# A 25: Attosecond physics

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

A 25.1 Wed 16:15 S Fobau Physik

**Tunneling time in attosecond experiments from time operator prespective** — •Ossama Kullie — Institute of Physics, Department of Mathematics and Natural Science, Universitity of Kassel, Germany

Using a semi classical model we found a tunneling time relation [1,2], which successfully calculates the tunneling (tunnel-ionization) time in attosecond experiment for He- and H-atom, with a good agreement with the experiment. The tunneling time in our model is real and can be interpreted as a delay time with respect to the ionization at atomic field strength, which marks the above-threshold ionization regime, where the ionization is classically allowed process. The model exploits the time-energy uncertainty relation without using an explicit time observable or time operator. The existence of such time operator is mathematically proven, however no unambiguous and generally accepted time operator is found so far, especially to calculate the tunneling time in attosecond experiment. In this work we discuss this issue, where our aim is to find a time operator, with which we can calculate the tunneling time given in [1,2] for He- and H-atom. [1] O. Kullie. (open access) Mathematics **6**, 00192 (2018). [2] O. Kullie, Annals of Physics **389** (2018) 333.

A 25.2 Wed 16:15 S Fobau Physik

**Mapping laser-driven electron dynamics by a time independent Hamiltonian** — •Soumi Dutta, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We study the dynamics of an electron after tunnel ionization in the presence of a strong elliptically polarized laser field. The motion of the electron in the presence of an oscillatory electric field can be described by a smooth trajectory in the Kramers Henneberger (KH) frame. In a series expansion of the time-averaged KH potential the zeroth-order contribution becomes dominant, implying a possible existence of a time independent potential governing the electron*s trajectory. We device a mapping from the KH initial conditions to reference initial conditions of simple Coulomb*s problem.

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A 25.5 Wed 16:15 S Fobau Physik

**Modeling time-resolved high-order harmonic generation in ZnO** — •Christian Hünecke[1], Thomas Lettau[2], Ulf Peschel[2], and Stefanie Gräfe[1] — [1]Institute for Physical Chemistry, Friedrich Schiller University Jena, Germany — [2]Institute for Solid State Theory and Optics, Friedrich Schiller University Jena, Germany

Recent pump-probe experiments with mid-infrared excitations in ZnO have provided evidence for a strong modulation of high-order harmonic spectra by optical phonons [1]. Motivated by these experiments, two approaches to theoretically describe such HHG spectra in the condensed phase are employed, which take into account the strong coupling of the phonons to the electronic degrees of freedom. On the one hand, we use a two-dimensional model system consisting of one electronic and one vibrational spatial degree of freedom, similarly to what is typically done in molecular strong-field physics, however with the difference of periodic boundary conditions for the electron. These results are compared with those obtained with a quasi-particle approach based on a numerical solution of the semiconductor Maxwell-Bloch equations, coupled to an optical phonon mode.

[1] R. Hollinger, V. Shumakova, A. Pugžlys, S. Khujanov, A. Baltuška, C. Spielmann, D. Kartashov, "High-order harmonic generation traces ultrafast coherent phonon dynamics in ZnO" Ultrafast Phenomena 2018, to be published in Eur. Phys. J. - Web of Conferences.

A 25.6 Wed 16:15 S Fobau Physik

**Trajectory control in XUV-initiated high-harmonic generation** — •Michael Krüger, Doron Azoury, Barry D. Bruner, and Nirit Dudovich — Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel

A major limitation of high-harmonic generation (HHG) is the fact that the strong driving laser field governs the entire generation process. XUV-initiated HHG replaces the tunnel ionization step in HHG by XUV-driven photoionization, overcoming this limitation [1]. Controlling the delay between an ionizing XUV field and a strong IR laser pulse determines the time instant when electrons are promoted to the continuum and undergo IR-driven recollision. Moreover, an additional second harmonic (SH) field breaks the symmetry of the system, probing the strong-field driven trajectories. In our study, we use the XUV and SH fields to fully control the HHG process, switching between long and short trajectories and achieving frequency tuning of the resulting harmonics. Moreover, we are able to directly observe a new class of trajectories, so-called “downhill” and “uphill” trajectories; here the excess energy of the photoelectron following XUV ionization leads to an extra momentum kick in the direction of the instantaneous IR field force (downhill) or against it (uphill). Our study bears the prospect of increasing the dimensionality of high-harmonic generation spectroscopy for probing complex systems and multi-electron effects.

[1] D. Azoury et al., Nature Communications 8, 1453 (2017).

A 25.7 Wed 16:15 S Fobau Physik

**Continuum dynamics of Helium in intense laser fields** — •Tobias Heldt, Paul Birk, Gergana D. Borisova, Maximilian Hartmann, Veit Stooss, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

We investigate electron dynamics in strong near-infrared laser fields on an attosecond time scale. Experimentally this is done by attosecond transient-absorption spectroscopy of different targets, e.g. on the benchmark-system helium.

In this work, we analyze which parameters modify observed features in the measured helium absorption spectrum close to and above the single ionization threshold. The helium atom is modelled in the single active electron and the dipole approximation on a discrete 1D grid. Its electron dynamics is examined by solving the time-dependent Schrödinger equation with an ab initio simulation taking into account the Coulomb potential and the laser field. We observe time-dependent electron dynamics below and above the ionization threshold on a subcycle time scale.

A 25.8 Wed 16:15 S Fobau Physik

**Effective Nonlinearity of Ionization Harmonics in Amorphous Solids** — •Benjamin Liewehr[1], Björn Kruse[1], Christian Peltz[1], Peter Jürgens[2], Anton Husakou[2], Mikhail Ivanov[2], Marc Vrakking[2], Alexandre Mermillod-Blondin[2], and Thomas Fennel[1,2] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, D-18051 Rostock — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2A, D-12489 Berlin

The notion of nonlinear optical phenomena in dielectric solids has been recently complemented by the physics of high-harmonic generation (HHG) [1], associated with interband recombination and Bloch oscillations in strong laser fields [2]. This picture, however, fails to explain recent measurements of the harmonic emission close to the damage threshold of amorphous wide-bandgap materials, as the subfemtosecond ejection dynamics of electrons has not been included so far. Using a rate equation based ionization-radiation model we show that the ionization current as well as the Brunel mechanism, known from gases [3], are also potential sources of low order harmonics in solids. We present an approach to discriminate the harmonics from ionization and Kerr-type contributions, by adapting the concept of nonlinear wave mixing and determine an effective nonlinearity order of the generating process.

[1] H. Liu et al., Nature Phys. **13**, 262 (2017)
[2] G. Vampa, et al. Nature **522**, 462 (2015)
[3] F. Brunel, J. Opt. Soc. Am. B **4**, 521 (1990)

A 25.9 Wed 16:15 S Fobau Physik

**Towards High-Harmonic Generation with a High-Repetition Rate laser for kinematically complete experiments** — •Farshad Shobeiry, Hemkumar Srinivas, Anne Harth, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, Heidelberg 69117

Attosecond time resolved measurements on atomic and molecular systems require an XUV-IR Pump-Probe scheme. This work involves the design and development of a new setup to generate attosecond pulses through High Harmonic Generation. A high repetition rate NIR laser source delivering pulses at 150 KHz, along with a novel target design is used to generate the XUV light. This beamline is used in combination with a Reaction Microscope (COLTRIMS), to provide a kinematically complete measurement of the atomic processes.