A 10: Interaction with strong or short laser pulses

Time: Tuesday 16:30–18:30 Location: P

A 10.1 Tue 16:30 P

Adiabatic models for the bicircular attoclock — •Paul Winter and Manfred Lein — Leibniz University Hannover

Using counter-rotating bicircular laser fields in an attoclock setup has some big advantages when studying ionization dynamics in strong fields: The field is quasilinear in the close temporal vicinity of the maximal electric field, where ionization is most probable, but nevertheless rescattering is avoided in contrast to purely linearly polarized fields.

The well-defined direction of the field at the ionization time enables us to look at orientation dependencies in the ionization of molecules. An important parameter range is the adiabatic limit, i.e. small Keldysh parameter $\gamma = \sqrt{2I_p}\frac{\omega}{E} \ll 1$. In this regime the ionization can be described by a two step model, where the electron travels classically after tunneling out. A crucial factor in these adiabatic models is the location of the exit point where the classical motion starts. The main observable is the attoclock shift of the electron final momentum due to the attractive Coulomb force towards the parent ion.

We compare two-dimensional simulations of the time-dependent Schrödinger equation for HeH^+ and H_2 to results from adiabatic models. A connection of the attoclock shifts to molecular properties such as dipole moment and polarizability arises due to the angle-dependent Stark shift of the ionisation potential.

A 10.2 Tue 16:30 P

Time operator, real tunneling in strong field interaction and the attoclok — •Ossama Kullie — Theoretical Physics, Institute of Physics, University of Kassel

In our work we found a relation to calculate the tunneling time in the attoclock experiment in both cases, the adiabatic and nonadiabatic field calibration [1,2]. Our real tunneling time can be derived from an observable, i.e. a time-energy ordinary commutation relation or a time operator. In addition, it is constructed from Fujiwara-Kobe time operator and the well-known Aharonov-Bohm time operator. The specific form of the time operator is not decisive and a dynamical time operator of a system refers to the intrinsic time of the system. The result contrasts the famous Pauli theorem, and confirms the fact that time is an observable, i.e. the existence of time operator and that the time is not a parameter in quantum mechanics. Furthermore, we discuss the relations with different types of tunneling times such as Eisenbud-Wigner time, dwell time and the statistically defined tunneling time. We conclude with the hotly debated interpretation of the attoclock measurement and the advantage of the real tunneling time picture [3,4]. [1] To be submitted. [2] O. kullie, PRA **92**, 052118 (2015). [3] O. Kullie, Ann. of Phys. **389**, 333 (2018). [4] O. Kullie, Qauntum report **02**, 233 (2020).

A 10.3 Tue 16:30 P

Non-sequential double ionization of Ne by elliptically polarized laser pulses — •Fang Liu[1,2,3], ZhangJin Chen[4], Birger Böning[1,2,3], and Stephan Fritzsche[1,2,3] — [1]Helmholtz Institute Jena, Jena, Germany — [2]FSU, Jena, Germany — [3]GSI, Darmstadt, Germany — [4]Shantou University, Shantou, China

We show through simulation that an improved quantitative rescattering model (QRS)[1] can successfully predict the nonsequential double ionization (NSDI) process by intense elliptically polarized laser pulses. Using the QRS model, we calculate the correlated two-electron and ion momentum distributions of NSDI of Ne exposed to intense elliptically polarized laser pulses with a wavelength of 788 nm at a peak intensity of 5.0×10^{14} W/cm^2. We analyze the asymmetry in the doubly charged ion momentum spectra that were observed by H. Kang *et al.*[2] in the transition from linearly to elliptically polarized laser pulses. Our model reproduces their experimental data well. In addition, we find that this ellipticity-dependent asymmetry is due to the drift velocity along the minor axis of the polarization ellipse. It is indicated that the correlated electron momentum distributions along the minor axis provide access to the subcycle dynamics of recollision and distinguish recollisions before and after the zero crossing of the field. Futhermore, our results demonstrate that the NSDI process can be driven by the elliptically polarized laser pulses.

[1]Z. Chen *et at.*, Phys. Rev. Lett. **79**, 033409 (2009).
[2]H. Kang *et at.*, Phys. Rev. Lett. **120**, 223204 (2018).

A 10.4 Tue 16:30 P

Accurate atomic states in the strong-field approximation with application to the Coulomb asymmetry — •Birger Böning[1,2] and Stephan Fritzsche[1,2,3] — [1]Helmholtz-Institut Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [3]Friedrich-Schiller-Universität, Jena, Germany

Strong-field ionization experiments are routinely performed with a variety of atomic targets. While such measurements play an important role for understanding light-matter interactions, theoretical models often treat the target atoms in a simplified manner and neglect most of their characteristic properties. Often major experimental findings are therefore only qualitatively understood. In particular, the angular distributions of photoelectrons in above-threshold ionization exhibit an asymmetry due to the Coulomb force between photoion and the field-dressed continuum electron if the process is driven by an elliptically polarized laser pulse. Here, we demonstrate how strong-field and atomic structure theories can be brought together to closely model such observations. More precisely, we combine a partial-wave representation of the so-called strong-field approximation with target-specific initial and continuum states from atomic many-body computations. We show that our implementation reproduces the Coulomb asymmetry for lithium, argon and xenon targets in agreement with experiment if a target-specific distorted-Volkov continuum is used for the active electron.

A 10.5 Tue 16:30 P

Modeling ultrafast plasma formation in dielectrics using FDTD — •Jonas Apportin, Christian Peltz, Benjamin Liewehr, Björn Kruse, and Thomas Fennel — Institute for Physics, Rostock, Germany

The Finite-Differences-Time-Domain (FDTD) method provides a real-time solution to Maxwell's equations on a spatial grid that can be easily extended by rate equations for e.g. ionization and is therefore optimally suited for the modeling of nonlinear laser-material interaction and plasma formation in dielectrics close to the damage threshold. The material response is modeled using nonlinear Lorentz oscillators for Kerr-type nonlinearities [1] and Brunel as well as injection currents associated with the excitation of electrons into the conduction band for higher order nonlinearities [2]. Along with strong field ionization, plasma formation is induced by impact ionization which is strongly dependent on the electron velocities. To avoid simulating the full electron velocity distributions required for the calculation of the impact ionization rates, we apply an effective rate equation model for the electron temperatures and drift velocities, by estimating equilibrium distributions. First simulation results for strong and ultrashort laser pulses tightly focused into thin fused silica films ($d \approx 10\mu m$) show the formation of a pronounced ionization grating.

[1] C. Varin et al., Comput. Phys. Commun. **222** 70-83 (2018)
[2] P. Jürgens et al., Nature Physics **160**, 1035-1039 (2020)

A 10.6 Tue 16:30 P

Theoretical description of relativistic tunnel ionization in highly charged ions by high intensity laser with the HILITE experiment — •Priyanka Prakash[1], Stefan Ringleb[1], Markus Kiffer[1], Nils Stallkamp[1,2], Bela Arndt[5], Axel Printschler[1], Sugam Kumar[6], Manuel Vogel[2], Wolfgang Quint[2,4], Thomas Stöhlker[1,2,3], and Gerhard G. Paulus[1,3] — [1]Friedrich-Schiller-Universität, Jena — [2]GSI Helmotzzentrum für Schwerionenforschung GmbH, Darmstadt — [3]Helmholtz Institute, Jena — [4]Ruprecht-Karls-Universität Heidelberg, Heidelberg — [5]Goethe Universität Frankfurt, Frankfurt — [6]Inter-University Accelerator Centre, New Delhi

With the HILITE (**H**igh-**I**ntensity **L**aser **I**on-**T**rap **E**xperiment) Penning trap we plan to investigate relativistic tunnel ionization with highly charged ions. High-intensity laser pulses of the order of $10^{19}\,\frac{W}{cm^2}$ from the JETI laser facility will be utilized. One of the resulting phenomena of high-intensity light-matter interaction is tunnel ionization, which is dominant at these parameters. We present related calculations for our setup from recent relativistic tunnel ionization theories. A comparison with results from the non-relativistic ADK theory is also made. The expected yields of ionizations is calculated considering the single-particle ionization rate and the overlap of the pulse with the ion cloud and the results of the theories are compared with each other.

A 10.7 Tue 16:30 P

Characterization of a Resonator for Non-Destructive Ion Detection — •Axel Printschler[1], Stefan Ringleb[1], Markus Kiffer[1], Nils Stallkamp[1,2], Bela Arndt[3], Priyanka Prakash[1], Sugam Kumar[4], Wolfgang Quint[2,5], Manuel Vogel[2], Gerhard Paulus[1,6], and Thomas Stöhlker[1,2,6] — [1]Friedrich-Schiller-Universität, Jena — [2]GSI Helmotzzentrum für Schwerionenforschung GmbH, Darmstadt — [3]Goethe Universität Frankfurt, Frankfurt — [4]Inter-University Accelerator Centre, New Delhi — [5]Ruprecht-Karls-Universität Heidelberg, Heidelberg — [6]Helmholtz Institute, Jena

Laser systems with intensities of the order of $10^{20}\,\frac{W}{cm^2}$ have electric fields that are similar to the electric fields in highly-charged ions which makes them interesting targets for laser experiments. HILITE (High Intensity Laser Ion Trap Experiment) supplies an ion target designed for the particular needs at different laser facilities.

To provide a well defined ion cloud, the ions should be as cool as possible. A common way to cool them to sub-meV energies is resistive cooling. A coil is connected in parallel to an electrode into which moving ions induce a current. When the motion frequency of the ions matches the resonance frequency of the resonator, this current is amplified resonantly, enabling efficient non-destructive detection. In resonance the ions transfer their energy to the resonantor and hence are cooled.

In order to increase the resonator's quality factor, a superconducting NbTi wire is used for the coil. We will present the assembly, properties and characterization measurements of the axial resonator.

A 10.8 Tue 16:30 P

Quantum mechanical aspects of high harmonic generation with Laguerre-Gaussian beams — •Shahram Panahiyan[1,2] and Frank Schlawin[1,2] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Center for Free Electron Laser Science, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

High harmonic generation has been intensively investigated for the past decades due to its fundamental and technological importance [1]. A recent study on the quantum nature of the high harmonic generation demonstrated the generation of Schrödinger cat states in the transmitted fundamental mode [2]. Given that light can carry both spin and orbital angular momentum [3], we study the quantum mechanical aspects of high harmonic generation with Laguerre-Gaussian beams. Specifically, we are interested in the role of orbital angular momentum and its interplay with spin angular momentum for the creation of optical "cat" and "kitten" states as well as modification from one to another one.

[1] K. Amini, et al., Rep. Prog. Phys., 82, 116001 (2019).
[2] M. Lewenstein et al., Nat. Phys., 17 1104 (2021).
[3] L. Allen, et al., Phys. Rev. A 45, 8185 (1992).

A 10.9 Tue 16:30 P

Impact of coherent phonon dynamics on high-order harmonic generation in solids — •Jinbin Li[1,2], Ulf Saalmann[2], Hongchuan Du[1], and Jan Michael Rost[2] — [1]School of Nuclear Science and Technology, Lanzhou University, Lanzhou, China — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We theoretically investigate the impact of coherent phonon dynamics on high-order harmonic generation (HHG), as recently measured [Hollinger et al., EPJ Web of Conferences 205, 02025 (2019)]. A method to calculate HHG in solids including phonon excitation is developed for a model solid. Within this model we calculate the signal of specific harmonics as a function of a pump-probe delay in the picosecond range. The characteristic behavior of the harmonic signal is traced back to underlying phonon dynamics.

A 10.10 Tue 16:30 P

Classical model for collisional delays in attosecond streaking at solids — •Elisabeth A. Herzig[1], Lennart Seiffert[1], and Thomas Fennel[1,2] — [1]Universität Rostock — [2]MBI Berlin

Scattering of electrons in solids is at the heart of laser nanomachining, light-driven electronics, and radiation damage. Accurate theoretical predictions of the underlying dynamics require precise knowledge of low-energy electron transport involving elastic and inelastic collisions. Recently, real-time access to electron scattering in dielectric nanoparticles via attosecond streaking has been reported [1,2]. Semiclassical transport simulations [3] enabled to identify that the presence of the field inside of a dielectric nanosphere cancels the influence of elastic scattering, enabling selective characterization of the inelastic scattering time [1]. However, so far a clear picture of the underlying physics was lacking. Here, we present an intuitive classical model for the prediction of collision-induced contributions to the delays in attosecond streaking at solids.

[1] L. Seiffert et al., Nat. Phys. 13, 766-770 (2017)
[2] Q. Liu et al., J. Opt. 20, 024002 (2018)
[3] F. Süßmann et al., Nat. Commun. 6, 7944 (2015)