A 10: Interaction with Strong or Short Laser Pulses I (joint session A/MO)

Time: Tuesday 11:00–13:00 Location: HS 1010

Invited Talk A 10.1 Tue 11:00 HS 1010

Strong-field coherent control in the extreme ultraviolet domain — •F. Richter[1], U. Saalmann[2], M. Wollenhaupt[3], E. Allaria[4], C. Callegari[4], M. Danailov[4], L. Gianessi[4], M. Zangrando[4], and L. Bruder[1] — [1]Institute of Physics, University of Freiburg — [2]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [3]Institute of Physics, University of Oldenburg — [4]Elettra - Sincrotrone Trieste S.C.p.A., Trieste, Italy

Coherent control drew a lot of interest in recent years spanning over various fields of research regarding the promising abilities for quantum computing and precision measurements. Coherent control extended to the strong-field regime is particularly promising for the manipulation of matter and the control of photochemical reactions. In this work, we develop a scheme to extend strong-field coherent control to the XUV domain. With intense XUV pulses, we induce Rabi oscillations in atoms, leading to Autler-Townes level splittings in the photoelectron spectra [1]. In the near infrared domain, the feasibility to coherently control the population of the Autler-Townes doublet has been shown, based on chirp manipulation of the laser pulses [2,3]. To establish comparable schemes in the XUV domain, we implement chirp control of the XUV pulses from the free electron laser FERMI. By manipulating the chirp of the XUV pulses in a controlled way, we demonstrate strong-field coherent control of Autler-Townes states in the XUV domain.

[1] S. Nandi et al. Nature 608, 488*493 (2022). [2] M. Wollenhaupt et al., Appl. Phys. B 82, 183*188 (2006). [3] U. Saalmann et al., Phys. Rev. Lett. 121, 153203 (2018).

A 10.2 Tue 11:30 HS 1010

Intra-cavity photoelectron tomography and pulsed standing waves at 100 MHz repetition rate — •Jan-Hendrik Oelmann, Tobias Heldt, Lennart Guth, Nick Lackmann, Lukas Matt, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

To get access to multiphoton ionization studies at high laser intensities ($\sim 10^{13}\,\mathrm{W/cm^2}$) while maintaining the high 100 MHz repetition rate of the driving frequency comb, we have recently developed a novel polarization-insensitive enhancement cavity with an integrated velocity-map imaging (VMI) spectrometer [1, 2]. Polarization-controlled pulse pairs with a variable time delay allow pump-probe experiments. With this polarization control but in single-pulse operation, we were able to tomographically reconstruct 3D photoelectron angular distributions [3] from xenon MPI at 100 MHz repetition rate, revealing resonant Rydberg states during ionization.

Now, we use counter-propagating pulses colliding at the focus to generate intense femtosecond standing waves in the cavity. We probe the phase of these at the nanometer scale using photoemission from a tungsten nanotip. Colliding pulses offer the dual advantage of enabling Doppler-free excitation schemes and of reducing the interaction volume at the focus.

[1] J.-H. Oelmann *et al.*, Rev. Sci. Instrum., 93(12), 123303 (2022). [2] J. Nauta *et al.*, Opt. Lett. 45(8), 2156 (2020). [3] M. Wollenhaupt *et al.*, Appl. Phys. B 95(4), 647-651 (2009).

A 10.3 Tue 11:45 HS 1010

Reconstruction of Three Dimensional Molecular Density from XFEL Scattering Images using Machine Learning — •Siddhartha Poddar, Ulf Saalmann, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems

As the three-dimensional electron density profile recovery technique for a single macro-molecule from a large dataset of coherent diffraction images generated using an X-ray free-electron laser, I have applied an unsupervised machine learning algorithm namely Generative Adversarial Network (GAN). It learns to mimic the high-dimensional distribution of given images by generating its own 'fake' distribution of images with the help of a deep convolutional neural network called the discriminator which distinguishes samples drawn from the original and fake distributions. To generate samples for this fake distribution of images, GAN creates and constantly modifies a three-dimensional structure. This structure is claimed to be unique and an equivalent version of the target electronic density profile of the molecule.

A 10.4 Tue 12:00 HS 1010

Retrieval of the time-dependent bond length in a molecule from photoelectron momentum distributions using deep learning — •Nikolay Shvetsov-Shilovskiy and Manfred Lein — Leibniz Universität Hannover

We apply a convolutional neural network (CNN) to photoelectron momentum distributions produced by strong-field ionization in order to retrieve the time-varying bond length in the dissociating two-dimensional H_2^+ molecule. We consider the pump-probe scheme and treat the motion of the atomic nuclei either classically, semiclassically, or quantum mechanically. In all these cases, the CNN trained on momentum distributions with fixed internuclear distances [1] predicts the time-dependent bond length with a good accuracy. We investigate whether the neural network can also simultaneously retrieve both the internuclear distance and the velocity with which it increases. Therefore, our results show that deep learning can be used not only for static, but also for dynamic molecular imaging.

[1] N. I. Shvetsov-Shilovski and M. Lein, Phys. Rev. A 105 L021102 (2022).

A 10.5 Tue 12:15 HS 1010

Shaped free electron vortices — •Darius Köhnke, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky university Oldenburg, Institute of Physics, Germany

Since their first theoretical proposal [1] and their experimental demonstration [2], free electron vortices have attracted significant attention. Very recently, a novel category of electron spirals, termed "reversible electron spirals" [3], was introduced. Departing from the conventional approach of employing a constant delay between two subpulses, two chirped subpulses were used. Building on this concept, we introduce tailored free electron vortices in multiphoton ionization (MPI) using two subpulses with circular polarization of opposite handedness, modulated by non-trivial spectral phase functions. Through the utilization of different MPI pathways, the quantum system multiplexes the fields of the subpulses, generating multiple complex spectral phases. These spectral phases are encoded in continuum states characterized by different magnetic quantum numbers. The interference of these continuum states gives rise to multiple interferograms of different symmetry that are multiplexed into a single 3D photoelectron momentum distribution. To demultiplex these interferograms and extract the encoded spectral phases, we perform photoelectron tomography and employ Fourier analysis on the measured wave packet. This approach enables the retrieval of spectral information, both from the input laser fields and signatures of the ionization process, embedded within the interferograms. [1] Phys. Rev. Lett. 115, 113004 (2015), [2] Phys. Rev. Lett. 118, 053003 (2017), [3] Phys. Rev. A 106, 043110 (2022)

A 10.6 Tue 12:30 HS 1010

Coherent control of 6Li multiphoton ionization by a bichromatic laser field — •Silva Mezinska[1], Klaus Bartschat[2], Thomas Pfeifer[1], and Alexander Dorn[1] — [1]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [2]Drake University, Des Moines, Iowa, USA

This work presents a coherent 6Li multiphoton ionization control by a bichromatic laser field at 780/390 nm. In particular, we demonstrate a control of the left-right asymmetry of the photoelectron angular distributions with respect to the plane orthogonal to the laser polarization direction with a subwavelength accuracy. In addition, we also consider a delay scan between the two harmonics extending between the second-harmonic pulse advancing the fundamental pulse and vice versa. Here, we study the delay-dependent features of the photoelectron spectra when the two harmonics are temporally overlapping and non-overlapping. All the experimental results are compared with calculations based on the solution of the time-dependent Schrödinger equation in the single-active electron approximation.

A 10.7 Tue 12:45 HS 1010

Nonspreading relativistic electron wavepacket in a strong laser field — •Andre G. Campos, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics

A solution of the Dirac equation in a strong laser field presenting a nonspreading wave packet in the rest frame of the electron is derived.

It consists of a generalization of the self-accelerating free electron wave packet [Kaminer et al. Nature Phys. 11, 261 (2015)] to the case with the background of a strong laser field. Built upon the notion of non-spreading for an extended relativistic wavepacket, the concept of Born rigidity for accelerated motion in relativity is the key ingredient of the solution. At its core, the solution comes from the connection between the self-accelerated free electron wave packet and the eigenstate of a Dirac electron in a constant and homogeneous gravitational field via the equivalence principle. The solution is an essential step towards the realization of the laser-driven relativistic collider [Meuren et al. PRL 114, 143201 (2015)], where the large spreading of a common Gaussian wave packet during the excursion in a strong laser field strongly limits the expectable yields.