A 34: Poster II

Zeit: Donnerstag 16:30–19:00 Raum: VMP 9 Poster

A 34.1 Do 16:30 VMP 9 Poster

Dynamics of rare-gas clusters in intense sub-10 fs laser pulses — •Siva Rama Krishnan[1], Robert Moshammer[1], Joachim Ullrich[1], and Krishnamurthy Manchikanti[2] — [1]Max Planck Institut fuer Kernphysik, Saupfercheckweg 1, D69117 Heidelberg, Germany — [2]Tata Institute of Fundamental Research, 1 Homi Bhabha road, Mumbai 400005, India

The experimental scheme and details of studies on the interaction of rare-gas clusters with intense sub-10 fs laser pulses are presented in this poster. Most experimental investigations hitherto have used femtosecond laser pulses of durations greater than 25fs on rare-gas or metallic cluster systems. In our study we use much shorter pulses to gain a better understanding of the dynamics in the sub-10fs regime.

A 34.2 Do 16:30 VMP 9 Poster

Auto-detaching multi-electron superexcited state in free C_{60} anions probed by photoelectron spectroscopy — •Mattias Svanqvist and Bernd von Issendorff — University of Freiburg

In photoelectron spectra of C_{60}^- irradiated by nanosecond laserpulses, evidence of electron Auger-like auto-detachment processes have previously been observed. To gain insight into the origin of this feature we have conducted a detailed study by investigating the photoelectron spectra for a photon energy range range of 3.8 to 4.8 eV. We observe a linear dependence of the peak position in the binding energy spectra on the photon energy as expected for auto-detachment, which allows us to determine the excitation energy of the autodetaching state as about 3.5 eV. The large photon energy range over which the feature is observable indicates a relaxation to a common state from which the auto detachment occurs. DFT calculations show that there is indeed a gap in the density of excited states in this energy region. Moreover, we have measured a red shift in the kinetic energy of the auto-detached electrons with increasing temperature. With a simple semi-empirical model we show that this shift is linear in the vibrational energy. An offset between the shifts of two different wavelengths supports a picture where the system transforms excess photon energy into vibrational energy before auto-detachment.

A 34.3 Do 16:30 VMP 9 Poster

X-ray photoionization spectroscopy of size selected aluminum cluster cations — •Marlene Vogel[1], Konstantin Hirsch[1], Andreas Langenberg[1], Jürgen Probst[1], Robert Richter[1], Jochen Rittmann[1], Vicente Zamudio-Bayer[1], Thomas Möller[1], Bernd von Issendorff[2], and Tobias Lau[1] — [1]Technische Universität Berlin, Institut für Optik und Atomare Physik, EW 3-1, Hardenbergstraße 36, D-10623 Berlin — [2]Universität Freiburg, Fakultät für Physik, Stefan-Meier-Straße 21, D-79104 Freiburg

X-ray absorption spectroscopy of size selected clusters has become feasible with the use of ion traps to increase target density and absorption length. Here we present first results on 2p X-ray absorption of size selected Al_n^+ (n=1–14) clusters. Cluster size dependent changes in the electronic and geometric structure can be deduced from the spectra. Since direct 2p photoionization is associated with a specific ion yield channel, direct and resonant photoionization can be distinguished, giving access to core level photoionization thresholds of size selected clusters for the first time. We will present first results and compare the size dependence of the aluminum 2p photoionization threshold to the image potential model.

A 34.4 Do 16:30 VMP 9 Poster

a closer look to the size dependence of the PES for water clusters:Inernalization of the electron and magic numbers — •Lei Ma[1,2], Fabien Chirot[1], and Bernd von Issendorff[1] — [1]Stefan-Meier-Str.21 79104 Freiburg — [2]Nanjing University, Jiangsu Provience, China

ABSTRACT We have recorded photodetachement spectra for cold water cluster anions. By a careful analysis of the spectral shape, we show that the spectral feature assigned to isomer I in previous work [1] has to be seen as the mix of the contributions from two classes of isomers with a slightly different VDE. As size increases, only the high binding energy contribution is left. Together with recent results from Ref[2], this allows to thinking of an alternative scenario for the electron internalization involving clear structural transitions. On the other hand, we note a particularly non monotonic behaviour of the recorded VDE with respect to size in the range n = 50 to 56, which is correlated with a marked structure in the measured mass spectrum.

[1]Aster Kammrath, Jan R. R. Verlet, Graham B. Griffin, and Daniel M. Neumarka THE JOURNAL OF CHEMICAL PHYSICS 125, 076101 (2006) [2]Characterization of Excess Electrons in Water-Cluster Anions by Quantum Simulations Science 309, 914 (2005)

A 34.5 Do 16:30 VMP 9 Poster

Interference structure in photoelectron spectra of cluster-anions by double pulse excitation — •Raphael Kuhnen, Christof Bartels, Christian Hock, and Bernd von Issendorff — Universität Freiburg, physikalisches Institut, Stefan-Meier-Strasse 19, D-79104 Freiburg

Interference of free electron wave packets generated by femtosecond double pulses which detach the excess electron of anionic atoms and clusters is investigated. Pulse sequences have been shown to be a powerful tool to study interference effects in molecular and atomic systems and controll the quantum mechanical phase of the state[1,2].
The experiment is done by one and two photon excitation with both parallel and perpendicular laser polarisation and an angle resolved photoelectron detection. In particular detaching the electron of the system via excitation of a resonant state offers a tool to study processes leading to decoherence of the system at ultra short timescales.

[1] Bouchene et al., Eur. Phys. J. D, **2**, 131 (1998)
[2] Wollenhaupt et al., Phys. Rev. A, **68**, 015401 (2003)

A 34.6 Do 16:30 VMP 9 Poster

Local electronic structure of exohedral, endohedral, and magic doped silicon clusters — •Jochen Rittmann[1], Marlene Vogel[1], Konstantin Hirsch[1], Andreas Langenberg[1], Philipp Klar[1], Jürgen Probst[1], Robert Richter[1], Fabian Lofink[1], Vicente Zamudio-Bayer[1], Thomas Möller[1], Bernd von Issendorff[2], and Tobias Lau[1] — [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, Stefan-Meier-Straße 21, D-79104 Freiburg

Because of its element specific nature, X-ray absorption spectroscopy is a perfect tool to study the local electronic structure of individual constituents of binary clusters. We apply this method to transition metal doped Si_n^+ clusters in the size range of n=4–19 and show how geometric and electronic structure are interlinked in 'magic' VSi_{16}^+ and 'close-to-magic' $TiSi_{16}^+$ and $CrSi_{16}^+$ clusters. The high symmetry of these doped silicon cages is evident from X-ray absorption spectra at the transition metal and silicon 2p edges. Determination of the direct silicon 2p photoionization threshold reveals electronic shell closure and a large HOMO-LUMO gap in VSi_{16}^+. The transition from exohedral to endohedral doping is reflected in changes of local electronic structure of Sc, Ti, V, Cr, and Mn doped Si_n^+ clusters. While the local magnetic moment seems to be quenched in $TiSi_{16}^+$, VSi_{16}^+, and $CrSi_{16}^+$, we find spectral signatures of a local d^5 configuration at the Mn dopant in $MnSi_{14}^+$, indicating a high magnetic moment in this doped semiconductor cage.

A 34.7 Do 16:30 VMP 9 Poster

Angle resolved photoelectron spectroscopy of small aluminum 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 small, size-selected Al_n^- clusters ($n = 3 \ldots 12$) has been performed. The electrons are photodetached by a ns laser pulse with photon wavelengths between 308 nm and 645 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 to our results for sodium clusters. In contrast to sodium, aluminum has three valence electrons per atom, and the influence of the lattice is expected to be much stronger than

in the case of sodium.

A 34.8 Do 16:30 VMP 9 Poster

Size dependence of $L_{2,3}$ branching ratio and 2p core hole screening in X-ray absorption of transition metal clusters — •Konstantin Hirsch[1], Jochen Rittmann[1], Marlene Vogel[1], Vicente Zamudio-Bayer[1], Andreas Langenberg[1], Philipp Klar[1], Jürgen Probst[1], Robert Richter[1], Fabian Lofink[1], Thomas Möller[1], Bernd von Issendorff[2], and Tobias Lau[1] — [1]Technische Universität Berlin, Institut für Optik und Atomare Physik, EW 3-1, Hardenbergstraße 36, D-10623 Berlin — [2]Universität Freiburg, Fakultät für Physik, Stefan-Meier-Straße 21, D-79104 Freiburg

Only very recently the first X-ray absorption spectra of size-selected free clusters could be recorded [1], marking an important breakthrough on the way to a detailed study of the local electronic structure of isolated nanoparticles. To achieve this aim, size-selected metal cluster cations were accumulated and studied in a linear ion trap. For the 3d transition metals Ti, V, Cr, Mn, Fe, and Co an atomic multiplet structure is only present up to the trimer, while tetra- and pentamers already show bulk-like line shapes. The $L_{2,3}$ branching ratio and the L_3 X-ray absorption onset, however, evolve over a much larger size range. Our analysis shows that the evolution of the $L_{2,3}$ branching ratio in 3d transition metals is independent of their effective 2p spin-orbit splitting and can rather be attributed to size-dependent electron delocalization and core hole screening effects. Furthermore, we show how spectral features in $L_{2,3}$ X-ray absorption of bulk transition metals can now be traced back to their atomic origin.

[1] J.T. Lau *et al.*, *Phys. Rev. Lett.* **101** 153401 (2008).

A 34.9 Do 16:30 VMP 9 Poster

Untersuchung massenselektierter Metallcluster unter Einwirkung von Laserfeldern in einem mobilen Paulfallensystem — •Martin Arndt, Gerrit Marx und Lutz Schweikhard — Institut für Physik, Ernst-Moritz-Arndt-Universität, 17489 Greifswald

Zur Untersuchung von massenselektierten Metallclustern unter Einwirkung eines Laserfeldes wurde im Rahmen des SFB 652 ein mobiles Paulfallensystem aufgebaut und getestet. Die geladenen Metallcluster werden in einer Magnetron-Sputterquelle erzeugt und dann in einer linearen Paulfalle akkumuliert, selektiert und gekühlt. Anschließend werden die Ionen gebündelt in eine zweite lineare Paulfalle transferiert. Die Geometrie dieser linearen RF-Falle ist radial offen gestaltet um die Cluster-Laser-Wechselwirkung zu vereinfachen und gleichzeitig den Nachweis der Reaktionsprodukte zu ermöglichen.

A 34.10 Do 16:30 VMP 9 Poster

Nano-plasma formation in clusters exposed to XFEL pulses: consequences for intra-atomic processes — •Christian Gnodtke, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden

We investigate the nano-plasma formation in neon clusters induced by intense femtosecond X-ray free electron (XFEL) pulses with a photon energy of 1keV, sufficient for K-shell photo-ionization of neon. Due to the low photon energy the trapping of photo-electrons becomes possible in larger clusters and a nano-plasma is formed. Electrons, which are emitted when a K-shell hole is filled in an Auger-process, may still escape leading to a delay in the build up of charge in the cluster, given by the typical Auger-decay time of about 2.5fs. The strong internal fields of the charged cluster lead to a delocalization or even ionization of the valence electrons, which has been predicted to lead to a reduction of Auger-decay rates [1]. We investigate how this reduction may become visible in the ionic charge states in a pump-probe scenario with two XFEL pulses by means of a molecular dynamics simulation combined with quantum-mechanical transition rates for photo-ionization and Auger-decay [2].

[1] U. Saalmann and J.-M. Rost, PRL **89**, 143401 (2002)
[2] Ch. Gnodtke, U. Saalmann and J.-M. Rost, submitted (2009)

A 34.11 Do 16:30 VMP 9 Poster

Photoelectron spectroscopy of potassium cluster anions — •Kiran Majer, Lei Ma, and Bernd von Issendorff — Institute of Physics, University of Freiburg, Stefan-Meier-Straße 21, 79104 Freiburg

The electronic structure of medium sized potassium clusters (K_n^-, n: number of potassium atoms) was investigated by photoelectron spectroscopy (PES). The obtained spectra can be compared size by size with spectra of sodium clusters from previous measurements. Especially the electronically signalized cluster sizes (e.g. shell closings) bear resemblance. Nevertheless there are other sizes which lack of any similarities.

Both, Potassium and Sodium pertain to the alkali metals. They posses a s^1 valence electron and a rare gas electron core configuration, which make the bulk alkalis to the simplest of metals. For these "free electron"systems one can expect similarities in spectral features of the PES. However, the deviations show, that the geometrical structure of cluster, even for the simple metals, can have an essential influence on his electronic configuration.

A 34.12 Do 16:30 VMP 9 Poster

Recursive Algorithm for Generalized Bessel Functions — •Erik Lötstedt[1] and Ulrich D. Jentschura[1,2] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg — [2]Department of Physics, Missouri University of Science and Technology, Rolla MO65409, USA

The generalized Bessel function (GBF), introduced by Reiss [1], is ubiquitous in the theoretical treatment of laser-matter interaction. By providing a Fourier expansion of the laser-dressed electron states, this special function can be used to write down analytic expressions for quantum mechanical matrix elements of laser-related processes, both nonrelativistic and relativistic ones. However, there are few reliable numerical algorithms to evaluate the GBF, compared to, for example, the vast amount of literature and software existing for the usual Bessel function. We demonstrate a new recursive algorithm for numerical evaluation of large arrays of GBFs [2], which is both fast and accurate. The algorithm is based on the recurrence relation satisfied by the GBF.

[1] H. R. Reiss, J. Math. Phys. **3**, 59 (1962).
[2] E. Lötstedt and U. D. Jentschura, submitted (2008).

A 34.13 Do 16:30 VMP 9 Poster

Charge Breeding in Dresden EBIT/S systems — •Alexandra Silze[1], Sabrina Geyer[2], Oliver Kester[2], Erik Ritter[1], Alexey Sokolov[2], Falk Ullmann[3], and Günter Zschornack[1] — [1]Institut für Angewandte Physik, Technische Universität Dresden, Germany — [2]Gesellschaft für Schwerionenforschung mbH, Darmstadt, Germany — [3]Dreebit GmbH, Dresden, Germany

Research in nuclear physics has brought up the request for experiments with high-Z radioactive ions accelerated to the Coulomb barrier and beyond. An efficient way of providing this kinetic energy is charge breeding, i.e. to inject low charged ions into an ion source which converts them into highly charged ions before the actual acceleration takes place. Charge breeding is also interesting for high-precision mass measurements using Penning traps since the accuracy of such experiments is directly proportional to the charge state of the investigated ion.

Electron beam ion traps or sources (EBIT/S) are of great interest for such applications because of their capability of providing beams of high purity and overall quality. Charge breeding with EBITs has been achieved successfully reaching breeding efficiencies of up to 18 %. The purpose of our work is to test the charge breeding performance of Dresden EBIT/S systems using permanent magnets instead of superconducting coils. This results in several advantages such as a compact and transportable design, operation at room temperature and, thus, the economization of resources.

We will present simulations for planned experiments as well as first results and measurements of source characteristics.

A 34.14 Do 16:30 VMP 9 Poster

Non-equilibrium Green function approach to photoionization processes — •David Hochstuhl, Sebastian Bauch, Karsten Balzer, and Michael Bonitz — Institut für theoretische Physik und Astrophysik, Leibnizstraße 15, 24098 Kiel

Recent progress in the experimental investigation of inner-atomic multi-electron processes, such as time-resolved Auger decay [1] and shake up processes by means of time-resolved stong field tunnelling [2] demands for a time-resolved correlated theoretical description.

We present a quantum kinetic approach based on the formalism of non-equilibrium Green functions. Starting from the correlated equilibrium state obtained by the solution of Dyson's equation, the Keldysh/Kadanoff-Baym equations are solved within the second Born approximation, the first perturbative correction to the Hartree-Fock mean-field.

For an efficient modelling of ionization processes we introduce an approximation scheme, which provides a complete single-particle de-

scription of the continuum, while the model atom is considered as correlated. This allows for a systematic time-resolved investigation of the above mentioned effects.

[1] Drescher et al, Nature (London) **419** 803–807 (2002)
[2] Uiberacker et al., Nature (London) **446** 627–632 (2007)

A 34.15 Do 16:30 VMP 9 Poster

Origin for the high harmonic spectral minimum in N_2 — •Markus Gühr, Brian K. McFarland, Joseph P. Farrell, and Philip H. Bucksbaum — Stanford PULSE Institute, SLAC National Accelerator Lab, Menlo Park, CA 94025 and Physics Department, Stanford University, Stanford CA 94305, USA

High harmonic generation is decomposed into three steps including 1) ionization from the highest occupied orbital, 2) acceleration of the ionized electron in the laser field and 3) recombination of that electron with the ionized orbital transferring the electron kinetic energy into a photon. Destructive interferences between the recombining free electron wave and the ionized molecular orbital modulate the high harmonic amplitude and phase according to a geometrical model [1]. We observe a phase jump accompanied by a spectral minimum for HHG in N_2. In alignment experiments, the minimum shifts to lower harmonics for increasing the angle between the molecular axis and harmonic generation polarization. Furthermore, the minimum shifts to higher harmonics with increasing harmonic generation intensity. We find that the features observed in N_2 cannot be fully explained by a geometrical model and discuss alternative approaches via a multi-orbital model [2].

[1] Lein *et al.*, Phys. Rev. A, **66**, 023805 (2002)
[2] B. K. McFarland, J. P. Farrell, P. H. Bucksbaum and M. Gühr, Science **322**, 1232 (2008)

A 34.16 Do 16:30 VMP 9 Poster

Breit interaction effects on the alignment of highly–charged heavy ions following dielectronic recombination — Andrey Surzhykov[1,2], •Thomas Stöhlker[1,2], and Stephan Fritzsche[2,3] — [1]Universität Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Frankfurt Institute for Advanced Studies

Dielectronic recombination (DR) is a resonant process in which a free electron is captured by a heavy ion under the simultaneous excitation of a bound electron, and where the resulting multiply excited ion is subsequently stabilized by photon emission. During recent years, this resonant capture has attracted a lot of interest, both by experiment and theory, since it provides a unique tool in order to investigate the electron–electron (e–e) interaction in the presence of strong fields. Sizeable effects due to the relativistic (Breit) contribution to the e–e interaction were predicted especially for the capture *cross sections* and confirmed in recent DR experiments with Li–like heavy ions [1].

In contrast to DR cross sections, much less is known of how the Breit interaction influences the alignment of the residual ions. In this contribution, we present the density matrix formalism for describing the magnetic sublevel population of the excited ionic states following DR. Based on this formalism, we show that the Breit interaction between the electrons may *qualitatively* affect the alignment of heavy ions and, hence, the angular distribution and polarization of the subsequent photon emission. Detailed calculations are presented for the DR of initially H– and Li–like iodine, bismuth and uranium ions.

[1] N. Nakamura *et al.*, Phys. Rev. Lett. **100** (2008) 073203.

A 34.17 Do 16:30 VMP 9 Poster

Charge state selective observation of resonant electron-ion recombination processes in the Heidelberg-EBIT — Lodewijk Arntzen, •Sven Bernitt, Rainer Ginzel, Hiro Tawara, Christian Beilmann, José R. Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

In an experiment at the Heidelberg-EBIT we observed dielectronic recombination in helium-like and lithium-like krypton, comparing the flux of extracted ions in neighbouring charge states, which were separated using a bending magnet and imaged with a multichannel plate detector equipped with a delay-line anode. In contrast to x-ray spectroscopic measurements, a striking feature of this method is the possibility to resolve resonances of ions in different charge states, even when they are blended in the x-ray spectrum. The experimental data were compared to predictions of DR cross sections, obtained with MCDF calculations and showed very good agreement.

In future experiments, it might be possible to detect resonant recombination processes of higher order, like trielectronic recombination (TR), which have recently been found at the Heidelberg-EBIT by spectroscopic methods.

A 34.18 Do 16:30 VMP 9 Poster

Kinematically complete (e, 2e) measurements of argon and argon dimers — •Thomas Pflueger, Xueguang Ren, Arne Senftleben, Alexander Dorn, and Joachim Ullrich — Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany

We present measurements of the triply differential cross-sections (TDCS) for argon and argon dimers for a incident energy of 100eV. These measurements have been carried out using a so-called reaction microscope (RM) which allows detection of the ejected electrons and residual ions over the whole solid angle.

The differences of the compared TDCS for Ar and Ar_2, though subtle in the projectiles scattering plane, are found to be larger outside of this plane. There, the dimer shows an enhanced intensity over the atom which can be explained by an increase of multiple scattering processes due to the additional scattering center. Furthermore, comparison of recent calculations and the measured TDCS for atomic argon show considerable discrepancies, even though the theory can reproduce measured data in the particles scattering plane reasonably.

A 34.19 Do 16:30 VMP 9 Poster

Angle-resolved hypersatellite emission following the dielectronic recombination of heavy ions — •Stephan Fritzsche[1,2], Nicolai Kabachnik[3], Thomas Stoehlker[2,4], and Andrey Surzhykov[2,4] — [1]Frankfurt Institute for Advanced Studies — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Moscow State University — [4]Universität Heidelberg

Dielectronic recombination (DR) is an important process in plasmas that leads to the radiative stabilization of muliple and highly-charged ions. At GSI Darmstadt, for example, the $K-LL$ dielectronic recombination of (finally) helium–like uranium U^{90+} ions has been studied in detail [1], along with its subsequent photon emission. However, while the measured cross sections are quite well understood already within an independent–particle model, a remarkable discrepancy was found for the angular distribution of the $K\alpha_1$ hypersatellite radiation following the $K-L_{1/2}L_{3/2}$ resonant electron capture [1,2].

In this work, the density matrix theory has been applied to re–investi-gate the DR of (initially) hydrogen–like ions with regard to the *non–dipole* contributions of the relativistic electron–photon interaction. In particular, it is shown how the angular distribution of the $K\alpha_{1,2}$ hypersatellite lines is notably influenced by the interference between the leading electric–dipole $E1$ and — the much weaker — magnetic–quadrupole $M2$ decay channels [3].

[1] X. Ma *et al*, Phys. Rev. A **68** (2003) 042712.
[2] S. Zakowicz *et al*, Phys. Rev. A **68** (2003) 042711.
[3] S. Fritzsche *et al.*, Phys. Rev. A **78** (2008) 032703.

A 34.20 Do 16:30 VMP 9 Poster

Spin-resolved electron scattering from lead (Pb) and europium (Eu) atoms — •Volker Hamelbeck and G. Friedrich Hanne — Physikalisches Institut, 48149 Münster, Germany

The interactions between low-energy spin-polarised electron beams and atomic as well as molecular targets have comprehensively been studied in our group. An interesting aspect of this field are collision experiments on heavy open-shell metal atoms such as Pb and Eu where spin-orbit and exchange effects occur simultaneously. This is still a difficult task for theory.

For a description of these processes, the scattering parameters S_P, S_A, $\vec{T}$ and $\vec{U}$ are introduced. Through the polarisation function S_A the spin-dependence of the DCS is quantified. The other parameters are determined by measurement of $\vec{P}$ and $\vec{P}'$, the electron polarisation before and after scattering respectively. These cover distinct effects such as exchange (T_x, T_y, T_z) and rotation (U_{xz}, U_{zx}) of the electron spin during scattering.

In our experiments, the spin-polarised electron beam is guided from a GaAs source to the collision centre where it hits the heavy metal vapour emanating from an oven. A rotatable spectrometer is used to collect the scattered electrons whose spin polarisation is determined in a Mott-detector, subsequently.

In the case of low energy electron scattering from Pb, the angular distribution of the spin asymmetry function S_A shows a significant dependence on the energy between 11 eV and 14 eV. For Eu, first results of S_A and the exchange parameter T_y are presented.

A 34.21 Do 16:30 VMP 9 Poster

Bound–free pair creation with simultaneous capture of the

electron in relativistic collisions of highly charged ions — •Anton Artemyev[1], Benasser Najjari[2], Andrey Surzhykov[1], and Alexandr Voitkiv[2] — [1]Universitaet Heidelberg, Germany — [2]MPI-K Heidelberg, Germany

During recent years some experimental and theoretical interest has arised to the studies of negative-continuum dielectronic recombination (NCDR) [1], which is new mechanism of electron–positron pair creation. For the experimental investigation of this process it is important to know all competitive processes which also yeld the change of the projectile charge by two units and a positron. Therefore in our contribution we discuss possible competitive processes. For example, we analyze the radiative and non-radiative capture of the target electron with simultaneous bound-free pair creation. Cross-sections of these processes are compared with NCDR ones.

[1] A. N. Artemyev *et al.*, Phys. Rev. A **67**, 052711 (2003).

A 34.22 Do 16:30 VMP 9 Poster

(e,eγ)-Koinzidenzexperimente mit spinpolarisierten Elektronen — •Frank Jüttemann und Georg Friedrich Hanne — Physikalisches Institut, WWU Münster, 48149 Münster

Die theoretische Beschreibung der Streuung von Elektronen an Atomen erzielte für leichte Targets wie z.B. Na in den letzten 10 Jahren entscheidende Fortschritte, u.a. weil nahezu vollständige und sehr genaue Messungen verschiedenster Streuparameter vorlagen, mit denen theoretische Ansätze verglichen werden konnten. Insbesondere spinaufgelöste Messungen trugen hierzu maßgeblich bei. Der Fortschritt bei der theoretischen Beschreibung für komplexe Targets wie Hg ging jedoch deutlich langsamer von Statten; es ist ein Ziel der Forschungsarbeit in unserer Arbeitsgruppe, für Modell-Targets wie Hg die verschiedensten Stoßphänomene (Orientierung, Ausrichtung, Spinaustausch, explizit spinabhängige Kräfte) gezielt zu studieren und sehr genaue und möglichst vollständige experimentelle Daten zu liefern, die zu einem ähnlich erfolgreichen Durchbruch der theoretischen Beschreibung auch für schwere Targets führen könnte.
Wir berichten über abgeschlossene Elektron-Photon-Koinzidenz-Messungen sowie winkelintegrierte Stokesparameter-Messungen an Hg.

A 34.23 Do 16:30 VMP 9 Poster

Dielectronic Recombination of Li- and Be-like Xenon Ions — •Dietrich Bernhardt[1], Sebastian Böhm[1], Holger Knopp[1], Stefan Kieslich[1], Paul Mokler[1], Alfred Müller[1], Stefan Schippers[1], Wei Shi[1], Peter Beller[2], Fritz Bosch[2], Carsten Brandau[2], Christophor Kozhuharov[2], Fritz Nolden[2], and Markus Steck[2] — [1]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität, 35392 Giessen, Germany — [2]Gesellschaft für Schwerionenforschung (GSI), Darmstadt, Germany

Dielectronic recombination (DR) rate coefficients of Li-like Xe^{51+} and Be-like Xe^{50+} have been measured by employing the merged electron-ion beam technique at GSI's heavy-ion storage ring ESR in a center-of-mass energy range from 0 to 550 eV. Due to the kinematics of the merged-beams arrangement the highest precision for the determination of energies can be obtained for resonances at very low relative energies. During DR, electrons populate highly exited autoionising Rydberg states. These states, particularly in highly charged heavy ions, lend themselves to precision spectroscopy. The resonance strength and energy are both sensitive to QED contributions and finite nuclear radius effects. Measurements with few electron Xenon ions close the gap between measurements with lighter low electron ions at TSR[1] and earlier measurements with heavy low electron ions at ESR[2].

[1] S. Schippers et al. Phys. Rev. A. **62**, 022708 (2000)
[2] C. Braundau et al. Phys. Rev. Lett. **89**, 053201 (2002)

A 34.24 Do 16:30 VMP 9 Poster

Collisions of low-energy antiprotons — •Armin Lühr and Alejandro Saenz — Humboldt-Universität zu Berlin, Institut für Physik, Moderne Optik, Hausvogteiplatz 5-7, D-10117 Berlin

During the last decades advances have been achieved in the understanding of antiproton ($\bar{p}$) collisions with the simplest one- and two-electron atoms H and He. However, in the case of $\bar{p}$ + He experiment and theory did not agree for impact velocities below the mean electron velocity for more than a decade stimulating a vivid theoretical activity. Additionally, the conditions for the production of slow antiproton beams already achieved at the antiproton decelerator AD at CERN will strongly improve with the upcoming low-energy $\bar{p}$ facility FLAIR at GSI. This provides the basis for fundamental physics like tests of the CPT-invariance or gravity of antimater. Accurate $\bar{p}$ collision data can be used for stringent tests of different theoretical approaches.

Theoretical investigations for collisions of $\bar{p}$ with atomic and molecular hydrogen [1], helium as well as the alkali metal atoms [2] Li, Na, K, and Rb in an energy range from 1 keV to 6 MeV were performed. Cross sections for excitation and ionization as well as electron-energy spectra and stopping power are presented together with comparisons to results for proton collisions. The calculations are based on a time-dependent close coupling approach. The present calculations should also be useful for the design of the new FLAIR facility where, e.g., the interaction of $\bar{p}$ with residual-gas atoms is important.

[1] A. Lühr and A. Saenz, Phys. Rev. A **78**, 032708 (2008)
[2] A. Lühr and A. Saenz, Phys. Rev. A **77**, 052713 (2008)

A 34.25 Do 16:30 VMP 9 Poster

State selective, angular differential cross sections for electron capture in slow collisions of highly charged argon ions with He and Ne — •Yingli Xue[1,2], Daniel Fischer[1], Steven Knoop[3], Myroslav Zapukhlyak[4], Rainer Ginzel[1], Tom Kirchner[4], Ronnie Hoekstra[3], José R. Crespo López-Urrutia[1], Robert Moshammer[1], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institute of Modern Physics, CAS, Lanzhou,China — [3]KVI, Atomic Physics, University of Groningen, Groningen, The Netherlands — [4]Institut für Theoretische Physik, TU Clausthal, Clausthal-Zellerfeld, Germany

Single and double electron capture in collisions of slow Ar^{q+}-ions ($q > 14$) with He and Ne targets have been studied using a 'Reaction Microscope'. For single electron capture, state selective and angular differential cross sections have been obtained. The comparison with the results of a close-coupling approach – the two-center basis-generator method (TC-BGM) – yields good overall agreement [1]. For double electron capture not only the Q-value and the projectile scattering angle but also – in the case of autoionization – the momenta of the emitted electrons have been measured. These results will provide first insight into ultra-fast, femtosecond electron transfer and stabilization mechanisms occurring in slow collisions between highly charged ions and atoms and will represent the most sensitive test for theoretical approaches like TC-BGM.

[1] S. Knoop et al., J. Phys. B **41**, (2008) 195203

A 34.26 Do 16:30 VMP 9 Poster

High precision measurements on recoil ion momenta using MOTRIMS — •Simone Goetz[1], Ina Blank[1], Terry Mullins[1], Wenzel Salzmann[1], Matthias Weidemueller[1], Brett DePaola[2], Roland Wester[3], Robert Moshammer[4], Daniel Fischer[4], Alexander Dorn[4], Alexey Sokolov[5], Wolfgang Quint[5], Gabriel Hasan[6], Reinhard Morgenstern[6], and Ronnie Hoekstra[6] — [1]Physikalisches Institut, Universität Heidelberg — [2]Kansas State University, Kansas, USA — [3]Physikalisches Institut, Universität Freiburg — [4]MPI für Kernphysik Heidelberg — [5]GSI mbH Darmstadt — [6]KVI, Atomic Physics

We present a versatile transportable experimental MOTRIMS setup consisting of a dark SPOT [1] for Rb atoms combined with a recoil ion momentum spectrometer (RIMS) [2]. Due to the low thermal spread of the target atoms, the recoil ion momentum can be measured with very high accuracy. We will study multiphoton ionization occuring during the interaction of the target atoms with ultrastrong laser pulses. At GSI, the same setup will be used for the investigation of correlation effects in multiple charge transfer processes in collisions between ultracold atoms and slow highly charged ions.

First experimental results, achieved at the MOTRIMS setup at the KVI Groningen, on the energy dependence of double electron transfer in collisions between laser-cooled Na and O^{6+} will be presented.

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A 34.27 Do 16:30 VMP 9 Poster

Produktion von H^+, H_2^+ und H_3^+ in Stössen von He^+ mit Kohlenwasserstoffen — Bärbel Siegmann[1] und •Udo Werner[2] — [1]Fakultät Physik, Technische Universität Dortmund, 44221 Dortmund — [2]Fakultät für Physik, Universität Bielefeld, 33615 Bielefeld

Es wurde die Mehrfachionisation und Fragmentation der einfachsten Alkane (CH_4, C_2H_6 und C_3H_8) in Stössen mit 100–300 keV He^+-Ionen untersucht. Die im Stoss erzeugten Elektronen und Ionen werden durch ein homogenes elektrisches Feld separiert und mit einem orts- und zeitauflösenden Multi-Hit-Detektor nachgewiesen, der die koinzidente Messung der Impulsvektoren korrelierter Fragmentionen erlaubt. Die verwendete Detektoranode gestattet es, auch gleichzei-

tig auftreffende Fragmentionen getrennt nachzuweisen, so dass neben Prozessen wie $CH_4 \rightarrow CH_{4-n} + H_n^+$ auch Fragmentationskanäle wie $CH_4 \rightarrow CH_2^+ + H^+ + H^+$ oder sogar $CH_4 \rightarrow C^+ + 4H^+$ einer kinematischen Analyse zugänglich sind. Auf den ersten Blick überraschend ist, dass neben H^+ und H_2^+-Fragmenten bei diesen Molekülen auch H_3^+-Ionen erzeugt werden. Die Koinzidenzspektren zeigen, dass H^+ und H_2^+ sowohl in Abspaltungsreaktionen als auch in Multifragmentationen erzeugt werden, wohingegen bei der Produktion von H_3^+ das Kohlenstoffgerüst intakt bleibt.

A 34.28 Do 16:30 VMP 9 Poster

The SPARC EBIT; Installation and Commissioning of a Test Ion Source for the HITRAP Project — •Brian O'Rourke[1], Sabrina Geyer[1], Alexandra Slize[2], Alexey Solokov[1], Gleb Vorobjev[1], Danyal Winters[1], Oliver Kester[1], and Thomas Stöhlker[1] — [1]Gesellschaft für Schwerionenforschung (GSI), Planckstrasse 1, D-64291 Darmstadt, Germany — [2]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Rossendorf, Postfach 51 01 19, D-01314 Dresden, Germany

In order to provide an off-line ion source for experiments at the HITRAP project a small permanent magnet electron beam ion trap (EBIT) has been installed at GSI. HITRAP is a new facility currently under construction at GSI which will decelerate highly charged ions (HCI) down to keV energies for use in a range of experiments. Results from initial commissioning tests of the EBIT will be presented in this contribution. Measurements of the x-ray spectra of radiation emitted from the EBIT trap region and the charge balance of the extracted ion cloud via magnetic and time of flight spectroscopy showed the presence of HCI in charge states up to Ar^{18+}, Kr^{22+} and Xe^{31+}. The EBIT has now been installed at the HITRAP experimental platform and we also briefly outline some of the future plans for the source at this platform. Some applications of the EBIT as a test-bed for instrumentation under development for the SPARC collaboration, part of the new FAIR facility to be built at GSI, will also be presented.

A 34.29 Do 16:30 VMP 9 Poster

Calculation of capture and ionisation processes in ion-water-molecule collisions — •Tobias Spranger[1], Tom Kirchner[1], and Hans-Jürgen Lüdde[2] — [1]Institut für Theoretische Physik, TU Clausthal, Germany — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt, Germany

The Basis Generator Method is a rather sucessful method for calculating ionisation, transfer, and excitation probabilities for ion-atom collisions. Since it is a two-centre basis method, an extension is necessary to address ion-molecule collisions. Some tests show that molecular orbitals (MO) of water can be described with sufficient accuracy in an atomic oxygen basis. Based on this insight we are developing an approach to calculate ionisation and capture processes during ion impact on water molecules. One further aspect of our approach is that we treat the system as an ensemble of all molecular orientations. By using the integral of the ensemble density over all orientations we only need one calculation in order to get mean results for randomly oriented molecules. First results of proton-water collisions will be presented.

A 34.30 Do 16:30 VMP 9 Poster

Relativistic Contraction Studies at Heavy Elements — •Mustapha Laatiaoui[1], Dieter Habs[1], Michael Sewtz[1], Hartmut Backe[2], and Werner Lauth[2] — [1]LMU, Sektion Physik, Amcoulombwall 1, 85748 Garching — [2]Uni Mainz, Institut für Kernphysik, 55099 Mainz

Some of the most fascinating studies of the actinides and the transactinides concern the influence of increasingly strong relativistic effects on the valence-electron configuration of the atoms and its consequences on their chemical behavior. Relativistic effects are caused, roughly speaking, by a contraction of the wavefunctions of s- and $p_{1/2}$-electrons. Inner shell electrons influence indirectly via the shielding of the nuclear potential the valence electrons and, thus, the chemical properties as well. The quantum mechanical observables r_{max} and $< r^2 >$ are both not only subjected to the above mentioned relativistic contraction but also reflect the electron configuration of the respective atoms and ions. Thus, systematic studies of r_{max} and $< r^2 >$ of actinides and transactinides will contribute to a better understanding of the electronic structure in nuclear fields. These observables can be determined by ion-mobility spectrometry, which is a well established technique for investigations of the ion mobility of stable elements. An ion-mobility spectrometer being developed for high-precision studies of the ion-mobility of actinides and transactinides will be presented. This work is supported by the BMBF(06ML236I).

A 34.31 Do 16:30 VMP 9 Poster

Theoretical analysis of multiple ionization of Ar-ions in gas targets — •Gerald Schenk and Tom Kirchner — Institut für Theoretische Physik, TU-Clausthal, D-38678 Clausthal-Zellerfeld, Germany

Electron stripping cross sections for fast highly-charged ions in gas targets are of interest for various reasons, e.g. in the framework of the FAIR project at GSI. We have considered electron loss from sixfold and eightfold argon ions in helium and argon gases at 10 MeV/amu and 19 MeV/amu, respectively. Our calculations are based on a mean-field description of the electron dynamics and the nonperturbative basis generator method for orbital propagation.

In the case of Ar^{6+} we find that a considerable fraction of electron loss is due to ionization from the L shell. Consequently, LMM Auger processes can contribute to multiple electron loss of Ar^{6+} ions. In Ar^{8+} ionization of the K shell also occurs. Even though the probability is low, most K Auger processes must not be neglected if higher charge states are of interest. We have taken Auger processes into account and find indeed a major influence on the final charge-state distributions of the ions.

A 34.32 Do 16:30 VMP 9 Poster

Design of an Ion Deceleration Platform for the Investigation of Slow Ion-Surface Interactions and Ion-Atom Collisions — •Rainer Ginzel, Stuart Higgins, Sven Bernitt, Benjamin L. Schmitt, José R. Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

To study the interaction of highly charged ions (HCIs) with surface or gas targets at low kinetic energies, a novel deceleration platform was constructed at the Heidelberg Electron Beam Ion Trap (EBIT). The new experimental setup will provide a slow, monoenergetic, and well-focused ion beam, allowing both slow ion-surface and ion-atom collisions to be studied in depth. Surface interaction research topics at the MPIK focus on the effects of low kinetic energy HCIs incident on surfaces. Interactions in this regime allow for the study of processes such as the creation of surface nanostructures, and processes involving ion impact induced electron emission, both have been previously investigated at the Heidelberg EBIT at intermediate ion energies. For ion-atom collisions in the gas phase the setup will allow for the study of the energy dependencies of single and multiple electron capture cross-sections at ultra-low impact energies (to 10eV/q). The (n,l)-selective observation of charge exchange processes, relevant to x-ray astrophysics and tokamak plasma diagnostics, are principal motives for the implementation of the new beamline.

The implementation of all beamline components has been completed and performance tests are underway. First experiments with decelerated HCIs on both surface and gas targets will begin soon.

A 34.33 Do 16:30 VMP 9 Poster

Laser assisted tunneling in alpha decay — •Héctor M. Castañeda, Adriana Pálffy, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Tunneling is a fundamental quantum mechanical effect underlying for many interesting physical processes in different areas of physics. The possibility of controlling the dynamics of tunnelling processes by external electromagnetic fields is sustained by the success of quantum control schemes in atomic physics. The advent of new light sources, with higher power, brilliance and coherence at low wavelengths opens unprecedented perspectives for related experiments in nuclear physics [1]. In particular, the tunneling process in nuclear α decay is an obvious candidate for the study of possible effects due to the interaction with intense laser fields.

Motivated by this, we calculate α tunneling widths in the framework of the WKB approximation, and investigate its validity in different approaches of the tunneling problem[2]. Furthermore, the process of laser-assisted tunneling in α decay is considered, using realistic parameters of upcoming coherent light sources both in the visible and in the x-ray region. Possible coherence effects in assisted α tunnelling are addressed also for other time-dependent electromagnetic fields, such as Coulomb excitation, following the formalism developed in [3].

[1] A. Pálffy, J. Mod. Opt. 55, 2603 (2008)
[2] N. G. Kelkar and H. M. Castañeda, Phys. Rev. C 76, 064604(2007)
[3] B. Ivlev, Phys. Rev. C 69, 037602 (2004)

A 34.34 Do 16:30 VMP 9 Poster

Multiphoton pair creation by relativistic proton and muon impact on intense laser beams — •Sarah Müller, Huayu Hu, Tim-Oliver Müller, and Carsten Müller — Max-Planck-Institut für Kernphysik, Heidelberg

Electron-positron pair production in combined laser and Coulomb fields is studied, with a focus on recoil effects. To this end, the Feynman diagram for multiphoton pair creation by muon impact on an x-ray laser beam is evaluated within the framework of laser-dressed quantum electrodynamics employing relativistic Volkov states. The result is compared with the known expression for multiphoton pair production by a proton which is treated as an external Coulomb field. In the limit of low laser intensity, both approaches are shown to coincide. The recoil distribution is calculated numerically and its dependence on the projectile mass is discussed.

A 34.35 Do 16:30 VMP 9 Poster

Hard x-ray harmonics from counter-propagating attosecond pulse trains — •Markus C. Kohler, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heildeberg, Germany

High-order harmonic generation with relativistically strong laser pulses employing highly charged ions is investigated. The magnetically induced drift of an ionized electron hinders the straightforward extension of the three-step process into the relativistic regime. However, the efficiency of rescattering can be significantly increased by employing counter-propagating attosecond pulse trains as fundamental laser source [1]. Here the electron is ionized by a first pulse undergoing a drift which can be reversed by a second counter-propagating pulse that yields the recombination. In this way, the energy of the revisiting electron at the atomic core can reach the MeV domain. In order to give evidence of a macroscopic harmonic yield after propagation through plasma, we analyze the conditions for rendering phase-matching of the harmonics possible and employ quasi-phase-matching schemes.

[1] K. Z. Hatsagortsyan, et al. J. Opt. Soc. Am. B 25, 93 (2008).

A 34.36 Do 16:30 VMP 9 Poster

Selective excitation of multiple states in atomic sodium by a single chirped femtosecond laser pulse — Marc Krug[1], Svetoslav Ivanov[2], Matthias Wollenhaupt[1], Tim Bayer[1], •Christian Lux[1], Nikolay V. Vitanov[2], and Thomas Baumert[1] — [1]Universität Kassel, Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Heinrich-Plett-Str. 40, D-34132 Kassel, Germany — [2]Theoretical Physics Division - Department of Physics, Sofia University - James Bourchier 5 blvd, 1164 Sofia, Bulgaria

Chirped femtosecond laser pulses generated by spectral phase modulation are used for strong-field Resonance Enhanced Multi-Photon Ionization (REMPI) of atomic sodium. Photoelectron Angular Distributions (PADs) are measured employing a photoelectron imaging spectrometer. Pronounced differences in the PADs with respect to the sign of the chirp (up-chirp/down-chirp) are observed experimentally. We identify three contributing ionization processes, i.e. a (2+1+1) REMPI, a (3+1) REMPI and ionization via the off-resonant 3p-state. The experimental data is supported by full quantum mechanical simulations of the excitation/ionization process. An analytical model to describe the (2+1+1) excitation channel and the selective excitation of multiple states is presented in addition.

A 34.37 Do 16:30 VMP 9 Poster

Tomographic analysis of photoelectron wave packets from strong-field excitation of potassium atoms with fs laser pulses — •Marc Krug, Matthias Wollenhaupt, Jens Köhler, Tim Bayer, and Thomas Baumert — Universität Kassel, Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology (CINSaT) , Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

We present an approach to employ a photoelectron imaging spectrometer for tomography of 3-dimensional electron wave packets resulting from excitation and ionization of potassium atoms with fs laser pulses. Ionization proceeds via a (1+2) Resonance Enhanced Multi-Photon Ionization process mainly leading to free electron wave packets with f–symmetry. Analysis of the 3-dimensional wave packets is performed by rotating the fs laser pulse about the propagation axis and measuring Photoelectron Angular Distributions (PADs) in a tomography-type procedure. Related to the latter, we present a method to deconvolute the information stored in the measured 2-dimensional projections in order to get the density of the 3-dimensional electron wave packet.

A 34.38 Do 16:30 VMP 9 Poster

Strong field ionization, rescattering and resonances in the extreme ultraviolet domain — •Hossein Ebadi, Karen Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Stimulated by the advances in the XFEL (FLASH) radiation sources, the strong field ionization dynamics is investigated in the short-wavelength (UV, XUV) domain. The investigation is based on numerical solutions of the time-dependent Schrödinger equation (the nonrelativistic treatment is valid in this frequency domain). The main focus is the over-the-barrier ionization regimes at high frequencies and the transition region to the stabilization regime. The strong field ionization dynamics is found to be substantially different in the XUV domain compared with what is known for the infrared regime. In particular, the atomic structure signatures (resonances) survive up to the over-the-barrier regime, the rescattering is modified and interference structures arise in the low-energy photo-electron spectrum.

A 34.39 Do 16:30 VMP 9 Poster

Ionization dynamics of H_2 in strong fields — •Timo Wilbois and Hanspeter Helm — Department of Molecular and Optical Physics, Stefan-Meier-Str. 19, 79104 Freiburg, Germany

We present experimental results from ionization of molecular hydrogen in strong laser fields. To assign ionization pathways to the observed resonant structures, we have calculated spectra for the ionization via selected intermediate states. Vibrational wavefunctions have been computed with a B-spline method, which then were used for the calculation of Franck-Condon factors of the transitions of interest.
A novel position-sensitive imaging spectrometer for multiple ion-electron-coincidence detection and its performance in the application to the above problem will also be presented.

A 34.40 Do 16:30 VMP 9 Poster

Single-shot scattering experiments on clusters at the FLASH-FEL deliver insight into nm-length- and fs-timescale — •D. Rupp[1], M. Adolph[1], D. Wolter[1], S. Schorb[1], H. Thomas[1], R. Unterumsberger[1], R. Hartmann[2], N. Kimmel[2], L. Strüder[2], T. Feigel[3], A. Rudenko[4], D. Rolles[4], K.U. Kühnel[5], J. Ullrich[5], H. Wabnitz[6], T. Laarmann[6], R. Treusch[6], T. Möller[1], and C. Bostedt[1] — [1]IOAP / TU Berlin — [2]MP Halbleiterlabor — [3]Fraunhover IOF — [4]ASG / MPG — [5]MPI Kernphysik — [6]DESY

Super-intense, ultrashort x-ray pulses from free-electron lasers allow imaging of nano structures with single-shot scattering experiments. The currently achievable resolution is given by the wavelength of the FLASH FEL in the nanometer regime. In the future atomic length scales of a few Angstrom can be investigated at the planned X-FELs.

We have performed single-shot scattering experiments at FLASH on single Xenon clusters with diameters comparable to the wavelength (20 to 150 nm). Our refocusing optics based on multilayer mirrors, yielded focal intensities up to $2 \cdot 10^{15}$ W/cm^2. With high performance pnCCDs we were able to aquire single-shot scattering images of one or two clusters in focus. Through simulations we identified geometrical information, as form, size and configuration. Analysis of the single cluster images via Mie's theory provided information about the optical properties of the clusters during the interaction with the laser pulse. As the optical constants are correlated to the degree of ionization of the cluster plasma, we gain insight into the ultrafast dynamics on the femtosecond timescale.

A 34.41 Do 16:30 VMP 9 Poster

Velocity Map Imaging of Xe-Clusters Irradiated with FEL-Radiation — •Sebastian Schorb[1], Rainer Unterumsberger[1], Per Johnsson[2], Heiko Thomas[1], Marc Vrakking[2], Thomas Möller[1], and Christoph Bostedt[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin — [2]FOM - AMOLF, Amsterdam

We performed first single-shot ion velocity map imaging (VMI) experiments on Xe clusters at the FLASH FEL at HASYLAB in Hamburg. Xe was resonantly excited at the 4d core level with power densities up to $10^{14}\,W/cm^2$. A special velocity map imaging spectrometer configuration was used to detect 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. The images show an isotropic spatial ion distribution and kinetic en-

ergy 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 recent theoretical predictions.

A 34.42 Do 16:30 VMP 9 Poster

Non-sequential Double Ionization of Neon and Argon below the Recollision Threshold — Yunquan Liu[1], Sebastian Tschuch[1], Artem Rudenko[2], Martin Dürr[1], Uwe Morgner[3], •Bettina Fischer[1], Manuel Kremer[1], Robert Moshammer[1], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Max-Planck Advanced Study Group within CFEL, Notkestrasse 85, 22607 Hamburg, Germany — [3]Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Kinematically complete experiments for single and double ionization of argon and neon in ultra-short (28 fs) laser pulses (800 nm) at intensities below and close to the classical recollision threshold for non-sequential double ionization are presented. In contrast to high intensity results we observe a dominant back-to-back emission of both electrons for double ionization of Ar below the threshold. The relationship between single and double ionization is discussed and the fundamental question of double ionization in strong laser fields is addressed. The transverse momentum distributions of electrons provide new insights into the role of the so-called Coulomb focusing effect.

A 34.43 Do 16:30 VMP 9 Poster

Phasenstabile Pump/Probe Messungen mit einem Reaktionsmikroskop — •Christian Hofrichter[1], Bettina Fischer[1], Manuel Kremer[1], Artem Rudenko[1], Matthias Lezius[2], Robert Moshammer[1] und Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Bei ultrakurzen Laserpulsen mit nur wenigen optischen Zyklen (6 fs) spielt die Phase zwischen Trägerwelle und Einhüllenden des Pulses (die sogenannte CEO-Phase) eine wichtige Rolle. Die Stabilisierung der CEO-Phase ermöglicht es, Effekte in Atomen und Molekülen zu untersuchen, die vom zeitlichen Verlauf des Laserfeldes abhängen. Mit der f-2f-Technik kann die Phase mit einer Genauigkeit von 0.2 rad durchgestimmt werden. Ein Stereo-ATI-Spektrometer ermöglicht es zusätzlich die Phase in Echtzeit sichtbar zu machen. Durch diese unabhängige Messung des Phasenverlaufs können Langzeitdrifts sofort erkannt werden. Es konnte damit gezeigt werden, dass die Phase auch bei Messungen über mehrere Stunden stabil bleibt. In geplanten Pump-Probe-Experimenten an Atomen und Molekülen soll das Verhalten der Elektronen sowohl im Pump- als auch im Probepuls zeitaufgelöst untersucht werden. Die dabei entstehenden geladenen Fragmente werden mit einem Reaktionsmikroskop detektiert, das die vollständige und koinzidente Messung der Impulsvektoren und die Unterscheidung verschiedener Reaktionskanäle erlaubt. Das Lasersystem und erste Messungen zur Dissoziation von H2 werden vorgestellt.

A 34.44 Do 16:30 VMP 9 Poster

Ultrashort pulse propagation in atomic Rubidium — •Wenjia Zhong[1], Christoph Marquardt[1], Ulrik L. Andersen[2], and Gerd Leuchs[1] — [1]MPI für die Physik des Lichts, Erlangen, Germany — [2]Department of Physics, Technical University of Denmark, Lyngby, Denmark

We investigate the propagation of 130-fs laser pulses through high density atomic Rubidium vapor. We measure the pulse spectra using a high resolution spectrometer both for the laser on resonance of the Rb D_1 line and for the laser detuned such that the resonance frequency is in the wing of the pulse spectrum.

For pulse areas below π, the expected Lorentzian dip at the resonance frequency increases with the light intensity. At pulse areas above π, the behavior is more complicated. Its dependence on pulse detuning, absorption path length and the spatial mode is studied.

A 34.45 Do 16:30 VMP 9 Poster

Towards Single Electron Holography with Carrier Envelope Phase Stabilized Few-Cycle Laser Pulses — •Ram Gopal[1], Konstantinos Simeonidis[1], Artem Rudenko[1], Kai-Uwe Kühnel[1], Thorsten Ergler[1], Manuel Kremer[1], Bettina Fischer[1], Moritz Kurka[1], Claus-Dieter Schröter[1], Oliver Herrwerth[2], Matthias Kling[2], Sergey Zherebtsov[2], Adrian Wirth[2], Martin Schultze[2], Eleftherios Goulielmakis[2], Matthias Uiberacker[2], Thorsten Uphues[2], Matthias Lezius[2], Robert Moshammer[1], Ferenc Krausz[2], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Single ionization of He with carrier-envelope-phase (CEP) stabilized few-cycle ($\approx$ 5 fs), intense ($4*10^{14}$ W/cm^2) laser pulses (740 nm) was studied using a Reaction Microscope. The recorded 3-D electron (and ion) momentum spectra exhibit a preferential emission of low-energy electrons (E_e<15 eV) to either hemisphere as a function of the CEP. Clear parallel interference stripes emerge in momentum-space at CEPs with maximum asymmetry, which are interpreted as attosecond holographic "self"-images of re-scattered electron wave-packets. The results are in qualitative agreement with a simple model and TDSE calculations.

A 34.46 Do 16:30 VMP 9 Poster

Multiphoton Ionization of Lithium — •Michael Schuricke[1], Jochen Steinmann[1], Ganjun Zhu[1], Igor Ivanov[2], Anatoli Kheifets[2], Alexander Dorn[1], and Joachim Ullrich[1] — [1]Max Planck Institut für Kernphysik, Heidelberg, Germany — [2]Australian National University, Canberra, Australia

For the first time a systematic study on multiphoton ionization (MPI) of atomic lithium by near-infrared fs-laser pulses has been conducted in both, experiment and theory. Due to its low ionization energy lithium shows a qualitatively different behavior compared to the widely studied noble gases. The classical over-the-barrier intensity where the electron is essentially field ionized is attained for a Keldysh parameter of roughly 5, i.e. deep within the MPI domain. Thus, lithium provides an excellent target to observe a direct transition from MPI to over-the-barrier ionization (OBI).

In the experiment Ti:Sa laser pulses of 30 fs duration and λ_{central} = 775 nm were focused onto an ultra-cold sample (T = 1 mK) of lithium to reach peak intensities between 10^{11} and 10^{14} W/cm^2. In the calculation the lithium atom is described in the frozen-core Hartree-Fock approximation in order to solve the time-dependent Schrödinger equation on a grid. To improve the comparability of experiment and theory several calculated spectra were averaged, weighted with the peak intensity distribution present in the experiment. Both, experimental and theoretical calculations suggest that the transition from MPI to OBI manifests itself in an increasing contribution of parity forbidden partial waves in the continuum wavefunctions.

A 34.47 Do 16:30 VMP 9 Poster

Excited neutral fragments in strong field dissociation of molecules — •Thomas Nubbemeyer[1], Ulli Eichmann[1,2], Bastian Manschwetus[1], Horst Rottke[1], Günter Steinmeyer[1], and Wolfgang Sandner[1,2] — [1]Max-Born-Institut, Berlin, Germany — [2]Technische Universität Berlin, Germany

We have measured excited neutral fragments with energies of up to 15eV from the strong field dissociation of small molecules (H_2, N_2, CO). The kinetic energy spectra of the excited fragments correspond to those fragmentation processes yielding singly charged ionic fragments, e.g. from the Coulomb explosion in N_2 and H_2 or bond softening in H_2. This suggests that the production of neutral excited fragments results from a recapture process of an electron into a Rydberg state by one of the repelling fragment ions. The dependence of the neutral excited fragment yield on the ellipticity of the laser polarization and correlated measurements of ionic and excited neutral fragments yield further evidence for the suggested model. Finally, classical trajectory calculations within the rescattering model are presented which provide theoretical support.

A 34.48 Do 16:30 VMP 9 Poster

High-power laser interacting with rare gases in the extreme ultra-violet — •Andrei A. Sorokin[1,2], Sergey V. Bobashev[2], Pavle Juranic[3], and Mathias Richter[1] — [1]Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, 10587 Berlin, Germany — [2]Ioffe Physico-Technical Institute, Polytekhnicheskaya 26, 194021 St. Petersburg, Russia — [3]Deutsches Elektronen-Synchrotron, Notkestraße 85, 22603 Hamburg, Germany

At the Free-electron LASer in Hamburg FLASH [1], we have studied the multi-photon ionization of rare gas atoms under the extreme conditions of ultra-high intensities in conjunction with short wavelengths. In the extreme ultra-violet (EUV) range at the wavelength of 13.7 nm, the generation of Ne^{7+}, Ar^{7+}, Kr^{7+}, and Xe^{19+} ions was observed under equivalent conditions at irradiance levels up to $2{\cdot}10^{15}$ W cm^{-2}. The comparison demonstrates the particular behaviour of Xe compared to

other gases which hardly can be explain within standard theories developed for optical radiation and based on ponderomotive motion of free electrons. In the EUV range, the electron structure of individual targets and the excitation of resonances play a significant role to describe the mechanisms of light-matter interaction. In particular, the high degree of non-linear photoionization of Xe and the unexpected irradiance dependence of the higher charge states obtained [2] might be explained by collective giant 4d inner-shell resonance and the wave character of EUV laser light.

[1] W. Ackermann et al., Nat. Photon. 1, 336 (2007) [2] A.A. Sorokin et al., Phys. Rev. Lett. 99, 213002 (2007)

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Multiple Ionization of N_2 by VUV Free-Electron Laser Radiation — •Yuhai Jiang[1], Artem Rudenko[2], Moritz Kurka[1], Kai-Uwe Kühnel[1], Thorsten Ergler[1], Lutz Foucar[3], Markus Schöffler[3], Sven Schössler[3], Tilo Havermeier[3], Mathias Smolarski[3], Kyra Cole[3], Reinhard Dörner[3], Stefan Düsterer[4], Rolf Treusch[4], Michael Gensch[4], Claus Dieter Schröter[1], Robert Moshammer[1], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Max-Planck Advanced Study Group at CFEL, 22607 Hamburg, Germany — [3]Institut für Kernphysik, Universität Frankfurt, 60486 Frankfurt, Germany — [4]DESY, Notkestrasse 85, 22607 Hamburg, Germany

Few-photon multiple ionization of N_2 was studied differentially in a Reaction Microscope using 43.5 eV, ∼25 fs, intense (∼10^{13} W/cm^2) photon pulses from the free-electron laser in Hamburg (FLASH). Sequential ionization is observed to dominate. For various intermediate charge states N_2^{n+} we find a considerable excess of photons absorbed compared to the minimum number that would energetically be required. Photo ionization of aligned N_2^{n+} ions, produced by photon absorption in sequential steps, is explored and few-photon absorption pathways are traced by inspecting kinetic energy releases and fragment-ion angular distribution. In the beam-time given just two weeks ago we were able to successfully commission the split-mirror delay stage and record first time-dependent data for dissociating N_2^{n+} molecules at 45.5 eV.

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Laser-induced nuclear excitation in muonic atoms — •Atif Shahbaz[1], Carsten Müller[1], Thomas Bürvenich[2], Anis Dadi[1], and Christoph Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Frankfurt Institute for Advanced Studies, Johann Wolfgang Goethe University, Ruth-Moufang-Str. 1, 60438 Frankfurt am Main

Coherent nuclear excitation in strongly laser-driven muonic atoms is calculated. The nuclear transition is caused by the time-dependent Coulomb field of the oscillating charge density of the bound muon. A closed-form analytical expression for electric multipole transitions is derived within a fully quantum mechanical approach and applied to various isotopes. The excitation probabilities are in general very small, though not out of experimental reach. We compare the process with other nuclear excitation mechanisms through coupling with atomic shells and discuss the prospects to observe it in experiment.

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Sequential Two-Photon Double Ionization of Ne — •Moritz Kurka[1], Artem Rudenko[2], Lutz Foucar[3], Kai-Uwe Kühnel[1], Yuhai Jiang[1], Tilo Havermeier[3], Sven Schössler[3], Markus Schöffler[3], Reinhard Dörner[3], Michael Gensch[4], Stefan Düsterer[4], Wenbin Li[4], Barbara Keitel[4], Rolf Treusch[4], Stephan Fritzsche[5], A.N. Grum-Grzhimajlo[6], Nikolay Kabachnik[6,7], Claus Dieter Schröter[1], Robert Moshammer[1,2], and Joachim Ullrich[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max-Planck Advanced Study Group at CFEL, Hamburg — [3]Institut für Kernphysik, Universität Frankfurt — [4]DESY Hamburg — [5]GSI Darmstadt — [6]Institute of Nuclear Physics, Moscow State University — [7]Fakultät für Physik, Universität Bielefeld

We present the results of a kinematically complete experiment on two-photon double ionization of Ne atoms with intense FLASH radiation at 44 eV photon energy. Employing the Reaction Microscope spectrometer, we were able to detect all three reaction products (a doubly charged ion and two emitted electrons) in coincidence, which ensures that no contributions from the competing processes (single ionization of Ne, ionization of the residual gas etc.) appear in the spectrum, and allows one us to distinguish the events corresponding to the different final states of the Ne^{2+} ion. Two-electron energy spectra undoubtedly confirm the sequential nature of the ionization process. We present electron angular distributions for the first and the second ionization step, as well as an angular correlation function, and compare them with recent theoretical predictions.

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Photoionization of the alkali dimer cations Li_2^+, Na_2^+ and $LiNa^+$: influence of the nuclear motion — •Irina Dumitriu and Alejandro Saenz — Humboldt-Universität zu Berlin, Institut für Physik, AG Moderne Optik, Hausvogteiplatz 5-7, D-10117 Berlin, Germany.

Photoionization cross sections for the three lightest alkali dimer cations (Li_2^+, Na_2^+, and $LiNa^+$) were calculated at the equilibrium internuclear distance for parallel, perpendicular and isotropic orientations of the molecular axis with respect to the field. A model-potential method was used for the description of the cores. The influence of the model-potential parameters on the photoionization spectra was investigated, and two different methods, a time-independent and a time-dependent one, were used for computing the cross sections. Going beyond the fixed-nuclei approximation from [1], an investigation of the probability of photoionization as a function of the internuclear distance was made and will be presented here.

[1] I. Dumitriu, Y. V. Vanne, M. Awasthi, A. Saenz, J. Phys. B: At. Mol. Phys. 40 1821 (2007).

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Photodissociation of the HeH^+ molecular ion — •Irina Dumitriu and Alejandro Saenz — Humboldt-Universität zu Berlin, Institut für Physik, AG Moderne Optik, Hausvogteiplatz 5-7, D-10117 Berlin, Germany.

The HeH^+ molecular ion has been of interest for astrophysics, for the tritium neutrino mass experiments, and in itself as a model system for a long time. More recently it has been drawing special attention due to an FEL experiment (FLASH) performed at DESY, in Hamburg [1].

The Hamburg experiment motivates the calculation of photodissociation cross sections for both parallel and perpendicular orientations of the molecular axis with respect to the field, since previous results existed only for the parallel spectra [2]. An analysis of the two dissociation channels He + H^+ (measured in the experiment) and He^+ + H was made. The calculations were performed within the adiabatic approximation, but the importance of the diabatic effects was estimated using the Landau-Zener formula. Since the experimental value is assumed to be obtained from a mixture of initial vibrational states, this aspect is also discussed and cross sections for transitions starting from the vibrational levels $\nu = 0, 1, 2, 3, 4$ are shown.

[1] H. B. Pedersen *et al.*, Phys. Rev. Lett. 98, 223202 (2007).
[2] A. Saenz, Phys. Rev. A 67, 033409 (2003).

A 34.54 Do 16:30 VMP 9 Poster

Angular correlations in sequential two-photon double ionization: A theoretical analysis — •Stephan Fritzsche[1,2], Alexei Grum–Grzhimailo[3], and Nicolai Kabachnik[3] — [1]Frankfurt Institute for Advanced Studies — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Institute of Nuclear Physics, Moscow State University

Recent experiments with intense ultraviolet (XUV) radiation sources, such as high harmonics or free electrons lasers, has opened the pathway for studying a variety of non-linear processes with atoms and molecules in the XUV regime. Among these, the two-photon double ionization (TPDI) has attracted much interest since it enables one to explore in detail the transition from a 'sequential' towards the 'simultaneous' emission of two electrons. In this contribution, the sequential TPDI is analyzed for the np^2 $(n = 2, 3)$ ionization of noble gas atoms. Theoretical results [1] are shown in different computational models and compared with recent experiments. In addition, we also analyzed the angular correlation function, as measured by experiment [2], if the two photoelectrons are detected angle-resolved and in coincidence.

[1] S. Fritzsche *et al.*, J. Phys. B **41** (2008) 165601.
[2] M. Kurka *et al.*, submitted (2008).

A 34.55 Do 16:30 VMP 9 Poster

Laserresonanzionisationsspektroskopie an Neptunium — •Tina Gottwald[1], Jens Lassen[2], Christoph Mattolat[1], Gerd Passler[1], Sebastian Raeder[1], Tobias Reich[3], Nils Stoebener[3] und Klaus Wendt[1] — [1]Universität Mainz, Institut für Physik, Staudinger Weg 7, 55128 Mainz — [2]TRIUMPF- ISAC Division, 4004 Wesbrook Mall, Vancouver, BC, Canada V6T 2A3 — [3]Universität Mainz, Institut für Kernchemie, Fritz Strassmann Weg 2, 55128 Mainz

Der empfindliche Ultraspurennachweis von Neptunium kann wichtige Beiträge zur Überwachung der Langzeit-Sicherheit von atomaren Endlagern leisten. Hierzu bietet sich Resonanz-Ionisations-Massenspektrometrie (RIMS) als selektives und empfindliches Nachweisverfahren an. In Vorbereitung auf einen analytischen Ultraspurennachweis, wie bereits am Plutonium demonstriert, wurden am Institut für Physik der Universität Mainz unter Verwendung eines hochrepetierenden Ti:Saphir Lasersystems spektroskopische Untersuchungen an dem Aktinid Neptunium vorgenommen. Hierbei wurde die Proben in einer geheizten Laserionenquelle verdampft und mittels resonanter Laserstrahlung angepassten spektralen und zeitlichen Profils ionisiert. Für die RIMS an Np konnten effiziente und selektive dreistufige Anregungsschemata mit Übergängen im fundamentalen und verdoppelten Wellenlängenbereich der Ti:Saphir Laser gefunden werden. Diese schließen im zweiten und dritten Anregungsschritt zahlreiche bisher unbekannte Energieniveaus ein.

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Angular distributions of atomic photoelectrons produced in the UV and XUV regimes — •Sebastian Bauch and Michael Bonitz — Christian-Albrechts-Universität Kiel, Institut für Theoretische Physik und Astrophysik, Leibnizstraße 15, 24098 Kiel, Germany

We present angular distributions of photoelectrons of atomic model systems excited by intense linearly polarized laser pulses in the VUV- and XUV-regime. We solve the multi-dimensional time-dependent Schrödinger equation for one particle on large spatial grids and investigate the direction dependence of the ionized electrons for isotropic *s*-states as well as *p*-states. Although the ponderomotive potential is small compared to the binding energy of the initially bound electron and the photon energy of the exciting laser field, richly structured photoelectron angular distributions are found which sensitively depend on the laser frequency and intensity as well as on the number of absorbed photons. The occuring shapes are explained in terms of scattering mechanisms

[1] S. Bauch and M. Bonitz, *Angular distributions of atomic photoelectrons produced in the UV and XUV regimes*, Phys. Rev. A **78** 043403 (2008)

A 34.57 Do 16:30 VMP 9 Poster

1s Photoionization of Ne2 - Decay Mechanisms and Core Hole Localization — •K. Kreidi[1,2], T. Jahnke[1], Th. Weber[3], T. Havermeier[1], R. Grisenti[1,4], X.-J. Liu[5], Y. Morisita[6], S. Schössler[1], L. Ph. Schmidt[1], M. Schöffler[1], M. Odenweller[1], N. Neumann[1], L. Foucar[1], J. Titze[1], B. Ulrich[1], F. Sturm[1], C. Stuck[1], R. Wallauer[1], S. Voss[1], I. Lauter[1], H.-K. Kim[1], M. Rudloff[1], H. Fukuzawa[5], G. Prümper[5], N. Saito[6], K. Ueda[5], A. Czasch[1], O. Jagutzki[1], H. Schmidt-Böcking[1], S. Semenov[7], N. Cherepkov[7], and R. Dörner[1] — [1]Institut für Kernphysik, J. W. Goethe Universität, Max-von-Laue-Str.1, 60438 Frankfurt,Deutschland — [2]DESY, Notkestrasse 85, 22607 Hamburg, Deutschland — [3]Lawrence Berkeley National Laboratory, Berkeley CA 94720, USA — [4]Gesellschaft für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt, Deutschland — [5]Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai 980-8577, Japan — [6]National Metrology Institute of Japan, AIST, Tsukuba 305-8568, Japan — [7]State University of Aerospace Instrumentation, 190000 St. Petersburg, Russland

The *1s* photoionization of Ne dimers was studied within the COLTRIMS technique. For this the ionic and electronic products from the photoreaction were detected with a solid angle of 4 π. Within the asymmetric charge breakup Ne^{2+} + Ne^{1+} the angular distribution of the photoelectrons as well as of the ICD electrons in the molecular system was determined to answer the question of localization or delocalization of vacancies in the Ne dimer.