A 14: Interaction with VUV and X-ray light I (joint session A/MO)

Time: Wednesday 11:00–12:45 Location: GrHS Mathe

A 14.1 Wed 11:00 GrHS Mathe

High-resolution photoelectron spectroscopy with broad bandwidth pulses from high-harmonic sources — •Sarang Dev Ganeshamandiram[1], Tobias Witting[2], Ulrich Bangert[1], Daniel Uhl[1], Lauren Drescher[2], Benjamin Maingot[2], Oleg Kornilov[2], Frank Stienkemeier[1], Marc J.J. Vrakking[2], and Lukas Bruder[1] — [1]Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany

Extreme ultraviolet time-resolved photoelectron spectroscopy (XUV-TRPES) is a promising emerging method to study molecular dynamics. However, XUV pulses generated by high harmonic generation (HHG) exhibit very broad spectra, which leads to low spectral resolution in PES experiments, especially involving molecules.

Here, we explore a new approach of Fourier-Transform (FT) based XUV-PES that provides high spectral resolution, while temporal resolution is retained. This approach avoids the photon broadening problem and can disentangle the photoelectrons produced by different harmonics within the HHG spectrum. As model systems serve Rb atoms, and N_2 and O_2 molecules.

A 14.2 Wed 11:15 GrHS Mathe

Coherent control of strongly driven quantum dynamics using shaped extreme ultraviolet pulses — •Lukas Bruder — Institute of Physics, University of Freiburg, Germany

The shaping of femtosecond light fields with pulse shapers is a powerful technique enabling the control of quantum dynamics with high selectivity. While the technique is well established in the visible to infrared domain, comparable methods do not exist at shorter wavelengths in the XUV or X-ray domain. We have recently demonstrated the first coherent control experiment using pulse shaping in the XUV domain [1]. We show high fidelity quantum control of Rabi dynamics in helium atoms. In particular, the selective suppression of the two-photon ionization rate could be demonstrated and the strong dressing of continuum states was revealed, which is otherwise difficult to access at long wavelengths.

The results originate from the joint effort of many international laboratories and of a large number of researchers[1], whose work is gratefully acknowledged.

[1] F. Richter et al., arXiv:2403.01835 (2024)

A 14.3 Wed 11:30 GrHS Mathe

Exceptional points at x-ray wavelengths — •Fabian Richter[1], Lars Bocklage[2], Ralf Röhlsberger[2], Xiangjin Kong[3], and Adriana Pálffy[1] — [1]Julius-Maximilians-Universität Würzburg — [2]Deutsches Elektronen Synchrotron DESY, Hamburg — [3]Fudan University, Shanghai

Non-Hermitian Hamiltonians effectively describe dissipative systems, exhibiting phenomena absent in the Hermitian realm. Exceptional Points (EPs) are a prime example of this. At EPs not only the complex eigenvalues, but also the eigenvectors coalesce and sensitivity to perturbations is drastically enhanced. This concept has recently advanced in optics, where non-Hermitian eigenstates arise through optical gain and loss [1]. So far, these concepts have been mostly discussed in the optical regime. Similar control of x-rays is desirable due to their superior penetration power, high focusability and detection efficiency.

Here, we investigate non-Hermitian x-ray photonics in thin-film cavities with Mössbauer nuclei under grazing-incidence x-ray radiation. These cavities present loss that can be controlled via adjustment of the cavity geometry and the incidence angle of the x-rays [2]. The application of a magnetic hyperfine field enables tuning the system towards EPs. We theoretically determine the magnetic field strength at which an EP occurs and predict qualitatively distinct behavior in the time spectrum at higher and lower field strengths. Analysis of experimental data confirms these predictions.

[1] L. Feng et al., Nature Photon. 11, 752-762 (2017).
[2] J. Evers, K. P. Heeg, Phys. Rev. A 88, 043828 (2013).

A 14.4 Wed 11:45 GrHS Mathe

Superradiant Parametric Mössbauer Radiation Source — •Zeán Peng, Christoph H. Keitel, and Jörg Evers — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Mössbauer nuclei facilitate a broad range of applications due to their extremely narrow resonance at x-ray frequency. However, it also renders a strong excitation via x-rays challenging. Here, we propose to construct a superradiant parametric Mössbauer radiation source, which is based on coherently modulated electron bunches exiting from x-ray free-electron laser (XFEL) undulator and passing through a crystal containing Mössbauer isotopes. Due to the constructive interference between the virtual-photon fields of different electrons in a single XFEL electron bunch, the intensity of Mössbauer radiation generated from the crystal can be boosted superradiantly, which scales with the square of electron number of XFEL electron bunch. This tremendous superradiant boost of Mössbauer radiation is also realized by a new geometry we proposed, which can be optimized by experimentally simple ways. Our study bears potential to enable coherent Mössbauer pump-probe spectroscopy, as well as nonlinear Mössbauer optical effects triggered by coherent XFEL electron beam.

[1] O. D. Skoromnik, I. D. Feranchuk, J. Evers, and C. H. Keitel, Phys. Rev. Accel. Beams 25, 040704 (2022).

A 14.5 Wed 12:00 GrHS Mathe

Single-shot electron spectroscopy of highly transient matter — •Sara Savio[1], Lars Funke[1], Niclas Wieland[2], Thorsten Otto[3], Lasse Wuelfing[1], Markus Ilchen[2,3], and Wolfram Helml[1] — [1]Technische Universitaet — [2]University of Hamburg — [3]Deutsches Elektronen-Synchrotron

Core-level photoionization is the process of absorbing a photon by an atom or molecule, ejecting an electron from one of its inner shells and creating a vacancy. This vacancy is then filled through various relaxation processes, which can lead to the emission of secondary electrons or energy redistribution within the system. We explore the generation of double-core holes (DCH) in gaseous neon atoms, which have a very short lifetime, using intense and ultrashort pulses on the attosecond scale at the European XFEL. The ultrafast electron dynamics are mapped on a single-shot basis using an electron time-of-flight (eTOF)spectrometer. Non-invasive systematic pulse characterization using the angular streaking technique provides spectral and temporal information about the ionizing XFEL pulses with attosecond resolution. We conduct a comprehensive study of how the contribution of DCH channels varies with beam parameters, including pulse duration, pulse energy, and the centres of the reconstructed spectra. Examining the electronic structure of the core-ionized system before relaxation, combined with the detailed information about the ionizing pulse, provides valuable insights into the nonlinear photoabsorption and the ultrafast process at extreme intensities on the time scales of electron dynamics.

A 14.6 Wed 12:15 GrHS Mathe

Cavity-controlled X-ray emission spectra — •Shu-Xing Wang[1,2], Xin-Chao Huang[3], Zhe-Qian Zhao[4], Xi-Yuan Wang[4], and Lin-Fan Zhu[4] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany — [2]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Campus Gießen, 35392 Giessen, Germany — [3]FXE instrument, European XFEL, Schenefeld 22869, Germany — [4]University of Science and Technology of China, Hefei, 230026, China

We report on the X-ray emission spectra from a thin-film cavity sample, measured using a von Hamos spectrometer at the GALAXIES beamline of the SOLEIL synchrotron radiation facility in Paris. The cavity consists of a multilayer structure: 21.8 nm Pt / 203.3 nm C / 29.4 nm WSi2 / 201.0 nm C / 144.6 nm Pt, deposited on a silicon substrate. X-ray emission spectra covering the Lα emission lines of W were recorded by scanning the incident X-ray energy across 10160-10240 eV (L_3 edge of W) at grazing angles near the first cavity mode. Our measurements reveal the collective Lamb shift and superradiant enhancement associated with the inner-shell transition. Notably, by concentrating on the resonant X-ray emission channel, we suppress the influence of the absorption edge, which might otherwise obscure the observed quantum optical effects.

A 14.7 Wed 12:30 GrHS Mathe

Measurement of resonant nuclear phase shift with a double-waveguide nano-interferometer — •Leon Merten Lohse[1,2,3], Ralf Röhlsberger[4,5,6,1,3], and Tim Salditt[2] — [1]The Hamburg

Centre for Ultrafast Imaging, Hamburg — [2]Georg-August-Universität Göttingen — [3]Deutsches Elektronen-Synchrotron DESY, Hamburg — [4]Friedrich-Schiller-Universität Jena — [5]Helmholtz-Institut Jena — [6]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

The phase of an electromagnetic wave is shifted upon scattering off atoms, coherently accumulating to result in the macroscopic index of refraction. In optical waveguides, propagating photons are spatially confined and can be coupled to resonant atoms in a controllable way. We interferometrically measured the phase shift that an ultrathin layer of ^{57}Fe Mössbauer nuclei coherently imprints onto x-ray photons propagating through a single-mode x-ray waveguide. Using the extracted phase shift, we were able to accurately quantify the coupling strength between individual photons and nuclei. Based on this, one can envision to actively control the phase in nanophotonic devices.