A 26: Poster III

Time: Thursday 16:00–18:30 Location: P2

A 26.1 Thu 16:00 P2

A two-dimensional MOT as a cold atomic source for ion-atom collision studies — •Dominik Globig[1], Renate Hubele[1], Aaron C. LaForge[1], Aditya Kelkar[1,2], Katharina Schneider[1,2], Martin Sell[1], Xincheng Wang[1,2], and Daniel Fischer[1] — [1]MPI für Kernphysik, Heidelberg, Germany — [2]EMMI at GSI, Darmstadt, Germany

A new atomic beam source was designed and developed at the MPIK which uses optical pumping combined with a spatially-dependent magnetic field to produce a cold atomic beam for use in ion-atom collision studies at the TSR at MPIK. A "push" laser is used to transfer the precooled atoms from this two-dimensional MOT to a three-dimensional one which is combined with a reaction microscope (MOT-REMI) capable of performing kinematically complete experiments with an energy resolution about ten times greater than that of a conventional reaction microscope. A 2D-MOT was chosen over other atomic target sources (e.g Zeeman slower) for its collimated beam which provides a higher density of atoms and for its compact design.

A 26.2 Thu 16:00 P2

Few-Body Dynamics studied with the In-Ring Reaction Microscope at the TSR of MPIK — •Katharina Schneider[1,2], Daniel Fischer[1], Michael Schulz[3], Marcelo Ciappina[4], Manfred Grieser[1], Siegbert Hagmann[5], Aditya Kelkar[1,2], Tom Kirchner[6], Kai-Uwe Kühnel[1], Aaron LaForge[1], Xincheng Wang[1,2], Robert Moshammer[1], and Joachim Ullrich[1] — [1]MPI für Kernphysik, Heidelberg, Germany — [2]EMMI at GSI, Darmstadt, Germany — [3]Missouri University of Science and Technology, Rolla, USA — [4]ICFO, Barcelona, Spain — [5]GSI, Darmstadt, Germany — [6]York University, Toronto, Canada

Ionization and charge transfer processes in ion-atom collisions are studied fully momentum resolved with a Reaction Microscope, which is implemented into the ion storage ring TSR at MPIK. The low emittance and high intensity of the ion beam allows to obtain even fully differential spectra of processes with small cross sections. By measurements of double ionization of helium, analysed by means of four-particle Dalitz plots, the significance of electron-electron correllation was studied over a broad range of perturbations. For studying Radiative Electron Capture (REC), a detector dedicated to measure low energy X-ray photons is implemented into the Reaction Microscope. REC is the dominant capture process in collisions of atoms and highly charged ions at high velocities. As it can be seen as the inverse process, REC data can provide information of atomic photo-ionization with high-energy photons in the strong-field domain. We aim at first kinematically complete measurements of REC, first results will be presented.

A 26.3 Thu 16:00 P2

Kinematically complete measurements for electron capture in collisions of keV energy ions with atomic and molecular targets. — •Aditya Kelkar, Xincheng Wang, Daniel Fischer, Robert Moshammer, and Joachim Ullrich — Max Planck Institut fuer Kernphysik, Heidelberg, Germany

We report on fully differential cross section measurements of electron capture to slow heavy ions using a Reaction Microscope. The Reaction Microscope is optimized for efficient detection of recoil-ions with large momentum and high energy (up to 200 eV) electrons. In order to achieve this we implemented large area position sensitive MCP detectors with central holes for the passage of the projectile beam. A ring electrode was also implemented within the recoil-ion drift tube for collection of recoil-ions produced with large transverse momentum on to the MCP. The experimental setup has been augmented with a low energy beam line optimized for transfer of few keV/q singly and doubly charged atomic/molecular ions obtained from a penning ion source or highly charged ions from an EBIT. The present experimental setup is adequate for collecting fully differential data sets for several reaction channels like single capture, double capture and resonant capture etc. Details of the experimental setup and results of ongoing measurements will be presented.

A 26.4 Thu 16:00 P2

Mutual Projectile and Target Ionization in $N^{4+,5+}$ +He collisions — •Xincheng Wang[1], Aditya Kelkar[1], Katharina Schneider[1], Michael Schulz[2], Bennaceur Najjari[1], Alexander Voitkiv[1], Manfred Grieser[1], Robert Moshammer[1], Daniel Fischer[1], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, — [2]Physics Department and LAMOR, University of Missouri-Rolla,

We have studied mutual projectile and target ionization processes in 1MeV/amu N^{4+} and N^{5+} +He collisions in a kinematically complete experiment. The data has been analyzed with four-particle Dalitz plots, in which multiple differential cross sections are presented as a function of the momenta of all four particles. Theoretical results from various quantum-mechanical models are convoluted with classical elastic scattering (nucleus-nucleus interaction) and the comparisons to experimental results show qualitatively good agreement with eikonal calculations. Better agreement is achieved for N^{5+} +He collision, while some discrepancies are observed for N^{4+} +He collision, where the significance of high order effects is underestimated.

A 26.5 Thu 16:00 P2

Design, construction and operation of a small ion source for measurements in a linear Paul trap — •Sita Eberle, José R. Crespo López-Urrutia, and Maria Schwarz — Max-Planck-Institut für Kernphysik

Gas atoms can be ionized by electron impact ionization in electron beam ion traps (EBIT) and sources (EBIS). A small EBIS based on a pair of Helmholtz coils with a low magnetic field has been designed and built at the MPIK Heidelberg for test operations with a cryogenic linear Paul trap. The device has the advantage of occupying an area of only about one square meter and is more than able to produce the required singly ionized gas atoms. At typical electron beam currents of 0,5mA and energies of 1keV, an ion yield of ~50nA is obtained. Different gases have been tested and yields have been compared with the values predicted by rate estimates.

A 26.6 Thu 16:00 P2

Electron-Positron Pair Creation in Heavy Ion Collisions — •Manuel Mai — Physikalisches Institut, Universität Heidelberg

A theoretical description of highly charged ion collisions is given. At collision energies near the Coulomb barrier the formation of so quasi molecules can happen, with a ground state that dives into the "Dirac sea" at short distances of the ions. In that way an electron-positron pair can be created.

For two ions traveling on classical Rutherford trajectories the two center Dirac equation is solved numerically with B-Splines. The solutions form a quasi complete set of basis functions at each instant of time. By means of coupled-channel calculations we perform the time evolution of the system, i.e. the transition from one basis set to another. Results are obtained in the monopole approximation in which only a monopole contribution of the potential is used in the Dirac equation.

A 26.7 Thu 16:00 P2

Electron induced dissociation of H2 and CO2: molecular frame (e, 2e) spectroscopy — •Xueguang Ren, Thomas Pflüger, Shenyue Xu, Arne Senftleben, Alexander Dorn, and Joachim Ullrich — Max-Planck-Institut für Kernphysik , 69117 Heidelberg, Germany

Collisions of energetic electrons with molecules that induce chemical and physical reactions are of fundamental importance for a range of areas from plasma physics to radiation damage in living tissue. The study of dissociative ionization of molecules where the molecular ion is fragmenting can provide detailed insight into the molecular reaction dynamics. In this work experiments were performed for H2 and CO2 at low collision energy (E0 = 54.5 eV). A Reaction Microscope was used to measure the momentum vectors of all charged particles emerging from the collision. While for fast electron impact ionization can be well understood as a pure binary collision of the projectile and the target electron, at low energy the ionic potential and, therefore, the molecular structure and its alignment relative to the projectile beam can strongly influence the electron emission pattern. This was demonstrated recently in non-perturbative calculations [1]. Therefore, an important aspect of our measurement is the determination of the molecular axis alignment during the collision. This was realized by detecting the momentum vector of an ionic fragment resulting from the post-collision dissociation of the molecular ion. Fully differential cross sections as well as their interpretation will be delivered at the conference. [1] J. Colgan, et al., Phys. Rev. Lett. 101, 233201 (2008).

A 26.8 Thu 16:00 P2

A Concept for a Spin-Polarized Electron Target in a Heavy Ion Storage Ring — •Michael Lestinsky and Thomas Stöhlker — GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt

We are presently designing a spin-polarized electron target. It builds upon a photocathode electron gun which is well established to serve as an efficient source of highly polarized electron beams. A mix of electrostatic and magnetic fields shall permit an arbitrary orientation of the incident electron polarization. Further, the interaction zone of the electrons with ions circulating in the storage ring will be featuring a flexible setup such that it allows for either transverse or longitudinal beam alignments. Here we lay out the planned design and report on its present status.

First experiments are foreseen to address a complete description of polarized electron induced emission of X-rays in inelastic collisions with heavy ions. These requires the knowledge of the full quantum state of all involved reactants, in particular determining the orientation of the polarization vector. We will employ Compton polarimetry of X-ray photons, which has become in our laboratory an established technique in such experiments. In the literature so far corresponding experiments were mostly carried out with unpolarized electron sources.

A 26.9 Thu 16:00 P2

Dominant interaction Hamiltonians — •Martin Gerlach and Jan-Michael Rost — Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany

Generic Hamiltonian systems do not show an obvious perturbative part, which makes it difficult to understand (or even calculate) their dynamics. Finding suitable approximations to such systems is therefore of general interest in order to gain a deeper understanding of the underlying principles. In this approach we try to separate the dynamics in time according to dominant interaction Hamiltonians. Being the canonical example in atomic physics, we apply this scheme to the classical dynamics of the helium atom [1].

[1] G.Handke, M.Draeger, and H.Friedrich, 1993, Physica A 197, 113

A 26.10 Thu 16:00 P2

Coulomb explosion of diatomic molecular clusters — •Alexey Mikaberidze, Ulf Saalmann, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

If a cluster is fully stripped of its electrons, the ions find themselves in a strongly repulsive potential energy landscape and rapidly undergo Coulomb explosion. The full ionization of a cluster can be achieved in a few femtoseconds by applying an intense near infrared or x-ray laser pulse.

We find using classical molecular dynamics calculations that clusters of diatomic molecules explode in a manner significantly different from atomic clusters. Moreover, it makes a difference whether the molecules in the cluster are oriented randomly or aligned. These differences manifest in the final kinetic energy distributions of ions, which can be measured experimentally. Understanding the underlying mechanisms is interesting in the context of Coulomb explosion imaging and laser-induced ion acceleration.

A 26.11 Thu 16:00 P2

Angular anisotropy parameters in photoionization processes of spherical metallic cluster anions — •Myroslav Zapukhlyak and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

Size-selected sodium cluster anions of approximately spherical form were studied by angle resolved photoelectron spectroscopy over a broad range of photon energies [1,2]. The role of possible correlation effects in this experiment has been discussed theoretically [3]. Recently, the measurements have been extended to copper and silver cluster anions [4]. When the anisotropy parameter dependence is plotted against the impulse of the photoelectron multiplied by the cluster radius, the obtained evolution of the beta parameter is very similar for the photoelectrons from l=4 levels for different cluster species. This striking similarity in the anisotropy parameter may be seen as a counter-argument of the distinct role of correlation effects in such photoionization processes at least for the weakest bound electrons. In this theoretical study we investigate the beta parameters with the goal to elucidate the underlying physics of the photoionization process, and compare our results with the available experimental data and theoretical calculations.

[1] C. Bartels, PhD thesis, University of Freiburg, Freiburg, (2008)
[2] C. Bartels et al., Science, 323, 1323 (2009)
[3] A. V. Solov'yov et al., Phys. Rev. A, 81, 021202 (2010)
[4] A. Piechaczek et al., In DPG Frühjahrstagung AMOP, (2010)

A 26.12 Thu 16:00 P2

Die Chemische Verschiebung der 2p-Rumpfniveaus freier Cluster — •Marlene Vogel[1], Felix Ameseder[2], Christof Ebrecht[2], Konstantin Hirsch[2], Christian Kasigkeit[2], Andreas Langenberg[1], Markus Niemeyer[2], Jochen Rittmann[1], Vicente Zamudio-Bayer[1], Bernd von Issendorff[3], Thomas Möller[2] und Tobias Lau[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Institut für Methoden und Instrumentierung der Synchrotronstrahlung, Albert-Einstein-Straße 15, D-12489 Berlin — [2]Technische Universität Berlin, Institut für Optik und Atomare Physik, EW 3-1, Hardenbergstraße 36, D-10623 Berlin — [3]Albert-Ludwigs-Universität Freiburg, Fakultät für Physik/FMF, Stefan-Meier-Straße 21, D-79104 Freiburg

Für Silicium und Aluminium wurden die 2p-Rumpfniveau-Bindungsenergien freier, größenselektierter Clusterkationen X_n^+ mittels geeigneter Kanäle in Ionenausbeute-Spektroskopie mit durchstimmbarer weicher Röntgenstrahlung bestimmt. Die Analyse der relativen Verschiebungen der so gemessenen 2p-Bindungsenergien gewährt Informationen über das Vorkommen von unterschiedlichen chemischen Umgebungen der Atome im Cluster. Mit Hilfe von DFT-Rechnungen lassen sich diese experimentellen Befunde mit elektronischen Eigenschaften der für die Cluster vorhergesagten geometrischen Strukturen vergleichen.

A 26.13 Thu 16:00 P2

Electronic Structure of Transition Metal Doped Gold Clusters — •Konstantin Hirsch[1,2], Jochen Rittmann[2], Vicente Zamudio-Bayer[2], Marlene Vogel[2], Jörg Wittich[1], Silvia Forin[1], Christian Kasigkeit[1], Felix Ameseder[1], Jürgen Probst[2], Thomas Möller[1], Bernd von Issendorff[3], and Tobias Lau[2] — [1]Technische Universität Berlin, Institut für Optik und Atomare Physik, EW 3-1, Hardenbergstraße 36, D-10623 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Wilhelm-Conrad-Röntgen Campus / BESSY II, Institut für Methoden und Instrumentierung der Synchrotronstrahlung, Albert-Einstein-Str. 15, D-12489 Berlin — [3]Albert-Ludwigs-Universität Freiburg, Fakultät für Physik/FMF, Stefan-Meier-Straße 21, D-79104 Freiburg

Small gold clusters show very suprising properties, like highly enhanced catalytical activity. The electronic properties of small clusters can be modified by doping with transition metal atoms. We investigated the local electronic structure of small doped gold clusters (Au_nM n=1-8, M=Sc,Ti,V,Cr) by means of X-ray absorption spectroscopy. The electronic structure is very sensitive to the doping and geometric structure of the cluster. Electron localization of the 3d orbitals of the impurity atom and shell closure effects in the gold host matrix can be deduced from comparison to atomic Hartree Fock calculations.

A 26.14 Thu 16:00 P2

Setup and first experiments with a new attosecond strong-field reaction microscope — •Martin Laux, Christian Ott, Philipp Raith, Andreas Kaldun, Claus-Dieter Schröter, Robert Moshammer, Joachim Ullrich, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We present the experimental setup of a new reaction microscope to study interactions of ultrashort light pulses with atoms or molecules which is currently being constructed in our attosecond laboratory. The instrument allows to measure, in coincidence, the momenta of ions and electrons produced within the interaction. The reaction microscope is designed to detect electrons up to a kinetic energy of at least 100 eV to be matched to similar photon energies exhibited by our soft-x-ray attosecond pulses. The target can be any atomic or molecular gaseous system of interest but the first experiments will concentrate on strong-field interactions with rare gases to judge the performance of the instrument. The setup of the reaction microscope, including important design considerations, and the first experimental results along with some simulations will be shown. Finally, we will provide an outlook on future experiments now possible with the new device.

A 26.15 Thu 16:00 P2

Impact of hollow-atom formation on coherent x-ray scattering at high intensity — •Sang-Kil Son[1], Linda Young[2], and Robin Santra[1,3] — [1]Center for Free-Electron Laser Science, DESY, Germany — [2]Argonne National Laboratory, USA — [3]Department of Physics, University of Hamburg, Germany

X-ray free-electron lasers (FELs) are promising tools for structural determination of macromolecules via coherent x-ray scattering. The key obstacle for scattering imaging is radiation damage by ultraintense x-ray pulses. We develop a toolkit to treat detailed ionization, relaxation, and scattering dynamics for an atom within a consistent theoretical framework, and investigate the coherent x-ray scattering problem for a carbon atom including radiation damage. We find that the x-ray scattering intensity saturates at a high fluence but can be maximized by using a pulse duration much shorter than the relaxation time scales of the inner-shell vacancy states created. Under these conditions, both inner-shell electrons are removed, and the resulting hollow atom gives rise to a scattering pattern with little loss of quality for a desirable resolution. Our numerical results predict that in order to scatter from a carbon atom 0.1 photons per x-ray pulse, within a spatial resolution of 1.7 Å, a fluence of 10^7 photons/Å^2 per pulse is required at a pulse length of 1 fs and a photon energy of 12 keV. By using a pulse length of a few hundred attoseconds, one can suppress even secondary ionization processes in extended systems. The present results suggest that high-brightness attosecond x-ray FELs would be ideal for single-shot imaging of individual macromolecules.

A 26.16 Thu 16:00 P2

Photoionization and resonant photon scattering of highly charged iron ions — •C. Beilmann[1], J.R. Crespo López-Urrutia[1], M.C. Simon[1], S.W. Epp[1,2], R. Steinbrügge[1], J. Rudolph[1,3], S.N. Eberle[1], M. Leutenegger[4], A. Graf[5], T.M. Baumann[1], F.R. Brunner[1], P. Beiersdorfer[5], R. Follath[6], G. Reichardt[6], and J. Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Max Planck Advanced Study Group at CFEL, Hamburg, Germany — [3]Justus-Liebig-Universität Gießen, Germany — [4]NASA Goddard Space Flight Center, Greenbelt MD, USA — [5]Lawrence Livermore National Laboratory, Livermore CA, USA — [6]Helmholtz-Zentrum Berlin - BESSY II, Berlin, Germany

Interactions of highly charged ions (HCI) and x-ray photons are important processes in astrophysical matter and for testing atomic structure theory. Resonant absorption of x-rays by HCI leads to excited states that can decay by autionization or radiative deexcitation. For the investigation of x-ray absorption, the trasportable electron beam ion trap FLASH-EBIT can be coupled to x-ray sources. Radiative deexcitation (RD) [1] as well as photoionization (PI) [2] were studied in separate experiments. We present results of an experiment at the synchrotron BESSY II, in which both decay channels could be detected simultaneously in the the astrophysically relevant ions Fe^{14+} and Fe^{15+}. The simultaneous detection at 800 eV of both RD and PI allows for the first time a detailed view of all branches of this process in HCI.

[1] S.W. Epp et al., Phys. Rev. Lett. 98, 183001 (2007)
[2] M.C. Simon et al., Phys. Rev. Lett. 105, 183001 (2010)

A 26.17 Thu 16:00 P2

Electron angular correlations in the sequential two-photon double ionization of noble gases — E.V. Gryzlova[1], A.N. Grum-Grzhimailo[1], •S. Fritzsche[2,3], and N.M. Kabachnik[1,4] — [1]Institute of Nuclear Physics, Moscow State University, Russia — [2]Department of Physics, University of Oulu, Finland — [3]GSI Helmholtzzentrum für Schwerionenforschung, Germany — [4]I. Institut für Theoretische Physik, Universität Hamburg, Germany

The study of non-linear atomic processes in the XUV and x-ray regime has attracted much interest following the recent developments of intense FEL sources. Among these processes, the two-photon double ionization (TPDI) of noble gases enables one to better understand the transition from a 'sequential' towards the 'simultaneous' emission of electrons [1,2]. For the TPDI emission of atoms, general expression for the angular correlation function has been derived and analyzed for suitable geometries in the experimental set-up of possible angle-differential measurements. Numerical calculations have been performed especially for the sequential TPDI of krypton [3] and xenon and will be presented in this contribution.

[1] S. Fritzsche *et al.*, J. Phys. B **41** (2008) 165601; B **42** (2009) 145602.
[2] M. Kurka *et al.*, J. Phys. B **42** (2009) 141002(FT).
[3] E. V. Gryzlova *et al.*, J. Phys. B **43** (2010) 225602.

A 26.18 Thu 16:00 P2

Nuclear coherent population transfer with x-ray laser pulses — •Wen-Te Liao, Adriana Pálffy, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

With present and upcoming light sources, the direct interaction between nuclei and super-intense laser fields has become feasible, opening the new field of nuclear quantum optics [1]. Inspired by atomic quantum optics techniques, we investigate the possibility of coherent nuclear population transfer between two ground states in a Λ-level scheme using two overlapping coherent x-ray light beams in a stimulated Raman adiabatic passage (STIRAP) setup [2]. The main question is under which conditions and parameters is control of nuclear states possible. We show that a truly coherent XFEL such as the future XFEL-Oscillator (XFEL-O) or seeded XFEL [3] to provide both probe and Stokes laser fields, together with acceleration of the target nuclei to achieve the resonance condition [1], allow for significant coherent nuclear population transfer at intensities within the present designed values. The most promising case requires laser intensities of 10^{17}-10^{19} W/cm^2 for complete nuclear population transfer. As relevant application, the controlled pumping or release of energy stored in long-lived nuclear states is discussed.

[1] T. J. Bürvenich, J. Evers and C. H. Keitel, Phys. Rev. Lett. **96** 142501 (2006).
[2] W.-T. Liao, A. Pálffy, C. H. Keitel, arXiv:1011.4423.
[3] E. L. Saldin *et al.*, Nucl. Instrum. Meth. A **475**, 357 (2001); K.-J. Kim *et al.*, Phys. Rev. Lett. **100** 244802 (2008).

A 26.19 Thu 16:00 P2

Differential cross sections for non-sequential double ionization of He by 52 eV photons from FLASH — •Moritz Kurka[1,2], Artem Rudenko[2,1], Yuhai Jiang[1], Lutz Foucar[2,1], Oliver Herrwerth[3], Matthias Kling[3], Claus Dieter Schröter[1], Robert Moshammer[1], and Joachim Ullrich[1,2] — [1]Max-Planck Institut für Kernphysik, 69117 Heidelberg — [2]Max-Planck Advanced Study Group at CFEL, 22607 Hamburg — [3]Max-Planck Institut für Quantenoptik, 85748 Garching

We present the results of recent measurements at the free-electron laser Hamburg (FLASH) on two-photon double ionization of helium at a photon energy of 52 eV. Inspecting the momentum distribution of He^{2+} ions we find first experimental evidence for an effect termed 'virtual sequential ionization' recently predicted in theoretical calculations [1]. Comparing our experimental data with state-of-the-art calculations solving the time-dependent Schrödinger equation we find good overall agreement except for cuts along the polarization direction, where we exhibit a siginifcant shift towards larger momenta [2].

[1] D.A. Horner et *al.*, PRA **76**, 030701 (2007). [2] M.Kurka et *al.*, NJP **12**, 073035(2010).

A 26.20 Thu 16:00 P2

Velocity Map Imaging of angular distributions of atomic photoelectrons produced in the XUV regime — •Torsten Hartmann[1], Tobias Vockerodt[1,2], Daniel Steingrube[1,2], Emilia Schulz[1,2], Uwe Morgner[1,2], and Milutin Kovačev[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST, Centre for Quantum Engineering and Space-Time Research

Angular distribution of atomic photoelectrons (PAD) is well understood concerning single-photon ionization and above threshold ionization. However, for the ionisation of an atom using two or three photon processes, theory predicts differing PADs. [1]

We present an experimental setup for the investigation of PADs which are dominated by the initial state of the atom and by rescattering effects with the parent ions only. This is done by using a high pulse energy laser source centered at a wavelength of 265 nm. With the help of a velocity map imaging spectrometer we expect to detect highly structured PADs from few-photon ionized Helium atoms and therefore validate the theoretical predictions.

[1] S. Bauch, M. Bonitz, "Angular distributions of atomic photoelectrons produced in the uv and xuv regime", PRA 78, 043403, 2008

A 26.21 Thu 16:00 P2

Fluorescence of a nanoplasma in clusters — Maria Müller[1], Marcus Adolph[1], •Daniela Rupp[1], Tais Gorkhover[1], Maria Krikunova[1], Yevheniy Ovcharenko[1], Lasse Schrödter[2], Tim Laarmann[2], and Thomas Möller[1] — [1]TU-Berlin, Institut für Optik und atomare Physik, Deutschland — [2]HASYLAB/DESY, Hamburg,

Deutschland

The intense short wavelength radiation provided by free-electron-lasers (FEL) opened up many new fields of research in the last five years. FEL in Hamburg (FLASH) produces soft X-ray pulses with pulse durations of several ten femtoseconds and peak intensities up 10** photons/cm* achieved when focused on a small spot. One domain of interest is the interaction of these intensive XUV femtosecond light pulses with matter, in particular nanosized clusters which form the link between the atomic- and molecule physics on the one hand and solid state physics on the other.

Our investigation concentrates on the development of the electronic and optical properties as well as on the dissociation dynamics of clusters, irradiated by the XUV pulse.

In this poster we intend to present studies of fluorescence of pure and core-shell clusters with dependence on size. In comparison to synchrotron radiation the intensity by the FLASH is much higher and for this reason allows different excitation processes which lead to a nanoplasma in the core of clusters. Fluorescence spectroscopy is a promising approach to study the recombination processes that are taking place in the created nanoplasma.

A 26.22 Thu 16:00 P2

End Station for Low Density Matter Experiments at the FERMI XUV Free Electron Laser — •Raphael Katzy, Viktor Lyamayev, Marcel Mudrich, and Frank Stienkemeier — Universität Freiburg, Physikalisches Institut, D-79104 Freiburg, Germany

With the High-Gain Harmonic Generation technique the FERMI Free Electron Laser offers short pulses of extremely high brilliance and tuneable wavelengths in the range of 20-100 nm. In combination with precision timing this provides outstanding conditions for IR/VIS-XUV pump probe experiments.

The described end station is set-up to combine FERMI with molecular beam experiments. Several sources for a wide range of atomic, molecular and cluster beams are provided. Laser ablation techniques and oven cells can be used for beam doping. A Combination of VMI, TOF and X-ray imaging detectors allow simultaneous detection of electrons and ions as well as recording of laser beam diffraction patterns. The pulsed cryogenic and versatile cluster sources are presented.

A 26.23 Thu 16:00 P2

Entwicklung eines hocheffizienten Elektron-Ion-Koinzidenz-Flugzeitspektrometers für zeitaufgelöste Experimente im XUV — •Sascha Deinert, Leif Glaser, Markus Ilchen, Frank Scholz, Jörn Seltmann, Peter Walter und Jens Viefhaus — Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg

Mit der Entwicklung hochbrillanter Röntgenstrahlungsquellen wie FLASH, PETRA III oder European XFEL wachsen nicht nur das Verständnis für Strukturen und Prozesse auf kleinster Ebene, sondern auch die Anforderungen an neue Diagnosegeräte. Ein nicht zu vernachlässigender Faktor ist dabei oft eine begrenzte Messzeit, die effiziente Experimente erfordert.

Vor diesem Hintergrund wird für die Untersuchung von Photoionisationsprozessen ein Elektron-Ion-Koinzidenz-Flugzeitspektrometer entwickelt, das an die Bedürfnisse von Weichröntgen-/XUV-Quellen im Allgemeinen und der P04 Variable Polarization XUV Beamline bei PETRA III (DESY, Hamburg) im Speziellen angepasst ist. Konzeptionell wird dabei ein kurzes Ionen-Flugzeitspektrometer in den Permanentmagneten eines sogenannten *magnetic-bottle*-Spektrometers für den Elektronennachweis implementiert. Die Kombination dieser beiden für sich effizienten Nachweismethoden sollte ebenfalls effiziente Koinzidenzmessungen gestatten. Modellsimulationen tragen zur Bestimmung der optimalen Parameter bei.

Vorgestellt werden Entwicklungsstand, Simulationsergebnisse und ein 25 mm kurzes Ionen-Flugzeitspektrometer nebst damit vorgenommene Messungen an Inertgasen bei FLASH und DORIS III (DESY).

A 26.24 Thu 16:00 P2

Relativistic signatures in the Kapitza-Dirac effect — •Sven Ahrens, Heiko Bauke, Carsten Müller, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The prediction of the Kapitza-Dirac effect [1], which is the diffraction of electrons by a standing wave of light, has been confirmed experimentally in recent years [2, 3]. The laser intensities, which were used in these experiments, are far below the highest intensities attainable with modern laser facilities and laser pulses with shorter wavelength are available today. Therefore, the question arises, if relativistic signatures of the Kapitza-Dirac effect are measurable in such strong laser fields.

We determine the time-evolution of the electron wavefunction by solving the Dirac equation analytically by a plane wave ansatz and with numerical simulations. We investigate the relativistic quantum dynamics and compare it to the non-relativistic Schrödinger theory focusing on relativistic signatures and spin effects in intense laser fields of short wavelengths.

[1] P. L. Kapitza, P. A. M. Dirac, Proc. Cambridge Philos. Soc. **29**, 297–300 (1933)
[2] D. L. Freimund, K. Aflatooni, H. Batelaan, Nature **413**, 142–143 (2001)
[3] P. H. Bucksbaum, D. W. Schumacher, M. Bashkansky, Phys. Rev. Lett. **61**, 1182–1185 (1988)

A 26.25 Thu 16:00 P2

Muon pair production in laser-assisted electron-positron collisions — •Sarah J. Müller and Carsten Müller — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

The production of muon-antimuon pairs in electron-positron collisions within an external laser field is studied. The effect of the laser field on the total cross section is examined in different kinematic regimes, in particular in the case where the free e^+e^- energies do not exceed the muon pair creation threshold of $2m_\mu c^2$. A comparison with the laser-free reaction is given regarding total cross sections and energy spectra.

A 26.26 Thu 16:00 P2

Multi-Photon Production and Single-Photon Annihilation of Electron-Positron Pairs — •Huayu Hu, Sven Augustin, Carsten Mueller, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg

Electron-positron pairs can be produced via a multiphoton trident process in the collision of a relativistic electron beam with an intense laser field available nowadays [1]. We have performed a complete laser-dressed QED calculation of this process, and investigate the transition from the perturbative regime to the quasi-static regime [2]. An all-optical setup is proposed for future experiments on laser-induced pair production.

We have also studied a time-reversed process, namely electron-positron annihilation with single-photon emission where the extra momentum is absorbed by a nearby spectator electron. We discuss the significance of this process in dense plasma environments.

[1] D. Burke et al., Phys. Rev. Lett. 79, 1626 (1997).
[2] H. Hu, C. Müller, and C.H. Keitel, Phys. Rev. Lett. 105, 080401 (2010).

A 26.27 Thu 16:00 P2

Solving the time-dependent Dirac equation on massively parallel architectures — •Heiko Bauke and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

New parallel computing architectures emerged in the last few years, as for example, multicore systems and graphics processing units with general purpose computing capabilities, and it is expected that all major future computing architectures will be parallel. The new emerging ubiquitous parallel architectures challenge the computational physics community by calling for new parallel numerical algorithms. In our contribution, we present a massively parallel implementation of the Fourier split operator method for propagating time-dependent Dirac equation on multicore systems or graphics processing units. Our implementation is up to more than one order of magnitude faster than traditional sequential implementations. Thus, it allows to propagate wave functions over larger time intervals than it is possible with sequential programs and it permits to propagate broad wave functions with high accuracy. We will also present some applications of our code to problems of light matter interaction in intense laser fields.

A 26.28 Thu 16:00 P2

Unconventional rescattering in strong long-wavelength pulses — •Alexander Kästner, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzerstr. 38, D-01187 Dresden, Germany

In recent experiments a low-energy structure (LES) in the photoelectron spectra of atoms and small molecules in strong long-wavelength pulses was observed [1,2]. This effect cannot be reproduced by the strong-field approximation as well as the simple-man theory, which should apply particularly well for long-wavelengths. Classical trajectory calculations can clearly reproduce the experimental data. By means of a phase-space analysis we could identify a class of trajectories which cause the observed LES. For this class electrons are rescattered aside of the ion they were emitted from. In contrast to conventional backscattering the electron can be accelerated or decelerated. This effect is in competition with the drift velocity. The LES emerges when both effects cancel each other over a wide range of tunneling times.

[1] C.I. Blaga et al., Nature Phys. **5**, 335 (2009)
[2] W. Quan et al., Phys. Rev. Lett. **103**, 093001 (2009)

A 26.29 Thu 16:00 P2

Strong-field ionization dynamics of rare-gas-doped helium nanodroplets — •Marcel Mudrich[1], Siva Krishnan[2], Lutz Fechner[1], Frank Stienkemeier[1], Robert Moshammer[2], and Joachim Ullrich[2] — [1]Physikalisches Institut, Universität Freiburg — [2]Max-Planck-Institut für Kernphysik, Heidelberg

The strong-field ionization dynamics of rare-gas-doped helium nanodroplets is studied using few-cycle femtosecond laser pulses. In accordance with recent theoretical predictions [1], efficient double-ionization of the helium atoms in the droplets is observed when doping the droplets with only a few heavy rare-gas atoms. Pump-probe measurements with identical few-cycle pulses reveal the resonantly enhanced formation of singly and doubly ionized helium atoms at delay times in the range 200-600fs. Both pump-probe transients as well as ion spectra are most sensitive to variations of the droplet size.

[1] A. Mikaberidze, U. Saalmann, and J. M. Rost, Phys. Rev. Lett. 102, 128102 (2009)

A 26.30 Thu 16:00 P2

Phenomenological model of multiphoto-production of charged pion pairs on the proton — •Anis Dadi and Carsten Müller — MPI für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The production of charged pion pairs via multiphoton absorption from an intense X-ray laser wave colliding with an ultrarelativistic proton beam is studied. Our calculations include the contributions from both the electromagnetic and hadronic interactions where the latter are described approximately by a phenomenological potential. Order-of-magnitude estimates for $\pi^+\pi^-$ production on the proton by two- and three-photon absorption from the high-frequency laser field are obtained and compared with the corresponding rates for $\mu^+\mu^-$ pair creation.

A 26.31 Thu 16:00 P2

Interference in above-threshold ionization electron distributions from molecules — •Jost Henkel[1,2], Manfred Lein[2], and Volker Engel[1] — [1]Institut für Physikalische und Theoretische Chemie and Röntgen Research Center for Complex Material Systems, Am Hubland, 97074 Würzburg, Germany — [2]Institut für Theoretische Physik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

We present quantum-mechanical studies on above-threshold ionization of H_2^+ and molecules with three atoms (H_3^{2+}) in two dimensions, varying their orientation relative to the laser polarization. Signatures of interfering emissions from the molecular centers are found in the angular resolved photoelectron momentum distribution. These structures are reproduced by an eikonal model and they deviate from a simple double-slit model, which ignores the electron-ion interaction. No clear signatures of interference are found in the electron energy spectrum.

A 26.32 Thu 16:00 P2

Characterization of the Carrier Envelope Phase (CEP) of a laser pulse by a non dispersive method — •Nicolas Camus, Manuel Kremer, Christian Hofrichter, Bettina Fischer, Vandana Sharma, Robert Moshammer, and Joachim Ullrich — Max Planck Institut for Nuclear Physics, 69117 Heidelberg, Germany

In few-cycle laser science, the CEP of the pulse (offset between the maximum of the electric field and the maximum of the envelope of the pulse) gives direct information on the shape of the electric field and consequently on the possible light-matter interactions induced by it. To measure it, interferometric techniques, such as the f-to-2f technique, are commonly used and provide stabilization of this phase. We report on a more recent technique based on Above Threshold Ionization (ATI) of rare gas atoms by linearly polarized laser pulses. The analysis of the left-right asymmetry of the escaping electrons allows a direct measurement of this phase. We present single-shot measurements done with a stereo-ATI device and compare them to phase stabilization with a dispersive method.

A 26.33 Thu 16:00 P2

Comparison of mixed quantum-classical and full quantum results for the multiphoton dissociation of H_2^+ — •Michael Fischer[1], Frank Grossmann[1], Rüdiger Schmidt[1], Jan Handt[2], Sebastian Krause[2], and Jan-Michael Rost[2] — [1]Institut fuer Theoretische Physik, Technische Universitaet Dresden,D-01062 Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Noethnitzer Strasse 38, D-01187 Dresden, Germany

We present a mixed quantum-classical approach for the time-dependent dynamics of para-H_2^+ exposed to short intense laser pulses with 800 nm wavelength including all nuclear as well as electronic degrees of freedom. Depending on the initial vibrational state, the angular distributions of photo fragments show characteristic shapes in very good agreement with our full quantum calculations. The results are interpreted in the framework of two-dimensional adiabatic Floquet surfaces which depend on the internuclear separation and the rotation angle, demonstrating that adiabatic light-dressed surfaces are a useful concept also for full dimensional nuclear dynamics. With the help of kinetic energy release spectra, we are able to extract the contribution of different photon channels also in the quantum-classical case.

A 26.34 Thu 16:00 P2

Accurate Realization of Mach-Zehnder Interferometer via Dressed State Interference in Atomic Beam Spectroscopy. — •Vents Valle[1,2], Vyascheslavs Kascheyevs[2,3], Juris Ulmanis[2], Zanda Krumina[2], and Aigars Ekers[2] — [1]Institute of Physics, Rostock University, Rostock D-18051, Germany — [2]Laser Center, University of Latvia, LV-1002 Riga, Latvia — [3]Faculty of Computing, University of Latvia, Riga LV-1586, Latvia

It is possible to manipulate energy levels of laser dressed atomic states via intensity and frequency of laser radiation. Such manipulations in abstract two level system may introduce additional time evolution that consists of two level crossings when the dressed energy levels are close (described approximately by Landau-Zener transitions) thus creating two alternative, in general, conjoined evolution paths between the crossings.

In our research we describe situation where an energy level of constant value is crossed twice by another energy level that evolves as a Gaussian curve. We develop a full model of such two level system using Mach-Zehnder interferometer as a base model and discuss accuracy of the model for different scenarios of energy levels' evolution.

A 26.35 Thu 16:00 P2

High Harmonic Generation for Pedestrians — •Carlos Zagoya[1], Christoph-Marian Goletz[2], Frank Grossmann[2], and Jan-Michael Rost[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, D-01187 Dresden, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden, Germany

Using the idea of the strong field approximation together with the semiclassical Herman-Kluk propagator [1], we are able to observe the main features of high harmonic generation (HHG) in a one-dimensional one-electron atom under the influence of a strong laser field by using a simplified classical dynamics. It is shown that only few percent of the trajectories needed in full semiclassical calculations are sufficient in the strong field approach due to the fact that chaotic dynamics induced by the laser field is *not* present.

This work is in part supported by the DFG through grant GR 1210/4-2

[1] M. F. Herman and E. Kluk, Chem. Phys. **91**, 27 (1984)

A 26.36 Thu 16:00 P2

Simulation von Atomen, Molekülen und Clustern in starken Laserfeldern mittels zeitabhängiger Dichtefunktionaltheorie — •Volker Mosert und Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Eine Vielzahl interessanter physikalischer Phänomene, die bei Atomen, Molekülen und Clustern in starken Laserfeldern beobachtet werden, können nur mithilfe einer vollständig quantenmechanischen Beschreibung theoretisch nachvollzogen werden. Die Methode der zeitabhängigen Dichtefunktionaltheorie ermöglicht dies in Form von Computersimulationen.

Bei der Umsetzung dieser Methode liegt die größte Herausforderung aus numerischer Sicht in der effektiven Propagation der Kohn-Sham Orbitale. Die Zeitabhängigkeit des Hamiltonians durch das Feld des Lasers und das Austausch-Korrelationspotentials machen eine Näherung des quantenmechanischen Propagators notwendig, deren Eignung vom betrachteten System abhängt. Durch unsere Zielsetzung auch komplexe Systeme behandeln zu können, wird dabei die Nutzung von räumlichen Symmetrien, z.B. durch geschicktes wählen einer Basis, ausgeschlossen. Greift man in folge dessen auf ein kartesisches Gitter zurück, ist eine Zahl von 10^8 nötigen Gitterpunkten pro Orbital nicht untypisch.

Im Poster werden unsere Wahl der numerischen Verfahren erläutert und erste damit erzielte Resultate präsentiert.

A 26.37 Thu 16:00 P2

Precision investigation of the momentum distribution after strong-field ionization — •Ingo Dreissigacker and Manfred Lein — Institut für Theoretische Physik and Centre for Quantum-Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover

Motivated by recent experimental progress in precision investigation of strong-field ionization by angular streaking [1] and velocity-map imaging [2], we employ linearly polarized half-cycle laser pulses to investigate the ionization process theoretically. Momentum distributions are calculated by numerical solution of the time-dependent Schrödinger equation for the hydrogen atom. For moderate intensities, the results support the picture that ionization occurs most probably at the peak of the field, without tunnelling delay time. The lateral width of the momentum distribution is in good agreement with tunnelling theory. Furthermore we find that the lateral width is maximum for electrons born near the peak of the field, even at high intensities for which the peak of the momentum distribution does not correspond to ionization at the peak of the field.

[1] Eckle *et al.*, Science **322**, 1525 (2008).

[2] Arissian *et al.*, Phys. Rev. Lett. **105**, 133002 (2010).

A 26.38 Thu 16:00 P2

Non-linear Compton scattering of ultrashort intense laser pulses — •Daniel Seipt and Burkhard Kämpfer — Institut für Strahlenphysik, Forschungszentrum Dresden Rossendorf, Bautzner Landstraße 400, 01328 Dresden

The Compton scattering of ultrashort intense laser pulses off relativistic electrons is discussed within a framework based on Volkov states. This approach within relativistic quantum electrodynamics fully takes into account the time dependent laser envelope. An expression for the cross section is provided which is independent of the considered pulse shape and pulse length. The ponderomotive broadening of the harmonic peaks, which was predicted within classical calculations of Thomson scattering is confirmed in the Thomson limit of our general quantum result with strong deviations in the high-energy Compton regime. We present a scaling law connecting the first with the latter one, which allows to easily account for recoil effects in classical radiation spectra. Furthermore, we identify regions in phase space, where quantum effects strongly modify the differential photon distribution, even in the Thomson limit.

A 26.39 Thu 16:00 P2

Acceleration of Rydberg atoms in strong laser fields — Thomas Nubbemeyer, •Henri Zimmermann, Sebastian Eilzer, Ulli Eichmann, and Wolfgang Sandner — Max Born Institut, Max Born Str. 2a , 12489 Berlin

Excitation of atoms in strong linearly polarized laser fields in the tunneling regime can be explained within the rescattering model if one includes the Coulomb potential[1]. Furthermore, an unexpectedly strong kinematic force on the surviving neutral atoms during the short laser puls with intensities up to 10^{16}Wcm^2 has been observed and identified as a ponderomotive force acting on the atoms[2]. Here we report on the acceleration of Rydberg atoms in a strong laser fields. In the experiments we excite a Rydberg wave packet with a linearly polarized strong laser field. After a variable time delay covering a range of a few hundred fs before and after the first pulse we apply a second circularly polarized laser pulse to accelerate atoms in excited states. The circularly polarized light alone is not able to excite Rydberg states. We present the results on the deflection of Rydberg atoms, the efficiency of the process including the survival rates of the Rydberg states and on possible wavepacket dynamics associated with the pump probe technique.

[1] Nubbemeyer et al., PRL 101, 233001 (2008).

[2] Eichmann et al., Nature 461, 1261 (2009)

A 26.40 Thu 16:00 P2

Twin-configuration of xenon clusters observed in single shot imaging experiments at FLASH — •D Rupp[1], M Adolph[1], T Gorkhover[1], S Schorb[1,4], H Thomas[1], D Wolter[1], R Hartmann[2], N Kimmel[2], C Reich[2], L Strüder[2], R Treusch[3], T Möller[1], and C Bostedt[1,4] — [1]IOAP, TU Berlin — [2]MPI Hll, München — [3]FLASH/DESY, Hamburg — [4]SLAC, Stanford

Intense, short laser pulses in the x-ray regime from free-electron lasers (FELs) hold great promise for single-shot single-particle imaging down to individual molecules. We performed first scattering experiments on individual free xenon nanoclusters with high intense soft x-ray laser pulses from FLASH-FEL[3] using novel high performance pnCCDs[2].

With less than one cluster in the laser focus, the diffraction patterns revealed three different geometrical configurations. The by far most frequent patterns of concentric rings reflect the event of a single cluster in focus, followed by a double-slit like pattern from a twin cluster configuration with two clusters in direct contact ($\sim 1\%$) and a fine structured interference pattern similar to Newton rings from two clusters one after the other at μm distance ($\sim 0.1\%$).

The twin clusters were so far not expected to be generated in gas expansion sources. Mass spectroscopy is not capable to identify them, only single shot scattering experiments can reveal their presence. Simulations of conceivable parameters as different orientation to the beam, sizes, and degree of fusion allow to explain all observed patterns. We discuss formation schemes and possible experimantal applications of twin clusters.

A 26.41 Thu 16:00 P2

Doppelresonanz-Spektroskopie hoch geladener Ionen — •Manuel Vogel[1], Gerhard Birkl[2], David von Lindenfels[1] und Wolfgang Quint[1] — [1]GSI Darmstadt — [2]TU Darmstadt

Wir präsentieren ein derzeit im Aufbau befindliches Experiment zur hochgenauen Bestimmung der magnetischen Momente des Elektrons und des Atomkerns in hoch geladenen Ionen mittels einer neuartigen Doppelresonanz-Spektroskopie. Diese Methode basiert auf der Speicherung in einer Penning-Falle und erlaubt die rein spektroskopische Messung magnetischer Momente (g-Faktoren) gebundener Elektronen auf dem ppb-Niveau, sowie die gleichzeitige Bestimmung des magnetischen Kernmoments auf dem ppm-Niveau in Abwesenheit diamagnetischer Abschirmung. Dadurch können erstmals neben Rechnungen der QED gebundener Zustände auch entsprechende Modelle der diamagnetischen Abschirmung getestet werden. Das Experiment findet im Rahmen des HITRAP-Projekts am Helmholtz-Zentrum für Ionenforschung statt.

A 26.42 Thu 16:00 P2

Dynamik einer Ionenwolke in einer Penning-Falle bei Kompression durch eine "rotating wall" — •Manuel Vogel[1], Shailen Bharadia[2], Zoran Andjelkovic[1,3], Richard Thompson[2] und Wilfried Nörtershäuser[1,3] — [1]GSI, Darmstadt — [2]Imperial College London — [3]Universität Mainz

Wir präsentieren systematische Messungen zur Dynamik gespeicherter Ionen in einer Penning-Falle, welche durch eine "rotating wall" komprimiert werden. Dazu wurden Ca^+-Ionen in einer Penning-Falle bei Raumtemperatur gespeichert, lasergekühlt und durch Einstrahlung eines rotierenden Dipolfeldes radial komprimiert. Form und Größe (Kompression) der Ionenwolke in der Falle wurden optisch gemessen als Funktion der Fallenparameter und der Parameter der Dipolstrahlung. Für bestimmte Frequenzen der "rotating wall" wurde ein Einbruch der Kompression beobachtet, der durch Aufheizung der Ionenwolke bei ihren Plasma-Frequenzen erklärt werden kann. Das Experiment fand statt vor dem Hintergrund einer "rotating wall" -Anwendung im Rahmen des SPECTRAP-Experiments am HITRAP-Projekt der GSI in Darmstadt. Dort sollen hoch geladene Ionen radial komprimiert werden, um Präzisionsspektroskopie an verbotenen Übergängen zu ermöglichen.

A 26.43 Thu 16:00 P2

A cryogenic Paul Trap for highly charged ions — •Maria

Schwarz, Franziska R. Brunner, and José Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

An electron beam ion trap (EBIT) is an effective tool for spectroscopy of highly charged ions (HCIs). However, the deep trapping potential leads to high temperatures of the stored ions, and limits the final resolution. A new linear cryogenic Paul-Trap experiment (CryPTEx) in-line with an EBIT will provide long storage times for HCIs due to the extremely low background pressure in a 4K enclosure. The device will use sympathetic cooling of the trapped HCIs with laser-cooled singly charged ions to resolve the natural line width of forbidden transitions. In addition, addressing individual ions should eventually become possible, since these arrange themselves in stable Coulomb crystals.

A 26.44 Thu 16:00 P2

Development of a High Current Electron Beam Ion Trap — •Thomas Baumann, José Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernpyhsik, Heidelberg, Germany

A novel high current electron beam ion trap (EBIT) charge breeder is currently being constructed at the MPI-K Heidelberg in collaboration with the NSCL (MSU) and TRIUMF. The design is based on the TITAN- and FLASH-EBIT, and will utilize an electron gun capable of producing an electron beam of up to 5 A, which is strongly compressed by a 7T magnetic field, to produce and trap highly charged ions from any element. The increased electron beam current will result in an extremely high current density within the trap region that allows for faster charge breeding compared to any other existing EBIT. This enables the new EBIT to produce He-, H-like or bare ions of heavy elements in hundreds of ms. These ions can be studied within the EBIT by various spectroscopic instruments or being extracted to further experiments. First performance tests of the EBIT are presented. Furthermore the machine allows for the study of charge state optimization and a further reduction of charge breeding times which will support the development of future EBIT charge breeders.

A 26.45 Thu 16:00 P2

Angular correlations in the two-photon decay of helium-like heavy ions — A. Surzhykov[1,2], A Volotka[3], F. Fratini[1,2], J.P. Santos[4], P. Indelicato[5], T. Stöhlker[1,2], and •S. Fritzsche[2,6] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Germany — [3]Technische Universität Dresden, Germany — [4]Departamento de Física, Universidade Nova de Lisboa, Portugal — [5]Laboratoire Kastler Brossel, Paris, France — [6]Department of Physics, University of Oulu, Finland

The two-photon decay of high-Z, helium–like ions has been studied theoretically in the framework of second-order perturbation theory and the Dirac equation, with emphasis placed especially on the angular emission of the two photons. In this work, we explored how the angular correlation function depends on the shell structure of the ions in their initial and final states as well as how the terms beyond the electric-dipole approximation affect the angular emission. Detailed calculations were performed for the two–photon decay of the $1s2s\,^1S_0$, $1s2s\,^3S_1$ and $1s2p\,^3P_0$ states of helium-like xenon Xe^{52+}, gold Au^{77+} and uranium U^{90+} ions. Our results display a strong dependence of the photon emission pattern with regard to the symmetry and parity of initial and final ionic states [1].

[1] A. Surzhykov et al., Phys. Rev. A **81** (2010) 042510.

A 26.46 Thu 16:00 P2

Precision Spectroscopy of Trapped Radium Ions — J.E. van den Berg, •G.S. Giri, D.J. van der Hoek, S.M. Hoekman, S. Hoekstra, K. Jungmann, W.L. Kruithof, M. Nunez-Portela, C.J.G. Onderwater, E.B. Prinsen, B.K. Sahoo, B. Santra, M. Sohani, P.D. Shidling, R.G.E. Timmermans, O.O. Versolato, L.W. Wansbeek, L. Willmann, and H.W. Wilschut — Kernfysisch Versneller Instituut, University of Groningen, The Netherlands

Radium ion is an ideal candidate for high precision experiments. Atomic Parity Violation (APV) can be measured in a single trapped and laser cooled Ra^+, enabling a precise measurement of the electroweak mixing angle in the Standard Model of particle physics at the lowest possible momentum transfer. Ultra-narrow transitions in this system can also be exploited to realize a high stability frequency standard. As an important step towards such high precision experiments, excited-state laser spectroscopy is being performed with trapped short-lived $^{209-214}Ra^+$ ions. The results on hyperfine structure, isotope shift and lifetime provide benchmark for the required atomic theory. The experimental set up to perform laser cooling of the trapped radium ions and trapping of a single radium ion is under way.

A 26.47 Thu 16:00 P2

Laser Spectroscopy of Radium — •Bodhaditya Santra, Umakanth Dammalapati, Klaus Jungmann, and Lorenz Willmann — KVI, University of Groningen

Searches for permanent electric dipole moments (EDMs) of fundamental particles are sensitive probes of physics beyond the Standard Model. Fundamental EDMs can experience enhancements in atomic and molecular systems. In particular, isotopes of the heavy alkaline earth element radium exhibit the largest known enhancement factors for any atomic systems due to their atomic and nuclear structure. A sensitive search for EDMs will require an efficient use of the rare isotops, which are available from radioactive sources or at rare isotope facilities like TRIμP at KVI. Here, laser cooling and trapping methods play a crucial role. The main transitions from the ground state have been identified by laser spectroscopy. Nevertheless, the strongest cooling transitions $7s^2\ ^1S_0$ - $7s7p\ ^1P_1$ suffers from strong leakage to metastable states, similar to the case of barium. We describe the experimental approach to determine the wavelength of the three needed repump transitions, which then will permit an efficient capture of radium atoms into a magneto optical trap.

A 26.48 Thu 16:00 P2

Absolute frequency measurement of Rubidium Rydberg transitions — •Markus Mack, Florian Karlewski, Helge Hattermann, Florian Jessen, Simone Höckh, Daniel Cano, and József Fortágh — Physikalisches Institut der Universität Tübingen, Center for Collective Quantum Phenomena and their Applications

We present absolute frequency measurements of ^{87}Rb $5S_{1/2}F=2 \rightarrow 5P_{3/2}F=3 \rightarrow$ nS and nD Rydberg transitions. These measurements were taken by observing electromagnetically induced transparency in a vapor cell as well as in a MOT. We report on our experimental setup, the results, and possible applications.

A 26.49 Thu 16:00 P2

Critical analysis of the methods of interpretation in the hyperfine structure of free atoms and ions. Case of the even configuration system of the titanium atom — •Jerzy Dembczyński, Magdalena Elantkowska, and Jarosław Ruczkowski — Chair of Quantum Engineering and Metrology, Faculty of Technical Physics, Poznan University of Technology, Nieszawska 13B, 60-965 Poznan, Poland

On the basis of experimental data, the even configuration system in the titanium atom was analyzed. Our investigations indicate that the operator

$$H_{\text{hfs}} = \sum_{K=1}^{3} T_e^{(\kappa k)K} \cdot T_n^{(K)}$$

describes the partition of the observed hyperfine splittings into the contributions of ranks K=1,2 and 3 within the experimental accuracy, while the operator

$$T_e^{(\kappa k)1} \cdot T_n^{(1)} =$$

$$\frac{\mu_0\mu_B}{2\pi}\sum_{i=1}^{N}\left[\widehat{l}_i\left\langle r^{-3}\right\rangle^{01} - \sqrt{10}\left(\widehat{s}_i\widehat{C}_i^{2}\right)^{(1)}\left\langle r^{-3}\right\rangle^{12} + \widehat{s}_i\left\langle r^{-3}\right\rangle^{10}\right]\cdot T_n^{(1)}$$

does not fully account for the partition of the interactions of rank K=1 into contributions κk = 01,12 and 10.

This work was supported by Politechnika Poznańska under the project DS-63-029/2011

A 26.50 Thu 16:00 P2

Investigation of the hfs splittings in chromium atom by LIF and ABMR-LIRF methods — Andrzej Krzykowski, •Przemysław Głowacki, Andrzej Jarosz, and Jerzy Dembczyński — Chair of Quantum Engineering and Metrology, Poznań University of Technology, ul. Nieszawska 13B, 60-965 Poznań, Poland

Due to a small amount of experimental data concerning the hfs (hyperfine structure) of chromium atom available in the literature, our research group undertook a systematic study on this element. Our investigations were performed on an atomic beam apparatus by the LIF method (laser induced fluorescence) and ABMR-LIRF method (atomic beam magnetic resonance, detected by laser induced resonance fluorescence). For the electron levels belonging to the multiplet $3d^54s$ a ^{5}P it was possible to obtain the values of the hfs intervals with the accuracy of about 1 kHz. This allowed us to determine precisely the values of the hfs constants A and B, representing magnetic dipole and electric quadrupole interactions. Additionally, for the presented levels the estimation of the value of the hfs constant C (magnetic octupole interaction) was made.

This work was performed within the framework of DS63-029/11.

A 26.51 Thu 16:00 P2

Entwicklungen zur direkten Bestimmung des g-Faktors eines einzelnen Protons — •Cricia Rodegheri[1], Klaus Blaum[2,3], Holger Kracke[1], Andreas Mooser[1], Wolfgang Quint[4], Stefan Ulmer[1,2,4] und Jochen Walz[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [3]Ruprecht-Karls-Universität, 69047 Heidelberg — [4]GSI Darmstadt, 64291 Darmstadt

Ein Überblick zur Messung des g-Faktors eines einzelnen, isolierten Protons in einer zylindrischen Doppel-Penningfalle wird gegeben. Die verwendete Methode soll die erste direkte Messung des g-Faktors an einem einzelnen Proton ermöglichen, wobei eine Messgenauigkeit von 10^{-9} angestrebt wird. Der g-Faktor lässt sich aus zwei experimentell zugänglichen Eigenfrequenzen des Protons gemäβ $g = 2\frac{\nu_L}{\nu_c}$ berechnen, wobei ν_c die freie Zyklotronfrequenz bezeichnet, welche über die Eigenfrequenzen in der sogenannten Präzisionsfalle bestimmt wird. Die Larmorfequenz ν_L wird über eine Spinflipresonanz ermittelt. Die Detektion des Spinzustandes erfolgt in der sogenannten Analysefalle, in die durch eine ferromagnetische Ringelektrode ein starker magnetischer Quadrupol von 300 mT/mm^2 eingebracht wird. Der Nachweis eines Protons unter diesen extremen magnetischen Bedingungen wird präsentiert.

A 26.52 Thu 16:00 P2

Laser spectroscopy of evaporatively cooled highly charged ions at the Heidelberg Electron Beam Ion Trap — •Volkhard Mäckel, Renee Klavitter, Günter Brenner, José Ramón Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

We report on two level laser fluorescence measurement of the forbidden $1s^22s^22p\ ^2P_{3/2}$-$^2P_{1/2}$ M1 transition in boron-like Ar^{13+} at the Heidelberg Electron Beam Ion Trap. The transition was resonantly excited using a tunable pulsed dye laser while simultaneously monitoring the fluorescence photons, yielding a wavelength of 441.25575(17) nm. Forced evaporative cooling on the trapped ions yielded a resolving power of $\lambda/\delta\lambda$=15000, thus being able to resolve the Zeeman splitting of the transition due to the magnetic field present in the trap. This approach in combination with further cooling and two-photon excitation techniques can yield for far more accurate transition energies in highly charged ions than currently possible, pointing toward new precision optical frequency standards based upon highly charged ions.

A 26.53 Thu 16:00 P2

Das 0°-Spektrometer für den Frankfurter Niederenergie-Speicherring (FLSR) — •Annika Jung, Kurt Ernst Stiebing, Lothar Ph. H. Schmidt, Reinhard Dörner, Thomas Felix, Thomas Kruppi, Steffen Enz und Marco Völp — Institut für Kernphysik der Goethe Universität Frankfurt, Max von Laue Straße 1, 60438 Frankfurt a.M.

Am Institut für Kernphysik an der Goethe Universität Frankfurt wird derzeit ein elektrostatischer Speicherring für Ionen bis zu einer Energie von 50 keV aufgebaut (Frankfurt Low Energy Storage Ring - FLSR[1]). Zur Spektroskopie der Lebensdauern der Ionen wird ein Spektrometer benötigt, welches die neutralisierten Ionen unter 0° nachweist (0°-Spektrometer). Im Rahmen dieser Arbeit wurde ein solches Spektrometer aufgebaut und in Betrieb genommen. Im Beitrag werden erste Messungen vorgestellt. [1] K.E. Stiebing et al. Nucl. Instr. And Meth A 614 (2010) 10-16

A 26.54 Thu 16:00 P2

Direct Determination of the Magnetic Quadrupole Contribution to the Lyman-α_1 Transition in a Hydrogen-like Ion — •Günter Weber[1,2,3], Harald Bräuning[1], Andrey Surzhykov[1,3], Stephan Fritzsche[1,4], Siegbert Hagmann[1], Renate Märtin[1,3], Regina Reuschl[1], Uwe Spillmann[1], Sergiy Trotsenko[1,2], Danyal Winters[1], and Thomas Stöhlker[1,2,3] — [1]GSI, Darmstadt, Germany — [2]Helmholtz-Institut Jena, Germany — [3]Physikalisches Institut, Universität Heidelberg, Germany — [4]Department of Physics, University of Oulu, Finland

By applying novel-type position sensitive x-ray detectors as Compton polarimeters we performed the first linear polarization measurement of the Lyman-α_1 radiation ($2p_{3/2}$ -> $1s_{1/2}$) in a high-Z system, namely in U^{91+}. Here, we observed an interference between the electric-dipole (E1) and the magnetic-quadrupole (M2) tranistion amplitudes leading to a significant depolarization of the Lyman-α_1 radiation. In the present work, we show that a combined measurement of the linear polarization and of the angular distribution enables a very precise determination of the ratio of the E1 and the M2 amplitudes and the corresponding transition rates without any assumptions concerning the population mechanism for the excited $2p_{3/2}$ state. This finding opens a new route to disentangle the population process of the excited ionic state from the subsequent decay properties. The accuracy of the obtained amplitude ratio will stimulate more detailed quantum-electrodynamical investigations on the transition amplitudes of highly-charged ions beyond Dirac's theory.

A 26.55 Thu 16:00 P2

Röntgenspektroskopische Untersuchungen an hochgeladenen Schwerionen — •Alexander Mayr[1,2], Joachim Jacoby[1], Thomas Kühl[2] und Olga Rosmej[2] — [1]Institut für Angewandte Physik, Goethe-Universität Frankfurt am Main — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt

Die Energien bestimmter Innerschalenübergänge hochgeladener (lithiumähnlicher) Ionen erlauben die direkte experimentelle Bestimmung verschiedener quantenmechanischer Zustandsgrößen, wie Kernspin oder Ladungsradien. Die präzise spektroskopische Bestimmung dieser Energien erlaubt die Überprüfung theoretischer Vorhersagen der QED, die bislang noch nicht ausreichend untermauert sind. Am GSI Helmholtzzentrum (Darmstadt), wird ein solches Spektroskopieexperiment über die Wechselwirkung eines Schwerionenstrahls mit einem Rötgenlaser realisiert. Eine Herausforderung ist dabei die Entwicklung geeigneter Detektorsysteme, die im Energiebereich einiger hundert eV eine besonders hohe Effizienz besitzen müssen. An einer hierfür konstruierten Testquelle wurden dazu verschiedene Untersuchungen zu möglichen Detektionsverfahren durchgeführt. Der vorliegende Beitrag gibt einen Überblick über das Spektroskopieexperiment und behandelt die bisher durchgeführten Experimente zur Realisierung des Röntgenlasers und des Detektors.

A 26.56 Thu 16:00 P2

New energy levels of Praseodymium with large angula momentum — •Shamim Khan, Imran Siddiqui, Bettina Gamper, Tanweer Iqbal Syed, Günter H. Guthöhrlein, and Laurentius Windholz — Inst. f. Experimentalphysik, Techn. Univ. Graz, Petersgasse 16, A-8010 Graz

The electronic ground state configuration of praseodymium $^{59}Pr_{141}$ is [Xe] $4f^36s^2$, with ground state level $^4I_{9/2}$. Our research is mainly devoted to find previously unknown energy levels by the investigation of spectral lines and their hyperfine structures. In a hollow cathode discharge lamp praseodymium atoms and ions in ground and excited states are excited to high lying states by laser light. The excitation source is a tunable ring-dye laser system, operated with R6G, Kiton Red, DCM and LD700. A high resolution Fourier transform spectrum is used for selecting promising excitation wavelengths. Then the laser wavelength is tuned to a strong hyperfine component of the spectral line to be investigated, and a search for fluorescence from excited levels is performed. From the observed hyperfine structure we determine J-values and hyperfine constants A of the combining levels. This information, together with excitation and fluorescence wavelengths, allows us to find the energies of involved new levels. Up to now we have discovered large number of previously unknown energy levels with various angular momentum values. We present here the data (energies, parities, angular momenta J, magnetic hyperfine constants A) of ca. 40 new, until now unknown energy levels with high angular momentum values: 15/2, 17/2, 19/2, 21/2.

A 26.57 Thu 16:00 P2

Hyperfine structure measurements and discovery of new energy levels in neutral Praseodymium — •Siddiqui Imran, Shamim Khan, Tanweer Iqbal Syed, Bettina Gamper, and Laurentius Windholz — Inst. f. Experimentalphysik, Techn. Univ. Graz, Petersgasse 16, A-8010 Graz

We present here 14 even and 17 odd parity new energy levels of the neutral praseodymium atom. Free praseodymium atoms in ground and excited states are produced in a hollow cathode discharge lamp by cathode sputtering. The hyperfine structure (hfs) of the spectral lines is investigated by the method of laser induced fluorescence (LIF) spectroscopy. As an example of the method used we discuss briefly the finding of the new level at 27304.431 cm^{-1}, even parity, J = 9/2 and A = 690(1) MHz. Laser excitation of the line at 6004.23 is performed and a LIF signal is detected at fluorescence lines 5246.709, 5412.95, 5925.10, 6107.88, 6287.02, 6419.16, and 6620.63 . The hfs is then recorded digitally and fitted to find reliable values of angular momentum J, magnetic and electric quadrupole hyperfine constants A and B for the combining fine structure levels. Assuming an unknown upper level, a lower level is searched in the data base of known levels, having the J and A values determined from the fit procedure. A level with 10654.11 cm^{-1}, odd parity, J = 7/2 and A = 169(2) MHz is found. The energy of the upper level is calculated by adding the center of gravity wave number of the excited line to the energy of the lower level. The existence of the new level is checked by at least one additional laser excitation from another known lower level.

A 26.58 Thu 16:00 P2

Comparison between measurements of hyperfine structures of Pr II - lines investigated by collinear laser ion beam spectroscopy (CLIBS) ans saturation spectroscopy — •Nadeem Akhtar[1,2], Naveed Anjum[1,2], Harry Hühnermann[1,3], and Laurentius Windholz[1] — [1]Inst. f. Experimentalphysik, Techn. Univ. Graz, Petersgasse 16, A-8010 Graz — [2]Optics Labs, Nilore, Islamabad, Pakistan — [3]Fachbereich Physik, Univ. Marburg/Lahn

Investigation of narrow hyperfine structures needs a reduction of the Doppler broadening of the investigated lines. Here we have used two methods: collinear laser spectroscopy (CLIBS) and laser saturation spectroscopy. In the first method, the Doppler with is reduced by accelerating Pr ions to a high velocity and excitation with a collinear laser beam, while in the second method ions with velocity group zero are selected by nonlinear saturation.

In this work the hyperfine spectra of several Pr II lines were investigated using CLIBS. A line with of ca. 60 MHz was measured. The same lines were then investigated in a hollow cathode discharge lamp using intermodulated laser-induced fluorescence spectroscopy. Using this technique a spectral line width of about 200 MHz was achieved. In both methods, the excitation source is a ring dye laser operated with R6G. Using a fit program, magnetic dipole interaction constants A and the electric-quadrupole interaction constants B of the involved levels have been determined in both cases. We discuss advantages and disadvantages of both methods.

A 26.59 Thu 16:00 P2

New even parity energy levels of Pr I found by excitation of transitions in the region 560 - 695 nm — •Tanweer Iqbal Syed, Shamim Khan, Siddiqui Imran, Uddin Zaheer, and Laurentius Windholz — Inst. f. Experimentalphysik, Techn. Univ. Graz, Petersgasse 16, A-8010 Graz

The knowledge of electronic levels is essentially needed for a description of the interactions between the electrons of an atom and for the classification of an atomic spectrum. We have studied the hyperfine structure of Praseodymium spectral lines in the region from 560 to 695 nm. The hyperfine structure of a large number of unclassified Pr I - lines have been investigated by using the method of laser induced fluorescence in a hollow cathode discharge. During this investigation, we have discovered twelve energy levels with even parity, which were previously unknown. The excitation source was a ring dye laser operated with R6G, Kiton red, or DCM. J-quantum numbers and magnetic dipole interaction constants A for upper and lower levels have been determined from the recorded hyperfine structures. The energies of new levels have been determined by using these constants, excitation and fluorescence wavelengths. Promising excitation wavelengths have been taken from Fourier transform spectra. The new levels were confirmed by at least one second laser excitation.

A 26.60 Thu 16:00 P2

Combine a Magneto-Optical Trap with a Magnetic Trap for ^7Li Atoms — •Christoph Schreyvogel, Matthias Strebel, Frank Stienkemeier, and Marcel Mudrich — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg

We utilize a magneto-optical trap (MOT) in combination with a decreasing field type Zeeman-slower to generate an ultracold cloud of ^7Li-Atoms for future scattering experiments (reactive and non-reactive collisions) with cold molecules produced by means of supersonic expansion out of a rotating nozzle. A special feature of our MOT-apparatus is the implementation of a magnetic trap with high field-gradients for trapping the atoms in the electronic ground state at high density. With this setup we will study reactive collisions, such as $Li+HF \rightarrow LiF+H$ at collision energies down to $\leq 1meV$ from which we expect to get insight into the quantum mechanical nature of cold reaction dynamics. The required laser-system for the magneto-optical trap and Zeeman-slower is based on a "master-slave-slave" scheme. The master laser is a low-power single-mode diode laser which is used for injection-locking of two slave-lasers which in turn are used for injection-locking of two additional slave diode lasers to produce high-power narrowband radiation for the MOT-operation.

A 26.61 Thu 16:00 P2

3D-self-trapping of Rydberg-dressed BECs — •Nils Henkel[1], Fabian Maucher[1], Stefan Skupin[1,2], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden — [2]Friedrich Schiller University, Institute of Condensed Matter Theory and Optics, 07743 Jena

We demonstrate that optical coupling of Bose-Einstein condensates can lead to the formation of stable three-dimensional bright solitons, bound by a single pair of Rydberg atoms. It is shown that off-resonant dressing with Rydberg d-states of Rubidium provides an anisotropic but attractive long range interaction which could enable the first realization of such three-dimensional structures. Taking into account both the long range interaction and the short range contact interaction between groundstates, we find large self-trapped three-dimensional solitons for realistic experimental parameters and study their stability.

A 26.62 Thu 16:00 P2

Excitation dynamics of bosons with driven interaction in harmonic trap — •Ioannis Brouzos and Peter Schmelcher — ZOQ Hamburg

We investigate the excitation properties of finite bosonic systems in a one-dimensional harmonic trap with time-dependent interaction. Periodically oscillating driving of the interparticle interaction strength induces excitations of relative motion of the many-body state with particular and controlable contributions of momentarily excited states, and mechanisms for quantum acceleration in the case of resonances occur. For the case of the relative coordinate sytem of two particles, we show the main excitation mechanisms, the role of driving frequency and strength and initial correlation of the bosonic state are discussed, while the Floquet spectrum is calculated revealing the acceleration modes. This simple case is used then for the bottom-up understanding of cases with higher particle numbers, and offers the possibility to design excitations of the many-body state exclusively in the relative motion.

A 26.63 Thu 16:00 P2

Feshbach Spectroscopy of Sodium and Sodium-Lithium — •Raphael Scelle, Tobias Schuster, Arno Trautmann, Steven Knoop, and Markus K. Oberthaler — Kirchhoff Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

We present our experimental setup for the creation of an ultracold Bose-Fermi mixture of ^{23}Na and ^{6}Li. In our first experiments we observed several new Na intraspecies and Na-Li interspecies Feshbach resonances, with the highest resonances located above 2kG. Our precise and extensive Feshbach spectroscopy of sodium up to g-wave resonances allows for a better determination of the Na-Na interaction potentials. The observed Na-Li spectrum at high magnetic fields deviates significantly from the previously predicted one and we propose an alternative scenario based on the Asympotic Bound-state Model.

A 26.64 Thu 16:00 P2

A transportable setup for high resolution measurements of ion-atom collisions — •Simone Götz[1], Bastian Höltkemeier[1], Thomas Amthor[1], Alexey Sokolov[2], Wolfgang Quint[2], and Matthias Weidemüller[1] — [1]Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt

We present a transportable setup combining a magneto-optical trap for rubidium atoms with a recoil ion momentum spectrometer. After interaction of the trapped atoms with highly charged ions the recoil ion momentum can be measured with very high precision due to the very low thermal spread of the target atoms. In collaboration with the GSI in Darmstadt we will investigate correlation effects in multiple charge transfer between the rubidium atoms and highly charged ions. We will discuss several improvements of this setup, including a new recoil ion momentum spectrometer with enhanced optical access and a new technique to calibrate the spectrometer by producing a high rate of short ion pulses from the trapped atoms based on an LED.

A 26.65 Thu 16:00 P2

Single particle and bound state condensation in interacting Bose gases — •Michael Maennel[1,2], Klaus Morawetz[1,3], Pavel Lipavsky[4,5], and Michael Schreiber[2] — [1]Department Physical Engineering, Münster University of Applied Science, 48565 Steinfurt, Germany — [2]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [3]International Institute of Physics, Universidade Federal do Rio grande do Norte, 59.072-970 Natal-RN, Brazil — [4]Institute of Physics, Academy of Sciences, 16253 Prague 6, Czech Republic — [5]Faculty of Mathematics and Physics, Charles University, 12116 Prague 2, Czech Republic

We investigate a Bose gas with finite-range interaction using a scheme to eliminate self interaction in the T-matrix approximation. In this way the corrected T-matrix becomes suitable to calculate properties below the critical temperature, without the use of anomalous functions. We calculate the phase diagram, excitation spectrum and equation of state. For attractive interaction, an Evans-Rashid transition occurs between a quasi-ideal Bose gas and a BCS-like phase. In the latter there is a condensation of bound states resulting in a gap in the excitation spectrum. The gap decreases with increasing density and vanishes at the critical density for Bose-Einstein condensation, where the single-particle dispersion becomes linear for small momenta. The investigation of the equation of state indicates however, that the mentioned phase transitions might be inaccessible due to a preceding liquefaction.

A 26.66 Thu 16:00 P2

Self-rephasing of a cold atomic ensemble for extended coherence times — •Christian Deutsch[1], Fernando Ramirez-Martinez[2], Wilfried Maineult[2], Clement Lacroûte[2], Friedemann Reinhard[1], Jean-Noël Fuchs[3], Fréderic Piéchon[3], Franck Laloë[1], Jakob Reichel[1], and Peter Rosenbusch[2] — [1]LKB - Ecole Normale Supérieure - UPMC - CNRS - Paris — [2]SYRTE - Observatoire de Paris - UPMC - CNRS - Paris — [3]Laboratoire de Physique des Solides- Univ. Paris-Sud - CNRS - Orsay

We report on the observation of very long coherence times on ultracold trapped 87Rb atoms. The experiment[1] is designed to operate a microwave atomic clock in the $10^{-13}s^{-1/2}$ stability regime in a compact setup. The spatial inhomogeneities of Zeeman and collisional shift are largely compensated. Remaining field inhomogeneities limit the frequency spread to $<$ 80mHz giving rise to dephasing of the individual atoms on a timescale of 2 to 3 s [2]. Surprisingly the coherence time is more than an order of magnitude larger than expected.

We explain this by a rephasing of the atomic spins driven by the Identical Spin Rotation Effect[3] acting as a continous spin echo. The interaction effect is demonstrated by tuning the atom density and thereby the ISRE rate[4].

The effect is very general in nature and should be observable in a multitude of systems.

[1] IEEE TUFFC 56, 106 (2010), [2] Appl Phys B 95, 227 (2009), [3] Phys Rev. Lett. 102, 215301 (2009), [4] Phys Rev Let 105, 2, 020401 (2010)

A 26.67 Thu 16:00 P2

Impact of anisotropy on vortex clusters and their dynamics — •Jan Stockhofe[1], Stephan Middelkamp[1], Panayotis G. Kevrekidis[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Department of Mathematics and Statistics, University of Massachusetts, Amherst MA 01003-4515, USA

We investigate the effects of anisotropy on the stability and dynamics of vortex cluster states which arise in Bose-Einstein condensates.

Sufficiently strong anisotropies are shown to stabilize states with arbitrary numbers of vortices that are highly unstable in the isotropic limit. Conversely, anisotropy can be used to destabilize states which are stable in the isotropic limit.

Near the linear limit, we identify the bifurcations of vortex states including their emergence from linear eigenstates, while in the strongly nonlinear limit, a particle-like description of the dynamics of the vortices in the anisotropic trap is developed. Both are in very good agreement with numerical results.

Collective modes of stabilized many vortex cluster states are demonstrated.

A 26.68 Thu 16:00 P2

d-wave confinement-induced resonances in harmonic waveguides — •Panagiotis Giannakeas[1], Vladimir S. Melezhik[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — [2]Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russian Federation

It is demonstrated that low energy pair collisions of bosonic atoms with isotropic interatomic interaction in harmonic waveguides can lead to coupled s- and d-wave confinement-induced resonances (CIRs). In analogy to the extensively studied s-wave case, we show that the d-wave CIR effect emerges in the quasi-1D regime of the confining trap as an imprint of the 3D d-wave resonant scattering properties. The presence of the centrifugal barrier for higher partial waves modifies the confinement strength dependence of the resonant condition, which is determined for the parameters of the applied model. The effect can be utilized for the realization of confined atomic gases interacting via higher partial waves and opens a novel possibility for studying such correlated atomic systems.

A 26.69 Thu 16:00 P2

Immersing Single Atoms into Cold and Ultracold Gases — •Farina Kindermann[1], Shincy John[1], Nicolas Spethmann[1], Amir Moqanaki[1], Claudia Weber[1], Dieter Meschede[1], and Artur Widera[2,1] — [1]Institut für Angewandte Physik, Wegelerstr. 8, 53115 Bonn — [2]Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Str., 67663 Kaiserslautern

We immerse single Cs atoms into a many body systems consisting of cold and ultracold Rb gases in order to use the single Cs atom as a sensitive probe for inter-species interaction and as an agent to manipulate the quantum gas.

From a UHV-MOT Rb is loaded into a magnetic trap. In this trap, the Rb ensemble is precooled by microwave evaporation to approximately $1\mu K$. Using a magnetic transport guided by a dipole trap, the Rb is moved to the center of the quadrupole coils and loaded into a crossed dipole trap. In this crossed dipole trap, further evaporation to quantum degeneracy is performed. Using rf and microwave fields, the Rb is prepared in the magnetic insensitive $F = 0$, $m_F = 0$ state. This enables the use of a high gradient MOT to capture single Cs atoms from the background gas. The overlap between both systems can be adjusted by optimizing the interaction between Cs atoms in the MOT and Rb atoms in the dipole trap. From the MOT, single Cs atoms are loaded into an one-dimensional lattice. Finally, the groundstate collisions between single Cs atoms and Rb gas can be studied in the conserative potential formed by the combination of the lattice and the dipole trap.

A 26.70 Thu 16:00 P2

Towards an Erbium BEC — •Albert Frisch[1], Johannes Schindler[1], Alexander Rietzler[1], Rudolf Grimm[1,2], and Francesca Ferlaino[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

Over the last years, the frontiers of ultracold quantum gases have been enlarged to new non-alkali atomic species, opening up intriguing possibilities for a variety of novel applications. We propose to produce and study quantum gases of erbium atoms. Erbium (Er) is an extremely heavy (166 a.u.) and strongly magnetic ($7\,\mu_B$) rare-earth atom with a rich isotopic variety and a complex energy level structure. The unique combination of interesting properties allows studies of dipolar effects where the anisotropic and long-range dipole-dipole interactions dominate over the simple isotropic contact interaction. With Er Feshbach molecules a more extreme situation can be achieved where the strength of the dipole-dipole interaction even gets comparable to the one between ground-state polar molecules. We present the latest progresses of our Er machine. These include spectroscopic measurements on the strongest cooling transition at 401 nm. The isotope shift has been determined and the hyperfine structure of the fermionic isotope ^{167}Er has been resolved. Measurements on the velocity distribution after the Zeeman slower will show us the best strategy for directly loading the atoms into a narrow-linewidth magneto-optical trap operating on the 170 kHz broad transition at 583 nm.

A 26.71 Thu 16:00 P2

Ultracold Fermi-Fermi Mixtures: The ^{6}Li-^{40}K System — •Frederik Spiegelhalder, Antje Ludewig, Tobias Tiecke, and

Jook Walraven — Van der Waals-Zeeman Instituut, Universiteit van Amsterdam, Netherlands

Fermi-Fermi systems, in particular ^{6}Li-^{40}K, are currently studied in great detail both theoretically as well as experimentally. We now understand the basic scattering properties of the Li-K system. Several interspecies Feshbach resonances have been found and characterized [1, 2]. Heteronuclear molecules have been created at various resonances [3, 4]. Still many effects only observable in a mass-imbalanced system have not been experimentally achieved, yet. One significant difference to the single-species experiments is the possibility to apply species-specific optical trapping potentials [5]. Several theoretical proposals suggest that by confining one species using species-selective optical lattices, interesting new phases could be realized [7]. For example, a long-lived universal trimer state is expected to be observed in a mixed-dimensional system [6]. Here we present our recent experimental efforts towards realising a mixed-dimensional system.

[1] Wille et al. Phys. Rev. Lett. 100 (2008) 053201
[2] Tiecke et al. Phys. Rev. Lett. 104 (2010) 053202
[3] Spiegelhalder et al. Phys. Rev. A 81 (2010) 043637
[4] Voigt et al. Phys. Rev. Lett. 102 (2009) 020405
[5] LeBlanc and Thywissen. Phys. Rev. A 75 (2007) 053612
[6] Levinsen et al. Phys. Rev. Lett. 103 (2009) 153202
[7] Nishida and Tan. Phys. Rev. Lett. 101 (2008) 170401

A 26.72 Thu 16:00 P2

Many-body effects for cold atoms in line-centered lattices — •Gediminas Juzeliunas[1], Tomas Andrijauskas[1], Congjun Wu[2], and Maciej Lewenstein[3,4] — [1]Institute of Theoretical Physics and Astronomy, Vilnius University, A. Goštauto 12, LT-01108 Vilnius, Lithuania — [2]Department of Physics, University of California, San Diego, California 92093, USA — [3]ICFO-Institut de Ciencies Fotoniques, Parc Mediterrani de la Tecnologia, E-08860 Castelldefels (Barcelona), Spain — [4]ICREA - Institucio Catalana de Recerca i Estudis Avancats, 08010 Barcelona, Spain

Recently a line-centered lattice has been proposed and analyzed for cold atoms [1]. A distinguished feature of such a lattice is that its dispersion contains a Dirac cone intersecting with a completely flat band [1]. Here we analyze effects of the atom-atom interaction of the Hubbard type for the line-centered lattice. The lattice is populated by fermionic atoms in two different internal states. We show that there are localized eigen-solutions of the non-interacting Hamiltonian which are preserved by including a sufficiently small atom-atom interaction. The situation resembles to a certain degree the one appearing in the p-band honeycomb lattice in which the interaction takes place between two different atomic p-states [2]. Yet in the present case we are dealing with the s-band of the line-centered lattice, and the interaction takes place between the atoms in different internal states.

[1] R. Shen et al. Phys. Rev. B 81, 041410 (2010). [2] C. Wu et al, Phys. Rev. Lett. 99, 070401 (2007).

A 26.73 Thu 16:00 P2

***Ab-initio* time-dependent investigation of two ultracold atoms in optical lattices** — •Philipp-Immanuel Schneider and Alejandro Saenz — AG Moderne Optik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin

Ultracold atoms in optical lattices and superlattices are good candidates for performing quantum information processing but also for studying fundamental phenomena such as quantum entanglement and transport. We are developing an *ab-initio* approach to solve the full time-dependent Schrödinger equation for two interacting atoms in two or three wells of a 3-dimensional optical lattice. We allow for various time-dependent perturbations of the lattice that correspond, e.g., to a shaking of the lattice or the lowering of the barrier between two lattice sites. Furthermore, the atoms can interact via realistic Born-Oppenheimer potentials or one can simulate the appearance of broad and narrow Feshbach resonances. We are going to present the numerical approach and first studies of several time-dependent processes.

A 26.74 Thu 16:00 P2

A study of CPT resonances in an optical dipole trap — •Carl Basler, Alexander Lambrecht, Florian Meinert, and Hanspeter Helm — Physikalisches Institut, Universität Freiburg, Germany

A table-top atomic clock based on coherent population trapping (CPT) resonances with parallel linearly polarized optical fields in a vapor cell has recently been demonstrated on the D1 line of Rb87[1]. We study this transition with counter-propagating laser beams in an optical dipole trap. One goal is to explore the suitability of this transition for an all optical path to continuous generation of low temperature trapped atom samples using the proposed EIT-cooling scheme [2,3]. Due to the low trapping frequencies which can be realized for neutral atoms, a magnetic-field insensitive CPT resonance transition appears paramount to success. A second attractive feature of this transition is the high contrast of the resonance amplitude[1]. The experiment is carried out using two externally phase-locked diode lasers and a crossed CO2 laser dipole trap which is loaded from a 2D-MOT. Research supported by Research supported by DFG HE2525/7

1 E. E. Mikhailov et al.
2 C. Morigi, Phys. Rev. A. 67 033402 (2003)
3 M. Roghani et al. Phys. Rev. A 81 033418 (2010)

A 26.75 Thu 16:00 P2

Towards Ultracold Mixtures on a Chip — •Sonali Warriar, Matthew Jones, Asaf Paris-Mandoki, Gal Aviv, Anton Piccardo-Selg, German Sinuco, Thomas Fernholz, Lucia Hackermuller, and Peter Kruger — University of Nottingham, Nottingham, UK

Ultracold mixtures hold the promise of understanding new phases of matter and collisions at very low energies. We are setting up experiments with lithium and cesium mixtures on a chip i.e, ^{6}Li - ^{7}Li mixtures, heteronuclear LiCs or homonuclear $^6Li_2$ molecules. By combining the capabilities of the atom chip with optical dipole trapping, it will be possible to trap these mixtures in low dimensions and tune their scattering lengths via Feshbach resonances. In this way, it will also be possible to realise experiments with additional magnetic potentials or investigate cold atoms interacting with a 2D electron gas. Here we present the current status of our experiment.

A 26.76 Thu 16:00 P2

Theory of photoassociation of ultracold trimers: long-range interactions — Maxence Lepers[1], Romain Vexiau[1], Nadia Bouloufa[1], Viatcheslav Kokoouline[2,1], and •Olivier Dulieu[1] — [1]Laboratoire Aimé Cotton, CNRS/Université Paris-Sud, Orsay, France — [2]Department of Physics, University of Central Florida, Orlando, Fl, USA

The electrostatic interaction between an excited atom and a diatomic ground state molecule in an arbitrary rovibrational level at large mutual separations is investigated with a general second-order perturbation theory, in the perspective of modeling the photoassociation between cold atoms and molecules. We find that the combination of quadrupole-quadrupole and van der Waals interactions compete with the rotational energy of the dimer, limiting the range of validity of the perturbative approach to distances larger than 100 a.u.. Numerical results are given for the long-range interaction between Cs and Cs_2, showing that the photoassociation is probably efficient whatever the Cs_2 rotational energy.

A 26.77 Thu 16:00 P2

Prospects for photoassociation of ultracold alkali-strontium compounds — Romain Guérout[2], Mireille Aymar[1], and •Olivier Dulieu[1] — [1]Laboratoire Aimé Cotton, CNRS/Université Paris-Sud, Orsay, France — [2]Laboratoire Kastler-Brossel, CNRS/Université Pierre et Marie Curie, Paris, France

In this work, we investigate the previously unknown electronic structure and properties of ionic and neutral diatomic molecules which could be formed from cold Strontium ions or atoms and ultracold alkali atoms A (A=Li, Na, K, Rb, Cs). The ionic (A-Sr^+) and neutral (A-Sr)species are modeled as effective two- and three-valence electron systems respectively, in the field of polarizable ionic cores Sr^+ and A^+ represented by effective core potentials. Potential curves, permanent and transition dipole moments are computed from a standard quantum chemistry approach with Full Configuration Interaction. Possible paths for charge exchange processes and for photoassociation are presented in the perspective of upcoming experiments.

A 26.78 Thu 16:00 P2

Ion - ion collisions in strongly coupled ultracold plasmas — •Georg Bannasch[1], Thomas Pohl[1], Jose Castro[2], Patrick McQuillen[2], and Thomas Killian[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden — [2]Physics & Astronomy Department, Rice University, Houston, USA

Collisions between charged plasma particles are often described by the famous Spitzer collision rate [1]. The Spitzer theory is based on the assumption that the Debye screening length is larger than the mean interparticle distance, i.e. that the plasma is weakly coupled. Laboratory-based ultracold plasmas, on the other hand, grant experimental access to the strong coupling regime, in which the Spitzer collision rate may diverge.

Here, we present a joint experimental theoretical study of ion - ion collisions in such an ultracold plasma. Velocity-selective optical pumping combined with fluorescence measurements permits to observe the dynamics of velocity relaxation on relevant timescales. In addition, we present exhaustive molecular dynamics simulations that yield good agreement with the experiment, and combined with a statistical description allow to characterize the collision rate at the onset of correlations and deep in the strongly coupled regime.

[1] Jr. L. Spitzer. Physics of Fully Ionized Gases. Wiley, New York, 1962

A 26.79 Thu 16:00 P2

Rydberg Atoms on an Atom Chip — •Atreju Tauschinsky, Vanessa Leung, H.B. van Linden van den Heuvell, and R.J.C. Spreeuw — Universiteit van Amsterdam, Amsterdam, The Netherlands

We present our new system for investigating Rydberg interactions on an atom chip. It is composed of a structured permanent magnetic film on an atom chip[1], allowing the creation of square and triangular arrays of hundreds of microtraps for ultracold atoms. The structure of the magnetic film has been designed for optimal trap geometries using a fast numerical algorithm[2]. The high trap frequencies (> 10kHz) and relatively small lattice constants of approximately 5μm allow the investigation of both inter- and intra-trap interactions, as well as further investigations of surface effects using Rydberg excited atoms[3]. The implementation of a high-NA imaging system should allow single-atom detection using absorption imaging. These characteristics make our system an excellent starting point for studies of atom-surface interactions, many-body physics and quantum information science involving interacting Rydberg atoms on chips.

[1]S. Whitlock *et al.* Two-dimensional array of microtraps with atomic shift register on a chip. New J. Phys. **11**, 023021 (2009)

[2]Roman Schmied *et al.* Optimized magnetic lattices for ultracold atomic ensembles. New J. Phys. **12**, 103029 (2010)

[3]Atreju Tauschinsky *et al.* Spatially resolved excitation of Rydberg atoms and surface effects on an atom chip. Phys. Rev. A **81**, 063411 (2010)

A 26.80 Thu 16:00 P2

Entanglement transport and conical intersections in flexible Rydberg aggregates — •Sebastian Wüster, Sebastian Möbius, Cenap Ates, Alexander Eisfeld, and Jan-Michael Rost — MPI-PKS Dresden

Transfer of electronic excitations on chains of atoms or molecules is important in many areas of physics, such as photosynthetic light-harvesting or assemblies of Rydberg atoms in optical lattices. The electromagnetic interactions responsible for excitation propagation also exert mechanical forces on the chain, inducing motion of the constituents. In such a flexible aggregate, the atomic motion is typically entangled with the state of the electronic excitation. We consider a linear and a circular arrangement of Rydberg atoms on which a single electronic excitation propagates via dipole-dipole transitions, forming a Frenkel exciton.

A 26.81 Thu 16:00 P2

Ion acoustic waves in strongly correlated ultracold neutral plasmas — •Cornelia Lechner, Christian Knapp, and Alexander Kendl — Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria

Recent experiments on ultracold neutral plasmas (UNPs) report on the creation and observation of ion acoustic waves, which belong to the class of low-frequency, electrostatic plasma waves [1]. Surprisingly, despite significant deviations from standard plasma parameters, e.g. the strong coupling regime of the ions and the expansion into vacuum, the observed density oscillations seem to be well described by the standard dispersion relation of ion acoustic waves.

We study the influence of strong Coulomb-coupling on ion acoustic waves in UNPs. By taking into account ionic correlations, we obtain the modified dispersion relation. Deviations from the standard dispersive behavior are expected with an increasing degree of correlations. Ion acoustic waves are usually affected by Landau damping, unless the ion temperature satisfies $T_i \ll T_e$. Since the latter is true for UNPs, a different kind of damping behavior might be expected.

[1] J. Castro, P. McQuillen, and T. C. Killian, Phys. Rev. Lett. **105**, 065004 (2010)