# Short Time-scale Physics and Applied Laser Physics Division
# Fachverband Kurzzeit- und angewandte Laserphysik (K)

Andreas Görtler
A. B. von Stetten Institut - Gymnasium und Realschule
Am Katzenstadel 18A
86152 Augsburg
agoertler@gmx.de

## Overview of Invited Talks and Sessions

(Lecture hall REC/C213; Poster HSZ OG2)

### Invited Talks

K 1.1 Tue 11:00–11:35 REC/C213 **Information, Abstände und Gravitation ?** — •Rudolf Germer

### Sessions

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|---|---|---|---|---|
| K 1.1–1.5 | Tue | 11:00–12:35 | REC/C213 | **Laser Applications and Laser-Beam Material Interaction** |
| K 2 | Tue | 12:35–13:00 | REC/C213 | **Members' Assembly** |
| K 3.1–3.2 | Tue | 16:45–17:45 | HSZ OG2 | **Poster** |
| K 4.1–4.4 | Wed | 11:00–12:00 | REC/C213 | **X-Ray Lasers** |

### Members' Assembly of the Short Time-scale Physics and Applied Laser Physics Division

Dienstag 12:35–13:00 Raum REC C213

- Bericht
- Verschiedenes

# K 1: Laser Applications and Laser-Beam Material Interaction

Time: Tuesday 11:00–12:35 Location: REC/C213

**Invited Talk** K 1.1 Tue 11:00 REC/C213

**Information, Abstände und Gravitation ?** — •Rudolf Germer — ITPeV und TU-Berlin, germer@physik.tu-berlin.de

Physikalische Experimente und Theorien vermitteln uns, dem Beobachter, Information und Erkenntnis. Ein Vergleich von Gravitations- und Coulombgesetz ermöglicht die Hypothese, daß die Verteilung von Massen im Universum Basis der "Gravitationskonstante" ist. Ausgang der Überlegungen ist die Frage nach kleinsten Informationseinheiten, kürzesten Zeitintervallen und Längen... Verstanden sind die Beziehungen zwischen den elektromagnetischen Quanten und zahlreichen Naturkonstanten, die sich, wie hier schon gezeigt, mit der Geometrie eines Quaders darstellen lassen. Kleinste Informationseinheiten lassen sich dann mit dem Planck'schen Wirkungsquantum h und einer beteiligten Energie E fassen. Bekannt ist die Abhängigkeit der Auflösung des Mikroskops von der Energie und Wellenlänge der Photonen. Der Zusammenhang bekannter elektromagnetischer Größen mit der Information über Abstände und Längen läßt sich am Beispiel des Wasserstoffatoms leicht demonstrieren. Viele Einzelheiten finden Sie im Wikibook "Die abzählbare Physik". Eine grobe Abschätzung läßt erwarten, daß diese Gedankenwelt auf die Gravitation übertragbar ist. Es sind dann lokal Abweichungen vom Mittelwert des Gravitationsfaktors zu erwarten.

K 1.2 Tue 11:35 REC/C213

**Validation of two-temperature hydrodynamics modeling by in-situ metrology and ex-situ analysis of the microstructure of a thin gold film** — •Markus Olbrich[1], Theo Pflug[1], Christina Wüstefeld[2], Mykhaylo Motylenko[2], Christiane Wächtler[2], David Rafaja[2], Stefan Sandfeld[3], and Alexander Horn[1] — [1]Laserinstitut Hochschule Mittweida — [2]Institute of Materials Science, TU Bergakademie Freiberg — [3]Institute for Advanced Simulation, Forschungszentrum Juelich GmbH

Irradiating a thin gold film (film thickness $d_z = 150\,\text{nm}$, 20 nm adhesion layer of chromium, fused silica substrate) with single-pulsed ultrafast laser radiation (pulse duration $\tau_H = 40\,\text{fs}$, wavelength $\lambda = 800\,\text{nm}$, peak fluence $H_0 = 1.4\,\text{J/cm}^2$) results in a flat ablation structure with a constant ablation depth, being replicable by two-temperature hydrodynamics modeling (TTM-HD). For validating the model, ultrafast imaging reflectometry is applied within a temporal range of up to 50 $\mu$s after the irradiation, resulting in a good agreement between the simulated electron temperature and the simulated dynamics of the ablated material with the measured change of reflectance. The modeling is further validated by comparing the calculated temperature and pressure distributions to the change of the microstructure and the diffusion depth of chromium into the gold film. The microstructure was investigated by electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM). Concentration profiles of chromium were determined by energy dispersive X-ray spectroscopy (EDS) performed on cross-sections in the scanning transmission electron mode (STEM).

K 1.3 Tue 11:50 REC/C213

**Laser-assisted atmospheric pressure plasma jet etching of optical glasses** — •Robert Heinke[1,2], Martin Ehrhardt[1], Pierre Lorenz[1], Thomas Arnold[1,2], and Klaus Zimmer[1] — [1]Leibniz Institute of Surface Engineering, Permoserstr. 15, Leipzig, 04318, Germany — [2]Institute of Manufacturing Science and Engineering, Technische Universitat Dresden, 01062 Dresden, Germany

The increasingly demanding requirements for high-performance optics, e.g. EUV and free-form optics, necessitate progressive improvements in manufacturing techniques. Atmospheric pressure plasma jet (APPJ) processing provides a tool for the generation and correction of highly precise optical surfaces due to its high flexibility and depth precision. During APPJ processing of optical glasses such as N-BK7 and N-SF6, a residual layer of nonvolatile compounds is formed, resulting in rough surfaces or even the abortion of the etching process. Lasers are utilized to remove the residual layer without damaging the glass underneath. Therefore, a 248 nm excimer laser was used and fluences as well as pulse numbers have been varied to determine a parameter set with optimum selectivity. The resultant surface structures were measured by WLI and SEM. The results show a strong dependence on the processed glass type and the residual layer thickness. The incorporation of laser ablation into APPJ etching provides higher etching rates and lower surface roughness.

K 1.4 Tue 12:05 REC/C213

**Laser-magnetization of $Fe_{60}Al_{40}$ investigated by pump-probe reflectometry** — •Theo Pflug[1], Javier Pablo-Navarro[2], Markus Olbrich[1], Alexander Horn[1], and Rantej Bali[3] — [1]Laserinstitut Hochschule Mittweida, Hochschule Mittweida, Germany — [2]Instituto de Nanociencia y Materiales de Aragón, Universidad de Zaragoza, Spain — [3]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany

Ultrashort pulsed laser irradiation enables the generation of ferromagnetism in initially non-ferromagnetic materials, such as B2-ordered $Fe_{60}Al_{40}$. The paramagnetic B2 phase, defined by atomic planes of pure Fe, separated by Al-rich planes is randomized due to irradiation leading to the formation of the disordered A2 $Fe_{60}Al_{40}$ being ferromagnetic. This phase transition has been reported to rely on melting and subsequent resolidification, estimated to occur within 5 ns. However, the physical dynamics during the B2-A2 transition have yet to be investigated. Here, we demonstrate the temporal evolution of the transient reflectance of $Fe_{60}Al_{40}$ during the B2-A2 transition measured by pump-probe reflectometry. The reflectance increases abruptly 5 ps after excitation with pulsed laser radiation (800 nm, 40 fs, 0.2 $\text{J/cm}^2$) which can be attributed to the disordering process. Ex situ observations (Kerr microscopy, HR-TEM, electron holography) confirm that the laser-irradiated areas possess a high magnetization and the A2 structure. Furthermore, materials whose phase transition does not necessarily rely on resolidification may lead to a further reduction in the time needed for generating ferromagnetism by laser irradiation.

K 1.5 Tue 12:20 REC/C213

**Double-pulse irradiation of a thin gold film using ultrafast laser radiation** — •Markus Olbrich, Theo Pflug, Nick Börnert, Philipp Lungwitz, Andy Engel, Peter Lickschat, Steffen Weissmantel, and Alexander Horn — Laserinstitut Hochschule Mittweida, Technikumplatz 17, 09648 Mittweida

Irradiating a thin gold film (film thickness $d_z = 150\,\text{nm}$, 20 nm adhesion layer of chromium, float glass substrate) with a double-pulse of ultrafast laser radiation (pulse duration $\tau_H = 40\,\text{fs}$, wavelength $\lambda = 800\,\text{nm}$, temporal delay $\Delta t = 400\,\text{ps}$, peak fluence per pulse $H_0 = 1.5\,H_{\text{thr}}$, $H_{\text{thr}}$ ablation threshold) results in a topology of the ablation structure deviating compared to the topology of the ablation structure induced by single-pulsed ultrafast laser radiation of the same total fluence ($H_0 = 3.0\,H_{\text{thr}}$). We demonstrate that the origin of these different topologies is revealed by two-temperature hydrodynamics modeling (TTM-HD) and is confirmed by ultrafast imaging reflectometry. Herein, the first pulse induces an ablation of liquid material by spallation, being transformed nearly completely into a liquid-vapor mixture of high temperature by absorbing the energy of the second pulse. The omnidirectionally expanding mixture pushes the liquid non-ablated material, being a residual from the first pulse interaction, out of the interaction zone. Thus, setting the optimum delay between the two pulses can drastically increase the energy deposition and with it the material processing efficiency.

# K 2: Members' Assembly

Time: Tuesday 12:35–13:00 Location: REC/C213

**All members of the Short Time-scale Physics and Applied Laser Physics Division are invited to participate.**

# K 3: Poster

Time: Tuesday 16:45–17:45 Location: HSZ OG2

K 3.1 Tue 16:45 HSZ OG2

**Organic distributed feedback lasers based on laser-inscribed periodic surface structures** — •Tiange Dong, Tobias Antrack, Jakob Lindenthal, Markas Sudzius, Johannes Benduhn, and Karl Leo — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute of Applied Physics, Technische Universität Dresden, 01062, Dresden, Germany

Laser ablation, as one of the well-approved alternative methods of photo-lithography in microfabrication, is limited in structuring resolution by the diffraction limit. However, it was observed that a laser-induced periodic surface structure (LIPSS) can be formed under ultrafast laser irradiation, and the periodicity resolution is significantly smaller than the wavelength of the incident laser ($\lambda/2$-$\lambda/10$). In this work, the periodic structure generated by LIPSS was utilized to build a distributed feedback (DFB) laser based on organic materials. The femtosecond laser ($\lambda = 515$ nm) was used to structure the SiO2 substrate, forming a surface grating with a periodicity of about 200 nm. Afterwards, an organic blend (Alq3:DCM, 450 nm thick) was evaporated on the top of the grating as an optically active waveguide. Photo-induced laser emission of the devices was measured under femtosecond optical pumping at 404 nm. We observed a narrow single peak laser emission at 620nm wavelength, which demonstrates optical feedback from the underlying 1st-order DFB structure. Our results show the potential of a laser-induced periodic surface structure to organic photonic devices and microlasers based on the artificially produced photonic structures on a subwavelength scale using laser micromachining techniques.

K 3.2 Tue 16:45 HSZ OG2

**Spectroscopic Pump-Probe-Reflectometry of NIR Excited Silicon** — •Philipp Lungwitz, Nick Börnert, Theo Pflug, and Alexander Horn — Laserinstitut Hochschule Mittweida, Technikumplatz 17, 09648 Mittweida

Ultrashort pulsed laser radiation with photon energies below the indirect bandgap of silicon enables the in-volume structuring of wafers due to multiphoton processes. Therefore, laser sources with wavelength in near infrared (NIR) spectral range are increasingly common for processing semiconductors. During laser mater interaction of ultrashort pulsed laser radiation ($\lambda_{\mathrm{pump}} = 1950\,\mathrm{nm}$, $\tau_{\mathrm{H}} < 50\,\mathrm{fs}$) with silicon, the resulting nonlinear excitation of electrons by NIR radiation also affects to the optical properties in the visual spectral range. Imaging pump-probe reflectometry enables the measurement of the transient reflectivity for different probe wavelengths ($420\,\mathrm{nm} \leq \lambda_{\mathrm{probe}} \leq 1000\,\mathrm{nm}$, $\tau_{\mathrm{H}} \approx 40\,\mathrm{fs}$) and time delays up to $\Delta t = 500\,\mathrm{ps}$ after irradiation. Assigning the spatial coordinates to local fluences allows a fluence dependent interpretation as well. Below the fluence for material modification $H_{\mathrm{th}}$, a reduction of reflectivity was detected which become more and more significant with an increasing probe wavelength. For fluences above $H_{\mathrm{th}}$, the reflectivity increases rapidly after irradiation and features a local minimum between $\Delta t = 2\,\mathrm{ps}$ and $\Delta t = 50\,\mathrm{ps}$ for all probe wavelengths.

# K 4: X-Ray Lasers

Time: Wednesday 11:00–12:00 Location: REC/C213

K 4.1 Wed 11:00 REC/C213

**Electron Optical Systems for High-Resolution Electron Time-of-Flight Spectrometer** — •Niclas Wieland[1], Sara Savio[1], Lars Funke[1], Lasse Wülfing[1], Arne Held[1], Markus Ilchen[2], and Wolfram Helml[1] — [1]Fakultät Physik, Technische Universität Dortmund, Maria-Göppert-Mayer-Straße 2, 44227 Dortmund, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

*Angular streaking* allows resolving the sub-femtosecond temporal structure of SASE free-electron laser pulses. A circularly polarized infrared laser imprints a phase-dependent momentum shift onto the photoelectron spectra of a gas target. Time-of-flight spectrometers can be used to resolve these. The latter devices consist of electron optics, a drift section and a detector with good time resolution. Parameters such as energy resolution and energy-dependent transmission for the whole system can be determined by simulation. In this talk, we present the finalized simulation-motivated spectrometer design used inside our new chamber for the SpeAR_XFEL project. Furthermore, we will introduce the possibility of adaptive electron optics in our spectrometer to further increase the resolution and transmission by applying specific voltage sets to our optics.

Gaining insight into electron motion using precise simulations appears to be an efficient way to improve the overall performance of such experiments. We would like to present our progress in terms of electrode design and applied voltages for a 0-4 keV electron energy spectrum, to further develop spectrometer research in this field.

K 4.2 Wed 11:15 REC/C213

**Angular streaking TOF spectrometer for ultrafast FEL pulse characterization** — •Sara Savio[1], Niclas Wieland[1], Lars Funke[1], Lasse Wülfing[1], Arne Held[1], Markus Ilchen[2], and Wolfram Helml[1] — [1]Fakultät Physik, Technische Universität Dortmund, Maria-Göppert-Mayer-Straße 2, 44227 Dortmund, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

Angular Streaking is a very successful and currently the only non-invasive tool used to measure the time-energy structure of X-ray pulses with sub-femtosecond resolution. A complete reconstruction of the ultrashort FEL pulses can be realized from the angle-resolved photoelectron momentum distribution due to the energy modulation by a circularly polarized optical laser. This work mainly evaluates the performance parameter like solid angle acceptance of the electron Time-of-Flight (eTOF) spectrometer with the help of SIMION software. A systematic investigation of the overall transmission and energy resolution while considering the pointing (displacement) of the beam in the interaction region is carried out using the charged particle optical simulation. Angle resolving photoelectron spectrometer is a potential candidate for polarization and short pulse measurements. The scope of the envisioned electron spectroscopy experiments is not only limited to pulse characterization but also includes measurements of ultrafast electron dynamics in gas-phase atoms, like the Auger-Meitner decay, and following electronic pathways in more complex molecules for ultrafast movies of photochemical reactions.

K 4.3 Wed 11:30 REC/C213

**Mechanical design and implementation of high-resolution electron time-of-flight spectrometers for angular atreaking** — •Lasse Wülfing[1], Sara Savio[1], Niclas Wieland[1], Lars Funke[1], Arne Held[1], Markus Ilchen[2], and Wolfram Helml[1] — [1]Fakultät Physik, Technische Universität Dortmund, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

In order to reconstruct the stochastic temporal shapes of SASE FEL pulses in a non-destructive manner, a specialized *angular streaking* chamber is built at DESY and XFEL. Angular streaking superimposes the ultrashort X-ray beams with a circularly polarized infrared laser and correlates relative phases in the laser to the momenta of photoelectrons in a plane perpendicular to the beam. The energies of these photoelectrons can be obtained by Time-of-Flight spectrometers (eTOF).

In the SpeAR_XFEL project (Spectroscopy with Angular Resolution for ultrafast experiments at X-ray FELs) we develop a novel detector aimed at angular streaking. It consists of a specialized vacuum chamber, designed along with a new kind of eTOF, suitable to be implemented in the magnetic shield of the chamber. Special care has to be taken in order to create a robust and precise design compatible with the material stress resulting from the high temperature baking process of UHV components.

We present the newly developed concept for a UHV compatible installation of a Time-of-Flight spectrometer array inside a magnetically highly sensitive area.

K 4.4 Wed 11:45 REC/C213

**Characterization of SASE FEL pulses with angular streaking**

— •Lars Funke[1], Kristina Dingel[2], Arne Held[1], Sara Savio[1], Lasse Wülfing[1], Niclas Wieland[1], Markus Ilchen[3], and Wolfram Helml[1] — [1]Fakultät Physik, Technische Universität Dortmund, Germany — [2]Intelligent Embedded Systems, Universität Kassel, Germany — [3]Deutsches Elektronensynchrotron DESY, Hamburg, Germany

SASE free-electron-laser pulses pose a challenge in terms of temporal diagnostics, due to their intrinsic stochastic structure. Few methods allow directly resolving the full spectro-temporal information. In *angular streaking*, photoelectron momenta are linked to their birth phase by superimposing a circularly polarized infrared laser pulse. This principle allows reconstructing a pulse spectrogram shot-by-shot, enabling "stochastic experiments" by evaluating measurements as a function of derived quantities such as pulse duration or delay in a (stochastic) double pulse.

The analysis of angular streaking data involves disentangling the spectral and temporal contributions to the measurement for a single shot. In this talk, we present a current adaptation of the iterative *Pacman* algorithm and further, advanced reconstruction methods.

Furthermore, we show the application of these methods to data measured using angular streaking at the SQS instrument of European XFEL in June 2022. Statistical analysis of the reconstructed spectrograms allows providing diagnostic feedback with regard to different short-pulse FEL modes.