A 22: Attosecond Science

Time: Wednesday 14:30–16:30 Location: N 2

Invited Talk A 22.1 Wed 14:30 N 2

Electron correlation dynamics in weak and strong fields — •Christian Ott — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

This talk gives an overview of recent progress in the experimental investigation of correlated electron dynamics by means of all-optical absorption spectroscopy. Turning to the most fundamental system to investigate such processes, the helium atom with two active electrons, asymmetric Fano absorption line shapes are identified as a direct view into the multi-channel interaction of different two-electron configurations [1]. In response to few-cycle near-infrared laser fields of tunable strength, these channels can be selectively altered, which can be measured and understood as a change in the absorption profile [2]. This concept also enables the controlled steering of a two-electron wave packet [3], where the correlated position of both electrons with respect to the helium core can be reconstructed from theoretical calculation of the corresponding two-electron states. A new approach to correlated electron dynamics in solids is then gained with the discussion of recent experimental results on the ultrafast electronic phase transition in vanadium dioxide [4], which is investigated via attosecond transient absorption spectroscopy.

[1] U. Fano, Phys. Rev. 124, 1866 (1961).
[2] C. Ott et al., Science 340, 716 (2013).
[3] C. Ott et al., Nature 516, 374 (2014).
[4] M. F. Jager et al., manuscript in preparation (2016).

A 22.2 Wed 15:00 N 2

Attosecond spectroscopy using XUV-initiated high harmonic generation — •Michael Krüger[1], Doron Azoury[1], Gal Orenstein[1], Henrik R. Larsson[2], Sebastian Bauch[2], Barry D. Bruner[1], and Nirit Dudovich[1] — [1]Weizmann Institute of Science, 76100 Rehovot, Israel — [2]University of Kiel, D-20489 Kiel, Germany

In XUV-initiated high harmonic generation (XiHHG), tunneling ionization is replaced by photoionization with an attosecond XUV pulse [1,2]. The resulting electron wavepacket is driven by an IR laser field and recollides with the parent ion, leading to coherent frequency upconversion of the incoming XUV light. The emitted radiation carries the spectroscopic fingerprint of the full light-matter interaction. Here we demonstrate XiHHG in helium by irradiating the gas with XUV light at photon energies mostly below the atomic ionization threshold. We observe a strong dependence of the intensity of the generated XiHHG light on the temporal delay of XUV and IR. With the help of a strong-field model we are able to reconstruct the full quantum dynamics of the process and determine the initial electron wavepacket in amplitude and phase. Our approach combines the accuracy of high harmonic spectroscopy with the flexibility of XUV-IR pump-probe techniques and can address a wide range of ultrafast phenomena, e.g. inner-shell dynamics of complex molecules.

[1] K. Schafer et al., PRL 92, 023003 (2004).
[2] G. Gademann et al., NJP 13, 033002 (2011).

A 22.3 Wed 15:15 N 2

Attosecond Electron Scattering in Dielectrics — •L. Seiffert[1], Q. Liu[2,3], S. Zherebtsov[2,3], A. Trabattoni[4,5], P. Rupp[2,3], M. C. Castrovilli[6], M. Galli[4,6], F. Süssmann[2,3], K. Wintersperger[2], J. Stierle[2], G. Sansone[4,6], L. Poletto[6], F. Frassetto[6], I. Halfpap[7], V. Mondes[7], C. Graf[7], E. Rühl[7], F. Krausz[2,3], M. Nisoli[4,6], T. Fennel[1,8], F. Calegari[5,6,9], and M. Kling[2,3] — [1]Universität Rostock — [2]MPQ Garching — [3]LMU München — [4]Politecnico di Milano — [5]Center for Free-Electron Laser Science, DESY — [6]National Research Council of Italy — [7]FU Berlin — [8]MBI Berlin — [9]University of Hamburg

Scattering of electrons in dielectrics is at the heart of laser nanomachining, light-driven electronics, and radiation damage. Accurate theoretical predictions of the underlying dynamics require precise knowledge of the low-energy electron transport involving elastic and - even more important - inelastic collisions. Here, we demonstrate real-time access to electron scattering in isolated SiO_2 nanoparticles via attosecond streaking [1]. Utilizing semiclassical Monte-Carlo trajectory simulations [2,3] we identify that the presence of the field inside the dielectric cancels the influence of elastic scattering, enabling selective characterization of the inelastic scattering time [4].

[1] R. Kienberger et al., Nature 427, 817-821 (2004)
[2] F. Süßmann et al., Nat Commun. 6, 7944 (2015)
[3] L. Seiffert et al., Appl. Phys. B 122, 1-9 (2016)
[4] L. Seiffert et al., submitted

A 22.4 Wed 15:30 N 2

Localized High-Harmonic Generation in Semiconductor Nanostructures — •Murat Sivis[1,2], Marco Taucer[2], Kyle Johnston[2], Giulio Vampa[2], André Staudte[2], Andrei. Yu. Naumov[2], David. M. Villeneuve[2], Paul B. Corkum[2], and Claus Ropers[1] — [1]4th Physical Institute - Solids and Nanostructures, Georg-August University, Göttingen, Germany — [2]Joint Attosecond Science Laboratory, National Research Council of Canada and University of Ottawa, Ottawa, Canada.

High-harmonic generation (HHG) in solid-state systems, as recently demonstrated in semiconductors[1–3], enables the transfer of gas-phase attosecond spectroscopy techniques to condensed matter. In general, HHG is sensitive to the electronic structure of the generation medium and the local driving laser field. Both of these properties can be routinely tailored in solids by modifying the chemical composition and the microstructure. Here, we study HHG in nanostructured zinc oxide and silicon crystals. We use wavelength-selective microscopic imaging to characterize the harmonics (at 2 μm driving wavelength) and find enhanced emission in nanofabricated grating structures as well as in gallium-implanted patterns. Our results illustrate novel means to control HHG and to use the harmonic emission as a unique local probe to investigate structural, chemical or electronic dynamics in solid-state systems.

[1]S. Ghimire *et al.* Nat. Phys. **7**, 138-141 (2011).
[2]O. Schubert *et al.* Nat. Photon. **8**, 119-123 (2014).
[3]G. Vampa *et al.* Nature **522**, 462-464 (2015).

A 22.5 Wed 15:45 N 2

Time Delay in Photoionization with Light Carrying Orbital Angular Momentum — •Jonas Wätzel and Jamal Berakdar — Institut für Physik, Martin-Luther Universität Halle-Wittenberg, Karl-Freiherr-Von-Fritsch Str. 3, 06120 Halle (Saale)

The pioneering experiment of Schultze *et al.* on time delay in photoemission triggered substantial experimental and theoretical activities with the aim to understand and quantitatively reproduce the results of the measurements. Up to date various mechanisms and calculation techniques were put forward.

Here we add yet a qualitatively new aspect to this topic. I will present our recent research considering an atom irradiated by a twisted light beam, also called optical vortex. Such a beam carries orbital angular momentum (OAM) which can be transferred to an electron and is controllable by the topological charge. The use of an OAM XUV laser beams to trigger photoionization implies a complete new set of optical selection rules with the consequence that the optical transitions are tuneable by the choice of the beam topological charge.

I will present the analytical and numerical results for the atomic time delay of the photoionization process of the argon $3p$ subshell initiated by a twisted light XUV pulse demonstrating that in different asymptotic directions either the co-rotating electron (relative to the field) or the counter rotating electron dominates photoionization amplitude. Furthermore the corresponding time delays are completely different in magnitude and sign, and depend sensitively on the position of the atom in the laser beam spot.

A 22.6 Wed 16:00 N 2

Tunneling time in attosecond experiments, how to understand the measurement of time and the tunneling process in attosecond experiments. — •Ossama Kullie — Institute of Physic, University of Kassel, Germany

The measurement of the tunneling time (T-time) in today's attosecond and strong field (low-frequency) experiments, despite its controversial discussion, offers a fruitful opportunity to understand time measurement, and the importance issue of the theory of time, the time operator and the time-energy uncertainty relation in quantum mechanics. In [1] I derived an estimation and a relation of the (real) tunneling time, which shows an excellent agreement with the time measured in

attosecond experiments of the He atom case [2]. This tunneling model, and the experiment [2], offers a realization of the Bohr-Einstein photon box Gedanken experiment. This has an important consequence to the time operator [3]. Some models used to calculate the T-time will be also discussed in relation to my model, where I showed that the important question is a more general one: How to understand the time and the measurement of the time of a quantum system [4]. The tunneling process itself is still not well understood, but I am arguing that a scattering mechanism offers a possibility to understand the tunneling process in the tunneling region [5].

[1] O Kullie 2015, Phys. Rev. A 92 052118. [2] P Eckle et al 2008, Nat.phys. 4 565. [3] M. Bauer, arxiv1608.03492v1 (2016). [4] O Kullie 2016, J. Phys. B 49, 095601. [5] O Kullie (2016), J. Phys. B, submitted.

A 22.7 Wed 16:15 N 2

The ion microscope as a tool for quantitative measurements in the extreme ultraviolet — •Nikolaos Tsatrafyllis[1,2], Boris Bergues[3], Hartmut Schröder[3], László Veisz[3,4], Emmanouil Skantzakis[1], David Gray[1], Bálazs Bodi[1,5], Sergei Kühn[6], George Tsakiris[3], Dimitris Charalambidis[1,2,6], and Paraskevas Tzallas[1,6] — [1]Foundation for Research and Technology - Hellas, Institute of Electronic Structure & Laser, Heraklion (Crete), Greece — [2]Department of Physics, University of Crete, Heraklion (Crete), Greece — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany — [4]Department of Physics, Umea University, Umeå, Sweden — [5]Wigner Research Center for Physics, Budapest, Hungary — [6]ELI Attosecond Light Pulse Source, Szeged, Hungary

We demonstrate a tool for quantitative measurements in the extreme ultraviolet (EUV) spectral region measuring spatially resolved atomic ionization products at the focus of an EUV beam. The ionizing radiation is a comb of the 11th-15th harmonics of a Ti:Sapphire femtosecond laser beam produced in a Xenon gas jet. The spatial ion distribution at the focus of the harmonics is recorded using an ion microscope. Spatially resolved single- and two-photon ionization products of Argon and Helium are observed. From such ion distributions single- and two-photon generalized cross sections can be extracted by a self-calibrating method. The observation of spatially resolved two-EUV-photon ionization constitutes an initial step towards future single-shot temporal characterization of attosecond pulses.