A 35: Poster: Interaction with VUV and X-ray light

Time: Wednesday 16:30–18:30 Location: Spree-Palais

A 35.1 Wed 16:30 Spree-Palais

Optische Untersuchung ^{229}Th dotierter CaF_2 Kristalle — •Christoph Tscherne, Simon Stellmer, Matthias Schreitl und Thorsten Schumm — Atominstitut, TU Wien, Österreich

Die typischen Energieskalen in der Atomphysik (eV) und Kernphysik (keV-MeV) unterscheiden sich um viele Größenordnungen, sodass eine Vereinbarkeit hinsichtlich der verwendeten Messmethoden nur schwer vorstellbar scheint. Das Isotop Th-229 zeichnet sich jedoch durch einen Isomerzustand aus, der die unter allen Isotopen einzigartig niedrige Anregungsenergie von lediglich 7.8±0.5 eV [1] besitzt. Diese Energie entspricht etwa 160 nm und erlaubt eine Untersuchung des Kernübergangs durch Laserspektroskopie.

Wir nutzen eine hauseigene Kristallzuchtanlage, um Thoriumatome in CaF_2-Kristalle einzubringen. Die dotierten Kristalle werden mit einem Excimer-Laser bei einer Wellenlänge von 157 nm bestrahlt und die UV-induzierten Lumineszenz des Kristalls in ihrem zeitlichen Verhalten und ihrer spektralen Zusammensetzung untersucht. Die gewonnenen Erkenntnisse dienen der weiteren Optimierung des Kristallzüchtungsprozesses und der Charakterisierung von Th:CaF_2-Kristallen als Plattform zukünftiger optischer Uhren.

[1] B. R. Beck et al., Phys. Rev. Lett. 98, 142501 (2007)

A 35.2 Wed 16:30 Spree-Palais

Improving the orientation recovery using diffusion map — •Martin Winter, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme

Upcoming X-ray free electron lasers offer the potential of single-molecule coherent diffractive imaging without prior crystallization of the molecule. Since the molecules are in the gas phase, their orientations vary from shot to shot and the averaging of faint images from similar orientations requires a reliable orientation recovery of each image.

Here we show that such an orientation recovery using diffusion map [1] works only under certain conditions. We diagonalize the Laplace-Beltrami operator, which is approximated by diffusion map, for an ensembles of diffraction patterns from randomly orientated molecules and quantify the breakdown of the orientation recovery. For certain classes of molecules we improve the orientation recovery by hitting the molecule simultaneously from multiple directions or by using more eigenvectors from the diagonalization.

[1] Optics Express, Vol. 20, Issue 12, pp. 12799-12826 (2012)

A 35.3 Wed 16:30 Spree-Palais

Time-domain control of quantum dynamics — •Patrick Reiser, Thomas Pfeifer, and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

A primary tool to investigate structure and dynamics of physical systems is spectroscopy, i.e., the study of light-matter interaction as a function of frequency. Alternatively, the system can be studied in the time domain, and it was shown recently that this complementary view provides a direct avenue to the controlling and interpreting of the underlying quantum dynamics [1]. Here, we present our recent progress in developing novel control techniques in the time domain, which are general and apply to a broad range of target systems across the electromagnetic spectrum. Particular implementations are discussed in attosecond spectroscopy of atomic systems [1] and in x-ray quantum optics with atomic nuclei [2].

[1] C. Ott et al., Science 340, 716 (2013).
[2] K. P. Heeg et al., Phys. Rev. Lett. **111**, 073601 (2013).

A 35.4 Wed 16:30 Spree-Palais

Electron beam ion traps at ultrabrilliant light sources — •Sven Bernitt[1,2], René Steinbrügge[1], Jan Rudolph[1,3], Sascha Epp[4], and José Ramon Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität, Jena, Germany — [3]IAMP, Justus-Liebig-Universität, Gießen, Germany — [4]Max Planck Advanced Study Group, CFEL, Hamburg, Germany

Many plasma properties are determined by the interaction of highly charged ions with photons. In the VUV and X-ray spectral region usually only the time reversed processes were accessible. With the newest generation of ultrabrilliant light sources it is now possible to directly study photonic interactions. We present results obtained with the transportable electron beam ion trap FLASH-EBIT [1], that was used to provide targets of various highly charged ion species for synchrotrons (BESSY II, PETRA III) and free-electron lasers (FLASH, LCLS). By resonantly exciting VUV and X-ray transitions and detecting fluorescence as well as changes in charge state it was possible to precicely measure transition energies, natural line widths, and properties of resonant photoionization. This provides valuable data for astrophysics and allows to test general atomic theory [2,3].

[1] S. W. Epp et al., Phys. Rev. Lett. 98, 183001 (2007). [2] S. Bernitt et al., Nature 492, 225 (2012). [3] J. K. Rudolph et al., Phys. Rev. Lett. 111, 103002 (2013).

A 35.5 Wed 16:30 Spree-Palais

Mössbauer meets Fano at x-ray energies: Controlled line shapes in cooperative emission from nuclei — •Kilian P. Heeg[1], Christian Ott[1], Daniel Schumacher[2], Hans-Christian Wille[2], 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

Control of spectroscopic line shapes at hard x-ray energies is demonstrated in the reflectance of a thin film cavity with embedded Moessbauer nuclei. Tunable Fano interference between a spectrally broad cavity response and a narrow bound state nuclear contribution enables us to switch between Lorentz- and Fano-profiles [1, 2]. Spectroscopic signatures such as the cooperative Lamb shift and superradiant line broadening are extracted from the recorded asymmetric line shapes with high precision and agree excellently with our theoretical model [3]. Our results advance spectroscopy and precision metrology in the hard x-ray domain, and provide access to a multitude of applications linked to Fano interference.

[1] U. Fano, Phys. Rev. **124**, 1866–1878 (1961)
[2] C. Ott et al, Science **340**, 716–720 (2013)
[3] K. P. Heeg, and J. Evers, Phys. Rev. A **88**, 043828 (2013)

A 35.6 Wed 16:30 Spree-Palais

A nuclear polariton with two entangled counter-propagating branches — Wen-Te Liao, •Fabian Lauble, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Recent developments of x-ray optics lay the foundation for controlling the quantum behavior of single x-ray photons. Apart from their potential in the field of quantum information, the probing proficiency of single x-ray quanta would be an appreciated counterpart to traditional imaging techniques with intense x-ray beams. Here we present a setup for generating the special superposition of a simultaneously forward- and backward-propagating collective excitation in a nuclear sample [1]. This can be achieved by actively manipulating the scattering channels of single x-ray quanta with the help of a normal incidence x-ray mirror to create a nuclear polariton which propagates in two opposite directions. The two counter-propagating polariton branches are entangled by a single x-ray photon, while their phase relation can be controlled by the hyperfine magnetic field in the sample either by coherent storage [2] or by magnetic field rotations [3]. The quantum nature of the polariton entanglement gives rise to a sub-Ångstrom wavelength standing wave excitation pattern [1] that can be used as a flexible tool to dynamically probe matter on the atomic scale.

[1] W.-T. Liao and A. Pálffy, arXiv:1308.3121 (2013).
[2] W.-T. Liao, A. Pálffy and C. H. Keitel, Phys. Rev. Lett 109, 197403 (2012).
[3] Y. V. Shvyd'ko et al., Phys. Rev. Lett. 77, 3232 (1996).

A 35.7 Wed 16:30 Spree-Palais

Determination of atomic fundamental parameters for quantitative X-ray fluorescence analysis — •Philipp Hönicke, Martin Gerlach, Michael Kolbe, Matthias Müller, Beatrix Pollakowski, Rainer Unterumsberger, and Burkhard Beckhoff — Physikalisch-Technische Bundesanstalt, Abbestr. 2-12, 10587 Berlin

For a reliable quantitative X-ray fluorescence analysis (XRF) exact knowledge of involved atomic fundamental parameters is essential. These parameters include the mass absorption coefficients and photo

ionization cross sections, fluorescence yields, Coster-Kronig transition probabilities and others. In this work, fundamental parameters for several chemical elements have been experimentally determined using the radiometrically calibrated XRF instrumentation of the Physikalisch-Technische Bundesanstalt (PTB). In addition, the dependence of selected fundamental parameters on the chemical species of an element of interest was analyzed using high resolution X-ray emission spectrometry. The experiments were carried out at both the laboratory of the PTB at the electron storage ring BESSY II, where monochromatized synchrotron radiation of high spectral purity up to 10 keV is available and at a wavelength shifter beamline (BAMline) at BESSY where higher photon energies are available. The determination of atomic fundamental parameters with low experimental uncertainties leads to significant improvements in quantitative XRF analysis.

A 35.8 Wed 16:30 Spree-Palais

Single-shot single-cluster measurements of large He nanodroplets irradiated by strong XUV laser pulses — •Bruno Langbehn, Leonie Flückiger, Jan P. Müller, Maria Müller, Yevheniy Ovcharenko, Daniela Rupp, Mario Sauppe, Anatoli Ulmer, and Thomas Möller — TU Berlin

With the advent of novel XUV light sources such as free electron lasers (FELs) imaging of non-periodic objects (nanoparticles, viruses and macromolecules) and studying their ultrafast ionization dynamics has become possible. Therefore a fundamental understanding of the interaction of short wavelength light pulses with matter can be obtained. In particular He clusters and nanodroplets can serve as model systems for studying ionization processes and plasma dynamics due to their simple electronic structure. When irradiated by intense FEL light, highly excited plasma states (far from ground state properties) will be generated and novel ionization channels can be explored.

In order to obtain single shot single cluster data, a He cluster beam will be set up using a pulsed Even-Lavie valve operating at temperatures down to 6 K with repetition rates up to 500 Hz. Large He nanodroplets ($\langle N \rangle \geq 10^6$) will be generated using extreme nozzle geometries to record high quality scattering patterns as well as ion and electron spectra simultaneously in experiments at XUV-FELs such as FERMI and FLASH.

A 35.9 Wed 16:30 Spree-Palais

Soft X-ray emission spectrometry of titanium oxide nanonlayers with an efficient wavelength dispersive spectrometer — •Rainer Unterumsberger, Matthias Müller, and Burkhard Beckhoff — Physikalisch-Technische Bundesanstalt, Abbestr. 2-12, 10587 Berlin

In this work the sensitivity of a calibrated grating spectrometer [1] was improved to analyze nanolayers of different titanium oxides with soft X-ray Emission Spectrometry (XES). The improvement up to a factor of 5 was achieved by a single bounce monocapillary, which is focusing monochromatized soft X-ray undulator radiation down to the micrometer range [2]. Using this set-up, the chemical species was successfully obtained for different titanium compounds by XES. In addition, the transition probabilities of the L-fluorescence lines after an ionization of the L3 subshell were determined. The measurements were carried out at the plane-grating monochromator beamline in the PTB laboratory at BESSY II using monochromatized undulator radiation and calibrated instrumentation [3].

References

[1] M. Müller et al., Phys. Rev. A 79, 032503 (2009)

[2] R. Unterumsberger et al., Spectrochimica Acta Part B 78 (2012) 37-41

[3] B. Beckhoff, J. Anal. At. Spectrom. 23, 845 (2008)

A 35.10 Wed 16:30 Spree-Palais

DESC: A multilayer based delay stage for CAMP at the FEL FLASH enables time-resolved experiments from fs to 100 ps range. — •Mario Sauppe[1], Jan P. Müller[1], Daniel Rolles[2], Rolf Treusch[2], Authors as in[3], Daniela Rupp[1], and Thomas Möller[1] — [1]IOAP, TU Berlin — [2]DESY — [3][1]

Brilliant light pulses from short wavelength free-electron lasers allow the investigation of nanosized particles with a very high temporal and spatial resolution. Radiation damage leads to fast destruction of the investigated objects. Ionization processes which dramatially change the electronic structure of the target objects take place on the fs timescale. Ionic motion, on the other hand, may start during the interaction with the pulse but can reach into a 100 ps range. In order to investigate the complex dynamics of radiation damage in nanosized particles on all relevant time scales, the **DE**lay **S**tage for **C**AMP *DESC* will be set up at the free-electron laser FLASH.

For splitting and delaying the light pulses, DESC will be based on highly reflective multilayer plane mirrors, e.g. for 13.5 nm but also other wavelengths are possible. Delays will be available from about 0 fs up to 600 ps with a femtosecond resolution due to high precision closed loop stages. After DESC, the double pulse can be focused by a Kirkpatrick-Baez optic, leading to extremely intense light pulses in a micrometer spot in the **C**FEL-**A**SG **M**ulti **P**urpose chamber *CAMP* [1]. The poster gives an overview of DESC and introduces challenges in the design.

[1] L. Strüder et al., Nucl. Instr. Meth. Phys. Res. A **614** (2010) 483.

A 35.11 Wed 16:30 Spree-Palais

CAMP - a Permanent User Endstation for X-Ray Imaging and Pump-Probe Experiments at FLASH — •Daniel Rolles[1], Benjamin Erk[1], Robert Moshammer[2], Jan P. Müller[3], Thomas Möller[3], and the CAMP collaboration[1,2,3] — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany — [3]Technische Universtität 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 being installed at FLASH BL1, which is being equipped with new micro-focusing KB optics, to become a permanent endstation available to all users. Here we present an overview of the layout and capabilities of this new endstation.

[1] L. Strüder et al., Nucl. Instr. Meth. Phys. Res. A. 614, 483 (2010)

A 35.12 Wed 16:30 Spree-Palais

Measuring Molecular-Frame Photoelectron Angular Distributions at High Kinetic Energies. — •Evgeny Savelyev[1], Cedric Bomme[1], Denis Anielski[1,2], Benjamin Erk[1], Rebecca Boll[1,2], and Daniel Rolles[1] — [1]Deutsches Elektronen-Synchrotron(DESY), Hamburg, Germany. — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany.

We have built a new double-sided velocity map imaging (VMI) spectrometer optimized for electron-ion coincidence measurements to determine molecular-frame photoelectron angular distributions (MFPADs) for photoelectrons with kinetic energies up to 300 eV. It was employed for the first time at the gas-phase beamline P04 at PETRA to record the MFPADs after inner-shell photoionization of several halogenated carbon compounds. We will present and discuss the results of these measurements along with describing the design of the new spectrometer.

A 35.13 Wed 16:30 Spree-Palais

Direct excitation of s-p E1 transitions in Ir^{17+} — •Alexander Windberger[1], Oscar O. Versolato[2], Hendrik Bekker[1], Sven Bernitt[1], Stepan Dobrodey[1], Rene Steinbrügge[1], Lisa Schmöger[2], Joachim Ullrich[2], Zoltan Harman[1], Natalia Oreshkina[1], Christoph Keitel[1], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Leibniz Universität, Hannover

Due to its electronic configuration displaying near degeneracies of 4f and 5s levels, the Ir^{17+} ion offers a quantum system of particular interest for the study of a possible variation of the fine structure constant at the highest sensitivity. It offers transitions in the optical domain that appear to be excellently suited for high-precision metrology. Disentangling its complex structure is beyond current theoretical capabilities, and therefore spectroscopy in the optical and VUV regime using electron impact excitation is a first step toward those goals. We carry out such measurements at 5 ppm (200 ppm) accuracy in the optical (VUV) regime with an electron beam ion trap (EBIT), and complement them with direct excitation of E1 allowed s-p transitions of both ground state configurations using photonic excitation by means of VUV synchrotron radiation. A campaign at BESSY II with FLASH-EBIT will allow for spectroscopy in the relevant 30-100 eV range that will improve accuracy by at least a factor of 10 and identify the ground state transitions.

The experimental requirements for fluorescence detection in the VUV range under magnetic trapping conditions will be presented.

A 35.14 Wed 16:30 Spree-Palais

Multi-photon ionization processes in rare gases — •Sadegh Bakhtiarzadeh[1,2], Tommaso Mazza[1], Markus Ilchen[1], and Michael Meyer[1] — [1]European XFEL GmbH, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany

Interaction of photons with matter has been subject to studies for a long time. Recently, it has entered a new area with the availability of intense VUV or X-ray Free Electron Lasers (FEL), where the short wavelength radiation can couple efficiently to inner electronic shells of the atoms. In this regards, we have performed a series of experiments on rare gases, especially Ar and Xe, using three different photon energies (105, 123 and 140 eV) from FLASH, Hamburg, Germany. Using a multilayer mirror the FEL beam was focused to a spot size of 5 μm diameter, i.e. intensities in the order of 10^{14} W/cm^2 could be reached. Under such high intensities, different ionization processes can happen, of which the most important are the two-photon sequential as well as the two-photon direct ionization. The relative importance of the individual channels has been investigated by energy-resolved electron spectroscopy. As additional proof for the non-linearity of the process the intensity dependence of the electron emission was monitored. For the expected quadratic dependence of the two-photon processes, an exponent smaller than 2 was generally observed. This can be explained by the extended acceptance angle in the experiment requiring proper volume integration, i.e. a careful consideration of regions with different intensities.

A 35.15 Wed 16:30 Spree-Palais

Time-resolved Measurement of Interatomic Coulombic Decay in Ne_2 at FLASH — •Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Artem Rudenko[2], Lutz Foucar[3], Georg Schmid[1], Thomas Pfeifer[1], Kristina Meyer[1], Denis Anielski[1], Rebecca Boll[1], Daniel Rolles[4], Matthias Kübel[5], Matthias Kling[2,5], Simona Scheit[6], Vitaly Averbukh[7], Joachim Ullrich[8], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]MPI für Kernphysik, Heidelberg — [2]J.R. Macdonald Laboratory, Kansas — [3]MPI für medizinische Forschung, Heidelberg — [4]DESY, Hamburg — [5]MPI für Quantenoptik, Garching — [6]Goethe-Universität, Frankfurt — [7]Imperial College, London — [8]PTB, Braunschweig

Interatomic Coulombic Decay (ICD) is a radiationless decay mechanism in weakly bound systems, where an excited atom relaxes via an energy transfer to a van-der-Waals–bound neighbour, which then emits an electron. The process has been theoretically predicted and experimentally confirmed in clusters and molecules. The lifetime of ICD is a crucial parameter for understanding the underlying mechanism. Here, we present the first direct time-resolved measurement of an ICD lifetime, applying an XUV pump-probe scheme to the neon dimer Ne_2. A 58 eV pump pulse of approximately 60 fs length creates a 2s hole, initiating the decay process, which is probed after an adjustable time delay by an exact copy of the first pulse. Whether or not ICD has happened by the time the probe pulse impinges, leads to the population of different energy levels. The resulting fragmentation channels are separated by means of a Reaction Microscope.

A 35.16 Wed 16:30 Spree-Palais

VUV Studies on Doped Helium Nanodroplets — •Raphael Katzy[1], Aaron LaForge[1], Michele Alagia[6], Lorenzo Avaldi[2], Carlo Callegari[3], Marcello Coreno[2], Michele Devetta[4], Marcel Drabbels[5], Antti Kivimaki[2], Viktor Lyamayev[7], Tommaso Mazza[7], Thomas Möller[8], Marcel Mudrich[1], Yevheniy Ovcharenko[8], Paolo Piseri[4], Kevin Prince[3], Robert Richter[3], Frank Stienkemeier[1], Stefano Stranges[9], and Michele DiFraia[10] — [1]Universität Freiburg, Germany — [2]CNR-IMIP Rome, Italy — [3]Sincrotrone Trieste, Italy — [4]Univerity of Milan, Italy — [5]EPFL Lausanne, Switzerland — [6]CNR-IOM Trieste, Italy — [7]European XFEL GmbH, Germany — [8]Technische Universität Berlin, Germany — [9]University of Rome "Sapienza", Italy — [10]University of Trieste

We performed measurements on doped helium nanodroplets by VUV-seeded FEL FERMI@Elettra.

In the strong field of the FEL clusters gain large amounts of enegy leading to highly excited and ionized states. Nanoplasma is formed and finally leads to a Coulomb explosion of the cluster. Going to short wavelengths in the XUV range the the plasma formation is not uniform anymore. Utilizing doped clusters we observe strong ionization at the surface while in the center of the cluster plasma formation is reduced due to recombination.