A 28: Poster: Interaction with VUV and X-ray light II

Time: Wednesday 17:00–19:00 Location: C/Foyer

A 28.1 Wed 17:00 C/Foyer

Few-Photon Quantum Optics with Nuclei in Thin-Film Cavities — •Paolo Longo, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik (MPIK), 69117 Heidelberg

Recent activities in the field of X-ray quantum optics [1–4] address, for example, the problem of single-photon superradiance in an extended sample of ^{57}Fe nuclei embedded in a thin-film cavity [5]. In the near future, new light sources [6] will further boost the study of such collective phenomena and eventually go beyond the level of at most one photon. Based on first principles and our earlier work on collective emission [7], we develop a theoretical description for the study of X-ray few-photon quantum optics, revealing the collective atomic states' properties in conjunction with the resulting far-field signatures.

[1] Adams *et al.*, J. Mod. Opt. **60**, 2 (2013).
[2] Röhlsberger *et al.*, Nature **482**, 199 (2012).
[3] Heeg *et al.*, Phys. Rev. Lett. **111**, 073601 (2013).
[4] Heeg *et al.*, arXiv:1411.1545 (2014).
[5] Röhlsberger *et al.*, Science **328**, 1248 (2010).
[6] http://www.xfel.eu/
[7] Longo *et al.*, Phys. Rev. Lett. **112**, 193601 (2014); arXiv:1408.2961 (2014).

A 28.2 Wed 17:00 C/Foyer

Angle-resolved study of resonant Auger decay and fluorescence emission processes after core excitations of the terminal and central nitrogen atoms in N_2O — André Knie[1], Markus Ilchen[2,3], Philipp Schmidt[1], Philipp Reiss[1], •Christian Ozga[1], Andreas Hans[1], Nicolas David Müglich[1], Leif Glaser[2], Peter Walter[2], Jens Viefhaus[2], Arno Ehresmann[1], and Philipp V Demekhin[1] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett Straße 40, 34132 Kassel, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [3]European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany

The linear molecule N_2O is one of the easiest showcase examples for the investigation of electronic properties within completely different chemical surroundings. Here we present our results of the study on interference effects between direct and indirect ionization processes (ESI) as well as between the relaxation into a specific vibronic state from different vibrational states of a higher lying electronic state (LVI). Since these effects are more pronounced in angle resolved measurements due to the sensitivity on the phases of the outgoing partial photoelectron waves we investigated the behavior of the angular distribution parameters of photoelectrons and fluorescence photons under variation of the energy of the exciting photons in the vicinity of the resonant 1s core excitations of the central and terminal nitrogen atom.

A 28.3 Wed 17:00 C/Foyer

Dynamical Phase Control in Resonant Nuclear Scattering — •Patrick Reiser, Andreas Kaldun, Christoph H. Keitel, Thomas Pfeifer, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg

In spectroscopy, the observed signatures arise from interference between the incident probing light and the light scattered by the sample. By imprinting a relative phase between incident and scattered light, a modification of spectral line shapes can be achieved [1,2]. Motivated by this, our aim is to establish dynamical phase control at x-ray energies. We propose a setup using resonant nuclear forward scattering of synchrotron radiation on ^{57}Fe Mössbauer nuclei. The phase shifts are mechanically mediated via piezoelectric film elements. Our theoretical calculations suggest that this setup provides access to a number of promising applications in nuclear quantum optics. Additionally, first results from a Mössbauer test experiment will be shown.

[1] C. Ott et al., Science 340, 716 (2013)
[2] K. P. Heeg et al., arXiv:1411.1545 [quant-ph]

A 28.4 Wed 17:00 C/Foyer

X-ray lasing with highly charged ions — •Chunhai Lyu, Zoltán Harman, Stefano M. Cavaletto, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We theoretically propose an approach to create population inversion by K-shell ionization of highly charged ions with x-ray free electron laser pulses, which results in subsequent lasing in the X-ray regime. The time-dependent dynamics of the population of the ionic states and the gain of the x-ray laser pulses are simulated numerically in the framework of a density matrix approach. Due to the absence of Auger decay, in selected ions, the bandwidth of the x-ray laser is decreased and hence the coherence is improved. Furthermore, the frequency of the laser can be increased approximately quadratically with the charge number of the ions, and can be extended to the hard x-ray regime if heavy ions are used.

A 28.5 Wed 17:00 C/Foyer

Trapped highly charged ions at ultrabrilliant light sources — •Sven Bernitt[1,2], René Steinbrügge[1], Jan Rudolph[1,3], Sascha Epp[4], and José Ramón Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]IOQ, Friedrich-Schiller-Universität, Jena, Deutschland — [3]IAMP, Justus-Liebig-Universität, Gießen, Deutschland — [4]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Deutschland

The properties of many astrophysical objects are determined by the interaction of highly charged ions with VUV and X-ray radiation. The newest generation of ultrabrilliant light sources – synchrotrons and free-electron lasers – in combination with high-resolution monochromators, allows to directly study those interactions.

In the experiments presented, the transportable electron beam ion trap FLASH-EBIT was used to provide targets of trapped highly charged ions for the synchrotrons BESSY II and PETRA III, as well as the free-electron lasers FLASH and LCLS.

By observing resonantly excited fluorescence and ion charge state changes, induced by resonant photoionization, we were able to measure precise wavelengths, line widths, and branching ratios. This provides valuable data for the interpretation of spectra from astrophysical and laboratory plasmas. Furthermore, by studying high-Z few-electron systems, we can benchmark atomic theory on the level of QED contributions.

A 28.6 Wed 17:00 C/Foyer

X-ray and gamma-ray polarimetry and imaging — •Stanislav Tashenov — Physikalisches Institut der Universität Heidelberg

To study fundamental atomic processes in the x-ray and gamma-ray regimes and to perform polarization diagnostics of laboratory fusion and astrophysical plasmas we develop a broad range of polarization sensitive and imaging x-ray and gamma-ray detectors. Two detectors are based on Silicon PIN diodes and Silicon Drift Detectors and dedicated to the energy range of 10–30 keV. This is the lowest energy range that was accessed by the Compton polarimetry. For the energy range of 30 keV – 2 MeV we use a segmented planar germanium detector. It employs a novel technique of Pulse Shape Analysis of the detector signals for a 3D sensitivity to the positions of the x-ray interactions. With this detector we for the first time employed the techniques of Compton Imaging and background reduction in a laboratory physics experiment. It also achieved the polarization resolution of 0.3 deg which is the record for Compton polarimetry. To improve this further we develop a high resolution polarimeter that is based on a rotationally symmetric annular planar segmented germanium detector.

A 28.7 Wed 17:00 C/Foyer

Diffraction effects in the Recoil-Frame Photoelectron Angular Distributions of Halomethanes. — •Cédric Bomme[1], Denis Anielski[1,2], Evgeny Saveleyv[1], Rebecca Boll[1], Benjamin Erk[1], Sadia Bari[3], Jens Kienitz[1,2], Nele Mueller[1], Thomas Kierspiel[1,4], Sebastian Trippel[1], Jens Viefhaus[1], Jochen Küpper[1,4], Mauro Stener[5], Piero Decleva[5], and Daniel Rolles[1,6] — [1]Deutsches Electronen-Synchrotron(DESY), Hamburg, Germany. — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany. — [3]European XFEL GmbH, Hamburg, Germany. — [4]Hamburg Center for Ultrafast Imaging, University of Hamburg, Germany. — [5]Universita' di Trieste, Trieste, Italy. — [6]Kansas State University, Manhattan, KS, USA.

We have measured the recoil frame photoelectron angular distributions (RF-PADs) for inner-shell photoionization of the halomethanes CH3F, CH3I, ClCH2I and CF3I in the gas-phase. Using our new double-sided

velocity map imaging (VMI) spectrometer optimized for electron-ion coincidence measurements of high-kinetic energy electrons, we are able to determined RF-PADs for photoelectrons up to 300 eV. For these high kinetic energies, the RF-PADs are dominated by diffraction effects that encode information on the molecular geometry in the RF-PADs.

A 28.8 Wed 17:00 C/Foyer

Measuring Molecular (Recoil) Frame-Photoelectron Angular Distribution of Halogenated Carbon Compounds. — •Evgeny Savelyev[1,2], Cédric Bomme[1], Rajesh Kushuwaha[3], Timur Osipov[4], Hui Xiong[5], Nora Berrah[5], and Daniel Rolles[1,3] — [1]Deutsches Elektronen-Synchrotron — [2]Georg-August-Universität Göttingen — [3]Kansas State University — [4]SLAC National Accelerator Laboratory — [5]University of Connecticut

We investigated Recoil Frame - Photoelectron Angular Distribution(RF-PADs) of halogenated hydrocarbons such as CH3I, CF3I, and 2,6-Difluoroiodobenzene molecules using a double-sided Velocity Map Imaging Spectrometer at beamline 10.0.1 of the Advanced Light Source (ALS) and at the FLASH Free Electron Laser. At the ALS, the RF-PADs were measured using a photoelectron-ion coincidence technique, while adiabatic laser alignment was used at FLASH in order to fix the molecular axis in the laboratory frame. Both experiments were performed approximately 50eV above the iodine 4d photoionization threshold (i.e. at 107 eV photon energy). The results as well as a comparison and discussion of these two measurements are presented on this poster.

A 28.9 Wed 17:00 C/Foyer

CAMP at BL1 - a Permanent User Endstation for X-Ray Imaging and Pump-Probe Experiments at FLASH — Daniel Rolles[1], Benjamin Erk[1], •Cédric Bomme[1], Rebecca Boll[1], Evgeny Savelyev[1], Elke Ploenjes-Palm[1], Barbara Keitel[1], Kai Tiedtke[1], Andrey Sorokin[1], Guenter Brenner[1], Siarhei Dziarzhytski1[1], Rolf Treusch[1], Robert Moshammer[2], Jan P. Müller[3], Thomas Möller[3], and CAMP collaboration[1,2,3] — [1]Deutsches Electronen-Synchrotron(DESY), Hamburg, Germany. — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany. — [3]Technische Universität Berlin, Berlin, Germany

CAMP is a multi-purpose instrument optimized for imaging and pump-probe experiments with Free-Electron Lasers (FELs) that was developed in the Max Planck Advanced Study Group at the Center for Free-Electron Laser Science (CFEL) in Hamburg [1] and that was employed at the LCLS, FLASH, and SACLA FELs for the last four years. It offers a choice of large-area, single-photon counting X-ray pnCCD imaging detectors as well as various charged particle spectrometers for electron and ion imaging and coincidence experiments. CAMP is now installed at FLASH BL1, which was equipped with new micro-focusing KB optics, as a permanent endstation available to all users. Here we present an overview of the endstation layout and the results of the commissioning beamtimes including focus imprints, wave front sensor measurements, and ion TOF spectra of rares gases. [1] L. Strüder et al., Nucl. Instr. Meth. Phys. Res. A. 614, 483 (2010).

A 28.10 Wed 17:00 C/Foyer

Multiphoton Ionization of Krypton Explored by Electron-Ion Coincidence Studies — •Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Georg Schmid[1], Sven Augustin[1], Yifan Liu[1], Artem Rudenko[2], Tatiana Marchenko[3], Marc Simon[3], Rolf Treusch[4], Joachim Ullrich[5], Thomas Pfeifer[1], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]J.R. Macdonald Laboratory, Kansas State University — [3]UPMC and CNRS, Paris — [4]Deutsches Elektronen-Synchrotron, Hamburg — [5]Physikalisch-Technische Bundesanstalt, Braunschweig

Understanding the mechanisms of multiphoton absorption and secondary relaxation processes in the XUV and X-ray regime is a prerequisite for all applications of short-wavelength free-electron lasers (FELs), e.g. for single-molecule imaging. Here, we present an electron-ion coincidence study on multiphoton ionization of krypton at 210 eV performed with a reaction microscope at the FEL facility FLASH. The production mechanisms for all observed charge states are analyzed by evaluating intensity-dependent Kr^{n+} ion spectra and the corresponding electron spectra. Even the highest charge state, Kr^{11+}, is found to be produced by sequential multiphoton ionization, which is in line with theoretical predictions (Rudek *et al.*, Nat. Phot. 6, 858-865 (2012)).

A 28.11 Wed 17:00 C/Foyer

Electron Rearrangement Dynamics in Dissociating I_2^{n+} Molecules Accessed by XUV Pump-Probe Experiments — •Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Georg Schmid[1], Sven Augustin[1], Yifan Liu[1], Thomas Pfeifer[1], Artem Rudenko[2], Kristina Meyer[1], Matthias Kübel[3], Matthias Kling[3], Björn Siemer[4], Michael Wöstmann[4], Helmut Zacharias[4], Stefan Düsterer[5], Rolf Treusch[5], Joachim Ullrich[6], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]J.R. Macdonald Laboratory, Kansas State University — [3]Max-Planck-Institut für Quantenoptik, Garching — [4]Westfälische Wilhelms-Universität, Münster — [5]Deutsches Elektronen-Synchrotron, Hamburg — [6]Physikalisch-Technische Bundesanstalt, Braunschweig

The dynamics of dissociating multiply charged iodine molecules, I_2^{n+}, is induced and probed by intense XUV pulses delivered by the free-electron laser in Hamburg (FLASH). A first pulse multiply ionizes I_2 and thereby triggers the fragmentation of the molecule. During the dissociation a probe pulse further ionizes the fragments after an adjustable time-delay. Depending on the internuclear distance the probe pulse may or may not initiate electron transfer between the ions. By detecting the charge states of coincident ion pairs as a function of the pump-probe delay, we determine the critical separation and time scales up to which electron transfer along the internuclear axis takes place. These scales are important for understanding the radiation damage occurring in X-ray single-molecule imaging.

A 28.12 Wed 17:00 C/Foyer

Coulomb-THz-Field-Coupling Induced Time Shifts in Atomic Photoemission — •Georg Schmid[1], Kirsten Schnorr[1], Sven Augustin[1], Jakob Kunz[1], Arne Senftleben[1,9], Shaofeng Zhang[1], Artem Rudenko[3], Matthias Kübel[4], Lutz Foucar[8], Michael Gensch[5], Yuhai H. Jiang[6], Joachim Ullrich[7], Alaa Al-Shemmary[2], Torsten Golz[2], Nikola Stojanovic[2], Claus-Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]MPI für Kernphysik, Heidelberg — [2]DESY, Hamburg — [3]Kansas State University, Manhattan, KS — [4]MPI für Quantenoptik, Garching — [5]HZDR, Dresden — [6]SARI, Shanghai — [7]PTB, Braunschweig — [8]MPI für medizinische Forschung, Heidelberg — [9]Universität Kassel

XUV pump - THz probe experiments were carried out at the free-electron laser in Hamburg. At a photon energy of 59.4 eV, neon 2p, 2s and valence shake-up photoelectrons (PEs) were emitted into a THz probe field of 152 um. Using a reaction microscope, the 3-dim PE momentum vectors were measured as a function of the pump-probe delay. By tracing the delay-dependent streaking spectrograms, a relative time shift in the emission of valence shake-up PEs and direct 2p PEs was observed. In the framework of attosecond streaking, it was shown that so-called Coulomb-laser-coupling leads to measurement-induced time shifts in addtion to the quantum mechanical EWS time shift. It is predicted that low-energetic PEs are strongly effected by the combined action of Coulomb and long-wave THz field. By selecting shake-up PEs with energies < 1 eV, we experimentally confirm Coulomb-laser-coupling time shifts in the range of low PE energies.

A 28.13 Wed 17:00 C/Foyer

Time Resolved Electron- and Ion-Spectroscopy of Iodine Containing Molecules — •Karolin Mertens[1], Nils Gerken[1], Stephan Klumpp[1], Ivan Baev[1], Tommaso Mazza[2], Alberto De Fanis[2], Michael Meyer[2], and Michael Martins[1] — [1]Physik Department, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]European XFEL, Notkestrasse 85, 22607 Hamburg

Using the intense soft x-ray laser pulses from FLASH, we have studied the photofragmentation and ionization behavior of small iodine containing molecules with the goal to investigate charge redistribution processes as well as the time scales of the involved dissociation processes. The molecules CH3I and CH2I2 have been chosen as model systems, as a strong local core hole excitation can easily be generated at one or two different iodine sites of the molecules by tuning the photon energy to the strong 4d-4f shape resonance. The photoionization- and dissociation process is studied by ion time-of-flight spectroscopy. We present first results of measurements with a XUV-pump-XUV-probe setup. By using a Mach-Zehnder type split- and delay setup it is possible to track the development of the different ionic charge states of the molecule fragments depending on the time delay between two XUV pulses. Delay-dependent intensity changes in the iodine ion charge states are a clear indication of charge migration processes within the molecule. We also present preliminary photoelectron spectra of these systems measured with a magnetic-bottle type of spectrometer. This

work is supported by the collaborative research center SFB 925 "Light induced dynamics and control of correlated quantum systems".

A 28.14 Wed 17:00 C/Foyer

An Experimental Setup for Multidimensional Soft X-Ray Spectroscopy — •Thomas Ding, Marc Rebholz, Faiq Bakar, Paul Birk, Kristina Meyer, Andreas Kaldun, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Information on both the structure and the dynamics of quantum systems is encoded in their optical-response spectra. In recent years multidimensional visible and ultraviolet spectroscopy has shed light on electronic/exciton dynamics in large molecular systems. However, due to the failure of standard optical elements for higher frequencies, the extension to the extreme ultraviolet or x-ray range to observe electronic core-level dynamics has not yet been realized. Here, we present an experimental design and first proof-of-principle results of a multidimensional soft x-ray spectroscopy scheme applicable for both attosecond high-harmonic sources and ultra-intense free-electron lasers. The heart of the setup is a dynamical soft x-ray-compatible four-segment split mirror to generate temporarily well-controlled multi-pulse sequences in a noncollinear box geometry for four-wave mixing. In the near future, one key application will be the time-resolved and site-specific spectroscopy of core- and valence-electron dynamics and the correlated electronic motion inside molecules.

A 28.15 Wed 17:00 C/Foyer

XUV-pump/IR-probe studies of photoionization and dissociation of N_2O — •Michael Schönwald[1], Philipp Cörlin[1], Andreas Fischer[1], Tomoya Mizuno[1], Alexander Sperl[1], Arne Senftleben[2], Joachim Ullrich[3], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck Institut für Kernphysik, Heidelberg, Deutschland — [2]Institut für Physik, Universität Kassel, Deutschland — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

We present the results of kinematically complete XUV-pump/IR-probe experiments on nitrous oxide (N_2O) using a reaction microscope. A train of attosecond XUV pulses, produced via high harmonic generation in an Ar-filled gas cell, covers the energy range from 20 to 50 eV, in which the molecule can either be singly ionized or directly doubly ionized. In addition, the excited cation N_2O^{+*} in a state near the double ionization threshold can either dissociate into a charged and a neutral fragment or it autoionizes into N_2O^{2+}, which subsequently leads to a Coulomb explosion into two charged fragments that are detected in coincidence ($N_2O^{2+} \rightarrow N^+ + NO^+$ or $N_2O^{2+} \rightarrow N_2^+ + O^+$). We investigated the influence of the additional IR-field on the double ionization yield. Both decay channels are enhanced but respond differently [1]. In addition we present the corresponding photoelectron energy spectra, which show indications for the autoionization process and its dependence on the delay and the kinetic energy release of the respective ions.

[1] X.Zhou et al., Nature Physics Vol.8, March 2012