MO 13: Interaction with Strong or Short Laser Pulses II (joint session A/MO)

Time: Wednesday 14:30–16:30 Location: HS 1010

MO 13.1 Wed 14:30 HS 1010

Focal volume reduction in pulsed standing waves for xenon multiphoton ionization — •Tobias Heldt, Jan-Hendrik Oelmann, Lennart Guth, Nick Lackmann, Lukas Matt, Fiona Sieber, Janko Nauta, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

To study the highly nonlinear light-matter interaction of multiphoton or tunnel ionization, intense light fields are needed. We use a femtosecond enhancement cavity to fulfill this requirement by reaching intensities of $> 10^{13}\,\mathrm{W/cm^2}$, even at the high 100 MHz repetition rate of a near-infrared frequency comb. The bow-tie cavity supports counter-propagating pulses, leading to a pulsed standing wave when two pulses overlap in the focus. There, we have integrated a gas nozzle and a velocity-map imaging (VMI) spectrometer to study the angular distribution of the emitted photoelectrons [1].

The joint focus of the counter-propagating pulses leads to a doubling of the maximum intensity. In addition, the ionization region along the beam propagation is also reduced because it no longer depends on the Rayleigh length but on the < 200 fs overlap of the pulses. Our experimental data show that this reduction of the focal volume renders the electrostatic focusing in the VMI technique unnecessary. Furthermore, the standing wave influences the emitted electrons over the structured ponderomotive potential, leading to the Kapitza-Dirac effect.

[1] J.-H. Oelmann et al., Rev. Sci. Instrum., 93(12), 123303 (2022).

MO 13.2 Wed 14:45 HS 1010

Controlling ionization with chirped circularly-polarized laser pulses — •Ulf Saalmann — Max-Planck-Institut für Physik komplexer Systeme, Dresden/Germany

We show that controlling two-photon ionization with a chirp, originally predicted for linearly-polarized pulses [X], applies to circular polarization as well. In this case the underlying mechanism is particular transparent in the rotating frame. Experimental demonstration of this mechanism for the Helium atom has been achieved at fermi by the Freiburg group and is presented elsewhere.

[X] Saalmann & Giri & Rost, Phys. Rev. Lett. 121 (2018) 153203.

MO 13.3 Wed 15:00 HS 1010

Coulomb-correlated multi-electron states generated by femtosecond laser-triggered nanotip photoemission — •Rudolf Haindl[1,2], Armin Feist[1,2], Till Domröse[1,2], Marcel Möller[1,2], John H. Gaida[1,2], Sergey V. Yalunin[1,2], and Claus Ropers[1,2] — [1]Department of Ultrafast Dyamics, Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Göttingen, Germany

Correlations between electrons are at the core of numerous phenomena in atomic, molecular, and solid-state systems. For free particles, detecting inter-particle correlations remains challenging, as ensemble-averaged detection typically conceals few-body effects.

A powerful approach to induce strong electron-electron correlations is spatio-temporally confined photoemission from field emitters employed in ultrafast electron microscopes. When n electrons are generated by the same laser pulse at the emitter, their initially meV-scale inter-particle Coulomb repulsion is acceleration-enhanced in a static electric field to an energy exchange of about 2 eV, as confirmed by trajectory simulations.

In our experiment, we measure distinct energy correlations of pair, triple and quadruple free-electron states in transverse and longitudinal direction [1]. Furthermore, we demonstrate control over the magnitude of Coulomb correlations and discuss how they can facilitate non-Poissonian electron pulse statistics with applications in free-electron quantum optics.

[1] R. Haindl *et al.*, *Nat. Phys.* **19**, 1410-1417 (2023).

MO 13.4 Wed 15:15 HS 1010

Strong-field Electron Emission of metal Nanotips with optical Single-Cycle Pulses — •Anne Herzig, Lennart Seiffert, and Thomas Fennel — University of Rostock, Institute of physics, Albert-Einstein-Straße 23, 18059 Rostock

Exposing nanostructures to strong fields enables the emission of energetic electrons via near-field driven elastic backscattering [1]. The availability of intense single cycle or sub-single cycle waveforms [2, 3] enables to explore the formation and propagation of attosecond electron pulses in previously inaccessible regimes of the strong-field interaction. Recent experimental studies [4] have shown promising results on analyzing the short backscattering electron signal. In this talk, the electron emission from tungsten nanotips under intense single-cycle pulses is inspected theoretically via one-dimensional single-active TDSE simulations. The calculated carrier-envelope phase-dependent photoelectron energy spectra reveal prominent signatures with pronounced differences to previous studies performed with many-cycle pulses [5]. The physical origins behind the observed spectral features are disentangled by extending the famous Simple Man's Model of strong-field physics.

[1] M. F. Ciappina et al., Rep. Prog. Phys. 80, 054401 (2017)
[2] A. Wirth et al., Science 334, 195 (2011)
[3] M. T. Hassan et al., Nature 530, 66 (2016)
[4] H. Y. Kim et al., Nature 613, 7945 (2023)
[5] L. Seiffert et al., J. Phys. B 51, 134001 (2018)

MO 13.5 Wed 15:30 HS 1010

Observing Laser-Induced Plasma Dynamics by Time-Resolved Coherent-Diffractive-Imaging — •Tom Böttcher, Richard Altenkirch, Christian Peltz, Thomas Fennel, Franziska Fennel, and Stefan Lochbrunner — University of Rostock, Institute of Physics, Albert-Einstein-Str. 23, 18059 Rostock

Resolving the excitation and relaxation dynamics of laser-induced solid state plasmas is crucial for a fundamental understanding of the response of condensed matter targets to intense laser radiation. Knowledge about the influence of laser parameters like the spatial, temporal and spectral pulse structure on the plasma dynamics is essential for taylored laser machining applications. We present a method for observing the plasma dynamics in laser-excited thin gold foils using single-shot pump-probe coherent diffractive imaging. By employing a phase retrieval algorithm, we can reconstruct the 2D-spatial and time resolved complex transmission from recorded diffraction patterns. Our targets are 30 nm thick, free-standing gold foils that are excited by a focused femtosecond (fs)-800 nm pump pulse and subsequently imaged by a low intensity fs-400 nm pulse. The plasma dynamics are monitored on a time scale from 50 fs to 2 ns giving access to the ultrafast excitation (fs-ps regime) as well as the melting and ablation (ps-ns regime) dynamics.

MO 13.6 Wed 15:45 HS 1010

Extreme-UV microscopy at ultimate spatial and temporal scales — •Sergey Zayko[1], Hung-Tzu Chang[1], Ofer Kfir[2], Murat Sivis[1], and Claus Ropers[1] — [1]Department of Ultrafast Dynamics, Max-Planck-Institute for Multidisciplinary Sciences, 37077 Göttingen, Germany — [2]School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, 69978Tel Aviv, Israel

Future developments in logic and storage devices heavily rely on versatile research tools operating at the relevant spatio-temporal scales. In applied research fields such as spintronics and strongly correlated electronic materials, these extend into previously unreachable femtosecond-nanometer regimes [1]. In this work, we demonstrate an experimental advance towards such capabilities with femtosecond element-specific, spin-sensitive microscopy at ultimate spatio-temporal scales, achieving simultaneous 18 nm spatial and 35 fs temporal resolution. This allows for a close examination of ultrafast phenomena in real space, providing, deeper insights into the puzzles surrounding ultrafast spin dynamics in the presence of nanoscale magnetic domains [2]. By optimizing the experimental conditions for static imaging, we demonstrate real-space resolutions of 13.5 nm and 12.5 nm for spin and charge scattering, using probe wavelengths close to the m-edges of Co and Ni, respectively. These results from our compact high-harmonic based microscope establish a set of new benchmarks for photon-based imaging techniques.

[1] Zayko et al., Nat. Commun. 12, 6337 (2021)
[2] Koopmans et al., Nat. Materials 9, 259-265 (2010)

MO 13.7 Wed 16:00 HS 1010

Tracing attosecond electron emission from a nanometric metal tip — •Lennart Seiffert[1], Philip Dienstbier[2], Timo

Paschen[2], Andreas Liehl[3], Alfred Leitenstorfer[3], Thomas Fennel[1,4], and Peter Hommelhoff[2] — [1]University of Rostock — [2]University of Konstanz — [3]Friedrich-Alexander-Universität Erlangen-Nürnberg — [4]Max Born Institute Berlin

Solids exposed to intense electric fields release electrons through tunnelling. This fundamental quantum process lies at the heart of various applications such as petahertz vacuum electronics where electron wavepackets undergoe semiclassical dynamics in an intense laser field, similar to strong-field physics in the gas phase. Recently, we measured the subcycle-dynamics at solids, inclunding the duration of the emission time window [1] and the temporal width of the recolliding wavepacket [2]. Here I present how the suboptical-cycle strong-field emission dynamics from a metallic nanotip is uncovered via two-colour modulation spectroscopy [1,3], where energy spectra of emitted photoelectrons are measured as function of the relative phase between the colors. Projecting the solution of the time-dependent Schrödinger equation onto classical trajectories relates phase-dependent signatures in the spectra to the emission dynamics and yields an emission duration of 710 ± 30 attoseconds.

[1] P. Dienstbier et al., Nature 616, 702-706 (2023)
[2] H. Y. Kim et al., Nature 613, 662-666 (2023)
[3] L. Seiffert et al., J. Phys. B 51, 134001 (2018)

MO 13.8 Wed 16:15 HS 1010

Axially Polarized Photoelectrons in Strong-Field Ionization — •Pei-Lun He, Zhao-Han Zhang, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The spin effects in strong-field ionization induced by a linearly polarized laser field are investigated, demonstrating that the photoelectrons exhibit axial polarization relative to the laser polarization axis typically. While the total polarization vanishes upon averaging over the photoelectron momentum, significant momentum-resolved spin polarization is found. The polarization originates from the spin-orbit coupling in the bound state, establishing a correlation between the orbital angular momentum and the spin of the valence shell electron. Consequently, the correlation extends to the spin and the initial transverse velocity of the photoelectron at the tunnel exit. The electron trajectories are thus spin-dependent and are scattered into different directions upon recollisions, resulting in the entanglement of the angular distribution with the electron spin. Furthermore, the interference between direct and rescattered electrons leads to the feasibility of spin-polarized electron holography, offering structural information about the atom.