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

Andreas Görtler
A.B. von Stettensches Institut Gymnasium
Am Katzenstadel 18A
86152 Augsburg
E-Mail agoertler@gmx.de

Overview of Invited Talks and Sessions

(Lecture halls K-H4; Poster P)

Invited Talks

K 3.1	Wed	14:00–14:30	K-H4	**Leistungsimpulstechnik: Im Rückblick und mit Blick auf aktuelle und künftige Anwendungen** — •Klaus Frank
K 3.2	Wed	14:30–15:00	K-H4	**Technischer Stand der Pulsed Power in medizinischen Excimer Lasern** — •Claus Strowitzki
K 5.1	Wed	16:30–17:15	K-H4	**Physikalische Information und Naturkonstanten** — •Rudolf Germer
K 6.1	Thu	10:30–11:00	K-H4	**Front and rear surface ablation within gold films with variable film thickness induced by ultrafast laser radiation** — •Markus Olbrich, Theo Pflug, Alexander Horn

Invited talks of the joint PhD symposium Solid-state Quantum Emitters Coupled to Optical Microcavities (SYPD)

See SYPD for the full program of the symposium.

SYPD 1.1	Mon	16:30–17:00	AKjDPG-H17	**Fiber-based microcavities for efficient spin-photon interfaces** — •David Hunger
SYPD 1.2	Mon	17:00–17:30	AKjDPG-H17	**A fast and bright source of coherent single-photons using a quantum dot in an open microcavity** — •Richard J. Warburton
SYPD 1.3	Mon	17:30–18:00	AKjDPG-H17	**New host materials for individually addressed rare-earth ions** — •Sebastian Horvath, Salim Ourari, Lukasz Dusanowski, Christopher Phenicie, Isaiah Gray, Paul Stevenson, Nathalie de Leon, Jeff Thompson
SYPD 1.4	Mon	18:00–18:30	AKjDPG-H17	**A multi-node quantum network of remote solid-state qubits** — •Ronald Hanson

Invited talks of the joint symposium SAMOP Dissertation Prize 2022 (SYAD)

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	14:00–14:30	Audimax	**New insights into the Fermi-Hubbard model in and out-of equilibrium** — •Annabelle Bohrdt
SYAD 1.2	Tue	14:30–15:00	Audimax	**Searches for New Physics with Yb$^+$ Optical Clocks** — •Richard Lange
SYAD 1.3	Tue	15:00–15:30	Audimax	**Machine Learning Methodologies for Quantum Information** — •Hendrik Poulsen Nautrup
SYAD 1.4	Tue	15:30–16:00	Audimax	**Precision Mass Measurement of the Deuteron's Atomic Mass** — •Sascha Rau

Sessions

K 1.1–1.6	Tue	10:30–12:00	K-H4	**Laser Systems**
K 2.1–2.17	Tue	16:30–18:30	P	**Poster**
K 3.1–3.4	Wed	14:00–15:30	K-H4	**Pulsed Power - XUV and EUV Sources and their Applications**
K 4	Wed	15:30–16:00	K-MV	**Annual General Meeting**
K 5.1–5.3	Wed	16:30–17:45	K-H4	**New Methods and Laser Diagnostics**
K 6.1–6.6	Thu	10:30–12:15	K-H4	**Laser-Beam Matter Interaction - Laser Applications I**
K 7.1–7.7	Thu	14:00–15:45	K-H4	**Laser-Beam Matter Interaction - Laser Applications II**

Annual General Meeting of the Short Time-scale Physics and Applied Laser Physics Division

Wednesday 15:30–16:00 K-MV

- Report
- Future Spring meetings

K 1: Laser Systems

Time: Tuesday 10:30–12:00 Location: K-H4

K 1.1 Tue 10:30 K-H4

High-power, ultra-broadband, femtosecond non-collinear optical parametric oscillator in the visible spectral range (VIS-NOPO) — •Robin Mevert[1,2], Yuliya Binhammer[1,2], Christian M. Dietrich[1,2], Luise Beichert[1,2], José R. Cardoso de Andrade[3], Thomas Binhammer[4], Jintao Fan[1,2], and Uwe Morgner[1,2] — [1]Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, D-30167 Hannover, Germany — [2]Cluster of Excellence PhoenixD, Welfengarten 1, D-30167 Hannover, Germany — [3]Max-Born-Institute, Max-Born-Straße 2A, D-12489 Berlin — [4]neoLASE GmbH, Hollerithallee 17, D-30419 Hannover, Germany

Ultrafast visible radiation is of great importance for many applications ranging from spectroscopy to metrology. Unfortunately, most of the visible range is not covered by laser gain media, hence optical parametric oscillators offer a solution. Besides a high-power broadband laser source, the rapid frequency tunability of pulses with high-power spectral densities is a clear advantage for experiments such as multicolor spectroscopy or imaging. Here, we demonstrate a high-power, ultra-broadband, rapidly tunable femtosecond non-collinear optical parametric oscillator with a signal tuning range of 440-720 nm. The VIS-NOPO is pumped by the third harmonic of an Yb-fiber laser at 345 nm. Moreover, the signal wavelength is tuned by changing the cavity length only. Output powers up to 452 mW and pulse duration down to 268 fs with a repetition rate of 50.2 MHz are achieved. To the best of our knowledge, this is the first demonstration of a quickly tunable femtosecond NOPO that covers nearly the entire visible spectral range.

K 1.2 Tue 10:45 K-H4

1 MHz - CEP stable, few-cycle OPCPA with dual channel output at 800nm and 2μm wavelength — Thomas Braatz, Ekaterina Zapolnova, Sebastian Starosielec, Torsten Golz, •Kolja Kolata, Mark Prandolini, Jan Heye Buss, Michael Schulz, and Robert Riedel — Class 5 Photonics GmbH, Research Campus Hamburg Bahrenfeld, Luruper Hauptstrasse 1, 22547 Hamburg, Germany

Active carrier envelope phase (CEP) stabilization in the few-cycle regime is essential for most attosecond experiments, e.g. studying the coherent evolution of electronic structure and dynamics in solids or complex many body phenomena crystals, require active carrier envelope phase stabilization in the few-cycle regime. We present an optical parametric chirped-pulse amplifier (OPCPA) design providing CEP stable, sub 9 fs pulses with a dual channel output around 800 nm center wavelength and 2 *m as a high-harmonic driver for attosecond experiments. Two CEP stable OPCPA designs (a) high repetition rate and (b) a high pulse-energy system will be demonstrated.

K 1.3 Tue 11:00 K-H4

a stabilized doubly resonant optical parametric oscillator for strong-field applications — •han rao[1,2], christian markus dietrich[1,2], josé ricardo cardoso de andrade[3], ayhan Demircan[1,2], ihar babushkin[1,2,3], and uwe morgner[1,2] — [1]Leibniz University Hannover, Institute of Quantum Optics, Hannover, Germany — [2]Cluster of Excellence PhoenixD, Hannover, Germany — [3]Max Born Institute, Berlin, Germany

Strong tailored two-and three-color optical waveshapes can be especially useful for effective generation of light at very high (XUV) and very low (THz) frequencies via the photoionization dynamics. In particular, for generation of THz radiation, strong and stable asymmetric time-waveshapes are needed. Phase locked doubly resonant optical parametric oscillators (DROPO) can provide, via strong intracavity enhancement, high enough intensities needed for this goal. DROPO can work in a self-locking regime, where the relative phases between the signal, idler and pump waves are locked. The region of cavity lengths (detuning) where DROPO is locked, is however typically small, and even if self-locking is achieved, the dynamics is destabilized on the long run. In this work, we stabilize our degenerate DROPO by using a locking scheme which utilizes monitoring of a "parasitic" sum-frequency generation (SFG) of the signal and pump-a method proposed very recently.

K 1.4 Tue 11:15 K-H4

InP-based Semiconductor Saturable Absorber Mirror (SESAM) for ultrashort laser pulse generation at 1560 nm — •Alexander Dohms[1], Steffen Breuer[1], Christoph Skrobol[2], Robert B. Kohlhaas[1], Lars Liebermeister[1], Martin Schell[1,3], and Björn Globisch[1,3] — [1]Fraunhofer HHI, Einsteinufer 37, 10587 Berlin, Germany — [2]TOPTICA Photonics AG, Lochhamer Schlag 19, 82166 Gräfelfing, Germany — [3]TU Berlin, Festkörperphysik, Hardenbergstraße 36, 10623 Berlin, Germany

Semiconductor Saturable Absorber Mirrors (SESAMs) are key to ultrafast lasers, as they allow for simple and self-starting passive mode-locking and pulse stabilization. However, SESAMs based on the standard AlAs/GaAs material system require highly strained InGaAs absorber layers, which may reduce the device efficiency and operational lifetime. Here, we report on an entirely strain-free SESAM based on InP/InGaAlAs, designed for 1560 nm operation with an Erbium-doped fiber laser. The SESAM is composed of a highly reflective InGaAlAs/InAlAs Bragg mirror and an InGaAs absorber, which provides ultrafast SESAM response ($\tau < 1$ ps), low non-saturable losses and high modulation depth (ΔR = 8 %) at the same time. The near anti-resonant SESAM design results in very high saturation fluence (25 μJ/cm2) and roll-over fluence (33 mJ/cm2), and is demonstrated to enable successful laser self-start and stable modelocking of 330 fs pulses at 80 MHz repetition rate and 17.5 mW average power. This illustrates the excellent optical performance of InP-based SESAMs, which will enable more reliable and efficient ultrafast laser systems.

K 1.5 Tue 11:30 K-H4

Compact Few-Cycle Source in the Mid-Infrared by Adiabatic Difference Frequency Generation — •Engjell Bebeti[1], Felix Ritzkowsky[1,2], Giulio M. Rossi[1,2], Nicholas H. Matlis[1,2], Haim Suchowski[3], Huseyin Cankaya[1,2], and Franz X. Kärtner[1,2] — [1]Center for Free-Electron Laser Science CFEL, Deutsches Elektronen-Synchrotron DESY, Germany — [2]Department of Physics and The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Germany — [3]Department of Condensed Matter Physics, Tel-Aviv University, Israel

Ultrafast electron emission in nano plasmonic structures is driven by the electric field of few-cycle infrared pulses. Shaping of the optical pulse waveform allows for controlling of the emitted electrons. We present a compact few-cycle source in the mid-infrared with a controllable center wavelength in the range of 2 and 3.5 microns, generating pulses with 60 nJ of energy at a repetition rate of 50 kHz, serving as an ideal driver for such experiments. Our setup is driven by a commercial regenerative Yb:KYW amplifier delivering 420 fs pulses at a wavelength of 1.03 microns. The nonlinear conversion scheme consists of an adiabatic difference frequency generation (ADFG) crystal subsequent to an optical parametric amplifier stage. The ADFG allows for a broadband and linear one-to-one conversion in spectral amplitude and phase of the incident pulse producing octave-spanning mid-infrared pulses with a pulse duration down to 13 fs. The tunability of the center wavelength will enable tailoring of the few-cycle waveform to tightly control ultrafast electron emission.

K 1.6 Tue 11:45 K-H4

Laser frequency stabilization using quasi-monolithic unequal-arm interferometers — •Miguel Dovale Alvarez, Victor Huarcaya, Juan Jose Esteban Delgado, and Gerhard Heinzel — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Callinstrasse 38, 30167 Hannover, Germany

Lasers with high and ultra-high frequency stability are a key resource in many areas of science and technology, such as high-precision time and frequency metrology, inertial sensing, and the search for gravitational waves. Typically the required stability is achieved by locking the laser to the narrow resonance of a structurally stable optical cavity, or to the narrow absolute reference frequency provided by atomic or molecular transitions. These frequency stabilization schemes usually involve many optical components, modulators, and complex electronics. Here we describe the advances in laser frequency stabilization via quasi-monolithic unequal-arm interferometers with DC balanced readout. In this scheme the setup consists of only a handful of optical components, as well as an analog circuit to perform the balanced readout and the feedback to the laser. The structural stability of the interferometer is transferred to the frequency stability of the laser, and hence a big effort is directed towards isolating the interferometer from external perturbations. Preliminary measurements show a stability of $100\,\mathrm{Hz}/\sqrt{\mathrm{Hz}}$ at $1\,\mathrm{Hz}$, worsening with $1/f$ at lower frequencies. In the next iteration of this experiment, we aim to reduce the noise floor at low frequency by enhancing several aspects of the setup. $\pm 1^{\circ}$

K 2: Poster

Time: Tuesday 16:30–18:30 Location: P

K 2.1 Tue 16:30 P

Extreme self-regulation in high-harmonic generation — •Evaldas Svirplys[1], Katalin Kovács[2], Muhammad Anus[1], Omair Ghafur[1], Katalin Varjú[3,4], Marc J. J. Vrakking[1], Valer Tosa[2], Balázs Major[3,4], and Bernd Schütte[1] — [1]Max-Born-Institut, Berlin, Germany — [2]National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca, Romania — [3]ELI-ALPS, Szeged, Hungary — [4]Department of Optics and Quantum Electronics, University of Szeged, Szeged, Hungary

We present a novel High-harmonic generation (HHG) scheme that shows extreme self-regulation of the driving laser intensity. Near-infrared (NIR) laser pulses are focused into a high-pressure atomic jet, leading to intensities of about 10^{16} W/cm^2, which is much higher than the optimal intensity for HHG. Substantial Spectral reshaping of the NIR 50-fs laser pulse was observed in each atomic species investigated (Xe, Kr, Ar, Ne, He), resulting in the observation of a ten-fold increase of the initial NIR bandwidth. Our experimental and numerical study shows that ionization-induced self-phase modulation is responsible for the spectral broadening, while plasma-induced defocusing results in a substantial decrease and self-regulation of the NIR intensity. This allows for the build-up of phase-matched HHG and results in the generation of continuous spectra ranging from 18-140 eV albeit using long driving laser pulses. This flexible and compact HHG scheme is ideally suited for absorption spectroscopy, allowing to access different spectral ranges without the need for tedious optimization procedures.

K 2.2 Tue 16:30 P

Attosecond streaking of an infrared parametric waveform synthesizer — •Fabian Scheiba[1,2,3], Giulio Maria Rossi[1], Roland E. Mainz[1], Miguel A. Silva-Toledo[1,3], Yudong Yang[1], Phillip D. Keathley[4], Giovanni Cirmi[1,2], and Franz X. Kärtner[1,2,3] — [1]Center for Free-Electron Laser Science CFEL and Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Universität Hamburg, Fachbereich Physik, Jungiusstraße 9, 20355 Hamburg — [4]Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Attosecond streaking measurements provide the temporal information of both, the ionizing XUV pulse and the infrared streak field. The method is utilized to characterize >1.5 octave spanning infrared (IR) waveforms as generated by our parametric waveform synthesizer and at the same time to characterize the isolated attosecond pulse (IAP) continua as generated via high harmonic generation (HHG) in gases. Here, a near-IR ((0.65-0.95) μm) and IR ((1.2-2.2) μm) spectral channel with a relative phase stability of 70 mrad are synthesized, resulting in a sub-cycle pulse of 1.4 μm central wavelength. Attosecond streaking measurements prove the excellent long-term pulse-to-pulse stability as well as versatility in shaping the synthesized waveforms to non-sinusoidal fields in the sub-cycle limit that in return allows for controlling the IAP in bandwidth and central energy in a single focussing geometry.

K 2.3 Tue 16:30 P

Generation of VUV radiation from two-color laser setup for nuclear spectroscopic measurements on thorium — •Kuldeep Singh Karda, Philip Mosel, Pranitha Sankar, Elisa Appi, Uwe Morgner, and Milutin Kovacev — Institut für Quantenoptik, Cluster of Excellence PhoenixD and QuantumFrontiers, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

The Thorium-229 nucleus is known to possess an isomeric state at an energy of about 8 eV above the ground state, several orders of magnitude lower than typical nuclear excitation energies [1]. Owing to the lower energy the 229Th isomer is accessible to resonant laser excitation. A main experimental challenge is to drive this nuclear excitation resonantly with a narrow-band laser [1]. However, exact knowledge of this energy level is crucial for laser spectroscopy and for the development of optical nuclear clocks. This problem could be overcome by using a tunable laser system in the vacuum ultraviolet (VUV) spectral range. In the presented work, VUV radiation between 140 and 160 nm is efficiently generated by using two-color frequency mixing of different laser modes inside gas-filled capillary. This technique allows to enhance the conversion efficiency of a tunable Ti:Sapphire laser system in the VUV. The presented setup can fulfill the requirements of a narrow-band light source for direct laser excitation laser applying schemes like internal conversion electron-Mössbauer spectroscopy (CEMS) in thin layer of neutral 229Th atoms[2].

[1] K.Beeks et al., Nature. Rev. Phys. 3, 238-248 (2021).
[2] L. von der Wense et al., Phys. Rev. Lett. 119, 132503 (2017).

K 2.4 Tue 16:30 P

Radiation from Electron - Laser Pulse Collisions — •Michael Quin, Antonino Di Piazza, Christoph H. Keitel, and Matteo Tamburini — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

The collision of relativistic electrons with a laser pulse can potentially generate short pulses of X-rays, capable of tracking molecular, atomic and sub-atomic dynamics. We consider how the spectrum and angular distribution of radiation emitted varies with the initial position and momentum of electrons colliding with a plane wave pulse, in the domain of Classical Electrodynamics. This informs how we can customise the radiation spectrum, which can be verified with simulations involving a focused laser pulse and realistic electron distribution.

K 2.5 Tue 16:30 P

A 100-kHz, high-brightness ultrafast electron diffraction set-up for sub-100-fs structural dynamics — •Fernando Rodriguez Diaz, Mark Meroe, Marc Vrakking, and Kasra Amini — Max Born Institute, Berlin, Germany

Photo-induced chemical reactions and phase transitions in gas-phase molecules and solid-state structures play an important role in biological processes and photoelectronics, such as photo-isomerization and photovoltaics. Such photo-induced processes occur on the few hundreds-to-thousands of femtoseconds timescale, with changes in the position of atoms in the molecular or lattice structure occurring on the sub-Angstrom spatial scale. So far, ultrafast electron diffraction (UED) has been utilized to visualize and track in real-time the structural dynamics of photo-induced reactions with sub-Å and sub-300-fs resolution. However, the temporal resolution of state-of-the-art UED set-ups, which operate at less than 5-kHz, is not sufficient to time-resolve some rapidly evolving photo-induced processes (e.g. <500-fs timescale of photo-isomerization). Here, we present a 100-kHz, 100-kV UED set-up recently built and commissioned at the Max-Born Institute, Berlin. Our set-up will be capable of operating in high-bunch charge single-shot mode (i.e. up to 1E6 electrons/pulse) or low-bunch charge high temporal resolution mode (i.e. less than 1E3 electrons/pulse) at 100-kHz. Using our set-up, we anticipate time-resolved measurements of photo-induced structural dynamics in solid-state and gas-phase systems with sub-Å spatial and sub-100-fs temporal resolution, which will go beyond the current state-of-the-art in UED.

K 2.6 Tue 16:30 P

Quantum coherent control of free electron wavefunction using ponderomotive potencial of optical travelling waves — •Kamila Moriová and Martin Kozák — Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Inelastic interactions between free electrons and photons have been studied extensively during the last few years. In this contribution, we describe theoretically the interaction of electrons with ponderomotive potential of optical travelling waves formed by two light waves at different frequencies in vacuum. Our current effort follows up previous experiments performed in the classical regime of the interaction, which showed the electron spectrum broadening and attosecond electron pulses generation as a result of the interaction [1], [2]. We describe how these experiments can be modified to allow quantum coherent optical modulation of the phase of electron wavefunction. [1] Kozák, M. et al. Nat. Phys. 14, 121-125 (2018), [2] Kozák, M. et al. Phys. Rev. Lett. 120, 103203 (2018)

K 2.7 Tue 16:30 P

Single-shot multi-frame shadowgraphy in laser-plasma interactions via sequentially timed all-optical mapping photography (STAMP) — •Yu Zhao, Daniel Ullmann, and Alexander Sävert — Helmholtz Institute Jena, Germany

Ultrafast shadowgraphy with transverse few-cycle transverse probe pulses enabled direct observation of laser-plasma interactions, which has been achieved femtosecond temporal and micrometer spatial resolution. However, in previous studies, only one shadowgram was captured from each of the laser-plasma interaction processes. Nevertheless, the shot-to-shot fluctuation of a high-power laser system is not negligible. This limits our understanding of laser-plasma interaction processes. In this study, we introduce a single-shot multi-frame shadowgraphy technique based on sequentially timed all-optical mapping photography (STAMP). The probe is seeded by a fraction of pump laser energy and coupled into a rare gas-filled hollow-core fiber to be spectrally broadened by self-phase modulation. Then the probe is temporally compressed to reach its Fourier limit pulse duration (few-fs) via chirped mirrors and glass wedges. Next, the few-femtosecond probe is linearly frequency-chirped via a glass rode, temporally stretched up to $\sim$100 fs. After the probe propagates through the interaction area, it is imaged by a microscopic imaging system, then separated into five replicas via a diffractive beam splitter. Five different narrow bandpass filters (10 nm, FWHM) are placed in front of the CCD camera to capture five frames that correspond to different time delays from a laser-plasma interaction with a sub-10 fs temporal resolution.

K 2.8 Tue 16:30 P

Precise diagnostic of high-power ultra-short laser — •Xinhe Huang[1,2,4], Alexander Sävert[1], Beate Heinemann[2,4], and Matt Zepf[1,3] — [1]Helmholtz Institute Jena, Jena, Germany — [2]DESY, Hamburg, Germany — [3]Friedrich Schiller Universität Jena, Jena, Germany — [4]Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

The LUXE (Laser Und XFEL Experiment) project aims to measure processes in the strong-field quantum electrodynamics regime with high precision by colliding electrons or a high-energy photon beam with high-power, tightly focused laser beam at a repetition rate of 1Hz. Simulations [1] predict that the probability of pair production responds highly non-linearly to the laser strength parameter. Consequently, small variations in the laser intensity lead to significant variations in the experimental observables. The required precision will be achieved by intensity tagging though precise measurements on the relative variation of intensity on a shot-by-shot basis. We present results of a laser diagnostic system performed on the JETI200 laser, with an ultimate aim to monitor the shot-to-shot fluctuations with precision below 1%.

[1] LUXE CDR, arXiv:2102.02032 [hep-ex]

K 2.9 Tue 16:30 P

Towards rapidly-tunable, femtosecond UV laser pulses — •Fridolin Geesmann[1,2], Robin Mevert[1,2], Yuliya Binhammer[1,2], Christian M. Dietrich[1,2], Luise Beichert[1,2], José R. Cardoso de Andrade[3], Thomas Binhammer[4], Jintao Fan[1,2], and Uwe Morgner[1,2] — [1]Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, D-30167 Hannover, Germany — [2]Cluster of Excellence PhoenixD, Welfengarten 1, D-30167 Hannover, Germany — [3]Max-Born-Institute, Max-Born-Straße 2A, D-12489 Berlin — [4]neoLASE GmbH, Hollerithallee 17, D-30419 Hannover, Germany

Optical parametric oscillators allow the generation of femtosecond, widely tunable radiation with high output power. This makes them a perfect tool for spectroscopy or imaging. Here, we show theoretical considerations for the generation of tunable UV radiation using intracavity processes in such a noncollinear optical parametric oscillator that provides fast tunable radiation in the visible spectral region from 440-720 nm. Two different conversion processes can be used for this purpose. First, an intracavity second harmonic generation process can be used to cover a wide range in the UV. However, this method has the disadvantage that the converted wavelength is selected by changing the crystal angle, which allows only slow tuning speeds. Therefore, an additional method is being investigated, which should enable fast tuning of the generated radiation by changing the cavity length only. This can be achieved via a non-collinear sum frequency generation process, but has the disadvantage that only the near UV region can be reached.

K 2.10 Tue 16:30 P

Electron-Lattice Relaxation Time Dynamics and Separation Time Dynamic of Multiple Pulses Femtosecond Laser Ablation Process on Gold. — •Hardik Vaghasiya[1,2], Stephan Krause[1,2], and Paul-Tiberiu Miclea[2,1] — [1]Martin Luther University Halle-Wittenberg, ZIK Sili-nano, Halle, Germany — [2]Fraunhofer Center for Silicon Photovoltaics CSP, Germany

To study the ultrashort laser pulse interaction on gold, a set of coupled partial differential equations of the two-temperature model was solved in the spatial and time domains with dynamic optical properties and phase explosion mechanism. In an extended Drude model considering interband transitions, the reflectivity and absorption coefficient are contemplated based on the electron relaxation time. The laser energy deposition and phase explosion ablation mechanism are analyzed in the case of succession of fs-laser pulses (180 fs, 1030 nm) on gold with experimental results. The simulation results demonstrate that by increasing the number of pulses with a shorter separation time compared to electron-lattice relaxation time, lattice temperature can be considerably increased without a noticeable increase in ablation depth. In the study of multiple pulses fs laser ablation, the computational model indicates that succession of laser pulses with a pulse separation time of 50 ps or longer can significantly boost the ablation rate at the same laser fluence. Thus, the deviation from experimental and simulation results gives rise to the conclusion that temporal pulse manipulation with separation time greater than the electron-lattice relaxation time is a useful technique for fast femtosecond laser processing.

K 2.11 Tue 16:30 P

Ultra-short laser micro-machining by spatially shaped ps- and fs-pulses for depth-selective μ-TLM resistivity test structures of sputter-deposited metal/oxid/semiconducting contact layers — •Stephan Krause[1,2], Stefan Lange[2], Hardik Vaghasiya[1], Christian Hagendorf[2], and Paul-Tiberiu Miclea[2,1] — [1]Centre for Innovation Competence SiLi-nano, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany — [2]Fraunhofer Center for Silicon Photovoltaics CSP, Halle (Saale), Germany

In this work, we applied spatially shaped ultra-short pulse laser micromachining for a new processing approach of μ-TLM test structures. These structures are used for resistivity measurements of multilayer systems with highly resistive interface layers, e.g. in oxide passivation layers for solar cells. For precise measurements of electrical sheet and contact resistivity of the individual layers, isolating trenches and homogenous ablation areas are required. Ultrashort pulses with 10 ps and 200 fs of different laser wavelength (532 nm, 1030 nm) as well as optical beam shaping elements for a redistribution of the intensity from gauss to top-hat profiles enables a selective removal of top metallic Ag and oxide layers on the multilayer stack. At the same time thermal damage is minimized in underlying material and adjacent region of the laser trenches. Small effective optical penetration and sub μm-adjustable ablation depth were achieved by an ultrafast ablation mechanism via absorption at the several multilayer interfaces. Morphology and microstructure of heat affected zones (HAZ) at the laser structures are characterized by scanning electron microscopy.

K 2.12 Tue 16:30 P

Orthogonally Superimposed 3D Laser-Induced Periodic Surface Structure (LIPSS) upon Femtosecond Laser Pulse Irradiation of Silicon surface for Surface Enhanced Raman Scattering (SERS) application. — •Hardik Vaghasiya[1,2], Stephan Krause[1,2], Christian Hagendorf[2], and Paul-Tiberiu Miclea[2,1] — [1]Martin Luther University Halle-Wittenberg, ZIK Sili-nano, Halle, Germany. — [2]Fraunhofer Center for Silicon Photovoltaics CSP, Germany.

We report on the generation of homogenous low spatial frequency LIPSS on crystalline silicon with beam-shaped femtosecond pulsed laser irradiation at 1030 nm wavelength. Three-dimensional laser-induced periodic surface structures with pattern sizes periodicity around laser wavelength are obtained on the silicon surfaces. The distinctive orthogonally superimposed 3D LIPSS is achieved by employing a double step technique that relies on irradiation with two temporally delayed and cross-polarized femtosecond-laser pulses. In silicon, orthogonally superimposed 3D LIPSS structure of a few nanometers to micron in amplitudes were produced over a larger area, and the influence of the applied laser fluence, pulse overlap, and angle of incidence on the periodic surface structures are investigated. The periodicity and amplitude of 3D LIPSS can be tuned by controlling the number of pulses irradiation and applied laser fluence. Finally, this work presents novel, multi-scale periodic patterns with three-dimensional symmetry generated on the silicon surface, for sensor application, e. g. SERS-substrates.

K 2.13 Tue 16:30 P

Generation of Nanoparticle for Investigation of Laser Induced Transfer — •Jannik Wagner, Philip Mosel, Pranitha Sankar, Elisa Appi, Uwe Morgner, and Milutin Kovacev — Institute of Quantum Optics, Cluster of Excellence PhoenixD and Quantum Frontiers, Leibniz Universität Hannover, Hannover, 30167, Germany

Nanoparticles are used for microfabrication technologies that enable controlled deposition of a wide variety of materials.[1] There are two established methods for nanoparticle generation: laser-induced forward transfer (LIFT) and laser-induced backward transfer (LIBT). These methods differ primarily in the direction in which the particle is ejected relative to the laser propagation. The laser pulse heats the metal donor substrate and forms a bubble of liquid metal due to surface tension. The collapse of the bubble produces a spherical nanoparticle.[2]

In this work, single particles with size <5 um are generated using a pulsed ns laser system in LIBT and LIFT configuration. The change of particle size with photon flux and varied laser focus position is investigated. In addition, the formation of the particles is optically tracked and imaged.

[1] Zacharatos et al., Optics & Laser Technology 135: 106660 (2021)
[2] Kuznetsov et al., Appl. Phys. A 106, 479-487 (2012)

K 2.14 Tue 16:30 P

Towards studying collective effects in laser-driven heavy ion acceleration — •Erin G. Fitzpatrick, Laura Geulig, Maximilian Weiser, Florian H. Lindner, and Peter G. Thirolf — Ludwig-Maximilians-Universität München, Germany

Laser accelerated ion bunches offer unique properties, like an ultra-high, almost solid-state density. This may affect their stopping behavior in matter via collective effects and ultimately enable to establish new nuclear reaction schemes like the 'fission-fusion' mechanism, aiming to generate astrophysically relevant, extremely neutron-rich isotopes near N=126. Two major prerequisites are needed for the realization of this reaction mechanism: (i)Laser-driven heavy ion bunches at energies above their fission barrier (7 MeV/u for ^{232}Th) with (ii)extremely high bunch densities. Experimental campaigns at different PW class laser facilities resulted in the acceleration of gold ions to maximum kinetic energies beyond 7 MeV/u and ion bunch densities of about 10^{13} cm^{-3} (10^{16} cm^{-3}) at 1 mm (100 μm) from the target.

At the Center for Advanced Laser Applications (CALA) in Garching we are preparing for studies to investigate collective effects, like a potential reduction of the stopping power of heavy laser-accelerated ion bunches in solid targets. They will be assessed via the energy deposition of accelerated ion bunches in solid targets placed closely downstream of the acceleration target. An overview of the project and its status will be given. This project is funded by BMBF [05P2018WMEN9].

K 2.15 Tue 16:30 P

Laser-driven proton acceleration based on expanded thin target — •Mingyuan Shi[1,2], Peter Hilz[1], Israa Salaheldin[1,2], Bin Liu[1], Bifeng Lei[1,2], Alexander Saevert[1,2], Georg Schaefer[1,2], and Matt Zepf[1,2] — [1]Helmholtz-Institute Jena, Jena, Germany — [2]Friedrich-Schiller-Universität Jena, Jena, Germany

With the development of ultra-fast and ultra-short laser technology, the interaction between femtosecond laser and matter has aroused people's great attention. Regarding to laser-ion acceleration, the ions are accelerated to relativistic velocity within a few optical cycles is still a challenge due to technical limitations and cost to date. But laser-based proton and ion acceleration has already demonstrated outstanding potential in beam divergency, acceleration gradient and beam duration[1,2].

In principle the near critical density plasma can deposit more laser energy[3], therefore increasing the energy of accelerated particle. But a controllable plasma density to solid target experiment is still a challenge up to date. Here we try to produce a controllable plasma near critical density and based on it to investigate the plasma density effect to ion acceleration. In particular we aim to diagnose the evolution of plasma maximum density after pre-pulse shooting. Investigating the optimum plasma density to the proton acceleration. At the same time the back reflection light will be collected bring rich information.

[1] Hegelich, et al. Nature 439.7075 (2006): 441-444. [2] Gaillard, et al. Physics of Plasmas 18.5 (2011): 056710. [3] Sharma, et al. Scientific reports 9.1 (2019): 1-10.

K 2.16 Tue 16:30 P

Enhancement of X-ray generation by ultrashort-pulsed laser-material interaction — •Patrick Markus Rössler, Philip Mosel, Pranitha Sankar, Elisa Appi, Uwe Morgner, and Milutin Kovacev — Institut für Quantenoptik, Cluster of Excellence PhoenixD and Quantum Frontiers, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Nowadays a large range of ultrashort-pulsed laser systems are able to reach intensities above 10^{13} W/cm^2 and can easily ignite a plasma on a solid target-sample. The laser-induced plasma can be used as a source of incoherent X-ray radiation [1]. Here, by focusing ultrashort laser-pulses on a rotating metallic cylinder under vacuum conditions, measurements of the photon flux and the spectrum in the range of 2 keV to 20 keV with a calibrated detector Silix lambda are shown [2]. In addition, the interaction between different pulses and heat accumulations effects are able to change the plasma dynamics which can lead to an increase of the generated X-ray photon flux. In the presented work, double pulse and burst-mode like schemes are investigate in order to enhance the X-ray generation and manipulate the spectral emission.

[1] Martín, L., et al. "Improved stability of a compact vacuum-free laser-plasma X-ray source" High Power Laser Science and Engineering, 2020
[2] Mosel, P., et al. "X-ray Dose Rate and Spectral Measurements during Ultrafast Laser Machining Using a Calibrated (High-Sensitivity) Novel X-ray Detector" Materials, 2021

K 2.17 Tue 16:30 P

Torus-knot angular momentum in bicircular high-harmonic generation — •Björn Minneker[1,2,3], Birger Böning[2,3], Anne Weber[1], and Stephan Fritzsche[1,2,3] — [1]Theoretisch Physikalisches Institut, Friedrich-Schiller-Universität, Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [3]Helmholtz Institut, Jena, Germany

We provide a model which demonstrates intuitively the conservation of the torus-knot angular momentum (TKAM) in bicircular high-harmonic generation and describes where it maid be found in the process. In addition, we discuss how topological non-trivial features can be formed from bicircular driving beams and the associated high-harmonic radiation. The topological non-triviality is a unique property that can not be seen in high harmonic generation by single beam configurations. In general, the topological non-trivial features of the harmonic radiation can be interesting for spectroscopy since topological structures are often robust with regard to various ambient conditions. However, to demonstrate these suggestions further investigations are necessary. Therefore, our work provides a different approach to thinking and speaking about high harmonic generation driven by bicircular twisted light beams.

K 3: Pulsed Power - XUV and EUV Sources and their Applications

Time: Wednesday 14:00–15:30 Location: K-H4

Invited Talk K 3.1 Wed 14:00 K-H4

Leistungsimpulstechnik: Im Rückblick und mit Blick auf aktuelle und künftige Anwendungen — •Klaus Frank — Department für Physik Erwin-Rommel Strasse 1 91058 Erlangen

Im ersten Teil des Vortrages wird beschrieben, wie man die Leistungsimpulstechnik (Pulsed/Pulse Power Technology) in den Bereich Leistungselektronik (Power Electronics) einordnen kann. Langmuir*s erste Realisierung des Thyratrons 1914 war eine mittels eines Gitters steuerbare gasgefüllte (Xenon) Röhre, Im Folgenden wird der Werdegang dieses und anderer Leistungsschalter kurz skizziert, wobei der Durchbruch als langlebiges Schaltelement für das Thyratron während des 2. Weltkrieges erfolgte. Der Begriff *Pulse Power* wurde dann erstmals in den 1950 -ern bei der Entwicklung von gepulste Röntgen-Radiographieanlagen in den USA und Großbritannien verwendet. 1976 fand dann in Lubbock, Texas die erste Pulse Power Conference statt. Danach wird anhand von zwei willkürlich gewählten Beispielen gezeigt wie die Leistungsimpulstechnik bereits jetzt sich technologisch etabliert hat bzw. ein großes Zukunftspotential bei erfolgreicher technischer Realisierung erreichen könnte. Es ist zum einen ein Beispiel aus dem Teilgebiet der Elektroporation, zum anderen eines aus der Anwendung der elektrodynamischen Fragmentierung. Seit Jahrzehnten wird daran geforscht und entwickelt, aber jetzt scheint der technologische Durchbruch bevorzustehen. Abschließend wird ein Paradebeispiel integrierter Ingenieurkunst aus dem Bereich Leistungsimpulstechnik vorgestellt.

Invited Talk K 3.2 Wed 14:30 K-H4

Technischer Stand der Pulsed Power in medizinischen Excimer Lasern — •Claus Strowitzki — MLase AG Germering

Die Erzeugung schneller Hochspannungspulse (30 kV; 100ns; 15 kA) ist ein wesentlicher Bestandteil medizinischer Excimerlaser. Der Vortag beleuchtet den aktuellen Stand der Technik und deren weitere Entwicklung. Es wird auch auf die besondere Anforderungen in der Medizintechnik eingegangen.

K 3.3 Wed 15:00 K-H4

Fast up-scalable SiC-MOSFET HV switching modules — •Rainer Bischoff, Ralf Himmelsbach, and Meik Stoll — French-German Research Institute of Saint-Louis (ISL), 5 rue du General Cassagnou, 68301 Saint-Louis, France

We report on the development of fast high voltage (HV) switching modules, which can be scaled-up because of the principle of a series arrangement of commercial-off-the-shelf (COTS) SiC-MOSFETs. In detail, the switching modules consist of two circuit boards. Each one features five SiC-MOSFETs commercialized by Wolfspeed/CREE that are getting stacked in order to minimize the area of the current loop between high voltage and ground connector, and, as a result, minimizing the inductance of the structure. An alternative solution for the power supply of the gate control circuit and the generation of the gate-source voltage was implemented. The SiC-MOSFET switching modules generate directly all necessary voltages out of the applied HV charging voltage obtained using voltage divider circuits consisting of resistors and Zener diodes. The realized switching modules reached a current turn-on time of 12 ns with 3M0075120 SiC-MOSFETs at a switching voltage of 10 kV and a drain current of 39 A. Three of these 10-kV modules equipped with C2M0080120D SiC-MOSFETS were successfully connected to an up-scaled 30-kV switching module. Its current turn-on time was experimentally determined to 12 ns at a drain current of 30 A.

K 3.4 Wed 15:15 K-H4

Table-top nanoscale imaging with XUV and soft X-ray radiation — •David Theidel[1], Philip Mosel[1,2], Elisa Appi[1,2], Pranitha Sankar[1,2], Uwe Morgner[1,2], and Milutin Kovacev[1,2] — [1]Institute of Quantum Optics, Leibniz University Hannover Welfengarten 1, 30167 Hannover — [2]Cluster of Excellence PhoenixD

With the development of high-flux coherent light sources in the extreme ultraviolet (XUV) regime by using high-order harmonic generation (HHG), table-top imaging of nanoscale structures is becoming an serious alternative to similar experiments at free-electron laser facilities. In this work, we present experimental challenges and development process of a new short-wavelength microscope with the goal to apply different imaging schemes on artificial nanostructured targets and biological samples. Using a HHG source, we generate coherent XUV radiation from infrared ultrashort laser pulses in gas down to 13.1 nm [1]. We analyse the generated radiation in terms of brilliance and coherence properties to evaluate their applicability for coherent and incoherent imaging methods [2, 3]. Moreover, future extension of these methods to partially coherent soft X-ray sources will be discussed.

[1] Steingrube, Daniel S., et al. "Phase matching of high-order harmonics in a semi-infinite gas cell." Physical Review A 80.4 (2009)

[2] Rothhardt, Jan, et al. "Table-top nanoscale coherent imaging with XUV light." Journal of Optics 20.11 (2018): 113001.

[3] Schneider, Raimund, et al. "Quantum imaging with incoherently scattered light from a free-electron laser." Nature Physics 14.2 (2018)

K 4: Annual General Meeting

Time: Wednesday 15:30–16:00 Location: K-MV

Annual General Meeting

K 5: New Methods and Laser Diagnostics

Time: Wednesday 16:30–17:45 Location: K-H4

Invited Talk K 5.1 Wed 16:30 K-H4

Physikalische Information und Naturkonstanten — •Rudolf Germer — ITP e.V. — TU-Berlin

Die hier vorgestellte Art physikalischer Information basiert auf einer abzählbaren Menge von Wirkungsquanten h und der Energie E als eine die Zahl der Wirkungsquanten ergänzende Größe mit Bezug auf Genauigkeiten. Eine solche Information erscheint kleinstmöglich als Beziehung zwischen Objekten, Ereignissen u.a. in Form von Abständen, Zeitdifferenzen, Kräften* Bei Information tragenden Photonen finden wir $E = h*f = h*c/\lambda$. Information existiert aber auch holistisch in Bezug auf Gruppen physikalischer Objekte. Diese Idee lässt sich an einigen bekannten Beispielen der Physik demonstrieren. Im elektromagnetischen Fall führt dies dazu, daß die dort bekannten Quanten mit zahlreichen Naturkonstanten in der Geometrie des elektromagnetischen Quaders (EMQ) veranschaulicht werden können. Daraus folgt, daß mehr als ein Dutzend Naturkonstanten auf nur vier Ausgangsgrößen zurückgeführt werden können. Weitere Einzelheiten finden Sie im wikibook *Die abzählbare Physik*. Zur Diskussion : germer@physik.tu-berlin.de

K 5.2 Wed 17:15 K-H4

Attoseconds on a Chip - Time Domain Measurement of a Near-IR Transient — •Felix Ritzkowsky[1,2], Mina Bionta[2], Marco Turchetti[2], Yujia Yang[2], Dario Cattozo Mor[2], William Putnam[3], Karl Berggren[2], Franz Kärtner[1], and Phillip Keathley[2] — [1]Deutsches Elektronen Synchrotron (DESY) & Center for Free-Electron Laser Science, Hamburg, Germany — [2]Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA — [3]Department of Electrical and Computer Engineering, University of California, Davis, CA, USA

We report on a cross-correlation technique based on perturbation of local electron field emission rates that allows for the full characterization of arbitrary electric fields down to 5 fJ using plasmonic nanoantennas. Plasmonic nanoantennas in combination with ultrafast, few-cycle laser pulses allow for highly non-perturbative experiments that have previously only been demonstrated in the gas phase with high power, low repetition rate laser systems. By exploiting the plasmonic excitation in a metallic nanostructured device, electric field strengths exceeding $\sim$30 GV m^{-1} can be reached at the nanostructure with optical pulse energies of several tens of pJ. This enables sub-cycle attosecond electron bursts to be coherently driven by the electric near field of the plasmon, which we use to sample the near-infrared field-transients at the nanoantenna tip *in-situ*. These results show that this technique can resolve electric fields in amplitude and phase with a potential PHz bandwidth. This technique will enable time-domain spectroscopy to be applied from the infrared to the visible spectral range.

K 5.3 Wed 17:30 K-H4

Recording terahertz pulses and their spectra in single-shot at the ELBE facility, by associating the photonic time-stretch and DEOS techniques — •Christelle Hanoun[1], Christophe Szwaj[1], Eleonore Roussel[1], Serge Bielawski[1], Pavel Evtushenko[2], Christof Schneider[2], Anton Ryzhov[2], Michael Kuntzsch[2], and Sergey Kovalev[2] — [1]PhLAM Laboratory, UMR CNRS 8523, Lille University, France — [2]Radiation Source ELBE, Helmholtz-Zentrum Dresden-Rossendorf, Germany

Sources of intense terahertz radiation and/or high repetition rate are available for applications in several laser and accelerator facilities worldwide. This opened new opportunities, and several high-performance THz metrology systems have been demonstrated and employed for experiments. Nevertheless, some significant challenges in the field of THz measurements remain open. This concerns both Time-Domain Spectroscopy Applications as well as real-time diagnostics of the sources. We present here a novel THz electro-optic measurement strategy that aims at a high repetition rate (up to tens of millions of THz spectra per second when needed) thanks to the use of the so-called photonic time-stretch technique, and that is also capable of high effective bandwidth by using the recently introduced Diversity Electro-Optic Sampling (DEOS) retrieval technique (https://arxiv.org/abs/2002.03782). We will present the first tests of this design using terahertz pulses in the 100 nJ range, with 50 kHz repetition rate, generated by the Coherent Diffraction Radiation (CDR) source of ELBE, at Helmholtz-Zentrum Dresden-Rossedorf (HZDR).

K 6: Laser-Beam Matter Interaction - Laser Applications I

Time: Thursday 10:30–12:15 Location: K-H4

Invited Talk K 6.1 Thu 10:30 K-H4

Front and rear surface ablation within gold films with variable film thickness induced by ultrafast laser radiation — •Markus Olbrich, Theo Pflug, and Alexander Horn — Laserinstitut Hochschule Mittweida, Technikumplatz 17, 09648 Mittweida

Irradiating gold films with a different film thickness ($d_z = 100$ - $8000\,\mathrm{nm}$) on a glass substrate ($d_z \approx 1$ mm) with single-pulsed ultrafast laser radiation ($\tau_H = 40\,\mathrm{fs}$, $\lambda = 800\,\mathrm{nm}$) results in different ablation structures in dependence on the applied peak fluence H_0. Thereby, for thin films ($d_z \leq 200$ nm) the complete film is removed, whereby for thicker films ablation structures featuring a cupola-like shape with a height of several microns are observed. The ablation structures are explained by two-temperature hydrodynamic modeling (TTMHD) identifying the interplay of front and rear surface ablation as the origin. The formation of the ablation structures is induced either by spallation and phase explosion at the front surface, and at the rear surface by the propagation of the emitted shock and rarefaction waves, generating also spallation. The performed simulations are validated by ultrafast time and space resolved reflectometry ($\tau_H = 60$ fs, $\lambda = 440$ nm, and $\lambda = 480$ nm) at both surfaces of the films within a self-developed optical setup. The complementary combination of reflectometry at the front and rear surfaces portrays the dynamics of the induced temperature and pressure distributions as well as the dynamics of the front and rear surface by comparing the measured relative change of reflectance $\Delta R/R$ to the simulated dynamics of the named parameters.

K 6.2 Thu 11:00 K-H4

Spatially intensity profiles shaping of ultra-short laser for enhanced selective thin film test structure processing on silicon multilayers — •Stephan Krause[1,2], Stefan Lange[2], Hardik Vaghasiya[1,2], Christian Hagendorf[2], and Paul-Tiberiu Miclea[2,1] — [1]Centre for Innovation Competence SiLi-nano, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany — [2]Fraunhofer Center for Silicon Photovoltaics CSP, Halle (Saale), Germany

In this work, we applied spatially shaped ultra-short pulses for laser micro-machining on SiNx/c-Si layer system for the investigation of the selectivity ablation behavior of the sub-μm thick SiNx top layer. By the comparison to gaussian beams, intensity spatially shaped pulses have the potential for a minimization of the superfluous energy in the peak region over the ablation threshold fluence as well as a steeper intensity drop at the side edge of the pulses. This can lead to more precise lateral and vertical ablation properties of the top thin film layer and lower modification/damage to the silicon substrate and the adjacent region. We compare ablation thresholds variations due to beam shaping via light microscopic measurements on the μm-laser spot structures as well as the crystalline phases and stress modification via μ-Raman in the ablated spot, adjacent modified regions and untreated reference areas.

K 6.3 Thu 11:15 K-H4

Fundamental Study of Ablation Mechanisms in Crystalline Silicon and Gold by Femtosecond Laser Pulses: Classical Approach of Two Temperature Model. — •Hardik Vaghasiya[1,2], Stephan Krause[1,2], and Paul-Tiberiu Miclea[2,1] — [1]Martin Luther University Halle-Wittenberg, ZIK Sili-nano, Halle, Germany. — [2]Fraunhofer Center for Silicon Photovoltaics CSP, Germany.

A fundamental study of the interaction between ultrashort laser pulses and the material will be valuable for studying ablation characteristics and ablation performance. A theoretical analysis of ultrashort laser-matter interaction can be represented by the two-temperature model which describes the temperature of the electron or carrier and lattice in non-equilibrium conditions when ultrashort laser pulses are applied. During ultrafast irradiation, due to peculiarities between the metal energy absorption to in contrast to semiconductor, a comparative study of silicon and gold ablation mechanism presented. A 2D axial symmetry simulated ablation profiles were compared with the experimental result at fluence ranging from 1 J/cm2 to 9 J/cm2 at the wavelength of 515 nm and 180 fs laser on the silicon and gold samples. The concordance between model calculations and experimental data demonstrates that fs laser ablation of silicon is thermal in nature in a low fluence regime, whereas it is non-thermal in a high-fluence regime. On the other hand, the phase explosion mechanism is prevalent to understand the ablation characteristics of gold with fs pulses.

K 6.4 Thu 11:30 K-H4

Simulating the optical response properties of solids using mean-field theory — •Kevin Lively[1], Guillermo Albareda[1], Shunsuke Sato[1,2], Aaron Kelly[1], and Angel Rubio[1,3,4] — [1]Max Planck Institut für Struktur und Dynamik der Materie, Hamburg Deutschland — [2]Center for Computational Sciences, University of Tsukuba, Japan — [3]Center for Computational Quantum Physics, Flatiron Institute, New York, USA — [4]Nano-Bio Spectroscopy Group and European Theoretical Spectroscopy Facility, San Sebastian, Spain

Capturing the interplay of electron and phonon dynamics is essential to achieve predictive power in simulating the response properties of materials. However, treating the interactions between these coupled degrees of freedom beyond a perturbative level in ab-initio simulations is extremely challenging. In this talk I will present a mean field method for periodic systems that is based on time dependent density functional theory coupled with an ensemble of Ehrenfest trajectories. I will demonstrate that this approach, which has recently been applied to study vibronic structure in molecular systems1, yields predictions for the absorption spectra of solids in agreement with static linear response approaches2, while also offering a viable path to simulate the dynamical response of driven solids.

[1] Lively, Albareda, Sato, Kelly, Rubio, J. Phys. Chem. Lett. 2021, 12, 3074-3081 [2] Zacharias, Giustino J. Phys. Chem. Lett. 2021, 12, 3074-3081

K 6.5 Thu 11:45 K-H4

The Fluence-Dependent Transient Reflectance of Stainless Steel Investigated by Ultrafast Imaging Pump-Probe Reflectometry — •Theo Pflug[1], Markus Olbrich[1], Jan Winter[2], Jörg Schille[1], Udo Löschner[1], Heinz Huber[2], and Alexander Horn[1] — [1]Laserinstitut Hochschule Mittweida, Mittweida, Deutschland — [2]Hochschule München, München, Deutschland

The ablation efficiency during laser processing strongly depends on the initial and transient reflectance of the irradiated material surface. This work reports on the transient relative change of the reflectance ΔR/R of stainless steel during and after ultrashort pulsed laser excitation (800 nm, 40 fs) by spatially resolved pump-probe reflectometry. The spatial resolution of the setup in combination with the spatial Gaussian intensity distribution of the pump radiation enables a fluence-resolved detection of ΔR/R. Within the first picosecond after irradiation with a peak fluence of 2 J/cm2, the spatially resolved ΔR/R of stainless steel evolves into an annular shape, in which the center almost remains at its initial reflectance, whereas the outer region features a decreased reflectance. The decreasing trend of ΔR/R is qualitatively supported by applying a two-temperature model, considering the transient optical properties of stainless steel from the literature. At larger fluences and thus higher electron temperatures, the experimental data deviates from the transient reflectance given in the literature. A decreased occupation of the states below the Fermi energy and the subsequent excitation of electrons into these new vacant states by the probe radiation is considered as the most probable origin for this behavior.

K 6.6 Thu 12:00 K-H4

Optical emission spectroscopy of laser-induced plasmas for rapid in-situ multi-element analysis of materials - basic physical processes and novel industrial applications — •Reinhard Noll — Fraunhofer-Institut für Lasertechnik, Steinbachstr. 15, 52074 Aachen

For nanosecond laser pulses (>10^9 W/cm2) focused at solid/liquid targets each material undergoes a rapid phase transition leading to a transient micro-plasma. The constituting species achieve significant population densities at excitation levels of up to 10 eV and more. During relaxation these species emit element specific optical radiation from deep UV to near IR. Tailored laser pulse bursts allow to penetrate non-representative surface layers and to generate optimized plasma states in terms of their optical emission features for spectro-chemical multi-element analysis (LIBS) [1].

Due to contactless excitation and measuring frequencies of 10 Hz to 1 kHz this method is predestinated for in-situ multi-element analyses in processing and producing fields of industry. An overview of novel applications of LIBS will be given ranging from metal producing industry to the fast identification of valuable materials for recycling processes. The worldwide first inverse production line will be presented to process printed circuit boards of end-of-life servers and cell phones for automized identification, extraction and sorting of valuable components based on laser 3D-measurements, LIBS, laser desoldering and cutting [2]. [1] C. Meinhardt et al, 2021, DOI: 10.1039/D0JA00445F; [2] R. Noll et al, doi.org/10.1016/j.sab.2021.106213

K 7: Laser-Beam Matter Interaction - Laser Applications II

Time: Thursday 14:00–15:45 Location: K-H4

K 7.1 Thu 14:00 K-H4

The Three-Backlink experiment: A phase reference distribution system for LISA. Design, construction and first measurements. — •Jiang Ji Ho Zhang, Lea Bischof, Stefan Ast, Daniel Jestrabek, Krishnapriya Rajasree, and Melanie Ast — Max Planck Institute for Gravitational Physics, Callinstraße 38, 30167 Hannover, Germany

LISA (Laser Interferometer Space Antenna) will be the first gravitational wave detector in space, aiming to use laser interferometry to detect gravitational-wave signals in the 0.1 mHz to 1 Hz band. It consists of three satellites forming a near-equilateral triangle with 2.5 million km arms. Due to the orbital mechanics, the inter-satellite distances and angles vary by about 1% and $\pm 1.5°$ per year, respectively. Each satellite features two moving optical sub-assemblies (MOSAs) that are connected via a flexible optical link, the so-called backlink or phase reference distribution system (PRDS), which articulates the payload to compensate for the angular dynamics. The optical pathlength difference between two counter-propagating beams along the PRDS is required to reach 1 pm/$\sqrt{\mathrm{Hz}}$ stability. The Three-Backlink Experiment is a trade-off study between different designs of the PRDS: a direct fibre backlink, a frequency separated fibre backlink and a free beam backlink. To simulate the angular motion of the MOSAs, the experiment features two rotation stages, each containing a Zerodur plate to which fused silica optical components are bonded using UV glue. We report on the first measurements of the backlink non-reciprocity, a first step towards achieving the required performance for LISA.

K 7.2 Thu 14:15 K-H4

Update on the laser heavy ion acceleration at CALA — •Laura Desiree Geulig, Erin Grace Fitzpatrick, Maximilian Weiser, Florian H. Lindner, and Peter G. Thirolf — LMU Munich

We report on the current work on laser driven heavy ion acceleration at the Centre for Advanced Laser Applications (CALA), using the ATLAS 3000 laser with a central wavelength of 800 nm, a pulse length of about 25 fs and currently up to 8 J energy on target in the context of developing the novel 'fission-fusion' nuclear reaction mechanism [1]. First the efficient acceleration of gold ions with kinetic cutoff-energies above 7 MeV/u is targeted. For our experiments the laser is focused with an f/2 parabola on gold foils with thicknesses ranging from 100 nm to 500 nm. To analyze the accelerated ion bunch, a Thomson Parabola Spectrometer was designed that resolves the full proton and gold spectrum as well as the individual gold charge states [2]. A radiative heating system is integrated into the setup to enhance the acceleration of gold ions by removing hydro-carbon surface contaminations. An integrated IR spectrometer allows for in-situ measurement of the heated foil temperature, while enabling a simultaneous monitoring with a camera to detect possible thermal damage to the foil [3]. With the current setup, proton cutoff energies above 21 MeV have already been realized.

[1] D. Habs et al., Appl. Phys. B 103, 471-484 (2011) [2] F.H. Lindner et al., arXiv:2104.14520, submitted to Scientific Reports (2021) [3] M. Weiser, Master Thesis, LMU Munich, 2021

This work was funded by BMBF (05P2018WMEN9).

K 7.3 Thu 14:30 K-H4

Effect of pre-excited charge carriers on high harmonic generation in silicon — •Pawan Suthar[1], František Trojánek[1], Petr Malý[1], Thibault Derrien[2], and Martin Kozák[1] — [1]Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 12116 Prague 2, Czech Republic — [2]HiLASE Centre, Institute of Physics, Academy of Science of the Czech Republic, Za Radnicí 828/5, 25241 Dolní Břežany, Czech Republic

High harmonic generation (HHG) in solids is a highly nonlinear optical process, in which electron-hole pairs are created via quantum tunneling, coherently accelerated and then recombined by the strong electric field of a non-resonant laser pulse. Here we study how the HHG yield in crystalline silicon is influenced by scattering of coherent wave packets by charge carriers resonantly pre-excited to the conduction and valence bands using a pump-probe like setup. The HHG is driven by few-cycle mid-infrared probe pulses with central photon energy of 0.61 eV and its spectrum and yield are characterized as functions of the time delay after a pump pulse, which resonantly excites carriers in silicon via direct (photon energy of 3.8 eV) or indirect (1.9 eV) transitions. We find that the HHG yield changes differently for different orientations of linear polarization of the mid-infrared pulse with respect to crystallographic orientation of silicon, for different photon energies of the resonant pump and that the response of each harmonic order differs. These results emphasize the role of band structure and Coulomb interactions between carriers in the HHG process.

K 7.4 Thu 14:45 K-H4

Laboratory evidence for proton energization by collisionless shock surfing — •Alice Fazzini[1], Weipeng Yao[1,2], Sophia Chen[3], Konstantin Burdonov[1,2], Patrizio Antici[3], Jérôme Béard[3], Simon Bolanos[1], Andrea Ciardi[2], Raymond Diab[1], Stanimir Kisyov[3], Vincent Lelasseux[1], Marco Miceli[3], Salvatore Orlando[3], Sergey Pikuz[3], Evgeny Filippov[3], Dragos Popescu[3], Viorel Nastasa[3], Quentin Moreno[3], Guilhem Revet[1], Emmanuel d'Humières[3], Xavier Ribeyre[3], and Julien Fuchs[1] — [1]LULI - CNRS, CEA, Ecole Polytechnique - F-91128 Palaiseau, France — [2]Sorbonne Université, Observatoire de Paris, Université PSL, CNRS, LERMA, F-75005, Paris, France — [3]Refer to J. Fuchs for the complete list of addresses

Collisionless shocks are present in many astrophysical phenomena, such as supernovae remnants and the Earth's bow shock. In these events, collisionless electromagnetic processes mediate the transfer of momentum and energy from the flowing plasma to the ambient one. Using our platform, where we couple high-power lasers (JLF/Titan at LLNL, and LULI2000) with strong magnetic fields, we have generated astrophysically relevant super-critical magnetized collisionless shocks. Kinetic Particle-In-Cell simulations based on our experimental results reveal that shock surfing acceleration is responsible for the energization of the background protons up to 100 keV. Our observations not only provide evidence of early stage ion acceleration by collisionless shocks, but they also highlight the role this mechanism plays in energizing ions initially at rest, with capacity to feed further stages of acceleration.

K 7.5 Thu 15:00 K-H4

Ultrafast single-photon detection at high repetition rates based on optical Kerr gates under focusing — •Amr Farrag[1], Abdul-Hamid Fattah[1], Assegid Mengistu Flatae[1], and Mario Agio[1,2] — [1]Laboratory of Nano-Optics and Cμ, University of Siegen, 57072 Siegen, Germany — [2]National Institute of Optics (INO), National Research Council (CNR), 50125 Florence, Italy

Abstract:

The ultrafast single-photon detection of quantum emitters has become recently vital, as there are faster emission processes that the current techniques cannot resolve. To overcome this limitation, here we present a semi-analytical model using the Optical-Kerr-shutter (OKS) technique at GHz rate under focused illumination, showing a gate efficiency around 70%. The findings will form the basis for experimental demonstration of time-resolved ultrafast detection of single emitters. In addition, it will be beneficial for various fields for instance, quantum nanophotonics, quantum information science and quantum optics.

Reference: A.-H. Fattah, A. M. Flatae, A. Farrag, and M. Agio, Opt. Lett. 46, 560(2021).

K 7.6 Thu 15:15 K-H4

X-ray dose rate and spectral measurements generated from ultrafast laser machining and research-grade laser systems — •Philip Mosel[1], Pranitha Sankar[1], Jan Düsing[2], Elisa Appi[1], Günter Dittmar[3], Uwe Morgner[1], and Milutin Kovacev[1] — [1]Institute of Quantum Optics, Cluster of Excellence PhoenixD and Quantum Frontiers, Leibniz Universität Hannover, Hannover, 30167 — [2]Laser Zentrum Hannover e. V., Hannover, 30419 — [3]Engineering office Prof. Dr.-Ing. Günter Dittmar, Aalen, 73433

In ultrashort pulsed laser machining, process speeds are increased by scaling the average power and pulse repetition rate, which can lead to potentially dangerous X-ray emission [1]. We present measurements with a novel calibrated X-ray detector in the detection range from 2 keV to 20 keV and show the dependence of X-ray dose rate and spectral emission of commonly used metals, alloys, and ceramics for ultrafast laser processing [2]. Our studies include the dependence of dose rate on various laser parameters available in ultrafast laboratories as well as on industrial laser systems. The results presented show that focused sub-picosecond pulses with intensity above 10^{13} W/cm^2 can exceed the annual irradiation limit even in just one hour, requiring adequate shielding for the safety of researchers.

[1] Legall, Herbert, et al., Applied Physics A 125.8 (2019): 1-8.
[2] Mosel, Philip, et al., Materials 14.16 (2021): 4397.

K 7.7 Thu 15:30 K-H4

Light-field control of electrons in graphene: approaching ultrafast electronics — •Tobias Boolakee[1], Christian Heide[1], Antonio Garzón-Ramírez[2], Heiko B. Weber[1], Ignacio Franco[2], and Peter Hommelhoff[1] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]Department of Chemistry, University of Rochester, Rochester, New York 14627, USA

Controlling the motion of electrons in solids on the timescale of an optical cycle is key to advance electronics to unprecedented switching bandwidths. Importantly, for this aim, we can distinguish and take advantage of two types of charge carriers: Real carriers, persisting after their excitation, and virtual carriers, existing during the light-matter interaction only. We show that in a gold-graphene-gold heterostructure, real and virtual charge carriers can be disentangled in the photogeneration of electric currents based on the carrier-envelope phase of incident few-cycle laser pulses. Our experimental observations are well supported by simulations on atomistically detailed charge transport in the heterostructure. These insights now enable us to design and demonstrate a proof-of-concept of an ultrafast logic gate with a potential bandwidth limited fundamentally by the frequency of light.