A 28: Interaction with VUV and X-ray light

Time: Thursday 10:30–12:30 Location: S HS 3 Physik

A 28.1 Thu 10:30 S HS 3 Physik

Coherent x-ray-optical control of nuclear excitons with zeptosecond phase-stability — •Kilian P. Heeg[1], Andreas Kaldun[1], Cornelius Strohm[2], Christian Ott[1], Rajagopalan Subramanian[1], Dominik Lendrodt[1], Johann Haber[2], Hans-Christian Wille[2], Stephan Goerttler[1], Rudolf Rüffer[3], Christoph H. Keitel[1], Ralf Röhlsberger[2], Thomas Pfeifer[1], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]ESRF - The European Synchrotron, Grenoble, France

Coherent control of nuclei using near-resonant x-ray fields is an open challenge since it requires a stability of the x-ray light in the few-zeptosecond range. Based on our recent work on spectral narrowing [1], we shape single x-rays delivered by modern x-ray facilities into tunable double pulses and demonstrate control of the relative phase with the desired stability on the few-zeptosecond level [2]. We experimentally exploit this phase control to steer the nuclear dynamics and switch between stimulated emission and enhanced excitation [2]. As application, we discuss strong driving of nuclear transitions [3]. As long-term perspective, we envision time-resolved studies of nuclear out-of-equilibrium dynamics and new prospects in nuclear quantum optics.

[1] K. P. Heeg *et al.*, Science 357, 375 (2017).
[2] K. P. Heeg *et al.*, *submitted.*
[3] K. P. Heeg, C. H. Keitel, J. Evers, arXiv:1607.04116 (2016).

A 28.2 Thu 10:45 S HS 3 Physik

Unexpected Polarization Transfer Echos in Atomic Inner-Shell Two-photon Ionization — •Jiri Hofbrucker[1,2,3], Andrey Volotka[1,3], and Stephan Fritzsche[1,2,3] — [1]Helmholtz-Institute, Jena, Germany — [2]Friedrich-Schiller Universität, Jena, Germany — [3]GSI, Darmstadt, Germany

Unexpected polarization transfer from incident to fluorescence photon is discovered in the case of two-photon inner-shell ionization by circularly polarized light. Beside the expected complete polarization transfer induced at incident photon energy tuned to intermediate resonances, echos of the polarization transfer occur at higher nonresonant incident photon energies due to vanishing of the dominant ionization channel. Measuring the polarization properties of the fluorescence light promises an opportunity to extract ionization properties out of an experiment with an unprecedented accuracy and carry out a critical comparison with available theory.

A 28.3 Thu 11:00 S HS 3 Physik

Photoionoization of low charged silicon ions — •Ticia Buhr[1], Alexander Perry-Sassmannshausen[1], Sebastian Stock[2,3], Jens Buck[4], Simon Reinwardt[5], Michael Martins[5], Sándor Ricz[6], Alfred Müller[1], Stephan Fritzsche[2,3], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen, Germany — [2]Helmholtz-Institut Jena, Germany — [3]Friedrich-Schiller-Universität Jena, Germany — [4]FS-PE, DESY, Hamburg, Germany — [5]Universität Hamburg, Germany — [6]Institute for Nuclear Research, Hungarian Academy of Sciences, Debrecen, Hungary

Single and multiple photoionization of low charged atomic silicon ions (Si^{1+}, Si^{2+} and Si^{3+}) have been investigated in the vicinity of the silicon K-edge using the PIPE setup [1] at the beam line P04 of the synchrotron light source PETRA III (Hamburg, Germany) employing the photon-ion merged-beams technique. Absolute cross sections, precise K-shell ionization resonance parameters (positions, widths and strengths) for these ions and branching ratios for the various product-ion charge states have been determined. The experimental results are compared with theoretical calculations. Such data are of immediate interest for x-ray astrophysics [2].

[1] S. Schippers *et al.*, J. Phys. B **47**, 115602 (2014).
[2] T. Holczer *et al.*, Astrophys. J. **708**, 981 (2010).

A 28.4 Thu 11:15 S HS 3 Physik

Inner-Shell Multiple Photodetachment of Carbon Anions — •Alexander Perry-Sassmannshausen[1], Alexander Borovik Jr.[1], Ticia Buhr[1], Michael Martins[2], Alfred Müller[1], Simon Reinwardt[2], Sandor Ricz[3], Florian Trinter[4,5], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen, Germany — [2]Universität Hamburg, Germany — [3]Atomki, Debrecen, Hungary — [4]FS-PE, DESY, Hamburg, Germany — [5]Molecular Physics, Fritz-Haber-Institut, Berlin, Germany

Negative atomic ions play an important role in low temperature plasmas such as Earth's upper atmosphere or the interstellar medium [1, 2]. A sensitive tool for studying the interactions between the valence and the core electrons is inner-shell ionization of negative ions [3]. Here we report on preliminary results from a recent beam time at the Photon-Ion-Spectrometer at P04 at PETRA III (PIPE) [4]. We investigated multiple photodetachment of carbon anions which led to final charge states up to C^{4+}. Absolute cross sections for all measurable product ion channels will be presented and discussed.

[1] T. Andersen, Phys. Rep. **394**, 157 (2004)
[2] T. Millar et al., Chem. Rev. **117**, 1765 (2017)
[3] S. Schippers et al., Phys. Rev. A **94** (2016) 041401(R)
[4] S. Schippers et al., J. Phys. B **47**, 115602 (2014)

A 28.5 Thu 11:30 S HS 3 Physik

Time-resolved XUV refraction using a gas-phase prism — Lorenz Drescher, Oleg Kornilov, Tobias Witting, Jochen Mikosch, Marc Vrakking, and •Bernd Schütte — Max-Born-Institut, Berlin

Recently, we have demonstrated the first refractive lens and the first refractive prism for XUV beams, which are based on the deflection of XUV radiation in an inhomogeneous atomic jet [1]. These results make it possible to transfer techniques that rely on refraction and that are well established in other spectral regions to the XUV domain.

Here we report on the time-resolved investigation of XUV refraction using a gas-phase prism. A broadband XUV pulse induces electric dipoles in a dense He jet that relax via free induction decay, thereby emitting phase-shifted XUV radiation. A time-delayed NIR pulse is used to perturb the free induction decay, leading to a time-dependent suppression of the refracted XUV signal. This allows us to measure the angle-dependent XUV pulse duration, which we find to increase with increasing deflection angle. The XUV pulse duration can be further controlled by varying the gas backing pressure. Our results demonstrate that gas-phase XUV prisms can be used as monochromators for broadband XUV radiation, enabling the generation of ultrashort XUV pulses with bandwidths ranging from the (sub-)meV level to hundreds of meV. In the future, the combination of gas-phase prisms with pump-probe techniques could be exploited to study and control transient refractive index changes in atoms and molecules in the XUV region.

[1] L. Drescher *et al.*, Nature doi.org/10.1038/s41586-018-0737-3

A 28.6 Thu 11:45 S HS 3 Physik

Dispersive soft x-ray absorption fine-structure spectroscopy in graphite with an attosecond pulse — Bárbara Buades[1], •Themistoklis P. H. Sidiropoulos[1], Dooshaye Moonshiram[2], Iker León[1], Peter Schmidt[1], Irina Pi[1], Nicola Di Palo[1], Seth L. Cousin[1], Antonio Picón[1], Frank Koppens[1,3], and Jens Biegert[1,3] — [1]ICFO-Institut de Ciencies Fotoniques, 08860 Castelldefels, Spain — [2]Institute of Chemical Research of Catalonia, 43007 Tarragona, Spain — [3]ICREA, 08010 Barcelona, Spain

X-ray absorption fine-structure (XAFS) spectroscopy is a powerful element-specific technique, providing electronic and structural information with atomic resolution. Electronic information is extracted from the near-edge XAFS (NEXAFS) spectrum, requiring high spectral resolution to resolve features that occur within a few eV near the absorption edge. Structural information is obtained from the extended XAFS (EXAFS), spreading over several hundred eV above the absorption edge. While XANES and EXAFS are both well-established methods, crucially lacking so far is the capability to connect electronic with structural information in real-time. Here, we present a decisive step towards such new methodology based on water-window-covering (280 eV to 540 eV) attosecond soft X-ray pulses that can simultaneously access electronic and lattice parameters via dispersive XAFS spectroscopy. We validate this approach with an identification of the orbital contributions to the density of states in graphite simultaneously with the four characteristic bonding distances. This work demonstrates the po-

tential of dispersive attosecond XAFS as a powerful spectroscopic tool.

A 28.7 Thu 12:00 S HS 3 Physik

Relativistic and resonant effects on x-ray multiphoton multiple ionization of heavy atoms — •Sang-Kil Son[1], Koudai Toyota[1], Robin Santra[1,2], Benedikt Rudek[3], Artem Rudenko[4], and Daniel Rolles[4,5] — [1]Center for Free-Electron Laser Science, DESY, Hamburg — [2]Department of Physics, Universität Hamburg, Hamburg — [3]Physikalisch-Technische Bundesanstalt, Braunschweig — [4]J. R. Macdonald Laboratory, Department of Physics, Kansas State University, Manhattan, KS, USA — [5]Deutsches Elektronen-Synchrotron (DESY), Hamburg

An accurate description of the interaction of intense hard x-ray pulses with heavy atoms, which is crucial for many applications of x-ray free-electron lasers (XFELs), represents a hitherto unresolved challenge for theory because of the enormous number of electronic configurations and relativistic effects to be taken into account. Here we present a joint experimental and theoretical study of xenon atoms irradiated by unprecedentedly high-intensity hard x-rays up to 2×10^{19} W/cm^2. Our results show the interplay of relativistic and resonant effects on x-ray multiphoton multiple ionization of heavy atoms and demonstrate the predictive power of the theoretical model, which provides a basis for accurate modeling of radiation damage in XFEL experiments.

A 28.8 Thu 12:15 S HS 3 Physik

Extreme Ultraviolet Core-Exciton Dynamics in Two-dimensional Molybdenum Disulfide — •Michael Zürch[1,8], Hung-Tzu Chang[1], Alexander Guggenmos[1], Diana Y. Qiu[2,3], Romain Geneaux[1], Yen-Chang Chen[4,5], Xuan Wei[5], Chang-Ming Jiang[6,7], Yufeng Liang[4], Felipe H da Jornada[2,3], Adam Schwartzberg[4], David Prendergast[4], Vincent C. Tung[5], Steven G. Louie[2,3], Daniel M. Neumark[1,6], and Stephen R. Leone[1,2,6] — [1]Department of Chemistry, University of California, Berkeley, USA — [2]Department of Physics, University of California, Berkeley, USA — [3]Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, USA — [4]Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, USA — [5]School of Engineering, University of California, Merced, USA — [6]Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, USA — [7]Joint Center of Artificial Photosynthesis, LBNL, Berkeley, USA — [8]Fritz Haber Institute of the Max Planck Society, Berlin, Germany

Novel tightly-bound core-excitons triggered by an XUV attosecond pulse are observed in two-dimensional transition-metal dichalcogenide molybdenum disulfide. State-of-the-art theory calculations confirm the observed features. The dynamics observed in the core-exciton states between the molybdenum 4p and 4d states indicate coherences, and population transfer between different states. The observation of strongly enhanced long-lived core excitons in two-dimensional semiconductors paves the way for further exploration into the properties of core excitons in two-dimensional materials and potential application of these.