A 8: Poster I

Time: Tuesday 16:30–19:00 Location: Lichthof

A 8.1 Tu 16:30 Lichthof

General mechanisms of electron dynamics in FEL-irradiated clusters — •Christian Gnodtke, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden

We describe the dynamics of electrons in clusters induced by radiation from free-electron lasers (FEL). Based on a simple molecular dynamics model with only four parameters, the total number of ionization events, the cluster radius, the atomic excess energy of the dominant ionization process and the pulse duration, we study the electron motion microscopically. The general dynamics may be categorized into four main parameter regions distinguished by the degree of electron trapping as well as the cross-over from sequential to non-sequential ionization. We identify within this parameter space the previously studied cases of a trapped equilibrium [1] and non-equilibrium plasma [2] as well as the regime of sequential ionization of the cluster [3]. Of particular interest is the region of non-sequential ionization with high excess energy for which we observe the novel phenomenon of ultra-fast formation of an exponential spectrum of the electrons, indicative of an equilibration of the electron system in the continuum.

[1] Ch. Bostedt et al. (experiment), U. Saalmann et al. (theory), to be published

[2] U. Saalmann et al., New J. Physics **10**, 025014 (2008)

[3] Ch. Bostedt et al., Phys. Rev. Lett. **100**, 133401 (2008)

A 8.2 Tu 16:30 Lichthof

Shortcomings of Lindemann-like melting criteria in finite systems — •Jens Böning, Torben Ott, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität, Leibnizstr. 15, D-24098 Kiel, Germany

For numerical studies of phase transitions, a rich variety of so called Lindemann and Lindemann-like criteria exists. Their popularity is mostly due to their simplicity, especially for numerical implementation. They are found to work reasonably well even in finite few-particle systems where no strict phases exist [1], which is also reflected in a softening in other melting criteria like the specific heat or magnetic moment. In this work, we provide an overview over available Lindemann-like parameters and their limitations. We focus on the *mean relative distance fluctuations* also known as *Berry parameter* which is often seen as Lindemann-like but differs fundamentally [2]. We demonstrate that this parameter is inherently flawed and requires renormalization to a universal time-scale [3].

[1] F. Baletto and R. Ferrando, *Rev. Mod. Phys.* **77**, 371 (2005)
[2] D.D. Frantz, *J. Chem. Phys.* **115**, 6136 (2001)
[3] J. Böning et al., *Phys. Rev. Lett.* **100**, 113401 (2008)

A 8.3 Tu 16:30 Lichthof

Studies of rare-gas clusters in intense IR laser fields — •Siva Rama Krishnan[1], Bettina Fischer[1], Manuel Kremer[1], Robert Moshammer[1], Joachim Ullrich[1], Jagannath Jha[2], and Krishnamurthy Manchikanti[2] — [1]Max Planck Insitut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Tata Institute of Fundamental Research, 1 Homi Bhabha Road, Mumbai 400005, India

We report studies on the dynamics of Argon clusters in intense IR femtosecond laser fields. These were carried out at intensities of $\sim 10^{15} W.cm^{-2}$ and a central wavelength of $800nm$ using a Ti:Sapphire based femtosecond laser system delivering $25fs$ pulses. Clusters with a log-normal size-distribution were generated by the supersonic expansion of Argon gas with sizes ranging from 10^3-10^5 atoms/cluster. We present results on kinetic energy spectra of ions and electrons from time-of-flight measurements. The general characteristics of the ion spectra compare well with earlier investigations on rare-gas clusters. We also compare these spectra with appropriate theoretical models which incorporate the final Coulomb explosion of charged clusters taking into account the distribution of cluster sizes in the target and the distribution of intensities in the laser focus.

A 8.4 Tu 16:30 Lichthof

Resolution enhancement in the magnetic bottle photoelectron spectrometer (PES) by means of a time-variable potential step — •Moritz Weigt and Bernd von Issendorff — Universität Freiburg

We present a new method for improving the resolution of a magnetic bottle photoelectron spectrometer. This is achieved by a time-variable potential step which the electrons cross after a certain part of their flightpath.

Normally, a number of effects lead to electrons of the same velocity and emission time being distributed in a packet of finite length. This leads to a distribution of arrival times at the detector, limiting the precision of the time-of-flight measurement.

The time-variable potential time-focuses these electron packets in the detector plane, in principle eliminating this measurement error. It can be shown that this correction is equally valid for all electron energies, in contrast to other methods using pulsed fields for resolution enhancement.

A PES using the new method is currently under construction and, according to detailed simulations, could achieve an energy resolution of at least 1/300 for electron energies between 0.25 and 10 eV. This would mean an improvement by a factor of 5 to 10 compared to the existing setup.

A 8.5 Tu 16:30 Lichthof

Clusters in XUV laser pulses: Electron emission and nanoplasma dynamics — •Mathias Arbeiter und Thomas Fennel — Institute of Physics, University of Rostock

The ionization dynamics of Argon clusters in ultrashort and intense XUV laser pulses is investigated by molecular dynamics simulation. Corresponding experiments[1] at FLASH free electron laser at $\lambda = 32$ nm and $\lambda = 13$ nm with intensities of $I = 10^{12-14}$ W/cm^2 have demonstrated the cluster response to be completely different to the behavior observed in the infrared and the VUV regime, where plasma heating processes dominate the laser- cluster coupling. In contrast, energy absorption due to the excitation of localized electrons, i.e. by the inner ionization processes itself, becomes increasingly important at high photon energy. The resulting signatures in electron energy spectra can be described by a multi-step ionization scheme as long as photoelectrons can escape directly from the cluster potential. Beyond this point, thermalization becomes the dominant process for further electron emission, as is demonstrated by corresponding simulation results.[2] From these scenarios, promising future experiments will be addressed for XUV pump-and-probe experiments, e.g. for monitoring nanoplasma built-up, cluster expansion and dark plasmon modes.

[1] C. Bostedt et al., Phys. Rev. Lett. 100, 133401 (2008)
[2] M. Arbeiter, Th. Fennel, in preparation

A 8.6 Tu 16:30 Lichthof

Core-level Photoelectron Spectroscopy on Free Mass-Selected Metal Clusters at FLASH — •V. Senz[1], T. Fischer[2], P. Oelssner[1], J. Bahn[1], A. Kickermann[1], M. Köther[1], J. Neville[3], M. Schöffler[4], L. Foucar[4], H. Thomas[5], S. Schorb[5], M. Neeb[6], J. Tiggesbäumker[1], M. Martins[7], E. Rühl[8], C. Bostedt[5], W. Eberhardt[6], M. Götz[2], G. Ganteför[2], T. Möller[5], H. Schmidt-Böcking[4], R. Dörner[4], W. Wurth[7], and K.-H. Meiwes-Broer[1] — [1]I. f. Physik, U Rostock — [2]FB Physik, U Konstanz — [3]University of New Brunswick, Canada — [4]I. f. Kernphysik, U Frankfurt — [5]I. f. Optik und Atomare Physik, TU Berlin — [6]Helmholtz-Zentrum Berlin — [7]I. f. Experimentalphysik, U Hamburg — [8]Phys. u. Theor. Chemie, FU Berlin

The electronic structure forms the basis for understanding and tailoring the physical and chemical properties of clusters. A promising method to study this issue is core-level photoelectron spectroscopy using the VUV free-electron laser FLASH at DESY. Our results on lead clusters feature a size-dependent 5d core-level shift and reveal a remarkable change of final state screening conditions due to a metal-to-nonmetal transition at a cluster size of 20 atoms. The interplay of geometry, bonding character and final state electron relaxation and screening of these finite size systems could be experimentally accessed and may challenge theoretical treatment [Phys. Rev. Lett. 102, 138303 (2009)]. In addition, first results on Au 4f spectroscopy will be discussed. A new experimental setup using a hemispherical electron spectrometer leading to improved energy resolution will be presented.

A 8.7 Tu 16:30 Lichthof

Entwicklng einer 1" Magnetronquelle zur Realisierung einer kompakten Clusterdepositionsapparatur — •Martin Pichot-

ka — FMF Freiburg

Wir stellen die Characteristika einer Maschine zur Deposition von geladenen metallischen Clustern vor. Die Maschine besitzt eine neuentwickelte, kompakte 1" Magnetron-Sputterquelle, ein Ionenführungs- und Massenselektionssystem, bestehend aus einer Anordnung von Octopolführung und Quadrupolselektor. Alternativ zur Quadrupolselektion kann ein Energieselektor, zur Selektion großer Cluster, oder auch ausschliesslich eine Octopolführung verwendet werden. Ein in den Strahlengang einführbarer Probenhalter kann zur Realisierung verschiedener Depostionsenergien auf Potential gelegt werden. Der Strahl kann ohne Veränderung der Quell- und Selektor- bwz. Führungsparameter in ein TOF-Spektrometer eingeschossen werden. Das Spektrometer, bestehend aus einem Reflektron und Even-Cup-Detektor, dient zur Kontrolle der selektierten Clustergrössen sowie zur Charakterisierung der Quelleneigenschaften. Mit diesem System wurde die Clusterproduktion der 1" Quelle in Abhängigkeit der Quellparameter untersucht.

A 8.8 Tu 16:30 Lichthof

Untersuchung der Transferionisation und des doppelten Elektroneneinfangs mit Heliumdimeren — •Jasmin Titze[1], Markus Schöffler[2], Nadine Neumann[1], Hong-Keun Kim[1], Florian Trinter[1], Markus Waitz[1], Jörg Voigtsberger[1], Matthias Odenweller[1], Birte Ullrich[1], Robert Wallauer[1], Lutz Foucar[4], Katharina Kreidi[3], Till Jahnke[1], Achim Czasch[1,5], Lothar Ph. H. Schmidt[1], Robert Grisenti[1], Ottmar Jagutzki[1,5], Reinhard Dörner[1] und Horst Schmidt-Böcking[1] — [1]Institut für Kernphysik Frankfurt, Goethe-Universität Frankfurt, Max-von-Laue-Str. 1, 60438 Frankfurt — [2]Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße1, 64291 Darmstadt — [4]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [5]RoentDek Handels GmbH, c/o Institut für Kernphysik, Max-von-Laue-Str. 1, 60438 Frankfurt am Main

Heliumdimere stellen das am weitesten gebundene atomare System dar. Seine Größe ist mit der eines DNA Moleküls vergleichbar. In Stößen mit Alphateilchen bei Projektilenergien von 150 keV/u wurde die Zerfallsdynamik von Heliumdimeren untersucht. Es wurden hierzu zwei Reaktionskanäle gleichzeitig vermessen, der doppelte Elektroneneinfang und die Transferionsation. Als Messtechnik wurde die COLTRIMS-Technik (COLd Target Recoil Ion Momentum Spectroscopy)verwendet. In den Ergebnissen zeigen sich 3 voneinander unterscheidbare Zerfallsprozesse.

A 8.9 Tu 16:30 Lichthof

Angle-resolved photoelectron spectroscopy of metal clusters — •Adam Piechaczek, Christian Hock, Raphael Kuhnen, Christof Bartels, and Bernd v.Issendorff — Fakultät für Mathematik und Physik, Universität Freiburg, Stefan-Meier Str.19, 79104 Freiburg

Angle and energy resolved photoelectron spectroscopy of size-selected K_{55}^-, Ag_{55}^- and Cu_{55}^- clusters has been performed. The electrons are photodetached by a ns laser pulse with photon wavelengths between 248 nm and 428 nm. The photoelectron angular distributions (PADs) of the outgoing electrons contain information about the angular momentum character of the bound state electrons. In the case of one photon excitation the PADs can be described by a single anisotropy parameter β. This parameter has been extracted for transitions from electrons detached from different bound states of the clusters as a function of photon energy. The data is compared with our results for sodium clusters [1]. When the evolutions of the betaparameter are plotted against the wavenumber k of the outgoing electrons multiplied by the clusterradius, the positions of the minima are astonishingly similar for the peaks of the 1g levels. This seems to indicate a very similar effective potential which is seen by the electron for the different clusters species. In this case the evolution of beta could possibly be described in a single active electron model.

[1] C. Bartels et al., Science **323**, 1323-1327 (2009)

A 8.10 Tu 16:30 Lichthof

High Resolution Mass Separation of Cluster Ions — •Kiran Majer[1], Lei Ma[1,2], and Bernd von Issendorff[1] — [1]Institut für Physik, Universität Freiburg, 79104 Freiburg, Germany — [2]Department of Physics, Nanjing University, 210093 Nanjing, China

In cluster physics most experiments study an observable depending on the cluster size (i. e. number of atoms or molecules composing the cluster), thus requiring an appropriated mass selection prior to the actual experiment. Our existing setup comprises a double reflector time-of-flight (TOF) mass spectrometer, with mass selection after the first reflector and a total flight length of about 4m. The achieved a mass resolution is $m/\Delta m \approx 4000$. This means for a medium sized cluster of ca. 6000 amu (e.g. Cu_{91}^-) the attachment of a hydrogen atom to the cluster can not be detected.

A straightforward approach to improve mass resolution is to increase the flight time elongating the ion flight path. To fit such a system into a common TOF apparatus, the physically given flight path must be used multiple times by reflecting the ions repeatedly between ion mirrors.

We introduce a newly build linear multi-pass reflectron composed of two coaxially arranged electrostatic mirrors. It is set up in series with our existing double reflector TOF, allowing us to enhance mass selectivity on request (according to simulations a mass resolution of 100 000 could be achieved). A comparison of the simulated and experimentally achieved resolution as well as a first application to cluster experiments will be shown.

A 8.11 Tu 16:30 Lichthof

2p-Photoionisation an freien größenselektierten Silizium-Clustern — •Marlene Vogel[1], Konstantin Hirsch[1], Andreas Langenberg[3], Jürgen Probst[1], Jochen Rittmann[3], Vicente Zamudio-Bayer[1], Jörg Wittich[1], Silvia Forin[1], Felix Ameseder[1], Bernd von Issendorff[2], Thomas Möller[1] und Tobias Lau[3] — [1]Technische Universität Berlin, Institut für Optik und Atomare Physik, EW 3-1, Hardenbergstraße 36, D-10623 Berlin — [2]Albert-Ludwigs-Universität Freiburg, Fakultät für Physik/FMF, Stefan-Meier-Straße 21, D-79104 Freiburg — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Institut für Methoden und Instrumentierung der Synchrotronstrahlung, Albert-Einstein-Straße 15, D-12489 Berlin

Die Röntgenspektroskopie an freien Clustern stellt aufgrund der niedrigen Targetdichte und des niedrigen Röntgenphotonen-Flusses eine Herausforderung dar. Nun ist es gelungen, Innerschalen-Röntgenspektroskopie an größenselektierten freien Siliziumclustern Si_n^+ im Größenbereich $n = 5 - 92$ an der 2p-Kante durchzuführen. Durch die angewandte Methode, die Ionenausbeutespektroskopie, können die direkte Rumpfniveau-Photoionisation und die resonante Rumpfniveau-Anregung getrennt analysiert werden, was eine zur XPS analoge Untersuchung ermöglicht.

Die vorgestellten Ergebnisse gewähren neue interessante Einblicke in die elektronische Struktur kleiner bis mittlerer Siliziumcluster.

A 8.12 Tu 16:30 Lichthof

Resonant 2p X-ray Absorption Spectroscopy of Size Selected Calcium, Scandium, Nickel and Copper Clusters — •Felix Ameseder[2], Jochen Rittmann[1], Silvia Forin[2], Konstantin Hirsch[2], Christian Kasigkeit[2], Andreas Langenberg[1], Jürgen Probst[2], Marlene Vogel[2], Jörg Wittich[2], Vicente Zamudio-Bayer[2], Thomas Möller[2], Bernd von Issendorff[3], and Tobias Lau[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Institut für Methoden und Instrumentierung der Synchrotronstrahlung, Albert-Einstein-Str. 15, 12489 Berlin — [2]Technische Universität Berlin, Institut für Optik und Atomare Physik, Hardenbergstr. 36, 10623 Berlin — [3]Universität Freiburg, Fakultät für Physik, Stefan-Meier-Str. 21, 79104 Freiburg

Studies on the 3d transition metals in the past have revealed interesting phenomena, including a so-called 'anomalous' branching ratio of the early transition metal atoms and the development of the branching ratio from the atom to the bulk. Here we present the first resonant 2p-3d measurements of size selected calcium, early transition metals (Sc) and later transition metals (Ni, Cu). By means of resonant x-ray absorption spectroscopy on size selected clusters an insight into the development of the electronic structure of calcium (d^0), scandium (d^1), nickel (d^9) and copper (d^{10}) clusters is obtained. A detailed discussion including a comparison between the early transition metal and calcium on the one hand and the late transition metals on the other hand will be given.

A 8.13 Tu 16:30 Lichthof

VUV photoionization spectroscopy of size selected silicon and aluminium cluster cations — •Christian Kasigkeit[1], Konstantin Hirsch[1], Andreas Langenberg[2], Jochen Rittmann[2], Marlene Vogel[1], Vicente Zamudio-Bayer[1], Jürgen Probst[1], Jörg Wittich[1], Thomas Möller[1], Bernd von Issendorf[3], and Tobias Lau[2] — [1]Technische Universität Berlin, Institut für Op-

tik und Atomare Physik, EW 3-1, Hardenbergstraße 36, D-10623 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Institut für Methoden und Instrumentierung der Synchrotronstrahlung, Wilhelm-Conrad-Röntgen Campus / BESSY II, Albert-Einstein-Straße 15, D-12489 Berlin, Germany — [3]Albert-Ludwigs-Universität Freiburg, Fakultät für Physik/FMF, Stefan-Meier-Straße 21, D-79104 Freiburg, Germany

Valence band photoionization spectroscopy of free size selected silicium and aluminium cluster cations has been performed in order to determine the lth ($l = 2-5$) ionization potentials with respect to cluster size. Cluster size has therefore been varied from $n = 6$ up to $n = 92$ atoms for silicon and $n = 7$ to $n = 56$ for aluminium. The measured behavior of the ionization potentials corresponds to the liquid drop model. Charged clusters have been accumulated using a nitrogen cooled ion trap colinear to the exciting synchrotron radiation beam to obtain sufficient target density and absorption length. The spectra have been measured by detecting the ion yield of the resulting fragments.

A 8.14 Tu 16:30 Lichthof

Parity-Violation in Hydrogen: Precision Enhancement through Many-Particle Squeezing — •Martin-Isbjörn Trappe, Thomas Gasenzer, and Otto Nachtmann — Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg

We discuss the propagation of hydrogen atoms in static electric and magnetic fields in a longitudinal atomic beam spin echo (lABSE) Interferometer. The atoms acquire geometric (Berry) phases that exhibit a manifestation of parity-(P-)violation effects arising from electroweak Z-boson exchange between electron and nucleus. We provide analytical as well as numerical calculations of the behaviour of the metastable n=2 states of hydrogen. Possible measurements of P-violating geometric phases in lABSE experiments require a high precision for detecting atoms in specific states. We investigate possibilities to enhance the precision of lABSE experiments beyond the standard quantum limit using squeezed many-particle hydrogen states.

A 8.15 Tu 16:30 Lichthof

A *Swiss army knife* for dealing with the hydrogen atom model — •Sean McConnell[1,2], Stephan Fritzsche[2,3], and Andrey Surzhykov[1,2] — [1]Physikalisches Institut der Universität Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung — [3]University of Oulu, Finland

Since its release in 2004, the Dirac program has become a *staple in the diet* of studies on the structure and behaviour of hydrogen–like ions [1]. With the help of this program, originally developed as a set of Maple procedures, a number of investigations were recently performed on the charge transfer in relativistic ion–atom collisions, the radiative transitions in high–Z projectiles and the spin entanglement phenomena in atomic photoionization. Here, we present a new version of the Dirac package which is designed within the framework of Mathematica [2]. While retaining all previous capabilities, the new version includes many new features and improvements. In particular, the new Mathematica procedures support the symbolic and numerical evaluation of the two–photon transition rates, Coulomb excitation cross sections and polarization properties of characteristic radiation, to name just a few. Furthermore, a built–in and interactive help system will ensure new users of Dirac can exploit the program's potential with greater ease than its predecessor.

[1] A. Surzhykov, P. Koval, and S. Fritzsche, Comput. Phys. Commun. **165** (2005) 139
[2] S. McConnell, S. Fritzsche, and A. Surzhykov, Comput. Phys. Commun. *accepted, in press*

A 8.16 Tu 16:30 Lichthof

Extension of imaginary time method for laser assisted tunneling of quasistationary states — •Héctor M. Castañeda[1], Sergey Popruzhenko[2], Adriana Pálffy[1], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Moscow State Engineering Physics Institute, Russia

The imaginary time method (ITM) [1] was originally introduced for description of nonlinear ionization in intense laser fields, or, in general, tunneling through time-dependent barriers [2]. Within ITM, the ionization process is described by classical equations of motion solved in complex time, so that the transition amplitude is determined by the respective classical action [1,2].

For atoms in the absence of an external field, the initial state is usually a true bound state and the electron cannot tunnel out freely. However, laser fields can also assist processes where tunneling occurs already without an external field, such as cold emission of electrons or decay of autoionizing states. For description of such intense-laser-assisted effects, ITM could also serve as an efficient tool. Here we extend the formalism of ITM to describe laser-assisted decay of quasistationary states and apply it to calculate the tunneling probability in the presence of an intense electromagnetic field. We show that the laser field modifies the total probability of decay and the shape of the spectrum. This opens a way to control the quasistationary state decay.

[1] V. S. Popov, V. P. Kuznetsov, and A. M. Perelomov, JETP **26**, 222 (1967)
[2] V. S. Popov, Phys. At. Nucl. 68, 686 (2005)

A 8.17 Tu 16:30 Lichthof

Efficient grid-based nonequilibrium Green's function calculations: I. General method and applications to atoms and molecules — •Karsten Balzer and Michael Bonitz — ITAP, Christian-Albrechts-Universität Kiel, Leibnizstr. 15, 24098 Kiel

For strongly inhomogeneous quantum systems, the use of finite elements (FE) in combination with the discrete variable representation (DVR) [1,2] allows for an optimal and flexible representation of the nonequilibrium Green's function (NEGF) in coordinate space [3]. In contrast to a general basis approach, the complementary features of the FE-DVR lead (i) to (semi-)analytic matrix elements of the kinetic, potential and interaction energy operators, (ii) to drastic simplifications of the self-energies and, in turn, (iii) to an essential speedup in the computation of the NEGF.

As atomic and molecular examples, we compute, in Hartree-Fock and second Born approximation, the equilibrium properties of the helium atom, the hydrogen molecule, and lithium hydride modeled in one spatial dimension [3]. The results comprise the self-consistent ground-state/binding energies, densities and bond-lengths which are compared with the solution of the few-particle time-dependent Schrödinger equation.

[1] T.N. Rescigno, and C.W. McCurdy, Phys. Rev. A 62, 032706 (2000). [2] B.I. Schneider, L.A. Collins, and S.X. Hu, Phys. Rev. E 73, 036708 (2006). [3] K. Balzer, S. Bauch, and M. Bonitz, arXiv:0910.5458, submitted to Phys. Rev. A (2009).

A 8.18 Tu 16:30 Lichthof

Efficient grid-based nonequilibrium Green's function calculations: II. Code parallelization and resolution of time-dependent atomic features — •Karsten Balzer and Michael Bonitz — ITAP, Christian-Albrechts-Universität Kiel, Leibnizstr. 15, 24098 Kiel

The real-time propagation of the nonequilibrium Green's function (NEGF) solving the two-time Schwinger/Keldysh/Kadanoff-Baym equations generally involves very large computational resources and, hence, reveals limited capabilities. For this reason, using the finite-element discrete variable representation [1-3], we develop a parallel code which gets along with minumum random access memory (RAM) at acceptable inter-node communication. The resulting program is ready for large cluster computation and should enable enhanced applicability of NEGFs in atomic problems.

As first benchmarks, we compute, in second Born approximation, the nonequilibrium behavior of the one-dimensional helium atom starting from the self-consistent (correlated) ground-state state [3]. From the time-propagation, we extract the dipole-strength and discuss one- and two-electron excitations. Also, the results are compared to solutions of the two-particle time-dependent Schrödinger equation.

[1] T.N. Rescigno, and C.W. McCurdy, Phys. Rev. A 62, 032706 (2000). [2] B.I. Schneider, L.A. Collins, and S.X. Hu, Phys. Rev. E 73, 036708 (2006). [3] K. Balzer, S. Bauch, and M. Bonitz, arXiv:0910.5458, submitted to Phys. Rev. A (2009).

A 8.19 Tu 16:30 Lichthof

Photoionization of one-dimensional model atoms — •David Hochstuhl, Sebastian Bauch, and Michael Bonitz — ITAP, Christian-Albrechts Universität zu Kiel, 24098 Kiel

Computer simulations using one-dimensional model atoms may often qualitatively reproduce experimental results, and in this way offer a great insight into the processes involved in the ionization in strong laser fields. The movement of the electrons is thereby restricted only to the polarization axis of the electromagnetic field. In particular, the one-dimensional helium atom is employed frequently in the literature, since it is able to describe several correlation effects like the double ionization knee. Simulations on larger systems are, however, only rarely

encountered. The focus of this poster lies thus on the usefullness of such models.
We present numerically converged calculations for one-dimensional atoms with four and six electrons, which are obtained by the multiconfigurational time-dependent Hartree-Fock method, and compare them to results from the helium model. Further, we analyze to which extent these models are able to approximate their three-dimensional analogues beryllium resp. carbon.

A 8.20 Tu 16:30 Lichthof

Complex atoms in strong laser fields: A multiconfigurational time-dependent Hartree-Fock approach — •David Hochstuhl and Michael Bonitz — ITAP, Christian-Albrechts Universität zu Kiel, 24098 Kiel

In the last decade simulations of real, three-dimensional complex atoms in strong laser fields became feasible within several methods, e.g. convergent close coupling, time-dependent density functional theory or R-matrix methods. Here we apply the multiconfigurational time-dependent Hartree-Fock method which is, in principle, able to yield exact, i.e. numerically converged results. For the treatment of the three dimensions, we employ an expansion in spherical harmonics times a radial function, which is expanded in a Coulomb-wave discrete variable representation. The main focus of this poster lies on the capabilities and performance of this scheme. Results are presented for photoionization of the helium atom and compared to convergent close coupling calculations. Further, the beryllium atom is considered.

A 8.21 Tu 16:30 Lichthof

State dependent optical lattice and coherent motional state control of single neutral atoms — Leonid Förster, Michał Karski, Jai-Min Choi, Andreas Steffen, Noomen Belmechri, •Arif Mawardi, Kohei Katayama, Wolfgang Alt, Dieter Meschede, and Artur Widera — Institut für Angewandte Physik der Universität, Wegelerstr. 8, 53115 Bonn, Germany

In our experiment we trap neutral cesium atoms in a state dependent 1D-optical lattice. Along the tight axial-confinement, the atoms can be controllably shifted to the left or to the right depending on their hyperfine state. We use this ability for coherent manipulation of the quantized motional states using microwave radiation. We experimentally show that by adjusting the wavefunction overlap, microwaves can induce sideband transitions between any two trapped motional states. Based on this we have implemented a microwave cooling scheme which we used to achieve a ground state population of 97% along the axial degree of freedom.

Beyond single-particle effects this experiment aims on the realization of controlled coherent collisions between atoms. For this, 3D ground state population is crucial. Cooling schemes so far are limited by the weak radial confinement provided by the Gaussian profile of the trapping laser. We discuss how this limit can be bypassed by an additional blue detuned ring shaped laser beam overlapped with the original lattice and we present our preliminary progress.

A 8.22 Tu 16:30 Lichthof

Strahldiagnostik und Quellenentwicklung an Dresden EBIS/T — •Erik Ritter[1], Ulrich Kentsch[2], Johannes König[1], Vladimir Ovsyannikov[2], Mike Schmidt[2], Andreas Schwan[2], Alexandra Thorn[1], Falk Ullmann[2] und Günter Zschornack[1] — [1]Institut für Angewandte Physik, Technische Universität Dresden, Germany — [2]Dreebit GmbH, Dresden, Germany

Es werden Strahldiagnostikmessungen der longitudinalen und der transversalen Emittanz an einer Dresden EBIS-A vorgestellt. Hierfür wurden ein neu entwickelter Gegenfeldanalysator sowie ein Pepper-Pot Emittanzmesssystem verwendet. Mit einer mittleren (rms-) Emittanz von generell weniger als 10 mm mrad, und einer Energieunschärfe kleiner 0,15 eV/u wurden der EBIS exzellente Strahleigenschaften nachgewiesen. Weiter werden Fortschritte im Bereich der Ionenquellenentwicklung vorgestellt. Neue, verkürzte Extraktionslinsensysteme der Quellen bieten in Kombination mit einem E×B-Filter (Wien-Filter) die Möglichkeit, ladungszustandsseparierte Ionenstrahlen in hochkompakten Anlagen zu erzeugen. Die Verbindung der hervorragenden Strahleigenschaften einer Dresden EBIS-A mit einem kompakten Ladungszustandsfilter eröffnen neue Applikationsmöglichkeiten, beispielsweise für den Einsatz von EBIS/T Systemen in Anlagen der medizinischen Ionenstrahltherapie. Weitere Anwendungsgebiete werden aufgezeigt.

A 8.23 Tu 16:30 Lichthof

Quantum Walks and Single Atom Inteferometry with neutral atoms in a 1D lattice — •Noomen Belmechri, Michał Karski, Leonid Förster, Jai-Min Choi, Andreas Steffen, Wolfgang Alt, Dieter Meschede, and Artur Widera — Institut für Angewandte Physik der Universität Bonn Wegelerstraße 8, 53115 Bonn, Germany.

We present applications of state-dependent transport in a 1D optical lattice, in particular matter-wave interference starting from a single atom. Individual Cs atoms are trapped in a standing wave that is composed of two polarizations acting independently on the two qubit states. By displacing the sublattices, we coherently transport atoms across several μm and spatially split the wavefunction of superposition states. Repeated application of a $\frac{\pi}{2}$-pulse and a transport step realizes a quantum walk with up to 24 steps, allowing us to observe superclassical spreading of the walk as well as recombination to a single site by unitary reversal. Adding state-selective detection, a full state tomography could be performed. The decoherence sources limiting the walk have been investigated.

We also split and recombine an individual atomic wavefunction, reading out the phase difference. In the presence of a magnetic gradient, the phase accumulation incorporates the Zeeman shift difference, making the atom interferometer the basis for a local magnetic field probe. We report on our characterization of the phase evolution caused by the lattice shift operation and our results in a strong gradient.

A 8.24 Tu 16:30 Lichthof

Exploring attosecond experiments beyond single active electron — •Sebastian Bauch and Michael Bonitz — Christian-Albrechts-Universität Kiel, Institut für Theoretische Physik und Astrophysik, Leibnizstraße 15, 24098 Kiel, Germany

Experimental achievements in the last decade allow for the creation and control of high-harmonics generated attosecond light pulses [1]. Among the most exciting applications of this technique is the exploration of time-resolved electronic processes inside atoms, including the dynamics of electronic correlations. One milestone-experiment addresses the time-resolved exploration of shake-up state population via strong-field tunneling [2]. Owing to the weak intensity of the xuv pulse, a strong probing infrared pulse is used, leading to a significant perturbation of the electronic structure of the atom and the corresponding laser induced transitions. To describe these phenomena beyond the commonly used single-active electron approximation, we solve the time-dependent Schrödinger equation for a two-electron model atom. We present results for experiment-alike situations and compare our model to single-active electron calculations with a sudden approximation for the xuv pulse. Our approach allows for a systematic investigation of the influence of various xuv pulse parameters, e.g. pulse durations. The experimentally observed delay dependence of the double ionization is well reproduced in our simulations.

[1] F. Krausz and M. Ivanov, Rev. Mod. Phys. 81, 163 (2009); [2] M. Uiberacker et al., Nature (London) 446, 627 (2007)

A 8.25 Tu 16:30 Lichthof

First Experiments on Quantum Dynamics with Attosecond Pulses in a Reaction Microscope — •Helga Rietz, Ram Gopal, Alexander Sperl, Konstantinos Simeonidis, and Joachim Ullrich — Max-Planck-Institut für Kernpyhsik, Heidelberg

We present the first measurements taken with the reaction microscope that has recently been installed at the attosecond beamline at Max-Planck-Institut für Kernpyhsik, Heidelberg. Combining a versatile HHG-source with a compact reaction microscope, this setup has been designed for the investigation of the electronic response in atoms and molecules.

As a first test of the assembly, we observed sidebands in electron spectra from He- and Ar-ionization that confirm the interferometric stability of the setup. These features were also used to confirm the duration of the applied IR-laser pulses. The following experiments in D_2, which were carried out with laser pulses of approximately 30 fs duration, showed a clear signature of bond softening [1] in presence of the IR-field. Changing to laser pulses that were further shortened down to about 8 fs by spectral broadening in an optical fiber and a subsequent chirped mirror compressor, we observed oscillations of the vibrational nuclear wavepacket in D_2^+ (see Ergler et al. [2]). The successful reproduction of these features explored earlier by other researchers now allows us to move on to new experiments.

[1] P. H. Bucksbaum et al., *Phys. Rev. Lett.* **64**, 1990
[2] Th. Ergler et al., *Phys. Rev. Lett.* **97**, 2006

A 8.26 Tu 16:30 Lichthof

Design and Setup of a Broadband Collinear Attosecond Beamline — •Michael Schönwald, Christian Ott, Philipp Raith, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We present the design of a new attosecond beamline which is currently being set up in our laboratory. Using 6-fs duration CEP-stabilized ultrashort laser pulses, high-harmonic radiation is generated in a cell filled with rare gases (typically Ar, Ne). The time delay (between the XUV and IR) is realized by a plane split mirror hit at gracing incidence. Another toroidal mirror is then used to refocus both the harmonic and the IR light onto a gas target in a 1:1 focusing geometry. With this novel experimental design we expect the advantage of the high interferometric stability of a monolithic scheme where both beams propagate exactly into the same direction. Furthermore, as we are only using gracing-incidence reflections off metal mirrors for refocusing of the EUV harmonics, we avoid bandwidth limitations associated with the normal incidence on a multilayer mirror. The beamline thus flexibly adapts to any harmonic photon-energy range obtained with different generation media. It also supports tunable and broad-band/ultrashort attosecond pulses by the application of gating techniques. Both design and construction stages of the setup will be shown, including simulations and first experiments on the characterization of the new source. As an outlook, possible future experiments will be briefly discussed, mainly focusing on interferometric approaches [1].

1. Pfeifer *et al.*, Chem. Phys. Lett. 463, 11-24 (2008)

A 8.27 Tu 16:30 Lichthof

Analysis of the recombination step in high-order harmonic generation — •Elmar Vincent van der Zwan[1,2], Maria Tudorovskaya[1,2], and Manfred Lein[1] — [1]Centre for Quantum Engineering and Space-Time Research (QUEST) and Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 31432 Kassel, Germany

Although single-active-electron harmonic spectra can be calculated routinely, both using the time-dependent Schrödinger equation and trajectory-based approaches, they still contain many unexplored aspects that have implications for molecular imaging. We study the question to what extent the recombination step in high-order harmonic generation is described by the laser-field-free continuum-bound transition amplitude. For different alignment angles of the molecule we study the harmonics generated from H_2^+ by linearly polarized laser pulses of both physical and artificial types. This is compared to harmonics from field-free collisions with Gaussian electron wave packets. We thus disentangle the influence of the Coulombic potential and the laser field on the two-center interference. The results provide information on the recombining electronic wave packet that can be used in imaging techniques, such as molecular orbital tomography. We find significant ellipticity in the polarization of the harmonics. Furthermore, we study the role of resonance states in harmonic generation, aiming at verifying the common belief that the time scales in high-order harmonic generation are too short for sharp resonances to develop fully.

A 8.28 Tu 16:30 Lichthof

Optimization of the charge state distribution in an electron beam ion trap using dielectronic recombination — •Sven Bernitt, Rainer Ginzel, Lodewijk Arntzen, José R. Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

When an energetic electron recombines with an ion, an inner-shell electron of the ion can be resonantly excited. The resulting excited state can decay radiatively, leaving the ion with its charge decreased by one (dielectronic recombination, DR). Due to large cross sections compared to non-resonant radiative recombination, DR has an substantial effect on the recombination rates in hot plasmas and thus on the charge state distribution. This can be systematically influenced due to the resonant nature of DR. To investigate this possibility highly charged krypton ions were extracted from the Heidelberg Electron Beam Ion Trap (HD-EBIT), separated into their charge states and counted as a function of the electron energy. Yield increases were observed in single charge states by factors larger than three, while other charge states were suppressed. These results further improve the unique ability of electron beam ion traps to generate ion beams in a very narrow charge state distribution, a highly desirable feature for example for studies of rare isotope ion beams.

A 8.29 Tu 16:30 Lichthof

Electron impact ionization of small rare gas clusters — •Thomas Pflüger, Arne Senftleben, Xueguang Ren, Alexander Dorn, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Atomic and molecular clusters present an excellent field of investigation bridging the gap between sole constituents and macroscopic matter. Therefore, structural as well as dynamical information can contribute to the understanding of more complex systems. Especially small argon clusters have been extensively studied for decades, however, coincidence experiments are rare. We performed kinematically complete electron impact ionization experiments were all final state particles were measured and differential cross sections could be obtained. Besides direct single ionization the results show a second distinct reaction channel which can be accounted for an additional inelastic scattering event inside the cluster. Furthermore, compared to the results for atomic argon, strongly increased intensities outside of the scattering plane, which is spanned by the incident and scattered projectile, are observed.

A 8.30 Tu 16:30 Lichthof

High precision wavelength measurements of X-ray Li- and Be-like Fe satellite lines — •Katharina Kubiček, José R. Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We report on high precision wavelength measurements of dielectronic satellite lines in Li- and Be-like iron excited through resonant electron capture by the monoenergetic electron beam of the FLASH-EBIT. A advanced flat crystal x-ray spectrometer was used while stepwise varying the beam energy. Whereas conventional experiments on dielectronic recombination focus on high electron beam energy resolution, and provide only poor photon energy resolving powers of about $E/\Delta E = 50$, in this configuration transition energies are measured with a value $E/\Delta E = 2000$ by determining absolute Bragg angles without the need of reference lines. Estimated experimental uncertainties of $\Delta E < 18$ meV allow to probe QED contributions of some few eV to transition energies with high sensitivity.

A 8.31 Tu 16:30 Lichthof

Resonant electron-ion photorecombination processes of higher order — •Christian Beilmann[1], Octavian Postavaru[1], Lodewijk Arntzen[1], Rainer Ginzel[1], Christoph H. Keitel[1], Volkhard Mäckel[1], Paul H. Mokler[1], Martin C. Simon[1], Hiro Tawara[1], Joachim Ullrich[1], José R. Crespo López-Urrutia[1], and Zoltán Harman[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]ExtreMe Matter Institute (EMMI), Darmstadt, Germany

Dielectronic recombination (DR), the fundamental process where a free electron is captured by the potential of a highly charged ion and its kinetic energy is transfered to a bound electron, has been intensively investigated due to its interest for fundamental atomic physics and the diagnostic of astrophysical and earthbound plasmas. Besides DR, there are resonant photorecombination processes of higher order. In these, two or three bound electrons can be simultaneously excited by the captured electron in the so-called trielectronic (TR) or quadruelectronic (QR) recombination. Measurements of TR are very scarce and the first observations of TR involved only low energy excitation of the L-shell. We present the first observation of TR with K-shell excitation as well as signatures of QR obtained by high electron energy resolution recombination measurements in an electron beam ion trap (EBIT) [1]. Investigations of Ar, Fe and Kr allow for Z dependency studies of TR cross sections, and show large, and even dominant contributions of this process to the total resonant photorecombination cross section.

[1] C. Beilmann, O. Postavaru, et al., PRA 80, 050702(R) (2009)

A 8.32 Tu 16:30 Lichthof

Fabrication and characterization of carbon nantubes structures on atom chipsvi — •Gabriela Visanescu, Peter Federsel, Michael Häffner, Philipp Schneeweiss, Michael Gierling, Dieter Kern, Andreas Günther, and Jozsef Fortágh — Center for Collective Quantum Phenomena and their Applications, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen http://www.pit.physik.uni-tuebingen.de/fortagh/

Carbon nanotubes have been grown using plasma enhanced chemical vapour deposition (PECVD) on the surface of a silicon substrate. Free standing multiwall nanotubes, lines of nanotubes, carpets of nan-

otubes, and suspended beams of single wall nanotubes have been fabricated. We characterize the structure and mechanical properties of the nanotubes by means of scanning electron microscopy (SEM) and an atomic force microscopy (AFM). We observe that the mechanical resonance frequency of the fabricated nanotubes (4-20um length) is in the range between tens of MHz and a few hundred kHz. The chips with carbon nanotubes find application in cold atom experiments as potential generating elements and in atom detectors based on field ionization near nanotube tips and subsequent ion counting.

A 8.33 Tu 16:30 Lichthof

Solar Wind Interacting with Comets: X-ray emission following charge exchange — •Rainer Ginzel, Stuart Higgins, Sven Bernitt, José R. Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Collisions of highly charged ions and neutrals resulting in X-ray emission are observed in cometary and planetary atmospheres [1] and also in supernova ejecta. Much of the necessary data to model these environments are unavailable and some of the existing data are even contradictory [2]. To overcome this unsatisfactory situation we have developed a novel deceleration platform at the Heidelberg Electron Beam Ion Trap (EBIT) which provides a slow, monoenergetic, and well-focused ion beam, allowing ion-atom collisions at energies between 10 keV/q and 30 eV/q to be studied in depth, featuring the possibility of ion-photon coincidence measurements.

First experiments with highly charged argon and sulfur ions were performed at energies between 100 and 600 eV/amu, an energy range relevant for modeling the slow components of the solar wind. These measurements have shown the importance of the formation of long lived metastable states. The X-ray emission caused by their decay could be separated and measured independently. The aforementioned contradictions in existing data could potentially be resolved through the reinterpretation of datasets, in light of these new findings.

[1] P. Beiersdorfer *et al.*, *Science* **300**, 1558 (2003)
[2] F. I. Allen *et al.*, *Physical Review* **A78**, 032705 (2008)

A 8.34 Tu 16:30 Lichthof

Interaction of swift heavy- ion beams with insulating targets — G Lanzanó[1], E De Filippo[1], I Lombardo[1], E La Guidara[1], F Amorini[1], N Rizzo[1], G Politi[1], E Geraci[1], P Russotto[1], G Cardella[1], C Volant[2], H Rothard[3], and •S Hagmann[4,5] — [1]INFN+LNS, Catania, Italy — [2]CEA, Saclay, France — [3]CIMAP-CIRIL-GANIL,Caen, France — [4]GSI-Darmstadt, Germany — [5]Inst.f Kernphysik, Univ Frankfurt, Germany

The interaction of ion beams with solids leads to ejection of electrons. For insulating targets, a charging-up of the surface occurs. At present,such phenomena are under inves-tigation in connection with guiding phenomena in nano-cap-illaries with the possible application of nano focused beams. Here, we report the results of a series of dedicated experiments with swift ion beams (C at 23 and 40 AMeV, but also heavier beams such as Ag at 40 A MeV and Xe at 23 and 30 AMeV) and insulating foil targets (Mylar,polypropylene). Also, sandwich-targets (insulators covered with a thin gold layer on one or both surfaces)were used. Fast electron spectra were measured by the time-of-flight method with the ARGOS multidetector at the superconducting cyclotron of LNS Catania. The slowing down of convoy- and binary encounter electrons allows to observe the dynamics of charge build-up leading to potentials of the order of 10 kV [1]. Surprisingly, also X-rays emitted from the projectile are affected by the charged surface, and puzzling results are observed with the double sandwich target. [1] G. Lanzanò, E. De Filippo, S. Hagmann, H. Rothard, C. Volant Rad. Eff. and Defects in Solids 162 (2007) 303-318

A 8.35 Tu 16:30 Lichthof

Fully differential measurements for electron capture in collisions of slow He^{q+} and Ne^{q+} with He and Ne. — •Aditya H. Kelkar, Xincheng Wang, Daniel Fischer, Robert Moshammer, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We report on kinematically complete studies of electron capture from He (and Ne) in collisions with slow He^{q+} (and Ne^{q+}) projectiles using a 'Reaction Microscope'. We succeeded in collecting fully differential data sets for several reaction channels like single and double electron capture, resonant capture and capture accompanied with subsequent auto-ionization. The results are compared with theoretical model calculations. In order to achieve an efficient detection of emitted recoil-ions and electrons we implemented large area position sensitive MCP detectors with central holes for the passage of the projectile beam. This enabled us to measure the recoiling target ion in coincidence with Auger-electrons emitted from the highly excited projectile ion after capture. The experimental setup and first results of ongoing measurements will be presented.

A 8.36 Tu 16:30 Lichthof

First results from 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 Hagman[5], Aditya Kelkar[1,2], Tom Kirchner[6], Kai-Uwe Kühnel[1], Xincheng Wang[1], 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]Institute of High Performance Computing, Singapore — [5]GSI, Darmstadt, Germany — [6]York University, Toronto, Canada

A Reaction Microscope, which enables fully momentum resolved measurements of ionization and charge transfer processes in ion-atom collisions, is implemented in the ion storage ring TSR at the MPIK. Due to the low beam emittance and high intensity achievable in the TSR, the collision dynamics can be studied with high statistics and very good resolution, even on the level of fully differential cross sections. In first measurements, double ionization of helium was studied over a wide range of perturbation parameters η (projectile charge to velocity ratio) and analyzed by means of so-called four-particle Dalitz plots. It is shown that for large η, as expected, the data can best be described by a process not involving the electron-electron correlation. In an upcoming beamtime we aim at kinematically complete measurements for radiative electron capture (REC) in ion-atom collisions, the dominant process for electron transfer at high collision velocities.

A 8.37 Tu 16:30 Lichthof

Characterization of the liquid droplet target beam at the ESR — •Nikolaos Petridis[1], Thomas Stoehlker[2], and Robert E. Grisenti[1] — [1]Institut fuer Kernphysik, JWG-Universität Frankfurt, Germany — [2]GSI, Darmstadt, Germany

At storage rings, atomic processes with small cross-sections (e.g. excitation) can only be studied efficiently when high-density targets are available, in spite of the fact that the ions collide several million times per second with the target. Even state-of-the-art internal targets, which are usually realized by expanding a gas through a nozzle into vacuum, provide target gas densities that are generally still too low. For many nuclear and atomic physics experiments, such as those planned at future facilities like FAIR, this is still a problem. Recently, we have successfully employed a novel cryogenically cooled liquid droplet beam source, and demonstrated that target densities of at least one order of magnitude higher, as compared to previous internal targets, are now experimentally feasible. In order to fully characterize the liquid target beam, we have carried out extensive investigations on ion beam heating and losses during the interaction of the droplets with relativistic hydrogen- and lithium-like uranium ions. Here, we will present the experimental data that are presently being analyzed, and discuss the possible use of droplets for the investigation of fully unexplored collision phenomena. For, the interaction of relativistic highly-charged heavy ions with droplets can, in some respect, be compared to that of intense ultra-short laser-cluster interactions.

A 8.38 Tu 16:30 Lichthof

X-ray spectroscopy of collisions between highly charged Ru ions and H_2 clusters — T. Aumann[1], S. Bishop[3], K. Blaum[9], K. Boretzky[1], F. Bosch[1], H. Bräuning[1], C. Brandau[1,3], T. Davinson[4], I. Dillmann[3], O. Ershova[1,5], H. Geissel[1], G. Gyürky[6], M. Heil[1], F. Käppeler[7], A. Kelic-Heil[1], C. Kozhuharov[1], C. Langer[1,5], T. Le Bleis[1,5,10], Y.A. Litvinov[1,9], G. Lotay[3], J. Marganiec[1], N. Petridis[5], R. Plag[1,5], U. Popp[1], R. Reifarth[1,5], B. Riese[1], C. Rigollet[8], C. Scheidenberger[1], H. Simon[1], Th. Stöhlker[1,11], T. Szücs[6], G. Weber[1,11], H. Weick[1], D.F.A. Winters[1,11], •N. Winters[1,11], P.J. Woods[4], and Q. Zhong[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [2]China Institute of Atomic Energy (CIAE), 102413 Beijing, China — [3]Technische Universität München, 85748 Garching, Germany — [4]University of Edinburgh, EH8 9YL Edinburgh, United Kingdom — [5]Goethe-Universität, 60438 Frankfurt a.M, Germany — [6]Institute of Nuclear Research of the Hungarian Academy of Sciences, H-4001 Debrecen, Hungary — [7]Forschungszentrum Karlsruhe, Institut für Kernphysik, 76131 Karl-

sruhe, Germany — [8]Kernfysisch Versneller Instituut, 9747 AA Groningen, The Netherlands — [9]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [10]Institut Pluridisciplinaire Hubert Curien, 67037 Strasbourg, France — [11]Ruprecht-Karls-Universität, 69120 Heidelberg, Germany

We performed x-ray spectroscopy of collisions between Ru^{44+} and H_2 clusters at low energies (≈10 MeV/u) at the Experimental Storage Ring in Darmstadt. This study was performed together with the main experiment, which looked at proton capture (from H_2 by the ion) during the collision (p-process). Our goal was to identify the influence of the target density (cluster size) on the collisions via the recorded x-ray spectra. The clusters were generated by a novel cryogenic cluster source, which can create clusters with area-densities as high as 10^{13} 1/cm^2. We will present the results of our analysis and discuss a follow-up experiment.

A 8.39 Tu 16:30 Lichthof

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

The diffraction of electrons by a standing light wave is referred to as the Kapitza-Dirac effect, which has been observed in recent experiments [1, 2] at moderate laser intensities. Current high-power lasers have relativistic intensities in the optical regime and reach short wave lengths in the X-ray range, which opens the possibility to study the Kapitza-Dirac effect in regimes, where relativistic effects become important.

The non-relativistic Kapitza-Dirac effect was studied theoretically in [3] by solving the Schrödinger equation by a plane wave ansatz, which yields the time-evolution of the electron momentum distribution. In our work, we generalize this approach and apply it to the Dirac equation. We will highlight differences between the relativistic and the non-relativistic description of the Kapitza-Dirac effect.

[1] Daniel L. Freimund, Kayvan Aflatooni, Herman Batelaan, Nature **413**, 142–143 (2001)
[2] P. H. Bucksbaum, D. W. Schumacher, M. Bashkansky, Phys. Rev. Lett. **61**, 1182–1185 (1988)
[3] H. Batelaan, Rev. Mod. Phys. **79**, 929–941 (2007)

A 8.40 Tu 16:30 Lichthof

Erzeugung hoher harmonischer Strahlung in dichten Medien — •Heiko G. Kurz[1,2], Tobias Vockerodt[1,2], Hendrik Thering[1], Uwe Morgner[1,2,3] und Milutin Kovacev[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST — [3]Laserzentrum Hannover e.V.

Die Erzeugung kohärenter Strahlung im vakuum-ultravioletten und extrem-ultravioletten Spektralbereich ist Gegenstand der aktuellen Forschung moderner Quantenoptik. Die Erzeugung hoher harmonischer Strahlung (HHG) erfolgt in einer nichtlinearen Frequenzkonversion intensiver Laserpulse in Gasen, Festkörpern oder Flüssigkeiten. Die verschiedenen Targets unterscheiden sich hinsichtlich ihrer Konversionseffizienz, wobei mit steigender Dichte des Targets eine Erhöhung der Effizienz beobachtet werden kann. In diesem Beitrag wird ein Experiment zur HHG in Flüssigkeitstropfen vorgestellt, welches die debrisfreie Konversion der Strahlung mit einer hohen Dichte des Targets verbindet. Aktuelle Ergebnisse werden präsentiert.

A 8.41 Tu 16:30 Lichthof

Crossed-beam laser acceleration of ions by high-intensity laser fields — •Benjamin Galow, Zoltán Harman, Dunfu Shi, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69029 Heidelberg, Germany

Simulations based on the coupled relativistic equations of motion show that an ensemble of ions stemming from laser-plasma acceleration processes can be post-accelerated using crossed pulsed laser beams focused to spot radii on the order of the laser wavelength. We demonstrate that the crossed beams produce monoenergetic accelerated particles of several hundred MeV/nucleon with small energy spreads and high densities as required for hadron cancer therapy.

A 8.42 Tu 16:30 Lichthof

Electron Dynamics of F_2^- in a Strong Laser Field. — •Hannes Hultgren and Igor Kiyan — Albert-Ludwig University, Faculty of Mathematics and Physics, D-79104 Freiburg, Germany

F^- and F_2^- are exposed to a strong, infrared laser pulse of linear polarization. An electron imaging spectrometer operated in the velocity mapping regime is used to record angular resolved photoelectron spectra. Both F^- and F_2^- spectra are recorded during the same run of experiment. The spectra exhibit a non-monotonic structure, which is associated with the quantum interference effect predicted by a Keldysh-like theory [1]. The character of this structure is similar in both spectra and it corresponds to detachment of an initially bound p-electron. However, the energy distribution of F_2^- extends to higher kinetic energies than the energy distribution of F^-.

Two different models are considered for the data interpretation. One of these assumes photodissociation of F_2^- at the leading front of the laser pulse, followed by photodetachment of F^- created in the photodissociation step. Another model involves simulations based on the theory presented in [2], which uses the molecular strong-field approximation.

[1] G.F Gribakin and M.Yu. Kuchiev, Phys. Rev. A, **55**, 3760 (1997).
[2] D.B. Milošević, Phys. Rev. A, **74**, 063404 (2006)

A 8.43 Tu 16:30 Lichthof

An efficient numerical propagation scheme for the Klein-Gordon equation — •Matthias Ruf, Heiko Bauke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The Klein-Gordon equation [1] is a Lorentz invariant equation of motion for spinless particles. We present a real space split operator method [2] for the solution of the time-dependent Klein-Gordon equation with arbitrary electromagnetic fields. Split operator methods for the Schrödinger equation and the Dirac equation typically operate alternately in real space and momentum space and, therefore, require the computation of a Fourier transform in each time step. However, the fact that the kinetic energy operator $\hat{K}$ in the two-component representation of the Klein-Gordon equation is a nilpotent operator, that is $\hat{K}^2 = 0$, allows us to implement the split operator method for the Klein-Gordon equation entirely in real space.

Consequently, the proposed split operator method does not require the computation of a Fourier transform. We implemented a highly parallel computer program for the propagation of the Klein-Gordon equation. Parallelization is based on domain decomposition. Our poster will outline the real space split operator method and will present applications as well as performance measurements.

[1] H. Feshbach and F. Villars, Rev. Mod. Phys. **30**, 24–45 (1958)
[2] Matthias Ruf, Heiko Bauke and Christoph H. Keitel, J. Comp. Phys. **228**, 9092–9106 (2009)

A 8.44 Tu 16:30 Lichthof

Velocity Map Imaging of Xe Clusters Irradiated with FEL Raditation — •Sebastian Schorb[1], Rainer Unterumsberger[1], Daniela Rupp[1], Tais Gorkhover[1], Benjamin Röben[1], Tobias Zimmermann[1], Thomas Möller[1], Per Johnsson[2], Marc Vrakking[3], and Christoph Bostedt[4] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin — [2]Department of Physics, Lund University — [3]FOM Institut AMOLF — [4]Linac Coherent Light Source, SLAC

For many potential experiments with free electron lasers it is of fundamental importance to study how the absorption and ionization properties of nanoscaled systems develop in the short wavelength – strong field domain. We performed first single-shot ion velocity map imaging (VMI) experiments on Xe clusters at the FLASH FEL at DESY in Hamburg. The Xe was resonantly excited at the 4d core level with power densities up to 1014 W/cm2. A special velocity map imaging spectrometer configuration was used to detect charged fragments with kinetic energies up to 600 eV per charge. By pulsing the detector, the kinetic energy distribution of different species and charge states could be investigated separately. With a piezo driven skimmer the density of the cluster beam could be reduced to a single cluster in the focal volume. The images show an isotropic spatial ion distribution and kinetic energy distribution changing with the charge state. This could be interpreted as an indication for a shell by shell explosion of the clusters. The data is discussed and compared to theoretical predictions and experimental results.

A 8.45 Tu 16:30 Lichthof

Effects of the carrier-envelope phase of few-cycle laser pulses on atomic bound states — •Fabian Elster[1,2], Anne Harth[1,2], Stefan Rausch[1,2], Thomas Binhammer[1,2], Mathias Hoffmann[1,2], and Uwe Morgner[1,2] — [1]Institut für Quantenoptik,

Leibniz Universität Hannover, Hannover, Germany — [2]Quest: Center for Quantum Engineering and Space-Time Research, Hannover, Germany

We present a setup to study effects of the carrier envelope phase (CEP) of a sub-5-fs pulse from a phase stabilized Ti:sapphire laser oscillator with pulse energies in the nJ regime by spectroscopic observation of the excited atomic gas target to obtain the population of an atomic bound state. Theoretical work indicates a small dependence of the population on the CEP of the exciting pulse. We analyze the qualification of different atomic systems (alkaline and alkaline earths) with respect to the expected overall signal strength with a comprehensive theoretical model. On this basis, we discuss the details of the experimental setup.

A 8.46 Tu 16:30 Lichthof

Coulomb effects on low-energy momentum spectra in strong field ionization — •Tian-Min Yan[1] and Dieter Bauer[2] — [1]Max-Planck-Institut für Kernphysik, Postfach 103980, 69029 Heidelberg, Germany — [2]Institut für Physik, Universität Rostock, 18051 Rostock, Germany

For low-energetic photoelectrons emitted from Coulombic binding potentials, the momentum spectra as they are predicted by the plain "strong field approximation" (SFA, see [1] for a review) are in strong qualitative disagreement with ab initio results and experiment. Recently, a surprising "low energy structure" (LES) has been identified in experiments using long wavelengths [2]. We present results from the numerical solution of the time-dependent Schrödinger equation and compare them to Coulomb-corrected SFAs. Plain SFA and some of the Coulomb-corrected SFAs do not reproduce the low-energy nodal pattern in the momentum spectra, while others do. The origin of the LES at long wavelengths is also discussed.

[1] D.B. Milosevic et al., J. Phys. B 39, R203 (2006).
[2] C.I. Blaga et al., Nature Phys. 5, 335 (2009).

A 8.47 Tu 16:30 Lichthof

Stabilization dynamics of a model hydrogen molecular ion: Floquet and time-dependent density functional theory analysis — •Varun Kapoor[1] and Dieter Bauer[2] — [1]Max-Planck-Institut für Kernphysik, Postfach 103980, 69029 Heidelberg, Germany — [2]Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Atomic and molecular systems put into strong high-frequency radiation are known to stabilize against ionization. In the molecular case the question arises how the dissociation dynamics is influenced by the stabilized electron. We solve the time-dependent Schrödinger equation for a model hydrogen molecular ion. The observed dynamics and the harmonics emitted are analyzed in terms of Floquet states. In general, several of the eigenstates of the combined electron-ion Kramers-Henneberger potential are occupied. The exact results are compared with results from a multi-component time-dependent density functional theoretical treatment of the system, evaluating different levels of approximation to the exchange correlation potential.

A 8.48 Tu 16:30 Lichthof

Strong-field ionization of N_2, O_2, and CO_2 — •Simon Petretti[1], Yulian Vanne[1], Alejandro Saenz[1], Alberto Castro[2], and Piero Decleva[3] — [1]Humboldt-Universität zu Berlin, Germany — [2]Freie Universität Berlin, Germany — [3]Universitá di Trieste, Italy

The availability of intense laser pulses with ultrashort pulse durations in the range of a few femtoseconds (or even attoseconds) offers a new way of exploring the behavior of molecules interacting with these intense laser fields. The femtosecond timescale should, e. g., be appropriate for time-resolved imaging of chemical reactions. Experimental progress towards this goal has been made by resolving molecular orbitals [1]. In order to check the assumption that molecular orbitals can be really imaged, we have set up a new theoretical model. The multiphoton ionization of molecules in intense laser fields is studied within the so-called single-active electron (SAE) approximation by solving the time-dependent Schrödinger equation (TDSE) numerically. Our code is designed in such a way that it can deal with in principle arbitrary molecules. The main focus of this presentation will be the alignment-dependent strong-field ionization of N_2, O_2, and CO_2 exposed to a short laser pulse (40 fs pulse duration) of a Ti:sapphire laser (800 nm) as recently investigated experimentally [2]. We do not only achieve qualitative agreement for N_2 and O_2, but provide also an explanation for the so far puzzling experimental CO_2 results.

[1] Itatani *et al.*, Nature **432**, 867 (2004).
[2] Pavičić *et al.*, Phys. Rev. Lett. **98**, 243001 (2007).

A 8.49 Tu 16:30 Lichthof

A Fraunhofer diffraction model of non-collinear high harmonic generation — •Andreas Vernaleken, Akira Ozawa, Igor Gotlibovych, Thomas Udem, and Theodor W. Hänsch — Max-Planck-Institut für Quantenoptik, Garching

Non-collinear high harmonic generation (NCHHG) is the nonlinear process where two infrared driving beams focused into a gas target at a small angle cause collimated emission of high harmonic radiation along the bisector of the driving beams [1]. Most of the striking features of NCHHG that we observed in our experiments can now be reproduced by our improved numerical simulation. The simulation results suggest that NCHHG can be seen as the Fraunhofer diffraction pattern of the high harmonic emission profile in the interaction region that is created by interference between the two driving beams.

A sound understanding of the physics of NCHHG is crucial considering its potential as a combined method for efficient generation and outcoupling of extreme ultraviolet radiation in future cavity-assisted HHG experiments at high power and high repetition rate. We will present the relevant details of our model and its current limitations and discuss possible future applications of NCHHG.

[1] Ozawa et al., Opt. Express **16**, 6233 (2008)

A 8.50 Tu 16:30 Lichthof

Visualizing the vibrational motion of D_2 by XUV-Pump/XUV-Probe experiments at FLASH — •yuhai jiang[1], artem rudenko[2], etienne plésiat[3], lutz foucar[2], moritz kurka[1], kai-uwe kühnel[1], jhon pérez[3], fernando martin[3], oliver herrwerth[4], matthias lezius[4], matthias kling[4], till jahnke[5], ali belkacem[6], michael schulz[7], kiyoshi ueda[8], theo zouros[9], stefan düsterer[10], rolf treusch[10], claus dieter schröter[1], robert moshammer[1], and joachim ullrich[1] — [1]MPIK, 69117 Heidelberg — [2]ASG at CFEL, 22607 Hamburg — [3]Universidad Autónoma de Madrid, 28049 Madrid — [4]MPIQ, 85748 Garching — [5]Universität Frankfurt, 60486 Frankfurt — [6]LBNL, 94720 Berkeley — [7]University of Missouri-Rolla, 65409 Rolla — [8]Tohoku University, 980-8577 Sendai — [9]University of Crete, 71003 Heraklion, Crete — [10]DESY, 22607 Hamburg

Two-photon double ionization (TPDI) of D_2 is studied for 38 eV photons at FLASH as function of the time delay between the two photoabsorption events using a XUV-pump/XUV-probe setup in combination with a reaction microscope. Instantaneous and sequential absorption pathways are identified as separated peaks in the measured D^++D^+ fragment kinetic energy release spectra. Sequential TPDI exhibits clear pump-probe delay time dependent structures originating from the ultrafast nuclear wave-packet motion in D_2^+ ($1s\sigma_g$-state). Time-dependent model calculations support this interpretation and are in agreement with the experimentally observed vibrational period of 22±4 fs (D_2^+).

A 8.51 Tu 16:30 Lichthof

Isomerisation of Acetylene followed in Real-Time by Pump-Probe experiments at FLASH — •yuhai jiang[1], artem rudenko[2], lutz foucar[2], moritz kurka[1], kai-uwe kühnel[1], oliver herrwerth[3], matthias lezius[3], matthias kling[3], till jahnke[4], ali belkacem[5], michael schulz[6], kiyoshi ueda[7], theo zouros[8], stefan düsterer[9], rolf treusch[9], claus dieter schröter[1], robert moshammer[1], and joachim ullrich[1] — [1]MPIK, 69117 Heidelberg — [2]ASG at CFEL, 22607 Hamburg — [3]MPIQ, 85748 Garching — [4]Universität Frankfurt, 60486 Frankfurt — [5]LBNL, 94720 Berkeley — [6]University of Missouri-Rolla, 65409 Rolla — [7]Tohoku University, 980-8577 Sendai — [8]University of Crete, 71003 Heraklion, Crete — [9]DESY, 22607 Hamburg

Isomerisation is an elementary chemical reaction where the conformation of a molecule evolves continuously through a sequence of transient species that are neither reactants nor products, but finally turning the former into the latter. Using a XUV-Pump/XUV-Probe setup in combination with a reaction microscope we were able to visualize the isomerisation of acetylene cations ($HC{=}CH^+$) that were created by ionization of neutral molecules in the gas phase during the pump pulse (38 eV photon energy). This has been achieved by analyzing the C^++CH^{2+} fragmentation channel, which serves as an indicator for the transfer of a proton from one end of the molecule to the other end, as function of the pump-probe delay time. We obtained a mean isomerization time of about 50 fs.

A 8.52 Tu 16:30 Lichthof

Erzeugung hochenergetischer 88 nm XUV-Laserpulse mit fs Pulsdauer — •Hendrik Thering[1,2], Tobias Vockerodt[1,2], Heiko Kurz[1,2], Emilia Schulz[1,2], Daniel S. Steingrube[1,2], Uwe Morgner[1,2,3] und Milutin Kovacev[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST Centre for Quantum Engineering and Space-Time Research — [3]Laser Zentrum Hannover e.V.

Wir stellen einen Ansatz vor, der die Erzeugung von Millijoule XUV-Laserpulsen mit Femtosekunden Pulsdauern in Aussicht stellt. Dies soll durch die mehrfache Erzeugung niedriger Harmonischer realisiert werden. Mittels SHG und SFG wird Ti:Sa-Strahlung (792 nm, 300 mJ, 100 fs) ins ferne UV konvertiert (264 nm, 36 mJ). Bei der anschließenden Frequenzverdreifachung in Argon streben wir Effizienzen von 1,5% an (Appl. Phys. B 75, 629 (2002)). Somit ergäben sich Pulsenergien von 0,5 mJ bei einer Wellenlänge von 88nm. Die resultierende Gesamtkonversionseffizienz läge bei 0,3% und somit ein bis zwei Größenordnungen über der für HHG typischen Konversionseffizienz.

A 8.53 Tu 16:30 Lichthof

Pion pair creation in ultrarelativistic proton-laser collisions — •Anis Dadi and Carsten Müller — Max-Planck-Institut für Kernphysik, Heidelberg

The production of charged pion pairs via few-photon absorption from an intense, circularly polarized X-ray laser wave colliding with an ultrarelativistic proton beam is studied. Our calculations include the contributions from both the electromagnetic and hadronic interactions. They moreover account for the finite size of the projectile and the composite nature of the created particles.

The pion production rates are compared with the corresponding ones for muon pairs. We also give a general discussion of similarities and differences between the pair creation of Bose versus Dirac particles.

A 8.54 Tu 16:30 Lichthof

The relevance of recoil effects in electron-positron pair creation by relativistic particle impact on intense laser fields — •Sarah Müller, Huayu Hu, and Carsten Müller — Max-Planck-Institut für Kernphysik, Heidelberg

Recoil effects in the process of pair creation by a relativistic particle beam colliding with an intense laser wave are studied. Within the framework of laser-dressed quantum electrodynamics, we evaluate to this end the Feynman diagram for multiphoton pair production by muon impact on a high–frequency laser beam of circular polarization. This allows us to calculate the recoil distribution of the projectile and to analyze its dependences on the particle mass and the number of absorbed laser photons. We also discuss the correlation between the emission angles of the produced pair.

[1] S. Müller and C. Müller, Phys. Rev. D 80, 053014 (2009)

A 8.55 Tu 16:30 Lichthof

Auger processes in multielectron ionization of xenon atoms induced by intense XUV laser pulse — •Myroslav Zapukhlyak, Roland Guichard, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

Recent experiments at FLASH show that the intense XUV laser pulse can produce Xe ions with up to 21+ charge state [1]. At a photon frequency of 93 eV autoionization processes significantly affect the ionization and make a theoretical description very challenging. Ab-initio TDDFT calculations were performed for the time propagation of the system. In order to obtain q-fold ionization probabilities and to include the effect of autoionization we adopt a statistical model which was developed for the description of multielectron ionization in ion-atom collisions [2]. Our calculations show that this model is able to reproduce qualitatively the prominent features of the experimental data. Taking into account the experimental uncertainties of the laser pulse profile is necessary to get a quantitative agreement between the theoretical and experimental values.

[1] A. Sorokin et al., Phys. Rev. Lett. 99, 213002 (2007)
[2] T. Spranger and T. Kirchner, J. Phys. B 37, 4159 (2004)

A 8.56 Tu 16:30 Lichthof

Bound Dirac electrons interacting with laser fields — •Octavian Postavaru[1,2], Zoltán Harman[1,2], and Christoph H. Keitel[1] — [1]Max-Plank-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, Planckstrasse 1, 64291 Darmstadt, Germany

We investigate the level structure and excitation processes of few-electron ions in laser beams. Interaction with the light field leads to dynamic shifts and splitting of the electronic energy levels. We apply a fully relativistic description of the electronic states by means of the Dirac equation. The frequency spectrum of the fluorescence photons for resonant driving, as well as excitation rates and light shifts in the case of two-photon excitation are presented. The results are relevant for experiments at present and near-future laser facilities.