K 1: Laser Systems and their Applications I

Time: Monday 11:30–13:15 Location: HS 20

Invited Talk K 1.1 Mon 11:30 HS 20

Explaining changes in the crystallinity of a thin gold film upon irradiation with ultrafast laser radiation by ultrafast metrology and ex situ analysis — Markus Olbrich[1,2], Petr Cejpek[3,4], Hariprasath Ganesan[5], Theo Pflug[1,6], Andy Engel[1], David Rafaja[3], Stefan Sandfeld[5,7], Andrés Fabián Lasagni[2,8], and •Alexander Horn[1] for the DFG Microstructure-Collaboration — [1]Hochschule Mittweida — [2]Technische Universität Dresden — [3]TU Bergakademie Freiberg — [4]Institute of Physics FZU Prague — [5]Forschungszentrum Jülich — [6]Carl Zeiss SMT GmbH — [7]RWTH Aachen — [8]Fraunhofer-Institut IWS Dresden

Complementary investigations combining ultrafast interferometry and reflectometry with ex-situ SEM, EBSD, TEM, and EELS analysis of the microstructure, as well as two-temperature modeling in combination with hydrodynamics (TTM-HD) and molecular dynamics (TTM-MD), are performed to study irreversible changes in the material's microstructure upon irradiation with ultrafast laser radiation. The approach is exemplified by irradiating a 150 nm-thick gold layer, including a 20 nm-thick chromium adhesion layer on a glass substrate with ultrafast laser radiation (800 nm, 40 fs). The results of ultrafast metrology are correlated with the final size and orientation of the metallic grains, with the interdiffusion of chromium and gold, and complemented by the TTM-HD and TTM-MD simulations. Thereby, the generation of nanovoids in the ps-range and the delamination of the films in the μs-range are the dominant effects, inducing changes in the size and orientation of the metallic grains.

K 1.2 Mon 12:00 HS 20

Single-shot time resolved diffractive imaging of ultrafast plasma-dynamics in gold foils — •Tom Böttcher, Maura Münier, Stefan Lochbrunner, Christian Peltz, Thomas Fennel, and Franziska Fennel — University of Rostock, Germany

Resolving the excitation and relaxation dynamics of laser-induced solid-state plasmas is essential for understanding how condensed matter targets respond to intense laser radiation. Knowledge about the influence of laser parameters, such as spatial, temporal, and spectral pulse structure on the plasma dynamics is crucial for tailored laser machining applications.

Here, we present an experimental method to observe plasma dynamics in laser-excited, thin, semi-transparent targets using single-shot pump-probe coherent diffractive imaging. Our targets are 30 nm thin, free-standing gold foils which are excited by a focused femtosecond 800 nm pump pulse. To capture the resulting dynamics, a low-intensity femtosecond 400 nm probe pulse images the excited target, and the resulting diffraction image is captured using a CMOS camera.

Using a phase retrieval algorithm [1], we reconstruct the 2D spatially resolved complex transmission from the diffraction patterns for different time delays of up to 2 ns. This allows us to probe ultrafast excitation processes in the femtosecond-to-picosecond regime, as well as melting and ablation dynamics in the picosecond-to-nanosecond regime.

[1] R. Altenkirch et al, *New J. Phys.* 26 (2024), 113010

K 1.3 Mon 12:15 HS 20

Coherent control in V-type system: Simulation insights using intense two-dimensional coherent spectroscopy — •Rishabh Tripathi, Krishna Maurya, and Rohan Singh — Indian Institute of Science Education and Research (IISER) Bhopal, Bhopal, India

Our study investigates coherent control in V-type three-level systems using high-intensity, ultrafast laser pulses, explored through two-dimensional coherent spectroscopy (2DCS). Employing numerical solutions of the optical Bloch equations, we analyze the response of a V-type system to Gaussian pulses of 10 fs and 120 fs. The research reveals that shorter pulses induce uniform Rabi oscillations, whereas longer pulses result in complex quantum interference and state-specific population dynamics. This distinction underscores the pivotal role of pulse duration and spectral properties in modulating quantum interactions. Our 2DCS simulations, utilizing phase-cycling methods, provide insight into the system's spectral response in both perturbative and non-perturbative regimes. These simulations reveal the manipulation of spectral peak amplitudes and phases by adjusting the pulse areas, demonstrating control over the system.

This work contributes to the understanding of light-matter interactions in quantum systems and highlights the potential of tailored laser pulses for advanced coherent control, with implications for atomic vapors, semiconductor nanostructures, and photonics research.

K 1.4 Mon 12:30 HS 20

Laser-induced processes during and after the laser-matter interaction of single-crystalline silicon irradiated with ultrashort pulsed laser radiation — •Andy Engel, Markus Olbrich, Theo Pflug, and Alexander Horn — Laserinstitut Hochschule Mittweida, Technikumplatz 17, 09648 Mittweida, Germany

The irradiation of single-crystalline silicon with ultrashort pulsed laser radiation leads to irreversible material changes when a material-dependent threshold is exceeded, starting with changes in crystallinity and extending to ablation. This work examines these material transformations for the irradiation of single-crystalline, <111>-oriented silicon as a function of both the fluence of the applied ultrashort pulsed laser radiation (40 fs, 800 nm) and the number of individual pulses delivered to each processing spot. The irreversible changes arising from the interaction between laser radiation and matter were identified by measuring the spatially and spectrally resolved refractive index using ex-situ ellipsometry and SEM analyses. Comparative investigations of the surface topography of the irradiated regions were conducted via confocal laser scanning microscopy and atomic force microscopy. Additional insights into the depth of thermally induced material alterations were obtained through subsequent wet chemical etching. When combined with ultrafast metrology, pump-probe imaging reflectometry, and interferometry, these methods enable a more comprehensive and precise characterization of the physical processes triggered by ultrashort pulsed laser irradiation.

K 1.5 Mon 12:45 HS 20

Utilizing Transient Effects for Ablating Glass Using Combined Picosecond and Nanosecond Laser Pulses — •Lasse Bienkowski[1,2], Liseth Y. Martinez Aponte[1], Andreas A. Brand[1], and Jan Nekarda[1] — [1]Fraunhofer Institute for Solar Energy Systems, Freiburg, Germany — [2]Institut für Ionenphysik und Angewandte Physik Universität Innsbruck, Innsbruck, Austria

Ultrashort pulsed lasers are essential for various glass processing applications. Nanosecond (ns) laser pulses typically offer higher ablation rates, while picosecond (ps) pulses generally improve process quality. We explore a hybrid approach utilizing a double-pulse laser system capable of generating near-infrared pulse pairs with durations of 1 ps and 10 ns with a tunable delay. Our goal is to enhance ablation efficiency by using a leading ps-pulse to induce transient effects, enabling the absorption of subsequent ns-pulses.

We investigate the interaction by focusing the beam on fused silica and soda-lime glass and measuring the transmitted ns-pulse intensity. For leading ps-pulses, the transmission of the ns-pulses is reduced by up to 40 %. For leading ns-pulses, no reduction is observed, suggesting the presence of a transient effect triggered by the ps-pulse glass interaction.

In a single-shot ablation experiment, pulse pairs are focused on the glass samples. The resulting craters show an enhancement in ablation depth for leading ps-pulses, surpassing the single-pulse ablation depth. The effect persists for delays of $>$ 200 ns, depending on the material and envelope energy. This approach provides a promising route to faster laser-glass machining processes.

K 1.6 Mon 13:00 HS 20

High resolution materials processing with temporally shaped femtosecond pulses — Cristian Sarpe[1], Florian Fiedler[1,2], Omar Elsheikh[1,2], Bastian Zielinski[1,2], and •Camilo Florian[1,2] — [1]University of Kassel, Institute of Physics and CINSaT, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]University of Kassel, Institute of Materials Engineering, Moenchebergstr. 7, 34125 Kassel,University of Kassel, Institute of Materials Engineering, Moenchebergstr. 7, 34125 Kassel, Germany

Femtosecond laser systems are becoming the mainstream processing tool for high lateral resolution materials processing. Traditional direct write laser systems employ nominal bandwidth limited pulses that typically display Gaussian temporal profiles, which most of the time produce crater shaped modifications at the surface level in dielectric, semiconductor, and metallic materials. Advancements in temporal pulse shaping techniques have demonstrated significant improvements in the final size and depth, increasing the overall ablation efficiency and the final lateral resolution. In this work, we present a survey that includes the formation of micro and nanometric size modifications induced by temporally shaped femtosecond laser pulses generated by an amplified Ti:Sa femtosecond laser system operating at 1 kHz, 790 nm nominal wavelength, and a pulse duration of 30 fs. Five types of femtosecond pulses were implemented. The results highlight the critical role of temporal pulse shaping in controlling laser material interactions and open new pathways for high precision material processing across many disciplines and fields of application.