A 2: Attosecond Physics I (joint session A/MO)

Time: Monday 11:00–13:00 Location: HS 1098

A 2.1 Mon 11:00 HS 1098

Ultrafast photoelectron spectroscopy with odd and even high-order harmonics — •Marvin Schmoll[1], Barbara Merzuk[1], Samuel Discher[1], Dominik Ertel[1], Ioannis Makos[1], Claus D. Schröter[2], Thomas Pfeifer[2], Robert Moshammer[2], Luca Poletto[3], Fabio Frassetto[3], and Giuseppe Sansone[1] — [1]Universität Freiburg, Physikalisches Institut, Freiburg, Germany — [2]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [3]CNR-Institute of Photonics and Nanotechnologies, Padova, Italy

High-order harmonic generation (HHG) in noble gases produces odd harmonics of the driving field. Adding a weaker second harmonic one can break the underlying symmetry and achieve both odd and even high-order harmonics.

We present an implementation of a collinear setup for such two-color HHG similar to what was first presented in ref. [1], which allows to adjust the relative phase between the fundamental and second harmonic component. Being implemented in combination with a collinear beamline for XUV-IR interferometry [2] we can perform high stability ultrafast photoelectron spectroscopy using these high order harmonics.

Our first results using Argon as a target gas show the viability of the method by demonstrating delay-dependent oscillations in the photoelectron yield for specific energies. These exhibit a period equal to that of the fundamental driving field as opposed to twice that period, which is known from experiments with odd orders only.

[1] N. Dudovich et al., Nature Phys. 2, 781 (2006)
[2] D. Ertel et al., Rev. Sci. Instrum. 94, 073001 (2023)

A 2.2 Mon 11:15 HS 1098

Extreme ultraviolet wave packet interferometry using table-top high harmonic generation — •Sarang Dev Ganeshamandiram, Fabian Richter, Ianina Kosse, Ronak Shah, Mario Niebuhr, Giuseppe Sansone, Frank Stienkemeier, and Lukas Bruder — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

Quantum interference techniques such as wave packet interferometry (WPI) in the extreme ultraviolet (XUV) domain set the basis for establishing advanced nonlinear spectroscopy methods in this wavelength regime [1]. These methods are however very difficult to implement at short wavelengths due to the required high phase stability and sensitivity. We are exploring methods based on acousto-optical phase modulation (PM) to solve these problems. First results from applications in seeded FELs and table-top high-harmonic generation (HHG) are promising [2,3]. Here, we will present an interferometer setup specifically designed for application with table-top HHG and discuss current challenges.

[1] S. Mukamel, et al., Multidimensional Attosecond Resonant X-Ray Spectroscopy of Molecules: Lessons from the Optical Regime, Annu. Rev. Phys. Chem. 64, 101 (2013).
[2] A. Wituschek, et al., Tracking attosecond electronic coherences using phase-manipulated extreme ultraviolet pulses, Nat Commun 11, 883 (2020).
[3] A. Wituschek et al., Phase cycling of extreme ultraviolet pulse sequences generated in rare gases, New J. Phys. 22, 092001 (2020).

A 2.3 Mon 11:30 HS 1098

Controlling Photoabsorption Interferometrically with Intense Laser Pulses from Microscopic to Macroscopic Gases — •Yu He[1], Shuyuan Hu[1], Gergana D. Borisova[1], Yizhu Zhang[1,3], Marc Rebholz[1], Mette B. Gaarde[2], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Louisiana State University, Baton Rouge, USA — [3]Tianjin University, Tianjin, China

Photoabsorption results from the interference between the incident field and the newly generated one radiated by the induced dipole oscillation. This dipole-emitted field can be controlled by the interplay of pulse propagation and intense laser pulses, giving rise to different absorption lineshapes. By temporally confining this new field through emptying the population of the excited state after its excitation, we achieve a local enhancement of absorbance in transient absorption spectroscopy [1,2]. In addition, in tandem with theory, we experimentally demonstrate the transition of absorption profiles from natural Lorentzian to Fano-like, which then become broader with further emergence of spectral bifurcations, finally turning back to near-Lorentzian lines in optically dense helium [3]. The integrated interferometric scenario in ultrafast absorption spectroscopy provides insights into the behavior of ensembles of dipole emitters and their temporal control.

Refs: [1] He at al., Phys. Rev. Lett. 129 273201 (2022). [2] He at al., manuscript submitted (2023). [3] He at al., manuscript in preparation.

A 2.4 Mon 11:45 HS 1098

Time- and Frequency-resolved Characterization of Collective Nuclear Dynamics — •Lukas Wolff and Jörg Evers — Max-Planck-Institut für Kernphysik Heidelberg, Germany

Mössbauer nuclei have become an important tool for high precision tests and spectroscopy owing to their extremely narrow linewidths and long coherence times. In recent years, ensembles of nuclei embedded in suitably engineered waveguide structures allowed for the observation of cooperative phenomena such as superradiant decay and collective level shifts. This constituted the field of nuclear quantum optics of collective nuclear excitations. A direct and unambiguous characterization of such level schemes in the time or frequency domain alone is challenging and, thus, new data acquisition and evaluation techniques are of great importance to access the underlying collective dynamics [1]. To this end, we study the time- and frequency-resolved collective behaviour of nuclear ensembles upon x-ray pulses with different temporal and spectral shape to extract signatures for collective and nonlinear dynamics of Mössbauer resonances [2]. We expect our results to help guide future experiments investigating such dynamics using suitably-shaped x-ray pulses and pulse sequences that can be created using time-domain control of nuclear resonances.

[1] L.Wolff and J.Evers, Phys.Rev.Res. **5**, 013071 (2023)
[2] L.Wolff and J.Evers, Phys.Rev.A **108**, 043714 (2023)

A 2.5 Mon 12:00 HS 1098

Designing a Topological Thin-Film X-Ray Cavity — •Hanns Zimmermann[1,2] and Adriana Pálffy[1] — [1]Julius-Maximilians-Universität Würzburg — [2]Universität der Bundeswehr München

A promising platform for the quantum control of high-frequency photons are thin-film cavities, with one or several embedded layers of resonant nuclei such as ^{57}Fe with a Mössbauer transition at 14.4 keV. At grazing incidence, incoming x-rays couple evanescently to the cavity. In turn, the cavity field drives the nuclear transitions. The resulting nuclear response is well described by a recently-developed quantum optical model based on the electromagnetic Green's function [1,2].

Here, we investigate theoretically a thin-film cavity design with multiple embedded ^{57}Fe layers, such that its inter-layer couplings are mostly restricted to the nearest neighbouring layers by intercalating additional layers with high electron densities. Via the geometrical properties of these domains and control of the evanescent field pattern, we implement alternating coupling strengths between the resonant layers. We show that this leads to an x-ray photonic realization of the non-hermitian Su-Schrieffer-Heeger model and investigate how for certain configurations localized nuclear excitations emerge at the edges of the cavity.

[1] X. Kong, et al. Phys. Rev. A 102, 033710 (2020)
[2] P. Andrejić and A. Pálffy, Phys. Rev. A 104, 033702 (2021)

A 2.6 Mon 12:15 HS 1098

Single-shot electron spectroscopy of highly transient matter — •Sara Savio[1], Lars Funke[1], Niclas Wieland[1,3], Lasse Wuelfing[1], Markus Ilchen[2,3], and Wolfram Helml[1] — [1]Fakultät Physik, Technische Universität Dortmund, Maria-Goeppert-Mayer-Straße 2, 44227 Dortmund, Germany — [2]Deutsches Elektronen-Synchroton DESY, Notkestr. 85, 22607 Hamburg, Germany — [3]University of Hamburg, Middle Way 177 , 20148 Hamburg, Germany

Single-shot electron spectroscopy can be used as a tool to investigate photo-ionization processes and the various subsequent relaxation dynamics, ie how the inner shell vacancies are redistributed and filled in atoms and molecules. This work investigates the generation of double-core holes (DCH) in neon atoms with very short lifetimes using the help of intense and tightly focused X-ray pulses at European XFEL at the attosecond frontier. An electron-time-of-flight (e-TOF) spectrometer equipped with a multi-electrostatic lens system followed by a

microchannel plate(MCP) based detector is used to specifically collect DCH Auger electrons in single-shot spectroscopy. The wavelength tunability and high X-ray intensity at European XFEL together with this spectroscopic technique enable the study of highly transient systems. Examining the electronic structure of a core-excited system before relaxation can allow for gaining essential insights into ultrafast processes and nonlinear photoabsorption under extreme intensities thus opening a new field of spectroscopy of transient matter.

A 2.7 Mon 12:30 HS 1098

Interatomic Coulombic Decay from Auger final states in aqueous solution — •Andreas Hans[1], Dana Bloss[1], Rémi Dupuy[2], Florian Trinter[3], Uwe Hergenhahn[3], Olle Björneholm[4], and Arno Ehresmann[1] — [1]Universität Kassel und CINSaT, Kassel, Germany — [2]Sorbonne Université, Paris, France — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [4]Uppsala University, Uppsala, Sweden

Interatomic Coulombic decay of resonant Auger final states (RA-ICD) has been discovered about a decade ago. Due to the site-selective character of the resonant excitation and the typically emitted slow electrons, RA-ICD has been envisioned to enhance the efficiency of radiation therapies. So far, the mechanism had only been observed experimentally in prototypical van der Waals dimers. Here, we present the transfer of the idea to the liquid phase. To this end we investigate the decay of $2p \rightarrow 3d$ resonantly excited solvated Ca^{2+} ions. We show, that using multi-electron coincidence spectroscopy increases the contrast for slow electrons drastically and that RA-ICD can be readily observed in the liquid phase.

A 2.8 Mon 12:45 HS 1098

Attoclock, what can or has actually been measured? — •Ossama Kullie — 1 Theoretical Physics, Institute of Physics, University of Kassel

Attoclock is designed to measure the delay time required for a particle to tunnel, or undergo field-ionization, from an atom interacting with a strong laser field. However, some authors claim that the duration the attoclock measures is not a good proxy for tunneling time. In previous works, we showed a model that describes the tunnel- or field-ionization of the attoclock experiment for He- [1] and H-atom [2], in the adiabatic and nonadiabatic field calibrations [3]. In the present talk, we show that it is possible to interpret the attoclock measurement in such a way that real-valued tunnel-time or the delay time due to the barrier region or the classically forbidden region can be determined. Furthermore, we show that in the limit of weak measurement the attoclock provides the interaction time inside the barrier, which is usually measured by the Larmro clock. The limit of thick barrier, the interaction time and the superluminal tunneling are discussed, [1] A. S. Landsman et al, Optica **1**, 343 (2014), U. S. Sainadh et al, Nature **586**, 75 (2019). [2] C. Hofmann et al. J. Mod. Opt. **66**, 1052 (2019). [3] O. Kullie, Phys. Rev. A **92**, 052118 (2015), O. Kullie J. Phys. Commun. **2**, 065001 (2018), O. Kullie and I. A. Ivanov, arXiv:2005.09938v6.