A 10: Atomic systems in external fields

Time: Monday 14:00–16:00 Location: BEBEL E44/46

Invited Talk A 10.1 Mon 14:00 BEBEL E44/46

Coulomb effects and correlation in strong laser-driven quantum dynamics — •Dieter Bauer — Institut für Physik, Universität Rostock

The theoretical treatment of atoms or molecules in strong laser fields is mostly based either on the numerical solution of the time-dependent Schrödinger equation (TDSE) or the strong field approximation (SFA).

The full *ab initio* solution of the TDSE for atoms or molecules in intense, long-wavelength laser fields is limited, in full dimensionality, to, at most, two active electrons. Hence, many-body *ab initio* approaches beyond linear response are badly needed.

The SFA, when expressed in terms of quantum trajectories, provides maximum insight into laser-driven quantum dynamics, as all features in photoelectron or high harmonics spectra can be interpreted in terms of (interfering) quantum trajectories. However, the Coulomb force on the outgoing electron is neglected in the plain SFA, while there have been several effects identified recently that are due to that Coulomb force, examples being holographic side lobes in photoelectron spectra, the low-energy structure, or rotated photoelectron distributions.

In our presentation we will discuss approaches (i) to incorporate Coulomb corrections into the SFA and (ii) to the simulation of many-electron strong-field quantum dynamics without running into the "exponential wall" of solving the many-body TDSE.

A 10.2 Mon 14:30 BEBEL E44/46

Time-resolved Fano spectroscopy and control of laser-coupled doubly-excited states — •Andreas Kaldun, Christian Ott, Alexander Blättermann, Martin Laux, Kristina Meyer, Thomas Ding, Andreas Fischer, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The precise characterization of quantum states is at the heart of atomic and molecular physics. In absorption spectroscopy, different spectral line shapes arise by the interference of the system's dipole response with the incoming light. We here present and experimentally confirm a method to extract dynamical phase- and amplitude modifications of quantum states in laser coupled few-level systems on the example of the lowest doubly-excited states in helium atoms. These states are coherently excited by an attosecond-pulsed extreme-ultraviolet (XUV) field and coupled by a near-visible (VIS) laser pulse. A controlled time delay between the pulses results in small changes in the absorption line shapes of the doubly-excited states, resolved with a home-built high-resolution (20 meV) XUV spectrometer. The observed changes can be understood by considering a coupled four-level system in second order perturbation theory, giving experimental access to the created two-electron wave packet. From the experimental analysis of dipole amplitudes and phases as a function of time delay and intensity, we are able to separate different few-photon transition pathways. We find evidence for a coherent contribution of the N=2 continuum to the two-electron wave packet.

A 10.3 Mon 14:45 BEBEL E44/46

Sub-cycle control of photoelectron emission from metal clusters exposed to intense bichromatic laser pulses — •Dzmitry Komar[1], Johannes Passig[1], Sergei Zherebtsov[2], Robert Irsig[1], Mathias Arbeiter[1], Christian Peltz[1], Frederik Süssmann[2], Slawomir Skruszewicz[1], Matthias Kling[2], Thomas Fennel[1], Josef Tiggesbäumker[1], and Karl-Heinz Meiwes-Broer[1] — [1]Universität Rostock, Universitätsplatz 3, 18051 Rostock — [2]Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Collective electron motion induces strong polarization fields in metal clusters when exposed to intense optical pulses. Highly charged and energetic species are generated by resonant excitation of the cluster plasmon mode via an optimized pump-probe sequence. We conducted pump-probe experiments on nm-sized silver metal clusters applying bichromatic (ω-2ω) pulses of 10^{14} W/cm^2 to probe the nanoplasma. A field-free time of flight spectrometer allows to resolve energetic (up to 100 Up) electron emission in opposite directions along the laser polarization axis. By using the ω-2ω technique, the dependence of the directional emission with respect to phase differences between red and blue spectral parts of the probe pulse has been studied. Strong anisotropies of re-scattered electrons have been obtained allowing to control energetic electron emission on a sub-cycle time scale.

A 10.4 Mon 15:00 BEBEL E44/46

Imaging sub-wavelength optical near-fields of isolated nanosystems — •Lennart Seiffert[1], Frederik Süssmann[2], Sergey Zherebtsov[2], Matthias Kling[2], and Thomas Fennel[1] — [1]Universität Rostock, 18051 Rostock, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

A comprehensive understanding of optical near-field dynamics is key to realizing ultrafast light-wave control of electron motion on the nanoscale. Imaging the near-fields of isolated nanosystems offers fundamental insights into the sub-wavelength spatiotemporal field evolution but requires new, non-invasive metrology. Here we investigate for silica nanospheres to which extend phase-controlled electron backscattering [1] can be used as a probe for localized fields and their particle size-dependent propagation. The electron dynamics is modelled using a quasi-classical trajectory-based mean-field Monte-Carlo approach [2], which is extended to account for propagation effects of the near-fields. We show that characteristic spatial information on the resulting local enhancement of the near-field can be extracted from the angular-resolved photoemission recorded as function of the carrier-envelope-phase of the driving few-cycle laser field [3]. In particular, we study the emergence of sub-wavelength nanofocusing via the size-dependent deformation of the near-field distribution.

[1] S. Zherebtsov et al., Nature Phys. 7:656 (2011)
[2] S. Zherebtsov et al., New J. Phys. 14:075010 (2012)
[3] F. Süßmann et al., submitted (2013)

A 10.5 Mon 15:15 BEBEL E44/46

Solving time-dependent Schrödinger and Schrödinger-like equations on a Graphical Processing Unit — •Yaroslav Lutsyshyn and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Efficient numerical solvers for the time-dependent Schrödinger equation (TDSE) are necessary to simulate the interaction of atoms and molecules with high-intensity laser pulses on an ab-initio level. In fact, current capabilities of TDSE solvers are limited to only two active electrons in full dimensionality, and even to one for long wavelengths or very high intensities. This is because of the exceedingly large numerical grids required to capture the huge electron excursions in strong laser fields. We explore the acceleration of TDSE solvers with the help of graphical processing units (GPU). Propagation algorithms and parallelization schemes that are best suited for GPUs will be discussed. Results obtained in benchmark calculations of high-harmonic spectra and photoelectron spectra will be presented.

A 10.6 Mon 15:30 BEBEL E44/46

Beams made of twisted atoms: A theoretical analysis — •Armen Hayrapetyan[1], Oliver Matula[1,2], Andrey Surzhykov[3], and Stephan Fritzsche[3,4] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, 69120 Heidelberg, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [3]Helmholtz-Institut Jena, 07743 Jena, Germany — [4]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

We have analyzed Bessel beams of two-level atoms that are driven by a linearly polarized laser light. Based on the Schrödinger equation for two-level systems, we first determine the states of two-level atoms in a plane-wave field by taking into account propagation directions both of the atom and the field. For such laser-driven two-level atoms, we construct Bessel beams by going beyond the typical paraxial approximation. In particular, we show that the probability density of these atomic beams exhibits a non-trivial, Bessel-squared-type behavior. The profile of such twisted atoms is affected by atom and laser parameters, such as the nuclear charge, atom velocity, laser frequency, and propagation geometry of the atom and laser beams. Moreover, we spatially and temporally characterize the beam of hydrogen and selected (neutral) alkali-metal atoms that carry non-zero orbital angular momentum (OAM). The proposed spatiotemporal Bessel states (i) are able to describe twisted states of any two-level system which is driven by the radiation field and (ii) have potential applications in atomic

and nuclear processes as well as in quantum communication.

A 10.7 Mon 15:45 BEBEL E44/46

Observation of a stability island in the high energy (E > 0) region of the hydrogen atom in crossed electric and magnetic fields — •Frank Schweiner, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, 70550 Stuttgart, Germany

The spectra of the crossed fields hydrogen atom at energies slightly above the Stark saddle point are influenced by unstable periodic orbits surrounding the saddle point. Following those periodic orbits to very high energies far above E=0 we demonstrate that different types of bifurcations between the orbits appear. For specific values of the energy and field strengths the orbits become stable, which is related to the formation of a stability island in phase space. The bifurcation scenario is analyzed. The possible existence of narrow resonances obtained by semiclassical quantization of the stable orbits is discussed.