A 41: Interaction with VUV and X-ray light II

Time: Thursday 14:00–16:00 Location: BEBEL E42

Invited Talk A 41.1 Thu 14:00 BEBEL E42

Quantum systems in ultra-strong lasers: from tunnel ionization to spin dynamics — •Heiko Bauke[1], Sven Ahrens[1], Michael Klaiber[1], Enderalp Yakaboylu[1], Karen Z. Hatsagortsyan[1], Carsten Müller[1,2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

We extend the well-known tunneling picture of a scalar tunneling barrier into the relativistic domain, that is where the laser's magnetic field becomes non-negligible and, therefore, requiring a non-zero vector potential. Going beyond the quasistatic WKB approximation and employing numerical methods allows us to identify two time scales of relativistic tunneling, the typical time that characterizes the probability density's decay of the ionizing electron under the barrier (Keldysh time) and the time interval which the electron spends inside the barrier (Eisenbud-Wigner-Smith tunneling time) [1]. Finally, we will consider spin effects in tunnel ionization [2] and demonstrate distinct spin dynamics in the relativistic Kapitza-Dirac effect [3] and for electrons moving in strong circularly polarized laser fields.

[1] Phys. Rev. Lett., **110**, 153004 (2013); E. Yakaboylu et al., arXiv:1309.0610; Proc. of SPIE, **8780**, 87801Q (2013)

[2] M. Klaiber et al., arXiv:1305.5379

[3] Phys. Rev. Lett. **109**, 043601 (2012); Phys. Rev. A, **88**, 012115 (2013).

A 41.2 Thu 14:30 BEBEL E42

Time-resolved spectroscopy and coherent control of autoionizing states in neon — •Thomas Ding, Christian Ott, Andreas Kaldun, Alexander Blättermann, Kristina Meyer, Martin Laux, Veit Stooss, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The understanding of few- or many-electron dynamics represents a central topic of modern quantum mechanics. Information about the concerted motion of two or more bound electrons in atoms is encoded in the spectral resonance line shapes. In the experiment presented here we achieved coherent control of short-lived (femtosecond-domain) auto-ionizing wave-packet dynamics in neon (Z=10). Our transient absorption scheme involves a two-color two-photon pump step to coherently populate both spectroscopically bright (odd parity) and dark states (even parity) at the same time. This makes use of weak broadband atto-second-pulsed light in the extreme ultraviolet (XUV) energy range to excite the system into various doubly- and inner-valence-excited states lying ~ 45 eV above the even-parity ground state. Moderately strong few-cycle near-infrared (NIR) pulses simultaneously facilitate the one-photon population transfer from those excited bright states to dark states. We study the initiated wave-packet oscillation under the influence of a time-delay-controlled and intensity-controlled replica of the NIR pump pulse inducing transient bright/dark level-couplings. This provides the opportunity to perform spectroscopy on dipole-forbidden states. Also, the method in principle allows to extract the coupling strength (dipole-matrix element) between quantum states.

A 41.3 Thu 14:45 BEBEL E42

Inelastic X-ray Scattering in Single Molecule Imaging with Free-Electron Lasers — •Jan Malte Slowik[1,2,3], Gopal Dixit[1,3], Sang-Kil Son[1,3], and Robin Santra[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

Imaging of the structure of bio-macromolecules with atomic resolution is essential to comprehend their function. Because many proteins do not form crystals, it would be enormously beneficial to be able to image single molecules. Free-electron lasers (FEL) offer an ideal tool to image nanocrystals and single-molecules with atomic resolution. The structural information is contained in the elastic x-ray scattering signal. However, in contrast to crystallography, in single molecule imaging there are no Bragg reflections, which means the elastic scattering is not enhanced. Because the usual scattering detectors cannot distinguish between elastically or inelastically scattered photons, the quality of the signal is attenuated by inelastic scattering. Here, we present a study of inelastic x-ray scattering under typical single molecule imaging conditions. We show the scattering spectrum as well as elastic and inelastic scattering probabilities, using the example of a carbon atom. Furthermore, we include the radiation damage caused by the highly intense FEL x-ray pulse by solving a rate equation model. In this way we obtain the elastic and inelastic scattering patterns of a carbon atom for different pulse durations and fluences.

A 41.4 Thu 15:00 BEBEL E42

Dominant secondary nuclear photoexcitation with the XFEL — •Jonas Gunst[1], Yuri A. Litvinov[2], Christoph H. Keitel[1], and Adriana Pálffy[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]GSI Helmholtzzentrum, Darmstadt

The highly brilliant photon beams provided by x–ray free electron lasers (XFEL) are expected to strongly advance the resonant driving of nuclei embedded in solid–state targets. Concurrently, the high electric field intensities may also generate new states of matter like cold, high density plasmas [1] where secondary nuclear excitation processes via the coupling to the atomic shell are rendered possible. Here, we investigate at the example of ^{93m}Mo isomer triggering the nuclear excitation by electron capture (NEEC) as secondary process in an XFEL scenario explicitly designed for direct photoexcitation.

In ^{93m}Mo triggering the isomeric energy of 2.4 MeV could be released via a 4.85 keV transition to an above lying level connected to freely radiating states. Our results prove that the triggering via NEEC is orders of magnitude higher than via direct photoexcitation mainly due to a higher cross section and an increased interaction time [2]. Moreover, due to the broad electron distribution in the plasma, the NEEC isomer activation is more robust against the fulfillment of the resonance condition. The latter can be essential for an experimental realization due to the present uncertainty of 80 eV in the ^{93m}Mo triggering transition.

[1] S. M. Vinko *et al.*, Nature **482**, 59 (2012)

[2] J. Gunst *et al.*, arXiv:1309.5835 (2013)

A 41.5 Thu 15:15 BEBEL E42

Small group velocities at large frequencies — •Kilian P. Heeg[1], Ralf Röhlsberger[2], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

We study the properties of x rays reflected from a thin-film cavity with embedded Moessbauer nuclei [1, 2] in the time domain. For a suitably chosen nuclear target, the phase imprinted on the field results in sub- or superluminal propagation of the x-ray light. The group delay can be controlled with external parameters such as the tilting angle of the cavity and its magnetization. Our calculations predict that temporal shifts of the pulses of order of several 10 ns are possible. We further propose a setup to measure this group delay based on existing instrumentation, and discuss a possible experimental implementation at a synchrotron light source.

[1] R. Röhlsberger et al, Science **328**, 1248–1251 (2010)

[2] K. P. Heeg et al, Phys. Rev. Lett. **111**, 073601 (2013)

A 41.6 Thu 15:30 BEBEL E42

Mössbauer meets Fano at x-ray energies: Controlled line shapes in cooperative emission from nuclei — Kilian P. Heeg[1], Christian Ott[1], Daniel Schumacher[2], Hans-Christian Wille[2], Ralf Röhlsberger[2], Thomas Pfeifer[1], and •Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Control of spectroscopic line shapes at hard x-ray energies is demonstrated in the reflectance of a thin film cavity with embedded Moessbauer nuclei. Tunable Fano interference between a spectrally broad cavity response and a narrow bound state nuclear contribution enables us to switch between Lorentz- and Fano-profiles [1, 2]. Spectroscopic signatures such as the cooperative Lamb shift and superradiant line broadening are extracted from the recorded asymmetric line shapes with high precision and agree excellently with our theoretical model [3]. Our results advance spectroscopy and precision metrology in the hard x-ray domain, and provide access to a multitude of applications linked to Fano interference.

[1] U. Fano, Phys. Rev. **124**, 1866–1878 (1961)
[2] C. Ott et al, Science **340**, 716–720 (2013)
[3] K. P. Heeg, and J. Evers, Phys. Rev. A **88**, 043828 (2013)

A 41.7 Thu 15:45 BEBEL E42

Polarization correlations in the Rayleigh scattering — •A. Surzhykov[1], V. Yerokhin[2], T. Jahrsetz[1], Th. Stöhlker[1,3,4], and S. Fritzsche[1,5] — [1]Helmholtz-Institut Jena, — [2]St. Petersburg State Polytechnical University — [3]GSI Helmholtzzentrum für Schwerionenforschung — [4]Institut für Optik und Quantenelektronik, Universität Jena — [5]Theoretisch-Physikalisches Institut, Universität Jena

Studies on the elastic Rayleigh scattering of photons by bound atomic electrons have a long tradition. Over the last decades, for example, a number of experimental and theoretical works have dealt with the total as well angle-differential cross sections. More recent investigations are focused on the linear polarization of the scattered photons. Of particular interest is the question of how this polarization is affected if the incident light is itself (linearly) polarized. In order to better understand such a *polarization transfer* between the incoming and outgoing photons, theoretical analysis has been performed by us based on the second-order perturbation approach [1]. Detailed calculations were carried out for Ne, Xe and U targets, and for photon energies up to ten times the $1s$ ionization threshold. Based on these calculations we found that the (degree) of linear polarization of scattered x-rays is generally significantly reduced comparing to the polarization of the incident light. Such a "depolarization" is mainly caused by the relativistic effects and non-dipole contributions to the electron-photon interaction and becomes most pronounced for the backward x-ray scattering.

[1] A. Surzhykov *et al.*, submitted to PRA.