendungsmöglichkeiten als Diagnostik in der Materialwissenschaft oder auch der Biophysik. Neben dem Radiographieren statischer Objekte es ist auch möglich, dynamische Prozesse mit einer Auflösung von weniger als 10 μm bzw. 10 ns zu untersuchen. Dabei ist auch eine Rekonstruktion der Dichteverteilung im Target mit einer Präzision von unter 1% möglich. Für die ersten dynamischen Experimente wurde ein Pulsed Power Generator als Treiber für Unterwasser-Drahtexplosionen entwickelt. Hierbei werden bis zu 300kA in ∼1.5 μs über einen dünnen Draht entladen, was zur Entstehung eines dichten, stark gekoppelten Plasmas führt. Ergebnisse der ersten Drahtexplosions-Tests, sowie Konzepte für weitere experimentelle Szenarien werden vorgestellt, auch für zukünftige Experimente am im Bau befindlichen Beschleunigerzentrum FAIR.

K 1.5 Mon 15:15 SPA SR203

Gas puff characterization by high harmonics of an intense laser-pulse — •Bastian Hagmeister, Dirk Hemmers, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

A method is presented for determining the temporal and spatial evolution of the gas density outside a pulsed nozzle. A set of High Harmonics of a short laser pulse is sent through the gas cloud, spectrally decomposed, and mapped using a CCD-camera. The partial absorption in the gas can be quantified and leads to the radial gas density distribution via Abel inversion. As an example, experiments with an Argon gas jet were carried out with densities in the range of $10^{17}\,\mathrm{cm}^{-3}$ to $10^{19}\,\mathrm{cm}^{-3}$.

K 1.6 Mon 15:30 SPA SR203

Time-resolved investigation of photoelectron dynamics by Attosecond Streaking Spectroscopy on solid surfaces. — •Michael Gerl[1], Stefan Neppl[2], Peter Feulner[3], and Reinhard Kienberger[1] — [1]Physik-Department E11, Technische Universität München (TUM) — [2]Lawrence Berkeley National Laboratory, Chemical Sciences Division — [3]Physik-Department E20, TUM

In refined experimental studies on tungsten single crystals, photoelectron dynamics in condensed matter systems is investigated by attosecond streaking spectroscopy. A reliable data basis of streaking measurements on W(110) and well-defined adsorbate systems could be established for an excitation energy of 105 eV. The main result is an improved accuracy of the time delay measured between photoemission from the conduction band states and the 4f core levels in tungsten. The potential of attosecond streaking spectroscopy could be rated by investigating possible systematic experimental errors. In this way, the accessibility of a resolving power of 15 as is confirmed. The datasets acquired at $\hbar\omega = 105$ eV provide an important milestone in a systematic study of streaking measurements involving different excitation energies, which could help to clarify the physical origin of time delays in photoemission from solids. Further steps towards a better understanding of photoemission time delays could be made by realizing experiments on adsorbate systems (Neppl *et al.*, PRL 109 (2012), 087401) which can be quantitatively compared to theoretically predicted effects in attosecond photoemission. Additionally, a novel experimental approach to access absolute photoemission time delays is demonstrated.

K 2: Strahlungsquellen und deren Anwendungen - Attosekundenexperimente

Time: Monday 16:30–18:15 Location: SPA SR203

Invited Talk K 2.1 Mon 16:30 SPA SR203

Elektronenstrahlgezündete Hochfrequenzentladung in Edelgasen bei hoher Pulsleistung — •Thomas Dandl[1], Hermann Hagn[1], Sebastian Jarosch[1], Robert Mühling[2], Jochen Wieser[2] und Andreas Ulrich[1] — [1]Physik Department E12/E15, Technische Universität München, James-Franck-Str. 1, 85748 Garching — [2]excitech GmbH, Branterei 33, 26419 Schortens

Ein Elektronenstrahl mit einer Teilchenenergie von 12 keV wird durch eine sehr dünne Siliziumnitridmembran in ein Edelgastarget eingeschossen. Dies führt zu einer brillanten und effizienten Lichtemission im vakuumultravioletten (VUV) Bereich [1]. Durch die Einkopplung einer zusätzlichen Hochfrequenzleistung (HF) kann die spektrale Form sowie die Intensität der Lichtemission verändert werden. Bei niedrigen HF-Leistungen zeigt sich im Wesentlichen eine Intensitätsverschiebung vom dominanten 2. Excimerkontinuum hin zum kurzwelligeren 1. Kontinuum. Durch die Zündung einer HF-Entladung bei höheren Leistungen wird zudem eine deutliche Inensitätszunahme beider Kontinua beobachtet [2]. Diese Effekte wurden zunächst mit einer 2,45GHz Mikrowellenanregung mit einer Leistung von bis zu ca. 25W untersucht. Durch die Verwendung eines 25kW X-Band Radar Magnetrons wurde nun die eingekoppelte Leistung drastisch erhöht. In diesem Vortrag werden Daten zur zeitlichen, örtlichen und spektralen Verteilung der Lichtemission bei einer Anregung mit 500ns langen HF-Pulsen vorgestellt. [1] A.Morozov et al, J.Appl.Phys. 103 (2008) [2] T.Dandl et al, EPL. 94 (2011) Gefördert durch das BMBF Förderkennzeichen 13N9528 und 13N11376.

K 2.2 Mon 17:00 SPA SR203

Vergleich verschiedener entladungsbasierter Konfigurationen für EUV Strahlungsquellen — •Norbert Böwering — Fakultät für Physik, Universität Bielefeld

Für industrielle Anwendungen im Bereich der EUV Lithographie bei einer Wellenlänge von 13,5 nm kommen unter anderem auch kompakte Gasentladungslichtquellen zum Einsatz. Durch niederinduktive Einkopplung von kapazitiv gespeicherter elektrischer Energie werden intensive Z-Pinch Plasmen erzeugt bei Spitzenströmen im Kiloamperebereich und mit Elektronentemperaturen von typisch mehr als ca. 20 eV. Zur Realisierung solcher Lichtquellen gibt es jedoch eine Vielzahl verschiedener konkurrierender Entladungsgeometrien, die zumeist vorteilhaft von einer einfachen Z-Pinch Elektrodenanordnung abweichen. Einige vielversprechende Konfigurationen werden hier beschrieben und hinsichtlich ihrer Eignung als EUV Strahlungsquelle diskutiert und verglichen. Dabei sind vor allem Lichtleistung, Konversionseffizienz, Komplexität, Stabilität, Debrisgenerierung und Elektrodenerosion entscheidende Kriterien. Zu den interessanten fortgeschrittenen Konfigurationen zählen insbesondere Hohlkathoden-getriggerte Pseudofunkenentladung, Laser-induzierter Vakuumfunken, durch Scherströmung stabilisierter Plasmafokus, Pinch mit induktiver Plasmastrom-Einkopplung, sowie hypozykloider Pinch.

K 2.3 Mon 17:15 SPA SR203

Applications of a table-top laser-induced plasma source emitting in the soft x-ray range — •Matthias Müller — Laser-Laboratorium Göttingen e.V., Hans-Adolf-Krebs Weg 1, 37077 Göttingen, Deutschland

The spectral range of the 'water window' ($\lambda = 2.3$ to 4.4 nm) represents a highly interesting regime for studying carbon-based specimen, due to a 10 times higher absorption of carbon compared to oxygen and water. This opens up a variety of applications, e.g. high resolution microscopy and near-edge x-ray absorption fine structure (NEXAFS) spectroscopy. These studies are typically conducted at synchrotons; however, as the interest in imaging techniques and surface sensitive chemical analytics is growing, there is also a considerable demand for compact lab-based soft x-ray sources.

In this talk, an overview on the soft x-ray activities of the Laser-Laboratorium Göttingen based on laser-driven plasma emission from pulsed gas jets is given. Results of NEXAFS measurements at the carbon K-edge ($\lambda = 4.4$ nm) and calcium L-edge ($\lambda = 3.58$ nm) are presented, along with a brief description of a table-top soft x-ray microscope using monochromatic radiation at 2.88 nm wavelength. Furthermore, caustic measurements are presented in order to characterize the imaging performance of the ellipsoidal condenser optic employed in the microscope.

K 2.4 Mon 17:30 SPA SR203

Attosecond radiation generation from a laser-irradiated nano foil. — •Hartmut Ruhl and Karl Ulrich Bamberg — Theresienstrasse 37, 80333 Munich

A laser irradiated nano foil can emit high frequency radiation with an attosecond time structure. We will present results from a numerical investigation and compare them to a nonlinear analytical model in 1D. A thorough account of the radiation signature of the foil will be given. In addition, self-field effects expected from the system at large laser intensities (a>100) will be discussed. It will be shown that the foil can become an efficient radiator.

K 2.5 Mon 17:45 SPA SR203

Femtosecond Time-Resolved Photoelectron and Photoion Studies of Perylene with High-Order Harmonics — •Markus Koch[1,2], Jakob Grilj[1,3], Emily Sistrunk[1], Thomas J. A. Wolf[1], and Markus Gühr[1] — [1]PULSE, SLAC National Accelerator Laboratory, Menlo Park, CA 94305, USA — [2]Institute of Experimental Physics, Graz University of Technology, A-8010 Graz, Austria — [3]Ecole Polytechnique Federale de Lausanne EPFL, CH-1015, Switzerland

We present femtosecond pump-probe photoelectron and -ion spectra of perylene collected with a novel set-up. After excitation to the S1 state with 400 nm ionization is achieved either by a multi photon transition with the 800 nm fundamental or with a single photon obtained from high-order harmonic generation (HHG). In the latter case we isolate the 9th harmonic (89 nm, 14 eV) using an In metal filter in combination with an Al mirror. Characterization of the spectrometer reveals cross correlations of about 75 fs for both 800 nm and 89 nm probe pulses, indicating that the duration of the HHG pulse does not limit the time resolution. The energy resolution obtained with the 9th harmonic is 200(20) meV.

In perylene we observe excited state dynamics with a 1 ps time constant. For 800 nm multiphoton probe ionization both the ion yield and the order of the ionizing transition (number of photons) change with pump-probe delay. In 9th harmonic probe photoelectron spectra the 400 nm pump excitation is observed as energy shift of photoelectron lines.

K 2.6 Mon 18:00 SPA SR203

High harmonics from a radio-frequency pre-excited medium — •Enikoe Seres[1,2], Jozsef Seres[2], Georg Winkler[2], and Thorsten Schumm[1,2] — [1]Wolfgang Pauli Institute, CNRS UMI 2842, Vienna, Austria — [2]Insitute of Atomic and Subatomic Physics, Vienna University of Technology, Vienna, Austria

To our knowledge, high harmonic generation is the only method, which can generate coherent VUV and EUV pulses at the 100 MHz repetition rate of frequency combs. However, Ti:sapphire frequency comb based HH sources suffer from the relatively low conversion efficiency of the process. This limitation originates from the high ionization potential of the gas, the ionization probability is very low. In VUV and EUV frequency combs, mainly Xe gas is used because it has the smallest ionization potential (12.1 eV) and so the highest laser-to- high harmonic conversion efficiency. However, this ionization potential of Xe is still too high, especially for a source in the VUV spectral range, where we aim to create a powerful HH source. Here we report the generation of high-order harmonics in Xe gas in the perturbative regime, which has been preexcited by radio-frequency discharge and pumped directly by the output of a Ti:sapphire frequency comb.

K 3: Lasersysteme

Time: Tuesday 11:00–11:15 Location: SPA SR203

K 3.1 Tue 11:00 SPA SR203

Auslegung und Charakterisierung eines deformierbaren Spiegels zur Kompensation von Phasenstörungen — •Elke Schmid, Jochen Speiser und Adolf Giesen — Institut für Technische Physik, Deutsches Zentrum für Luft- und Raumfahrt, 70569 Stuttgart

Die Zielsetzung der hier vorgestellten Arbeit ist die Entwicklung eines deformierbaren Spiegels für hohe Laserleistungen. Dieser Spiegel soll verwendet werden, um thermisch induzierte Phasenstörungen im laseraktiven Medium zu kompensieren. Grundlegendes Funktionsprinzip ist hierbei die gezielte lokale Deformation eines hochreflektierenden Laserspiegels. Diese Deformation wird durch lokales Aufheizen des Glassubstrats des Spiegels erzielt. Diese Aufheizung wird durch räumlich strukturierte Beaufschlagung mit Strahlung bei einer vom Glassubstrat absorbierbaren Wellenlänge erreicht. Die Intensitätsverteilung der Bestrahlung wird mittels eines DLP (Mikrospiegelarray) gesteuert. Als Bestrahlungsquelle wird ein fasergekoppelter Diodenlaser verwendet. Für die Auslegung des Spiegels wurden numerische Simulationen durchgeführt und die erzielten Deformationen des Spiegels analysiert. Wichtige Auslegungsparameter sind die erreichbare Auflösung sowie der maximale Phasenhub. Basierend auf diesen Berechnungen wurden die Komponenten entwickelt und hergestellt. Für die experimentelle Charakterisierung des Spiegels wurde dessen Oberflächendeformation mit einem Shack-Hartmann Sensor gemessen. Hierbei wurde vor allem das Verhalten des deformierbaren Spiegels bei verschiedenen Bestrahlungsintensitäten und Intensitätsverteilungen untersucht.

K 4: Laser-Materie-Wechselwirkung und Laseranwendungen I

Time: Tuesday 11:15–12:15 Location: SPA SR203

K 4.1 Tue 11:15 SPA SR203

Laser-induced cavitation bubbles near surfaces — Christian Menninger[1,2], Marvin Tammen[1,2], •Yun Kai[1], Bernd Meyerer[1], Walter Garen[1], and Ulrich Teubner[1,2] — [1]Institut für Lasertechnik Ostfriesland, Hochschule Emden/Leer, University of Applied Sciences, Constantiaplatz 4, 26723 Emden, Germany — [2]Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg, Germany

Applying a nanosecond frequency-doubled Nd:YAG laser, cavitation bubbles can be induced in liquids. During the evolution process of the bubbles, shock waves can be generated. Within the scope of the experiments, cavitation bubbles are generated near the liquid (currently distilled water) surface. The interaction between the shock waves and the liquid surface is studied. Using shadow procedure, the water jet on the surface and the rarefaction waves are investigated with a high-speed CCD camera together with a second Nd:YAG laser as light source. The phenomena observed in these experiments are analogues to those that may be present in turbines or hydraulic systems.

K 4.2 Tue 11:30 SPA SR203

Laser-induced shock waves in glass capillary — Marvin Tammen[1,2], Christian Menninger[1,2], •Yun Kai[1], Bernd Meyerer[1], Walter Garen[1], and Ulrich Teubner[1,2] — [1]Institut für Lasertechnik Ostfriesland, Hochschule Emden/Leer, University of Applied Sciences, Constantiaplatz 4, 26723 Emden, Germany — [2]Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg, Germany

Shock waves in spherical geometry in liquid can be generated after the optical breakdown induced by intense laser pulses. In the scope of the on-going experiments, the optical breakdown is designed to occur in different glass capillaries (several millimeters as inner diameter), which are placed in a glass cuvette filled with liquid (distilled water in present work). External pressure is applied into the capillary to control the position of the air-water boundary. The propagation of the shock waves within the capillary and the resulting evaporation process are investigated by applying optical ultra short time measurement techniques. The study of the velocity of the shock waves propagating in capillaries of different diameters and in different liquids is carried out. The acquired results contribute to the further understanding of shock wave dynamics, which is of interest for applications such as micro fluidics, nano technology, medical physics and many other topics.

K 4.3 Tue 11:45 SPA SR203

Nonthermal melting in semiconductors under X-ray free-electron laser pulse irradiation — •Nikita Medvedev[1], Harald Jeschke[2], and Beata Ziaja[1] — [1]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, D-22607 Hamburg, Germany — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt am Main, Max-von-Laue-Strasse 1, D-60438 Frankfurt, Germany

After irradiation of a covalently bonded material with a femtosecond intense X-ray pulse, one can observe an ultrafast nonthermal melting occurring on sub-picosecond timescale. Such melting is induced by a modification of the interatomic potential, triggered by the electron excitation. We studied such process in detail with newly developed hybrid approach MC-TBMD [1-3]. It revealed the multistep nature of the nonthermal melting: an interplay between the high-energy electron relaxation, bandgap collapse and modification of the electronic structure, and atomic relaxation into the new phase. We calculated the damage threshold of the nonthermal graphitization of diamond as a function of photon energy within a wide energy range: from a few eV up to tens of keV [2,3]. It appeared that the higher the photon energy, the longer it takes for the atomic relaxation and the subsequent phase transition [3].

[1] N. Medvedev, H. Jeschke, B. Ziaja, New J. Phys. 15, 015016 (2013)

[2] J. Gaudin et al., Phys. Rev. B 88, 060101 (2013)

[3] N. Medvedev, H. Jeschke, B. Ziaja, Phys. Rev. B (2013 in press)

K 4.4 Tue 12:00 SPA SR203

Laser-induced thermal neutron production at high repetition rates using novel cluster/gas targets — •Friederike Schlüter[1], Thomas Brückel[4], Markus Büscher[1], Mirela Cerchez[5], Laura Di Lucchio[3], Ilhan Engin[2], Paul Gibbon[3], Patrick Greven[2], Silke Grieser[6], Astrid Holler[2], Alfons Khoukaz[6], Esperanza Köhler[6], Ulrich Rücker[4], Julian Sohn[6], Toma Toncian[5], and Oswald Willi[5] — [1]Peter Grünberg Institut (PGI), FZ Jülich — [2]Institut für Kernphysik (IKP), FZ Jülich — [3]Jülich Supercomputing Centre (JCHP), FZ Jülich — [4]Jülich Centre for Neutron Science (JCNS), FZ Jülich — [5]Institut für Laser-Plasma Physik (ILPP), Heinrich-Heine Universität Düsseldorf — [6]Institut für Kernphysik, Westfälische Wilhelms-Universität Münster

The physics of laser driven particle sources has undergone great developments in recent years. With increasing laser powers it is nowadays possible to accelerate particles to multi-MeV kinetic energies. Such proton and deuteron beams can be used to generate short MeV neutron pulses in a secondary converter made, e.g., from Be [Roth]. Using a novel target concept, we want to realize a high repetition rate thermal neutron source at the 300 TW 10 Hz Düsseldorf ARCturus laser facility. For that purpose a source for frozen H_2 or D_2 clusters - each with up to 10^6 molecules - has been prepared at Münster University which will be combined with a conventional gas jet. In a first measurement in 2014 we will optimize the p and d fluxes from the cluster/gas target, and then build tailored (i.e. compact) neutron converter targets and moderators to deliver intense neutron pulses at meV energies.

K 5: Laser-Materie-Wechselwirkung und Laseranwendungen II

Time: Tuesday 14:00–15:45 Location: SPA SR203

K 5.1 Tue 14:00 SPA SR203

Nanostrukturierung von einkristallinem Silizium durch Sub-15 Femtosekundenpulse — •Marco Schüle[1], Martin Straub[1], Maziar Afshar[2], Dara Feili[2], Helmut Seidel[2] und Karsten König[1] — [1]Universität des Saarlands, Lehrstuhl für Biophotonik und Lasertechnologie, Fakultät für Physik und Mechatronik, Campus am Markt, Zeile 5, 66125 Saarbrücken — [2]Universität des Saarlands, Lehrstuhl für Mikromechanik, Mikrofluidik und Mikroaktorik, Fakultät für Physik und Mechatronik, Campus A5.1, 66123 Saarbrücken

Mit Ziel neuer Anwendungen in der Lasermaterialbearbeitung wurde die Nanostrukturierung einkristalliner Siliziumoberflächen durch stark fokussierte sub-15 fs Pulse eines Ti:Saphir Lasers ($\lambda \approx 800$ nm, Repetitionsrate 85 MHz, sub-nJ Pulsenergie, fokale Spitzenintensität ca. 15 TW/cm^2) in Wasser untersucht. Die Bestrahlung erzeugt drei charakteristische Typen von Oberflächenstrukturen [1,2]. Bei Bestrahlungsdosen in unmittelbarer Nähe der Ablationsschwelle bilden sich auf der Oberfläche wenige Nanometer breite Risse. Wellenartige Strukturen senkrecht zur Laserpolarisation (sog. Ripples) mit einer Periode von ca. 130 nm, Breite von 50 - 60 nm und Tiefe von ca. 60 nm entstehen bei etwas höherer Dosis (ca. 100 kJ/cm^2). Bei noch stärkerer Bestrahlung wird die Oberfläche schwammartig nanoporös, wobei die Strukturelemente zwischen den Poren eine typische Größe von 40 - 60 nm aufweisen. Im Mittelpunkt unserer Experimente steht der Einfluß von Dotierung und Kristallorientierung auf die Nanostrukturentstehung.

[1] M. Straub et al., Opt. Lett. 37, 190-192 (2012), [2] K. König et al., J. Laser Appl. 24, 042009 (2012). Gefördert durch DFG-SPP1327.

K 5.2 Tue 14:15 SPA SR203

Machining of Biocompatible Polymers with Shaped fs laser pulses — •Conrad Schuster[1], Christoph Merschjann[1], Neeke Rothe[1], Steffen Fiedler[1], Volkmar Senz[2], Katrin Sternberg[2], and Stefan Lochbrunner[1] — [1]Institut für Physik, Universität Rostock, Germany — [2]IBMT, Universität Rostock, Germany

In contrast to nanosecond pulses, femtosecond laser pulses offer high peak intensities at low pulse energies, thus enabling the controlled ablation of polymers without any bubbles or melting. Via multi-photon effects transparent materials become processable as well. Furthermore, working on the fs scale is not limited to single pulses. Shaped pulses open up a variety of new processing parameters: The spectrum of the single fs pulses emitted from the laser can be modulated in phase and amplitude to change the pulse duration, create double pulses or complex multi-pulse structures. These structures can last several ps and show features on the time scale of the original pulse (here 50 fs).
We optimized the shape of the applied pulse structure for precise machining of biodegradable poly-L-lactide (PLLA) foils, used for medical implants.
Using pulse shaping, we can precisely control the parameters of the machining process, including groove width and depth as well as the roughness of the adjacent surface. Further, in contrast to commercial picosecond laser machining systems we could reduce the dimensions of created holes to diameters less than 10 μm.

K 5.3 Tue 14:30 SPA SR203

Einfluss von Laserparametern auf Qualität und Prozesseffizienz beim Mirkobohrprozess mit ultrakurzen Laserpulsen — •Anne Feuer, Christoph Kunz, Volkher Onuseit, Rudolf Weber und Thomas Graf — Institut für Strahlwerkzeuge (IFSW), Pfaffenwaldring 43, D-70569 Stuttgart, Germany

In dieser Arbeit wird der Bohrprozess für Mikrobohrungen in Metall mit Pikosekunden-Laserpulsen hinsichtlich Effizienz und Qualität der resultierenden Bohrkapillare untersucht. Trotz Anwendung des Wendelbohrverfahrens bleibt die Qualität der Mikrobohrung für kleine Dimensionen (Bohrungsdurchmesser $\leq$ 30 μm) und hohen Bohrtiefen (10- bis 15-fache des Bohrungsdurchmessers) gerade in Hinblick auf die Prozesseffizienz eine Herausforderung. Eine Erhöhung der mittleren Laserleistung, entweder durch Verwendung höherer Pulsenergien oder durch eine Erhöhung der Pulswiederholungsrate, reduziert zwar die Prozesszeit, führt in diesem Falle infolge von zunehmender Plasmabildung und Wärmeakkumulation zu verstärkter Schmelz- und Gratbildung sowie zur Ausbildung einer unregelmäßigen Bohrkapillare (Riefen, Ausbrüche, Seitenkanäle) und damit zu einer Verschlechterung der Bohrungsqualität. In einem ersten Schritt wurde der Einfluss von Pulsenergie und Pulswiederholungsrate auf die Bohrungsqualität sowie Prozesseffizienz beim Perkussions- und Wendelbohren untersucht. Die Auswertung der Untersuchung des Einflusses von Pulsenergie und Pulswiederholungsrate auf die Bohrqualität und Prozessdauer wird in diesem Beitrag vorgestellt.

K 5.4 Tue 14:45 SPA SR203

Simulation of Laser Ablation of Aluminum with Double Pulses — •Johannes Roth, Armin Krauss, Jan Lotze, and Hans-Rainer Trebin — FMQ, Universität Stuttgart

Lasers are becoming a more and more important tool in cutting and shaping materials. Improving precision and effectivity is an ongoing demand in science and industry. One possibility are double pulses. Here we study laser ablation of aluminum by the two-temperature model, where the laser is modeled as a source in a continuum heat conduction equation for the electrons, whose temperature then is transferred to a molecular dynamics particle model by an electron-phonon coupling term. The melting and ablation effectivity is studied depending on the relative intensity of two Gaussian shaped laser pulses and of the time delay between two pulses. For double pulses with delay times up to 200 ps we find a behavior as observed in experiment with reduced ablation depths beyond a delay of 10 ps. Thus we can exclude increased reflectivity from laser plasma interaction as the only source of such a behavior.

K 5.5 Tue 15:00 SPA SR203

Prediction of ablation thresholds: Simulations and experiments in the fs-regime — •Daniel J. Förster[1], Margit Wiedenmann[1], Johannes Roth[2], Rudolf Weber[1], and Thomas Graf[1] — [1]Institut für Strahlwerkzeuge, Universität Stuttgart, Pfaffenwaldring 43, 70569 Stuttgart — [2]Institut für funktionelle Materie und Quantentechnologien, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart

The ablation threshold of materials is an important quantity in short-pulse laser materials processing. Molecular dynamics (MD) simulations of metals irradiated by femtosecond laser pulses were performed to predict ablation thresholds. Materials are described in the nanometer scale by atoms given as point particles interacting via classical force fields. The results given by simulations with the MD program IMD in comparison to experimental results with a 800 nm laser system are discussed.

K 5.6 Tue 15:15 SPA SR203

Calibration-free analysis of major components in steel slag by laser-induced breakdown spectroscopy by combination of UV and VIS spectra — •Philipp Kolmhofer[1], Simon Eschlböck-Fuchs[1], Roman Rössler[2], Johannes Pedarnig[1], and Johannes Heitz[1] — [1]Christian Doppler Laboratory for Laser-Assisted Diagnostics, Institute of Applied Physics, Johannes Kepler University Linz, A-4040 Linz, Austria — [2]voestalpine Stahl GmbH, A-4031 Linz, Austria

Slag samples from industrial steel production (secondary metallurgy) are analyzed by calibration-free laser-induced breakdown spectroscopy (CF-LIBS) using a transportable LIBS measurement system. The system uses nanosecond Nd:YAG laser pulses (1064 nm) for ablation and a fiber coupled Echelle spectrometer with ICCD camera for optical spectrum detection. The emission lines of major elements are detected in the VIS and UV range of the spectrometer (350-850 nm, 220-350 nm). An automated procedure corrects the measured spectra for self-absorption effects, determines the plasma temperature Te (Saha-Boltzmann plots), and calculates the concentration of major oxides in the slags. The nominal oxide concentration is determined by reference analysis. The Te values derived from either Ti, Mn, or Ca lines are very similar and show small uncertainty. The measured oxide concentrations are in reasonable agreement with reference data.

K 5.7 Tue 15:30 SPA SR203

Boosting lifetime and optical emission of laser-induced plasma by electric discharge sparks — •Simon Eschlböck-Fuchs, Philipp Johann Kolmhofer, Marius Aurel Bodea, Josef Gerald Hechenberger, Norbert Huber, Johannes Heitz, and Johannes Pedarnig — Christian Doppler Laboratory for Laser-Assisted

Diagnostics, Institute of Applied Physics, Johannes Kepler University Linz, A-4040 Linz, Austria

Laser-induced breakdown spectroscopy (LIBS) is a sensitive analytical measurement technique with limits of detection (LOD) in the range 1-30 ppm for many chemical elements depending on the matrix. Different techniques have been tried to enhance the optical emission of laser-induced plasma and to improve the sensitivity of the LIBS method. The techniques include double-pulse excitation, radiofrequency and microwave plasma, and high voltage discharge sparks. We report on the combination of LIBS with low-voltage high-current discharge sparks and the investigation of the properties of combined plasma. The spark between two metal electrodes is triggered by the laser-induced plasma on the sample surface. Time-resolved photography reveals very long lifetimes for the combined plasma (up to several milliseconds) and an increased plasma volume. LIBS spectra of combined plasma in general show emission lines of higher intensity than the spectra of conventional LIBS plasma.

K 6: Laser-Materie-Wechselwirkung und Laseranwendungen III

Time: Tuesday 16:30–17:15 Location: SPA SR203

K 6.1 Tue 16:30 SPA SR203

Direct observation of self-compression and pulse-splitting dynamics along a filament — •Martin Kretschmar[1,2], Carsten Brée[3], Ayhan Demircan[1], Tamas Nagy[1,4], Heiko G. Kurz[1,2], Uwe Morgner[1,2], and Milutin Kovacev[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, D-30167 Hannover, Germany — [2]QUEST, Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, D-30167 Hannover, Germany — [3]Weierstraß-Institut für Angewandte Analysis und Stochastik, Mohrenstr. 39, 10117 Berlin, Germany — [4]Laser-Laboratorium Göttingen e.V., Hans-Adolf-Krebs-Weg 1,37077 Göttingen, Germany

Filamentation has become a versatile tool for pulse shortening, making it applicable for attosecond science. The evolution of the pulses undergoing filamentation are strongly influenced by complex spatio-temporal dynamics, leading to few-cycle pulse generation directly inside the filament. We present a setup, which directly investigates the fundamental pulse dynamics along the filamentary propagation direction. The analysis of the unperturbed pulse structures reveals pulse-splitting dynamics and self-compression to 5.30 fs. Simulations according to the experimental conditions are performed and show a good agreement with the experimental findings.

K 6.2 Tue 16:45 SPA SR203

Real Time Observation of Transient Electron Density in High Bandgap Dielectrics Irradiated with Tailored Femtosecond Laser Pulses — •Nadine Götte[1], Thomas Winkler[1], Cristian Sarpe[1], Bastian Zielinski[1], Jens Köhler[1], Thomas Kusserow[2], Tamara Meinl[2], Yousuf Khan[2], Hartmut Hillmer[2], Matthias Wollenhaupt[1], Arne Senftleben[1], and Thomas Baumert[1] — [1]University of Kassel, Institute of Physics and CINSaT, D–34132 Kassel, Germany — [2]University of Kassel, Institute of Nanostructure Technologies and Analytics and CINSaT, D–34132 Kassel, Germany

The generation of a high density free electron plasma is the first step in the laser ablation of dielectric materials. We have demonstrated that tailored ultrashort laser pulses are suitable for robust manipulation of optical breakdown, increasing the precision of ablation to one order of magnitude below the optical diffraction limit [1].

In this study ionization mechanism in dielectrics irradiated with bandwidth-limited and temporally asymmetric femtosecond laser pulses are investigated via ultrafast spectral interferometry [2]. An extremely stable common-path interferometer is used to extract accurate information about the electron plasma and its dynamics. Our measurements directly prove that temporally, asymmetric shaped pulses control the ionization mechanism through which the free electrons are generated in high band gap transparent dielectrics.

[1] L. Englert *et al.*, J. Laser Appl., **24**, 042002 (2012)
[2] C. Sarpe *et al.* NJP **14**, 075021, (2012)

K 6.3 Tue 17:00 SPA SR203

Visualization of ultrafast two-dimensional atomic motions in a single crystal of bismuth — •Eeuwe Zijlstra and Martin Garcia — Theoretische Physik, Universität Kassel, Deutschland

A new method to optically control two-dimensional atomic motions in a bulk solid has recently been demonstrated [1]. In addition, the controlled motions were quantitatively visualized by density functional theory calculations [1]. The newly developed visualization scheme, which is based on the calculation of optical properties in two independent atomic directions, allows to follow the real-space atomic motions from time-resolved optical reflectivity measurements only. Here, details of the optical calculations are presented and the conditions of validity of our novel scheme are discussed.

[1] H. Katsuki et al, Nature Communications 4, 2801 (2013).

K 7: Poster

Time: Wednesday 16:30–18:30 Location: SPA Foyer

K 7.1 Wed 16:30 SPA Foyer

High energy laser sources for space debris detection — •Daniel Kolbe, Daniel Sauder, and Jochen Speiser — Deutsches Zentrum für Luft- und Raumfahrt e.V., Stuttgart

The large and rising number of space debris particles in low earth orbit (LEO) is posing an increasing danger to LEO satellites and the ISS. For example, even sub-centimeter particles can cause significant damage to solar panels; cm-class objects can destroy satellites. In the medium term, this threat can limit the use of popular orbits that have a high density of space debris. A first step in dealing with space debris entails locating and tracking even small debris objects with high precision to calculate orbital data and evaluate the threat they pose to satellites. After an initial passive optical detection of particles, a ground-based, high energy laser is required to obtain precise distance information through time-of-flight measurements. For this purpose, a 1 J, 1 kHz laser system with good beam quality based on thin-disk laser amplifiers is under development. Here we present the current status of the experiment and give an overview of the planned laser setup.

K 7.2 Wed 16:30 SPA Foyer

Molecular Dynamics Simulations of Laser Ablation in Covalent Materials — •Alexander Kiselev, Johannes Roth, and Hans-Rainer Trebin — Institut für Theoretische und Angewandte Physik, Universität Stuttgart, Germany

Non-equilibrium phenomena in highly excited covalent systems induced by strong laser radiation fields have received much attention in recent years. Despite of many theoretical and computational investigations these ultrafast processes are still not well understood. Here we use multi-million particle molecular dynamics simulations to study the laser ablation in covalently bonded materials. A combined self-consistent continuum-atomistic model [1] was applied for carrier-lattice interaction and electron-hole recombination processes. In addition, the temporal and spatial dependence of the exited carrier density was taken into account by fitting the interatomic forces to finite-temperature density functional theory calculations.

Both, spatially homogeneous and Gaussian distributed laser power densities have been carried out. In the first case the heat conduction in the system can be treated as one-dimensional. Furthermore, by using single- and double-pulse femtosecond laser irradiations the influence of the pulse shape on the ablation threshold has been investigated for a wide range of laser fluences.

[1] J.K. Chen, D.Y. Tzou, J.E. Beraun, Int. J. Heat Mass Transfer. **48**, 501-509 (2005)

K 7.3 Wed 16:30 SPA Foyer

Broadband XUV-Polarimetry of High Harmonics from Plasma Surfaces by multiple Fresnel Reflections — •Thomas Hahn[1], Jana Bierbach[2,3], Christian Rödel[2,3], Dirk Hemmers[1], Mark Yeung[3,4], Brendan Dromey[4], Silvio Fuchs[2,3], Arpa Galestian Pour[2], Stephan Kuschel[2,3], Matt Zepf[3,4], Gerhard Paulus[2,3], and Georg Pretzler[1] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf — [2]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena — [3]Helmholtz-Institut Jena — [4]Centre for Plasma Physics, School of Mathmatics and Physics, Queen's University Belfast, United Kingdom

High harmonic generation (HHG) from the nonlinear interaction of intense laser pulses with gases or plasma surfaces is the most prominent way of creating coherent extreme ultraviolet (EUV/XUV) pulses. The measurement and control of the polarization may become important in future applications. We present an broadband XUV polarimeter based on multiple Fresnel reflections providing an extinction rate of 5 to 25 for 17-45 nm that has been tested at a gas harmonic source. In a further experiment using HHG from plasma surfaces the XUV polarimeter allowed a polarization measurement of high harmonic radiation from plasma surfaces for the first time which reveals a linear polarization state as predicted for our generation parameters. The generation and control of intense polarized XUV pulses - together with the availability of broadband polarizers in the XUV - open the way for a series of new experiments.

K 7.4 Wed 16:30 SPA Foyer

Characterization of the complex refractive index of metals by high harmonic XUV radiation — •Christian Halter, Dirk Hemmers, and Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Two methods to characterize the complex refractive index of thin metal foils are presented. The first method is based on the comparison of the intensities of two high harmonic XUV spectra. The XUV beam passes a gold grating and one of the two first orders is transmitted through a metal foil and thus harmonics are attenuated depending on their wavelength. The comparison to the second first order spectrum allows the calculation of the real part of the complex refractive index.

The second method uses a double pinhole setup. The interference pattern is changed by the introduction of an optical path difference via inserting a metal foil in one of the two optical paths which interfere. This reveals the imaginary part of the complex refractive index.

K 7.5 Wed 16:30 SPA Foyer

Polarization Dependence of Laser Dressed States in Helium — •Johan Hummert[1], Maurizio Reduzzi[1], Fabio Frasetto[2], Antoine Dubrouil[1], Chengyong Feng[1], Francesca Calegari[1], Mauro Nisoli[1], Luca Poletto[2], Kenneth Schafer[3], Mette Gaarde[3], and Giuseppe Sansone[1] — [1]Politecnico di Milano, Italy — [2]Universita degli Studi di Padova, Italy — [3]Louisiana State University, USA

Measuring the spectrally resolved absorption of atoms grants direct insight into their electronic structure. Paired with the high time resolution obtained with attosecond pulses this allows us to investigate the dynamics of bound electrons in a strong laser field.

Here we present transient absorption measurements in helium with attosecond time resolution. The experimental setup uses a few cycle near infrared pulse with variable polarization as a pump and an attosecond extreme ultraviolet pulse as a probe. The attosecond pulses are generated by few cycle IR pulses using high harmonic generation in combination with the polarization gating technique.

Apart from other strong-field effects light-induced features corresponding to so-called laser dressed states are observed. It is found that the absorption cross section of these laser dressed states depends strongly on the relative polarization of the pulses. We show that Floquet theory can be used to understand this behaviour. A simple analytic approach to the time-independent Floquet Hamiltonian method proves sufficient to reproduce the observed polarization dependence of dressed state absorption completely.