A 22: Poster: Interaction with strong or short laser pulses

Time: Tuesday 16:00–18:30 Location: Empore Lichthof

A 22.1 Tue 16:00 Empore Lichthof

Trap-Assisted Studies at High-Intensity Lasers — •Manuel Vogel[1,2], Wolfgang Quint[2,3], Gerhard Paulus[4,5], and Thomas Stöhlker[2,3,4] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt — [3]Physikalisches Institut, Ruprecht Karls-Universität Heidelberg, 69120 Heidelberg — [4]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, 07743 Jena — [5]Helmholtz-Institut Jena, 07743 Jena

We present a Penning trap experiment dedicated to studies with atomic and molecular ions in extreme laser fields. Within this experiment, trap-specific manipulation techniques allow control over the stored particles' localization and spatial density on a high level. It is possible to select and prepare well-defined particle ensembles and to control the laser-particle interaction. Non-destructive detection of reaction products with up to single-ion sensitivity supports advanced studies by maintaining the products for further studies at confinement times of minutes and above. Of particular interest for intial studies are nonlinear processes such as multiphoton ionization of atoms, singly-, and particularly highly-charged ions.

A 22.2 Tue 16:00 Empore Lichthof

Spin Dynamics in Tunnel Ionization — •Enderalp Yakaboylu[1], Michael Klaiber[1], Carsten Müller[2], Heiko Bauke[1], and Karen Z. Hatsagortsyan[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institut für Theoretische Physik I, Heinrich-Heine Universität Düsseldorf, Universitätsstrasse 1, 40225 Düsseldorf, Germany

Spin effects at above-threshold ionization of hydrogen-like highly-charged ions in a laser field are investigated. The spin-resolved ionization rates are calculated employing the relativistic standard strong-field approximation (SFA) and a modified Coulomb-corrected SFA. Analytical expressions for the spin-resolved ionization rates are obtained and the scaling laws for the spin asymmetry and spin-flip parameters are derived. An intuitive explanation for the spin effects is given. It is shown that the intuitive picture supports the results for the spin effects obtained in the modified Coulomb-corrected SFA where the impact of the laser field on the electron spin evolution in the bound state is taken into account.

A 22.3 Tue 16:00 Empore Lichthof

High-harmonic spectra of molecular hydrogen H_2 — •Johann Förster, Yulian V. Vanne, and Alejandro Saenz — Institut für Physik, Humboldt-Universität zu Berlin, Germany

High-harmonic spectra of molecules are of steadily growing interest. However, full-dimensional theoretical *ab-initio* high-harmonic spectra of even the simplest multi-electron molecule H_2 have (even for fixed nuclei) - to our knowledge - not yet been reported. The approach developed in our group [1-3] allows us to solve the time-dependent Schrödinger equation of the two-electron problem with a fixed internuclear distance in full dimensionality. This includes an arbitrary alignment of the molecule. Therefore, it is possible to examine how well widely used models work out in "reality" and how the expected structure (plateau, cutoff, etc.) is influenced by the use of spectral filters. We present high-harmonic spectra of H_2 generated by ultrashort linear polarized laser pulses for different orientations of the laser polarization with respect to the molecular axis. Effects like the minimum in the high-harmonic spectra of "two-dimensional H_2" [4] are thus reinvestigated in full dimensionality. Additionally, we compare our results with the ones obtained if we "turn on" the widely used single-active-electron approximation.

[1] Y.V. Vanne and A. Saenz, *J. Phys. B* **37**, 4101 (2004).
[2] Y.V. Vanne and A. Saenz, *J. Mod. Opt.* **55**, 2665 (2008).
[3] Y.V. Vanne and A. Saenz, *Phys. Rev. A* **82**, 011403(R) (2010).
[4] M. Lein *et al.*, *Phys. Rev. Lett.* **88**, 183903 (2002).

A 22.4 Tue 16:00 Empore Lichthof

Multiple Ionization of Fullerenes in Intense XFEL Pulses — •Abraham Camacho Garibay, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS Dresden, Germany

Ultra-intense ultra-short pulses, as provided from XFEL sources, allow the study of many-body dynamics in molecules and clusters. In the case of fullerenes, when irradiated by photons with energy well above the ionization threshold, many electrons are removed, creating a Coulombic potential in the fullerene. For the current state of intensities, we find that this process is carried on in a sequential fashion. Electron spectra differ qualitatively from low-intensity spectra as measured with synchrotrons. Emerging plateaus can be understand by means of simple model.

A 22.5 Tue 16:00 Empore Lichthof

Comparison of the carrier-envelope phase dependence of strong-field photoemission from atomic Xenon and a sharp metal tip — Lothar Maisenbacher[1], Dominik Hoff[2], •Michael Krüger[1], Michael Förster[1], A. Max Sayler[2], Gerhard G. Paulus[2], and Peter Hommelhoff[1,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching bei München — [2]Institut für Optik und Quantenelektronik and Helmholtz-Institut Jena, 07743 Jena — [3]Universität Erlangen-Nürnberg, 91058 Erlangen

The carrier-envelope phase (CEP) dependence of strong-field photoionization is a powerful tool to understand electron dynamics on ångström and attosecond scales. Recently, photoemission from metal nanotips has also been shown to be highly sensitive to the CEP [1]. The solid-state material response leads to a strongly enhanced near-field that is phase-shifted with respect to the incident field. So far, it was possible to assign the CEP only by comparison to theory. Here we present a direct comparison of the CEP dependence of photoemission from atomic Xenon and a metal nanotip employing a phase-tagging scheme [2]. We are able to characterize the full dielectric response of different nanotips for the first time, which is of high interest in the emerging field of nano-optics. Moreover, the nanotip represents an ideal electric field sensor due to its size. By scanning through the focal spot of a Gaussian beam it is possible to map out the spatial phase and intensity of such a beam.

[1] M. Krüger, M. Schenk, P. Hommelhoff, *Nature* **475**, 78 (2011).
[2] T. Rathje et al., *J. Phys. B: AMOP* **45**, 074003 (2012).

A 22.6 Tue 16:00 Empore Lichthof

Time evolution of the vacuum – pair production in high intensity laser fields — •Anton Wöllert, Heiko Bauke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Interaction between the vacuum and high intensity lasers will lead to new possibilities in high-field physics [1–2]. We present numerical ab initio studies for time evolution of the vacuum state into multiple pair states. The high intensity laser field of two counter-propagating beams is treated classically and in the non-perturbative regime ($E_0/\omega \sim 1$). In this regime, the time needed by an electron to become relativistic in presence of a static field E_0 is of same order as the period of the laser field. Pair state probabilities as well as correlations are investigated in real-time depending on polarization and field strength.

[1] The Extreme Light Infrastructure, http://www.extreme-light-infrastructure.eu
[2] A. Di Piazza *et al.*, Rev. Mod. Phys. **84**, 1177 (2012)

A 22.7 Tue 16:00 Empore Lichthof

Comparison of atomic photoelectron spectra obtained using the strong field and Coulomb-Volkov approximations with ab initio TDSE results — •Mohammad Adel Almajid and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

We investigate the agreement between photoelectron spectra for intense laser-atom interaction obtained using the strong field approximation (SFA) with or without Coulomb-Volkov approximation (CVA) and the results from the ab initio solution of the time-dependent Schrödinger equation (TDSE). In particular, we calculate the electron momentum distributions following strong-field ionization of atomic hydrogen by few-cycle, linearly polarized laser pulses. Within the plain-SFA the Coulomb potential is neglected after the emission of the photoelectron. A good agreement with the TDSE results is obtained only for the most energetic, rescattered photoelectrons whereas the low-energy part of the electron spectra differs significantly. For instance, the SFA is not able to reproduce the bouquet-shape patterns in the low-energy part of the photoelectron spectra, clearly visible in the TDSE results.

Within the CVA the influence of the Coulomb potential on the outgoing photoelectron is accounted for in an approximate manner. In the multiphoton regime, the low-energy part of the photoelectron spectra obtained in CVA is in good agreement with the TDSE results. However, the agreement deteriorates as the tunneling regime is approached.

A 22.8 Tue 16:00 Empore Lichthof

Dense Monoenergetic Proton Beams from Chirped Laser-Plasma Interaction — •Jianxing Li[1], Benjamin J. Galow[1], Yousef I. Salamin[1,2], Zoltán Harman[1,3], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69029 Heidelberg, Germany — [2]Department of Physics, American University of Sharjah, POB 26666, Sharjah, United Arab Emirates — [3]ExtreMe Matter Institute EMMI, Planckstrasse 1, 64291 Darmstadt, Germany

Interactions of linearly and radially polarized frequency-chirped laser pulses with single protons and hydrogen gas targets are studied analytically and by means of particle-in-cell simulations, respectively. The feasibility of generating ultraintense (10^7 particles per bunch) and phase-space collimated beams of protons is demonstrated. Phase synchronization of the protons and the laser field, guaranteed by the appropriate chirping of the laser pulse, allows the particles to gain sufficient kinetic energy (around 250 MeV) required for such applications as hadron cancer therapy, from state-of-the-art laser systems of intensities of the order of 10^{21} W/cm^2.

A 22.9 Tue 16:00 Empore Lichthof

Electron-Positron Pair Generation in a Bichromatic Laser Field — •Martin Josef Alexander Jansen and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

The creation of an electron-positron pair resulting from the collision of photons was first considered by Breit and Wheeler [1] and experimentally observed at SLAC [2]. We regard the case of a bichromatic laser field, where quantum inferences can be expected [3]. In our analysis, the generated particles are described by Volkov solutions of the corresponding Klein-Gordon Equation. We discuss effects related to the relative phase of the two fields as well as interference effects between different absorption channels.

[1] G. Breit and J.A. Wheeler, Phys. Rev. 46, 1087 (1934)
[2] D.L. Burke et al., Phys. Rev. Lett. 79, 1626 (1997)
[3] N.B. Narozhny and M.S. Fofanov, J. Exp. Theor. Phys. 90, 415 (2000)

A 22.10 Tue 16:00 Empore Lichthof

Kapitza-Dirac diffraction in a two-color laser field — •Matthias Maximilian Dellweg and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

The Kapitza-Dirac effect [1] is the diffraction of an electron beam on the periodic potential generated by a standing light wave. An experimental verification of the effect, as originally proposed, was accomplished only recently [2].

In this contribution, we study a generalization of the Kapitza-Dirac effect to the case of a bifrequent light field, where quantum interferences can be expected. To this end, we solve the Schrödinger equation numerically with a ponderomotive potential. Besides, a mathematical model in reduced dimensionality for the transition amplitude is presented. We demonstrate distinct interference signatures for various commensurate frequency ratios.

[1] P. L. Kapitza, P. A. M. Dirac, Proc. Cambridge Philos. Soc. **29**, 297-300 (1933)
[2] D. L. Freimund, K. Aflatooni, H. Batelaan, Nature **413**, 142-143 (2001)

A 22.11 Tue 16:00 Empore Lichthof

High-resolution electron momentum spectra for single ionization of atoms in strong laser fields for various wavelengths — •Lutz Fechner[1], Nicolas Camus[1], Andreas Krupp[1], Thomas Pfeifer[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Using a Reaction Microscope we studied single ionization of noble-gas atoms and small molecules in femtosecond laser pulses over a large range of intensities and wavelengths. By means of an optical parametric amplifier (OPA) that is pumped by 25 fs laser pulses (at 800 nm) we generate intense pulses ($> 10^{13}$ W/cm^2) with central wavelengths covering the range from 350 to 1300 nm. First results show unexpected and pronounced target specific features in the momentum distributions especially in the low energy region (up to 0.5 eV). The appearance of these "low-energy-rings" can be attributed to the decay highly excited states, which are populated during the laser pulse and autoionize long after. As a next step, and to further probe the dynamics of highly excited electronic states, we intend to perform two-color pump-probe experiments using the variable wavelength output of the OPA as a pump and the 800 nm pulse as probe (cf. poster A 159).

A 22.12 Tue 16:00 Empore Lichthof

Two-colour pump-probe experiments on single ionization of atoms in strong laser fields — •Andreas Krupp[1], Lutz Fechner[1], Nicolas Camus[1], Thomas Pfeifer[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

In order to study the ultra-fast dynamics of atoms and molecules we apply a two colour pump-probe scheme with intense ($> 10^{13}$ W/cm^2) 25 fs laser pulses. After splitting the output of an amplified laser system at 800 nm central wavelength we sent one part into an optical parametric amplifier (OPA) to generate pulses in the wavelength range of 350 to 1300 nm. With these we induce dynamics probed after variable time delays with the 800 nm pulses. A Reaction Microscope (REMI) provides us with kinematically complete data. Results obtained in experiments on noble gases with single pulses from the OPA showed unexpected and pronounced target specific features in the electron momentum distributions especially in the low energy region (cf. poster A 158). The new setup can help to uncover the dynamics underlying these features.

A 22.13 Tue 16:00 Empore Lichthof

Solving the Kohn-Sham equations for matter in high-intensity laser fields — •Volker Mosert and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

Solving for the many-body wave function of the interacting electrons via the time-dependent Schrödinger equation is prohibitive. Instead, in time-dependent density functional theory the problem is transformed to a set of one-particle, nonlinear Schrödinger-like equations, the time-dependent Kohn-Sham (KS) scheme. However, solving one-particle Schrödinger equations for strong-field interactions is still very demanding because large simulation volumes due to the extensive electron excursions are required. Pseudo potentials are commonly used in order to avoid dealing explicitly with inner electrons and the need to resolve the small spatial scale set by them. However, we found that a proper description of the inner electrons is essential to obtain, e.g., the correct ionization rate. Moreover, inner electrons are directly involved in the dynamics if the interaction with short-wavelength (e.g., FEL) radiation is to be simulated. We implement a method which can handle the large simulation volumes necessary for strong-field simulations without resorting to pseudo potentials. For this purpose we use an adaptive resolution strategy to handle the Coulomb potentials close to the ionic centers via a coordinate transformation in our finite difference approximation of the KS-Hamiltonian. An important goal of our work is high scalability with respect to the number of grid points. We show that the application of multi-grid techniques to the discretized KS equations leads to very good scaling properties.

A 22.14 Tue 16:00 Empore Lichthof

Combining a reaction microscope with a high repetition laser system — •Sascha Birkner, Federico Furch, Claus Peter Schulz, and Marc J.J. Vrakking — Max Born Institute, Max-Born-Str. 2a, 12489 Berlin, Germany

Strong field and attosecond induced electron dynamics and electron localisation in small molecules, e.g. H_2, have been studied in recent years [1,2]. In these experiments the energy and angular distribution of the ions from the laser induced dissociative ionisation have been measured. To study these type of photo induced reactions in more detail we have built a reaction microscope which enables experiments to measure the energy and angular distributions of ions and electrons in coincidence. Coincidence experiments typically have low data rates and thus require long data acquisition times. To overcome this problem we have combined our setup with a high repetition 400 kHz laser system delivering carrier envelope phase (CEP) stable sub-10 fs pulses with pulse energies up to 4 μJ. With tight focusing an intensity of

$> 10^{14}$ W/cm^2 can be reached. First data on strong field ionisation will be presented.

[1] M. F. Kling, *et al.*, Science **312**, 246 (2006).
[2] G. Sansone, *et al.*, Nature **465**, 763 (2010).

A 22.15 Tue 16:00 Empore Lichthof

Single shot scattering and ion spectroscopy of silver clusters — •Ramona Rothfischer[1], Tais Gorkhover[1], Leonie Flückiger[1], Daniela Rupp[1], Mario Sauppe[1], Ingo Barke[2], Stephan Bartling[2], Hannes Hartmann[2], Karl-Heinz Meiwes-Broer[2], and Thomas Möller[1] — [1]TU Berlin — [2]Universität Rostock

Cluster birdge the gap between atomic and condensed matter. As size scalable particles in the gas phase, they are ideal model systems for analyzing of the interaction of intense laser pulses with matter. A new type of experiments, simultaneous single cluster imaging and ion spectroscopy at free-electron lasers, gives access to processes and mechanisms of this interaction on different timescales[1]. A new setup with a combination of a light scattering detector and ion spectroscopy measurement was designed which uses a table-top picosecond-UV-laser system as light source. In first measurements on large silver clusters using only ion spectroscopy, charge states up to 5+ were observed and single particle ion spectra could be achieved. The setup will be discussed and first results will be presented.

[1] T. Gorkhover et al., Phys. Rev. Lett 108, 245005(2012)