A 23: Atomic Clusters (joint session A/MO)

Time: Wednesday 14:30–16:30 Location: HS 1015

A 23.1 Wed 14:30 HS 1015

Experimental studies on core-level interatomic Coulombic decay in heterogeneous rare gas clusters — •Catmarna Küstner-Wetekam[1], Lutz Marder[1], Dana Bloss[1], Christina Zindel[1], Uwe Hergenhahn[2], Arno Ehresmann[1], Přemysl Kolorenč[3], and Andreas Hans[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [3]Institute of Theoretical Physics, Charles University, V Holesovickach 2, 180 00 Prague, Czech Republic

To understand the fundamental mechanisms of radiation chemistry in realistic environments, it is crucial to examine prototypical systems where molecules or atoms interact with their surroundings. Weakly bound van der Waals clusters serve as promising model systems for investigating novel relaxation pathways. In contrast to isolated atoms, electronically excited states may now decay via different interatomic processes such as interatomic Coulombic decay (ICD) or radiative charge transfer (RCT). Due to the relatively low probability of ICD following inner-shell ionization in rare gas clusters, multicoincidence spectroscopy is essential for its detection. Here, we present the observation of changes in branching ratios when going from homogeneous Ar and Kr clusters to heterogeneous ArKr clusters. This transition effectively introduces a distinct environment for the excited atom in each cluster, providing valuable insights into the influence of cluster composition on interatomic decay pathways.

A 23.2 Wed 14:45 HS 1015

Self-organized supersolidity in ion doped Helium droplets — •Juan Carlos Acosta Matos, Panagiotis Giannakeas, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

It is well known that crystallized shells, of Helium atoms, a so called snowball, forms around the ion in the otherwise (super-)fluid Helium droplet [1]. Here, we show that for sufficiently large droplets a third regime appears between the snowball and the liquid one with a supersolid structure where the Helium density exhibits a periodic modulation of the particle density on a spherical shell. The periodic modulation emerges due to the inner shell snowball structure that provides a lattice substrate for the outer droplet shells yielding an accumulation of superfluid particles. To identify supersolidity in a geometrically confined scenario of a droplet we combine modified density functional theory (DFT), allowing us to describe large enough droplets, with a Gaussian Imaginary Time Dependent Hartree (G-ITDH)[2] method which traces the emergence of crystallized structures. Our approach works well as a comparison to Quantum Monte Carlo results [3] for smaller droplets reveals. [1] D. E. Galli etal, J. Phys. Chem. A 2011, 115, 7300-7309 [2] W. Unn-Toc etal, J. Chem. Phys. 137, 054112 (2012) [3] M. Rastogi etal, Phys. Chem. Chem. Phys. 2018, 20, 25569

A 23.3 Wed 15:00 HS 1015

Disentangling the decay cascade of inner-shell vacancies in krypton clusters — •Lutz Marder, Catmarna Küstner-Wetekam, Niklas Golchert, Johannes Viehmann, Emilia Heikura, Nils Kiefer, Arno Ehresmann, and Andreas Hans — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Noble gas clusters represent prototype systems well-suited for the investigation of fundamental atomic and molecular processes; their van der Waals bonds enable new relaxation pathways not available in isolated systems. Many of these have been studied during the recent years, often using coincidence measurement techniques.

Our state-of-the-art experiment, where electrons and photons are detected in coincidence, allows for investigation of multi-particle decay pathways after ionization with synchrotron radiation. Upon introduction of an inner-shell vacancy in a homogeneous Kr cluster, the well-known atomic relaxation pathways – consisting of Auger-Meitner decays and fluorescence – is altered significantly by the opening of new interatomic relaxation mechanisms such as interatomic Coulombic decay (ICD), electron-transfer mediated decay (ETMD) and radiative charge transfer (RCT), all of which have been observed and are presented here.

A 23.4 Wed 15:15 HS 1015

Measurements of Electron-Photon Coincidences from Local and Non-Local Electronic Relaxation Processes in Rare-Gas Clusters after Excitation with Synchrotron Radiation from Multi-Bunch Operation Mode — •Johannes Viehmann[1], Andreas Hans[1], Christian Ozga[1], Nils Kiefer[1], Emilia Heikura[1], Lutz Marder[1], Catmarna Küstner-Wetekam[1], Uwe Hergenhahn[2], and Arno Ehresmann[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Fritz Haber Institute of the Max Planck Society, Faradayweg 4-6 14195 Berlin Germany

Investigating interatomic (or intermolecular) processes in dense media is of interest for understanding the emergence of new properties in conglomerates of interacting particles. This is a stepping stone in bottom up approaches to describe complex environments like biological relevant systems. Our group has used electron-photon coincidence measurements to investigate local and non-local electronic relaxation processes after inner-valence excitation with synchrotron radiation of rare gas clusters. Coincidence measurements at synchrotrons have been restricted to single bunch operation modes of the facilities due to necessities of proper time references. Here, we suggest a technique to expand the use of such electron-photon-coincidence measurements to arbitrary synchrotron filling patterns and show first benchmark results.

A 23.5 Wed 15:30 HS 1015

Extreme shift of Auger cascade energies after deep inner-shell ionization in rare-gas clusters — •Niklas Golchert[1], Nils Kiefer[1], Catmarna Küstner-Wetekam[1], Lutz Marder[1], Minna Patanen[2], Christina Zindel[1], Arno Ehresmann[1], and Andreas Hans[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Nano and Molecular Systems Research Unit, Faculty of Science, P.O. Box 3000, FI-90014, University of Oulu, Oulu, Finland

Closing the gap between isolated atoms and macroscopic objects, clusters serve as ideal prototype systems for fundamental research of local and non-local processes in dense media. By investigating their electron emission spectra after photoionization, detailed insights about the interactions between the constituents of a medium are gained.

Here, we present recent experimental results obtained by multi-electron coincidence spectroscopy showing the strong dependence of Auger cascade energies in clusters on the charge state of the emitting ion caused by the polarization of its surrounding. These findings will deliver valuable information for future spectroscopic experiments on dense media such as clusters or liquids using high-energetic light sources.

A 23.6 Wed 15:45 HS 1015

Reconstructing the anisotropic expansion of a laser driven nanoplasma — •Paul Tuemmler[1], Felix Gerke[2], Christian Peltz[1], Hendrik Tackenberg[1], Björn Kruse[1], Bernhard Wassermann[2], Thomas Fennel[1], and Eckart Rühl[2] — [1]University of Rostock, D-18059 Rostock, Germany — [2]Freie Universität Berlin, D-14195 Berlin, Germany

Coherent diffractive imaging (CDI) at X-ray free-electron lasers (FELs) has evolved into a well-established method for the structural investigation of unsupported nanoparticles. This inherently static method can be readily adopted to time-dependent studies by incorporating a second pulse in a pump-probe scheme.

In a recent experiment at LCLS, we utilized this method to study the fundamental process of free plasma expansion into vacuum using the example of laser-pumped SiO_2 nanospheres. The resulting plasma expansion rapidly and isotropically softens the initial surface density step. This, in turn, increases the radial decay of the scattering signal eventually precluding meaningful measurements due to a diminishing signal-to-noise ratio within only a few hundred femtoseconds [1].

Here, we present the results of a follow-up experiment at the European XFEL where we revisited SiO_2 as a target, but operated in a weaker excitation regime. This approach allowed us to record images over far longer timescales and revealed a strong anisotropic expansion dynamic, as predicted by theory [2].

[1] C. Peltz *et al.*, New J. Phys. **24**, 043024 (2022).
[2] C. Peltz *et al.*, Phys. Rev. Lett. **113**, 133401 (2014).

A 23.7 Wed 16:00 HS 1015

Superradiant parametric Mössbauer radiation — •Ze-An Peng, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Mössbauer nuclei facilitate a broad range of applications based on their spectrally narrow resonances at energies of hard X-rays. However, the narrow resonances render a strong excitation via intense X-ray beams challenging. This motivates a search for alternative excitation sources.

Parametric X-ray radiation (PXR) is a well-known mechanism for generating high-quality x-ray beams, which is based on intense relativistic electron beams passing through crystals. If the crystal contains Mössbauer nuclei, then under suitable conditions spectrally narrow parametric Mössbauer radiation (PMR) can be emitted [1]. Recently, a new scheme of superradiant PXR was proposed which employs coherently modulated electron bunches produced in X-ray free-electron laser accelerators [2]. This boosts the PXR intensity generated from the crystal by orders of magnitude.

Here, we construct a superradiant parametric Mössbauer radiation source, which is rendered possible by an extended configuration in which the conditions for superradiant PXR and the Mössbauer resonance condition can be satisfied simultaneously. After illustrating the operation principle of the source, the properties of the generated X-ray beam and possible applications will be discussed.

[1] O. D. Skoromnik, I. D. Feranchuk, J. Evers, and C. H. Keitel, Phys. Rev. Accel. Beams 25, 040704 (2022). [2] I. D. Feranchuk, N. Q. San, and O. D. Skoromnik, Phys. Rev. Accel. Beams 25, 120702 (2022).

A 23.8 Wed 16:15 HS 1015

Nonlinear effects in the charge fractionalization of critical chains — •Flávia Braga Ramos[1], Imke Schneider[1], Sebastian Eggert[1], and Rodrigo Pereira[2] — [1]University of Kaiserslautern-Landau, Kaiserslautern, Germany — [2]International Institute of Physics, Natal, Brazil

Using the density matrix renormalization group we investigate how a single particle excitation is accommodated in a strongly correlated chain using an out-of-equilibrium protocol. By creating an initial Gaussian wave packet with fixed momentum, we are able to control the regime of energy excitations. Remarkably, the late-time dynamics of the wave packet comprises up to three descendent humps: two counter-propagating low-energy modes and an additional high-energy contribution, whose existence depends on the energy scale set in the initial state. We interpret this unconventional charge fractionalization in terms of the nonlinear Luttinger liquid theory which has attracted great theoretical interest in recent years. Our results provide a new perspective to observe the dynamics of critical chains in the whole range of energy excitations which could potentially be realized in ultracold atomic gases.