A 18: Attosecond Physics II / Interaction with VUV and X-ray Light (joint session A/MO)

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

Invited Talk A 18.1 Wed 11:00 HS 1010

Attosecond photoionization dynamics in CO_2 using coincidence spectroscopy — •Ioannis Makos[1], David Busto[1,2], Dominik Ertel[1], Jakub Benda[3], Barbara Merzuk1[1], Fabio Frassetto[4], Luca Poletto[4], Claus Dieter Schröter[5], Thomas Pfeifer[5], Zdeněk Mašín[3], Serguei Patchkovskii[6], and Giuseppe Sansone[1] — [1]Albert-Ludwigs-Universität Freiburg, Germany — [2]Lund University, Sweden — [3]Charles University, Prague, Czech Republic — [4]IFN-CNR, Padova, Italy — [5]MPIK, Heidelberg, Germany — [6]MBI, Berlin, Germany

Attosecond photoelectron interferometry is used to investigate molecular dynamics upon photoionization, revealing electron correlation effects and electron-nuclear motions interplay. Combining two-color interferometric methods with photoelectron-photoion coincidence spectroscopy enables angle-resolved studies in the recoil frame, providing insights into molecular potential anisotropy. In our study, we investigate carbon dioxide photoionization dynamics using attosecond coincidence spectroscopy. Absorption of an extreme ultraviolet photon, provided by an attosecond pulse train, leads to a superposition of cationic states, coupled to the photoelectron wave packet. Additional infrared photon absorption or emission forms a two-color photoelectron spectrogram. Our work presents CO_2 photoionization time delays, considering the impact of field-induced coupling of ionization channels. Furthermore, we show time-resolved photoelectron angular distributions in the recoil frame by measuring ejected electrons in coincidence with O^+ dissociation fragments.

A 18.2 Wed 11:30 HS 1010

Investigation of Correlated Electronic Dynamics by Nonlinear Attosecond Spectroscopy — •Samuel Kellerer[1], Ioannis Makos[1], Dominik Schomas[1], David Busto[2], Dominik Ertel[1], Robert Moshammer[3], Claus Dieter Schröter[3], Thomas Pfeifer[3], Arjun Nayak[4], Debobrata Rajak[4], Naveed Ahmed[4], Sourin Mukhopadhyay[4], Tamás Csizmadia[4], Balázs Nagyillés[4], Zsolt Divéki[4], Katalin Varjú[4], Jörn Adamczewski-Musch[5], Fabio Frassetto[6], Luca Poletto[6], Paraskevas Tzallas[7], Dimitris Charalambidis[7], and Giuseppe Sansone[1] — [1]Uni Freiburg — [2]Uni Lund — [3]MPIK Heidelberg — [4]ELI ALPS Szeged — [5]GSI Darmstadt — [6]CNR-IFN Padova — [7]IESL-FORTH Hellas

The investigation of ultrafast processes like electronic dynamics in small quantum systems demands for generation and control of laser pulses with durations comparable or even shorter than the timescale of the investigated processes. Combining an attosecond source and a photoelectron/photoion coincidence spectrometer offers the possibility to investigate in detail the photoionization process, returning information on the role played by electronic correlation in multiple ionization of atoms. Despite its conceptual simplicity, the study of the two-photon double-ionization process in helium presents formidable experimental challenges, which we plan to address using the intense attosecond pulses provided by the SYLOS laser system available at ELI ALPS. We will present the attosecond beamline and the photoelectron/photoion apparatus used as an end-station for coincidence spectroscopy as well as first results.

A 18.3 Wed 11:45 HS 1010

Extracting relative dipole moments from a laser-driven two-electron wave packet in helium by combining attosecond streaking and transient absorption spectroscopy — •Shuyuan Hu, Yu He, Gergana D. Borisova, Maximilian Hartmann, Paul Birk, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, 69117 Heidelberg

The electronic structure of atoms and their interaction with light is reflected in complex-valued transition-matrix elements that have a magnitude and phase. In this work, a state-resolved phase of the time-delay dependent modulation of absorption is used to determine the relative signs of transition dipole matrix elements. This measurement relies on precise absolute calibration of the time-delay information, which is achieved by combining attosecond transient absorption and attosecond streaking spectroscopy to simultaneously measure the resonant photoabsorption spectra of laser-coupled doubly excited states in helium, together with the streaked photoelectron spectra. The streaking measurement reveals the absolute time delay zero and the full temporal profile of the interacting electric fields which is then used for a time-dependent few-level simulation of the relevant states. By comparing the 1-fs time-scale modulations across the $2s2p$ (^1P) and $sp_{2,3+}$ (^1P) states between the time-delay calibrated simulation and measurement, we quantify the signs of the transition dipole matrix elements for the laser-coupled autoionizing states $2s2p$-$2p^2$ and $2p^2$-$sp_{2,3+}$ to be opposite of each other.

A 18.4 Wed 12:00 HS 1010

Driving the high harmonic process using a multi-pass cell — •Benjamin Steiner[1], Dominik Ertel[1], Dennis Groschupf[1], Anne-Lise Viotti[2], Mario Niebuhr[1], Barbara Merzuk[1], David Busto[1,2], Ioannis Makos[1], and Giuseppe Sansone[1] — [1]Institute of Physics, University of Freiburg, Freiburg, Germany — [2]Division of Atomic Physics, Lund University, Sweden

The investigation of electronic-correlation driven processes, such as the Auger decay in krypton [1] or single-photon double-ionisation in helium [2], requires photon energies of 100 eV or higher. Using electron-electron-ion coincidence and attosecond pulses in the XUV spectral range obtained by high-order harmonic generation (HHG), these processes can be resolved in time in a pump-probe scheme. The first challenge is to demonstrate an attosecond source operating at high repetition rates (>50kHz) characterised by a cut-off energy well above 100 eV. For this purpose, we developed a temporal pulse compression scheme based on a gas-filled multi-pass cell for high-power throughput driven by a commercially available Yb-based laser system. The achieved pulses lead to high enough peak intensities for driving the HHG process in neon efficiently, maintaining a sufficient photon flux in the desired energy range. The generated attosecond XUV pulses will then be employed in the already existing attosecond coincidence spectrometer in Freiburg [3] for time-resolved investigations of electron dynamics occurring during the above-mentioned processes.

[1] M. Drescher et al, Nature, 419 (2002) [2] C. Ott et al, Nature, 516 (2014) [3] D. Ertel et al, Rev. Sci. Instrum. 94, 073001(2023)

A 18.5 Wed 12:15 HS 1010

Polarization dependence of high-order harmonic generation in the direct measurement of optical waveforms — •Ronak Narendra Shah[1], Jahanzeb Muhammad[1], Ianina Kosse[1], Samuel Bengtsson[2], Riccardo Mori[1], Mario Niebuhr[1], Fabio Frassetto[3], Luca Poletto[3], and Giuseppe Sansone[1] — [1]Physikalisches Institut, Albert-Ludwigs Universitaet Freiburg, Freiburg, 79104, Germany — [2]Department of Physics, Lund University, PO Box 118, SE-221 00 Lund, Sweden — [3]Istituto di Fotonica e Nanotecnologie, CNR, Padova, Italy

We present the polarization effects in an all-optical technique to measure the electric field of a few cycle laser pulse via high harmonic generation (HHG). In our approach, the generation of an isolated attosecond pulse (IAP) and the associated photon yield serves as an ultrashort temporal gate to characterize the electric field of a weak perturbing unknown pulse. Changing the polarization of the unknown laser pulse from parallel to orthogonal polarization with respect to the pulse generating IAP, we report the modulation in the harmonic yield at twice the laser period. The experimental results are in good agreement with simulations based on the strong-field approximations.

A 18.6 Wed 12:30 HS 1010

Towards AI-enhanced online-characterization of ultrashort X-ray free-electron laser pulses — •Thorsten Otto[1,2,4], Kristina Dingel[2], Lars Funke[3], Sara Savio[3], Lasse Wülfing[3], Bernhard Sick[2], Wolfram Helml[3], and Markus Ilchen[4] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]Intelligent Embedded Systems, University of Kassel, Wilhelmshöher Allee 73, 34121 Kassel, Germany — [3]Technische Universität Dortmund, Fakultät für Physik, Maria-Göppert-Mayer-Straße, 44227 Dortmund, Germany — [4]Universität Hamburg, Institut für Experimentalphysik, Luruper Chaussee 149 22761 Hamburg

X-ray free-electron lasers provide ultrashort X-ray pulses with durations typically in the order of femtoseconds, but recently even entering the attosecond regime. The technological evolution of XFELs towards well-controllable light sources for precise metrology of ultrafast pro-

cesses can only be achieved using new diagnostic capabilities for characterizing X-ray pulses at the attosecond frontier. The spectroscopic technique of photoelectron angular streaking has successfully proven how to non-destructively retrieve the exact time-energy structure of XFEL pulses on a single-shot basis. By using deep learning algorithms, we show how this technique can be leveraged from its proof-of-principle stage towards routine diagnostics at XFELs providing precise feedback in real time.

A 18.7 Wed 12:45 HS 1010

Angular Streaking at 1030 nm – measurement of gigawatt-power attosecond pulses at European XFEL — •Lars Funke[1], Sara Savio[1], Lasse Wülfing[1], Niclas Wieland[1], Kristina Dingel[4], Torsten Otto[2], Ruda Hindriksson[4], Lutz Marder[4], Christopher Passow[2], Rebecca Boll[3], Alberto De Fanis[3], Simon Dold[3], Tommaso Mazza[3], Dirk Raiser[3], Michael Meyer[3], Terence Mullins[3], Markus Ilchen[5], and Wolfram Helml[1] — [1]Technische Universität Dortmund, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]European XFEL GmbH, Schenefeld, Germany — [4]Universität Kassel, Germany — [5]Universität Hamburg, Germany

Angular Streaking can be used as a method for characterizing ultrashort X-ray pulses by overlapping the pulse with a circularly polarized IR laser pulse in a gaseous target. Photoelectron momenta are shifted in a characteristic way for a given spectro-temporal X-ray pulse structure. Measuring the photoelectron energy spectra with multiple time-of-flight spectrometers allows the reconstruction of pulse structure.

A *Cookiebox*-type photoelectron spectrometer array was set up at the SQS instrument of European XFEL to characterize specially tuned sub-femtosecond soft X-ray FEL pulses.

In the measurement, we found intense attosecond X-ray pulses, with pulse durations on the order of 300 as and a peak power in the hundreds of gigawatts. The lower-than-planned streaking laser wavelength of 1030 nm turned out beneficial for characterizing the ultrashort pulses provided.