# Fachverband Atomphysik (A)

Uwe Becker
Fritz-Haber-Institut der Max-Planck-Gesellschaft
Faradayweg 4-6
14195 Berlin
becker_u@fhi-berlin.mpg.de

## Übersicht der Hauptvorträge und Fachsitzungen

(Hörsäle Audimax-B, VMP 6: HS-B, HS-C und HS-E; VMP 8: R208, Poster: VMP 9 Poster)

### Hauptvorträge

| | | | | |
|---|---|---|---|---|
| A 1.1 | Mo | 10:45–11:30 | VMP 6 HS-B | **Optimierter und selbst-optimierender magnetischer Einschluß** — •Friedrich Wagner |
| A 2.1 | Mo | 10:45–11:15 | VMP 6 HS-E | **Angular distributions and continuous intensity behavior in multiphoton processes** — •Markus Braune, Axel Reinköster, Jens Viefhaus, Sanja Korica, Uwe Becker |
| A 3.1 | Mo | 14:00–14:30 | VMP 6 HS-B | **Laser spectroscopy of highly charged argon at the Heidelberg electron beam ion trap** — •Volkhard Mäckel, Renee Klawitter, Sven Bernitt, Günter Brenner, José Ramon Crespo López-Urrutia, Joachim Ullrich |
| A 4.1 | Mo | 14:00–14:30 | VMP 6 HS-E | **Relativistic quantum dynamics in extremely strong electromagnetic fields** — •Andrey Surzhykov, Anton Artemyev, Stephan Fritzsche, Thomas Stöhlker |
| A 5.1 | Mo | 16:30–17:00 | VMP 6 HS-B | **Exceptional points in atomic spectra and Bose-Einstein condensates** — •Holger Cartarius, Jörg Main, Günter Wunner |
| A 6.1 | Mo | 16:30–17:00 | VMP 6 HS-E | **Atomic parity violation in one single radium ion** — •Rob Timmermans |
| A 6.2 | Mo | 17:00–17:30 | VMP 6 HS-E | **Ultracold few-boson systems** — •Sascha Zoellner, Hans-Dieter Meyer, Peter Schmelcher |
| A 9.1 | Di | 10:30–11:00 | VMP 6 HS-C | **Atomic and molecular ionization dynamics in strong laser fields: Excited neutral fragments after tunneling** — •Ulli Eichmann |
| A 13.1 | Di | 16:30–17:00 | VMP 6 HS-B | **The total break-up of two-electron atoms: from highly doubly excited states to double ionization of helium** — •Javier Madroñero, Johannes Eiglsperger, Bernard Piraux |
| A 14.1 | Di | 16:30–17:00 | VMP 6 HS-C | **Squeezing and enanglement in a Bose Einstein condensate** — •Markus Oberthaler |
| A 17.1 | Mi | 14:00–14:30 | VMP 6 HS-C | **Atoms and Clusters in Intense Laser Fields** — •Dieter Bauer |
| A 20.1 | Mi | 16:30–17:00 | VMP 6 HS-B | **Frequenzkammgestütze Laserspektroskopie kurzlebiger Isotope zur Kernladungsradienbestimmung des Halokerns $^{11}$Be** — •Ch. Geppert, W. Nörtershäuser, J. Krämer, A. Krieger, R. Neugart, R.M. Sanchez Alarcon, D. Tiedemann, M. Zakova, M.L. Bissell, D.T. Yordanov, M. Kowalska, F. Schmidt-Kaler, C. Zimmermann |
| A 26.1 | Do | 14:00–14:30 | VMP 6 HS-B | **X-ray spectroscopy in an ion trap: doped semiconductor cages, transition metal molecules, and water clusters** — •Tobias Lau, Konstantin Hirsch, Philipp Klar, Andreas Langenberg, Fabian Lofink, Jürgen Probst, Robert Richter, Jochen Rittmann, Marlene Vogel, Vicente Zamudio-Bayer, Bernd von Issendorff, Thomas Möller |
| A 26.2 | Do | 14:30–15:00 | VMP 6 HS-B | **Electron and ion emission from clusters in intense laser pulses** — •Thomas Fennel |
| A 26.3 | Do | 15:00–15:30 | VMP 6 HS-B | **Helium-embedded clusters exposed to intense laser pulses: From "local ignition" to "global cooling"** — •Ulf Saalmann |

| | | | | |
|---|---|---|---|---|
| A 26.4 | Do | 15:30–16:00 | VMP 6 HS-B | **Resonant amplification of quantum fluctuations with a spinor gas** — Carsten Klempt, Oliver Topic, Manuel Scherer, Thorsten Henniger, Garu Gebreyesus, Philipp Hyllus, Wolfgang Ertmer, Luis Santos, •Jan Arlt |
| A 27.1 | Do | 14:00–14:30 | VMP 6 HS-C | **Quantum gases of ultracold polar molecules** — •Silke Ospelkaus |
| A 29.1 | Do | 14:00–14:30 | VMP 8 R208 | **Radiometry and the nature of light** — •Mathias Richter, Andrei A. Sorokin, Kai Tiedtke |
| A 29.2 | Do | 14:30–15:00 | VMP 8 R208 | **Threshold Fragmentation of Simple Atoms by Electron Impact and FLASH VUV Light** — •Alexander Dorn |
| A 29.3 | Do | 15:00–15:30 | VMP 8 R208 | **Ring molecules as tunable light sources** — •Andrey Moskalenko, Jamal Berakdar |
| A 32.1 | Do | 16:30–17:00 | VMP 6 HS-E | **Änd, action! Video clips of electron motion in molecules** — •Matthias Kling |

## Hauptvorträge des Symposiums Lokalisierung und Verschränkung in photoinduzierten Prozessen (SYLV)

Siehe SYLV für das komplette Programm des Symposiums.

| | | | | |
|---|---|---|---|---|
| SYLV 1.1 | Mo | 14:00–14:30 | VMP 8 HS | **Coherence, interference and entanglement in the photoionization of homonuclear diatomic molecules** — •Reinhard Dörner, M. Schöffler, T. Jahnke, K. Kreidi, D. Akoury, L.Ph.H. Schmidt, H. Schmidt-Böcking, J. Titze, N. Neumann, T. Weber, M.H. Prior, A. Belkacem, P. Ranitovic, C.L. Cocke, A. Landers, S. Semenov, N. Cherepkov |
| SYLV 1.2 | Mo | 14:30–15:00 | VMP 8 HS | **Quantum Interfaces between Nanomechanical Systems and Cold Atoms** — •Peter Zoller |
| SYLV 1.3 | Mo | 15:00–15:30 | VMP 8 HS | **Electron entanglement studied by Dopppler-resolved electron spectroscopy** — •Svante Svensson |
| SYLV 1.4 | Mo | 15:30–16:00 | VMP 8 HS | **Entanglement-assisted Ramsey Spectroscopy with Atomic Ensembles** — •Eugene Polzik |
| SYLV 2.1 | Mo | 16:30–17:00 | VMP 8 HS | **Coherent photoelectron emission from diatoms: Influence of scattering, recoil, and dissociation** — •Kiyoshi Ueda |
| SYLV 2.2 | Mo | 17:00–17:30 | VMP 8 HS | **Atom-Photon Entanglement** — •Harald Weinfurter, Florian Henkel, Julian Hofmann, Michael Krug, Norbert Ortegl, Wenjamin Rosenfeld, Jürgen Volz, Markus Weber |
| SYLV 2.3 | Mo | 17:30–18:00 | VMP 8 HS | **Space-time entanglement: A realization of EPR's original proposal** — •Burkhard Langer, Uwe Becker |
| SYLV 2.4 | Mo | 18:00–18:30 | VMP 8 HS | **A long-distance quantum gate between matter qubits** — •P. Maunz, S. Olmschenk, D. Hayes, D. N. Matsukevich, L.-M. Duan, C. Monroe |
| SYLV 2.5 | Mo | 18:30–19:00 | VMP 8 HS | **Space-QUEST: Experiments with quantum entanglement in space** — •Rupert Ursin, Thomas Jennewein, Anton Zeilinger |

## Hauptvorträge des Symposiums S-AMOP Dissertationspreis (SYDI)

Siehe SYDI für das komplette Programm des Symposiums.

| | | | | |
|---|---|---|---|---|
| SYDI 1.1 | Di | 10:30–11:00 | VMP 8 HS | **Experimental manipulation of atoms and photons: the application in quantum information processing** — •Yu-Ao Chen |
| SYDI 1.2 | Di | 11:00–11:30 | VMP 8 HS | **Cavity QED with a Bose-Einstein Condensate** — •Tobias Donner, Stephan Ritter, Ferdinand Brennecke, Anton Oettl, Thomas Bourdel, Michael Koehl, Tilman Esslinger |
| SYDI 1.3 | Di | 11:30–12:00 | VMP 8 HS | **Poking and probing strongly correlated gases in optical lattices** — •Simon Fölling, Artur Widera, Stefan Trotzky, Olaf Mandel, Tatjana Gericke, Torben Müller, Fabrice Gerbier, Patrick Cheinet, Immanuel Bloch |
| SYDI 1.4 | Di | 12:00–12:30 | VMP 8 HS | **Discrete optics in femtosecond-laser written photonic structures** — •Alexander Szameit |

## Hauptvorträge des Symposiums Ultra-fast Dynamics in FEL Light Pulses (SYUF)

Siehe SYUF für das komplette Programm des Symposiums.

| | | | | |
|---|---|---|---|---|
| SYUF 1.1 | Mi | 14:00–14:30 | VMP 8 HS | **Atoms and molecules in intense FEL radiation** — •Artem Rudenko |
| SYUF 1.2 | Mi | 14:30–15:00 | VMP 8 HS | **Electronic decay in clusters and molecules subject to intense FEL radiation** — •Vitali Averbukh, Ulf Saalmann, Jan Michael Rost |
| SYUF 1.3 | Mi | 15:00–15:30 | VMP 8 HS | **Spectroscopy of Highly Charged Ions with Free Electron Lasers** — •Sascha Epp, Martin Simon, Thomas Baumann, Günter Brenner, Volkhard Mäckel, Paul Mokler, Hiro Tawara, Natalia Gueras-simova, Evgeny Schneidmiller, Rolf Treusch, José Crespo Lopéz Urrutia, Joachim Ullrich |
| SYUF 1.4 | Mi | 15:30–16:00 | VMP 8 HS | **Ultra-fast dynamics in atoms and solids** — •Alexander Föhlisch |
| SYUF 2.1 | Mi | 16:30–17:00 | VMP 8 HS | **Pump-probe experiments at FLASH** — •Stefan Düsterer |
| SYUF 2.2 | Mi | 17:00–17:30 | VMP 8 HS | **Chemistry with Free Electron Laser Radiation: Proof of Principle** — •Simone Techert |
| SYUF 2.3 | Mi | 17:30–18:00 | VMP 8 HS | **Ultrafast processes and single shot imaging of clusters with intense soft x-ray radiation from the FLASH free electron laser** — •Christoph Bostedt |
| SYUF 2.4 | Mi | 18:00–18:30 | VMP 8 HS | **Ultrafast Coherent Diffractive Imaging at FLASH** — •Henry Chapman |

## Fachsitzungen

| | | | | |
|---|---|---|---|---|
| A 1.1–1.5 | Mo | 10:45–12:30 | VMP 6 HS-B | **Plasma Interactions / Rydberg Atoms** |
| A 2.1–2.5 | Mo | 10:45–12:30 | VMP 6 HS-E | **Interaction with VUV and X-Ray Light I** |
| A 3.1–3.6 | Mo | 14:00–16:00 | VMP 6 HS-B | **Precision Spectroscopy of Atoms and Ions I** |
| A 4.1–4.5 | Mo | 14:00–16:00 | VMP 6 HS-E | **Electron Scattering and Recombination** |
| A 5.1–5.5 | Mo | 16:30–18:00 | VMP 6 HS-B | **Atomic Systems in External Fields I** |
| A 6.1–6.4 | Mo | 16:30–18:00 | VMP 6 HS-E | **Scattering Processes** |
| A 7.1–7.8 | Di | 10:30–12:30 | Audi-B | **Ultracold atoms I: Traps and cooling (with Q)** |
| A 8.1–8.6 | Di | 10:30–12:30 | VMP 6 HS-B | **Atomic Clusters I** |
| A 9.1–9.6 | Di | 10:30–12:30 | VMP 6 HS-C | **Interaction with Strong or Short Laser Pulses I** |
| A 10.1–10.6 | Di | 14:00–15:45 | Audi-B | **Ultracold atoms II: Single atoms (with Q)** |
| A 11.1–11.6 | Di | 14:00–16:00 | VMP 6 HS-B | **Attosecond Physics I** |
| A 12.1–12.7 | Di | 14:00–16:00 | VMP 6 HS-C | **Precision Spectroscopy of Atoms and Ions II** |
| A 13.1–13.4 | Di | 16:30–18:00 | VMP 6 HS-B | **Atomic Systems in External Fields II** |
| A 14.1–14.4 | Di | 16:30–18:00 | VMP 6 HS-C | **Ultra-Cold Atoms, Ions and BEC I (with Q)** |
| A 15.1–15.58 | Di | 16:30–19:00 | VMP 9 Poster | **Poster I** |
| A 16.1–16.6 | Mi | 14:00–16:00 | VMP 6 HS-B | **Atomic Clusters II** |
| A 17.1–17.7 | Mi | 14:00–16:00 | VMP 6 HS-C | **Atomic Systems in External Fields III** |
| A 18.1–18.5 | Mi | 14:00–16:00 | VMP 8 R208 | **Photoionization I** |
| A 19.1–19.9 | Mi | 16:30–18:45 | Audi-B | **Ultracold atoms III: Manipulation and detection / Rydbergatoms (with Q)** |
| A 20.1–20.4 | Mi | 16:30–18:00 | VMP 6 HS-B | **Precision Spectroscopy of Atoms and Ions III** |
| A 21.1–21.5 | Mi | 16:30–18:00 | VMP 6 HS-C | **Interaction with Strong or Short Laser Pulses II** |
| A 22.1–22.3 | Mi | 16:30–17:30 | VMP 8 R208 | **Attosecond Physics II** |
| A 23.1–23.5 | Do | 10:30–12:30 | VMP 6 HS-B | **Interaction of Matter with Ions** |
| A 24.1–24.6 | Do | 10:30–12:15 | VMP 6 HS-C | **Ultra-Cold Atoms, Ions and BEC II (with Q)** |
| A 25.1–25.3 | Do | 10:30–11:15 | VMP 8 R208 | **Interaction with Strong or Short Laser Pulses III** |
| A 26.1–26.4 | Do | 14:00–16:00 | VMP 6 HS-B | **Atomic Clusters III** |
| A 27.1–27.6 | Do | 14:00–16:00 | VMP 6 HS-C | **Ultra-Cold Atoms, Ions and BEC III (with Q)** |
| A 28.1–28.4 | Do | 14:00–15:00 | VMP 6 HS-E | **Precision Spectroscopy of Atoms and Ions IV, Interaction with VUV and X-Ray Light III** |
| A 29.1–29.3 | Do | 14:00–15:30 | VMP 8 R208 | **Photoionization II** |
| A 30.1–30.4 | Do | 16:30–17:45 | VMP 6 HS-B | **Precision Spectroscopy of Atoms and Ions V** |
| A 31.1–31.4 | Do | 16:30–18:00 | VMP 6 HS-C | **Ultra-Cold Atoms, Ions and BEC IV (with Q)** |
| A 32.1–32.4 | Do | 16:30–18:00 | VMP 6 HS-E | **Attosecond Physics III** |
| A 33.1–33.5 | Do | 16:30–18:30 | VMP 8 R208 | **Interaction with VUV and X-Ray Light II** |
| A 34.1–34.57 | Do | 16:30–19:00 | VMP 9 Poster | **Poster II** |
| A 35.1–35.6 | Fr | 10:30–12:30 | VMP 6 HS-B | **Precision Spectroscopy of Atoms and Ions VI** |

| | | | | |
|---|---|---|---|---|
| A 36.1–36.6 | Fr | 10:30–12:30 | VMP 6 HS-C | **Ultra-Cold Atoms, Ions and BEC V (with Q)** |
| A 37.1–37.6 | Fr | 14:00–16:00 | VMP 6 HS-B | **Precision Spectroscopy of Atoms and Ions VII** |
| A 38.1–38.5 | Fr | 14:00–15:15 | VMP 6 HS-C | **Atomic Clusters IV** |

## Mitgliederversammlung Fachverband Atomphysik

Dienstag 13:30–14:00 VMP 6 HS-C

- Bericht
- Verschiedenes

# A 1: Plasma Interactions / Rydberg Atoms

Zeit: Montag 10:45–12:30 Raum: VMP 6 HS-B

**Preisträgervortrag** A 1.1 Mo 10:45 VMP 6 HS-B

**Optimierter und selbst-optimierender magnetischer Einschluß** — •Friedrich Wagner — Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, EURATOM Association — Träger der Stern-Gerlach-Medaille

Der Stand der Tokamakline erlaubt den Bau des ersten experimentellen Fusionskraftwerks. ITER soll in D-T Plasmen 500 MW Fusionsleistung erzeugen. Der Stellarator ist ein alternativer Vertreter des toroidalen Einschlusses, wobei mit Wendelstein 7-X das am weitesten fortgeschrittene Konzept dieser Linie in Greifwald realisiert wird. Die Optimierung beider Systeme gilt der Qualität der thermischen Isolation des Plasmas. Der Tokamak profitiert von seiner reduzierten Dimensionalität; das Stellaratorplasma ist notwendigerweise 3-D erreicht aber durch die Optimierung eine Quasisymmetrie der für den Einschluss bedeutsamen Größen. Die Spulenformgebung erlaubt beim Stellarator eine rigorose Systemoptimierung u.a. mit dem Ziel, den *laminaren* Anteil am radialen Transport auf das niedrige Niveau kontinuierlich symmetrischer Systeme zu senken. Fusionsplasmen sind andererseits offene Systeme, wobei der Einschluß in Tokamaks und optimierten Stellaratoren durch Turbulenzprozesse gegeben ist. Selbst-organsierende Prozesse bestimmen die Plasmaeigenschaften. Der selbst-induzierte Übergang in die H-Mode (high confinement) verbessert die Einschlussqualität um einen Faktor der erlaubt, die Systemgröße zu reduzieren und damit die Baukosten deutlich zu senken. Korrelationen im Turbulenzfeld führen zu einer makroskopischen Strömung im Plasma, welche die Turbulenz letzlich unterdrückt. Mechanismen turbulenter klassischer Systeme finden sich auch in Hochtemperaturplasmen wieder.

A 1.2 Mo 11:30 VMP 6 HS-B

**Mapping the composite character of magnetically trapped Rydberg atoms** — •Michael Mayle[1], Igor Lesanovsky[2], and Peter Schmelcher[1,3] — [1]Theoretische Chemie, Universität Heidelberg — [2]School of Physics and Astronomy, University of Nottingham, UK — [3]Physikalisches Institut, Universität Heidelberg

By investigating the quantum properties of magnetically trapped $nS_{1/2}$ Rydberg atoms, it is demonstrated that the composite nature of Rydberg atoms significantly alters their trapping properties opposed to point-like particles with identical magnetic moment. Employing an off-resonant two photon coupling scheme, a setup is proposed which allows to observe the signatures of the Rydberg trapping potential using a gas of ground state atoms. In addition, such a scheme provides new possibilities for designing trapping potentials for ground state atoms.

A 1.3 Mo 11:45 VMP 6 HS-B

**Ionization–Recombination Balance in the Cold Rydberg Gas** — •Yurii V. Dumin — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

A well-known property of the cold Rydberg gas (formed, for example, in the magneto-optical traps) is its spontaneous ionization, resulting in ultracold plasmas [1]. Although this phenomenon is commonly treated as individual acts of ionization and recombination, such an approach is hardly appropriate for a sufficiently dense gas, whose Thomson radius exceeds the interparticle distance. Just this situation was implemented recently in the cryogenic gas jets [2]. A more adequate description of such systems should be based on the consideration of multi-particle interactions *ab initio*. This can be performed in the model of quasi-localized electrons, moving in the effective centrifugal potentials formed by the nearest ions; while influence of the distant particles is treated as a thermal bath with the effective virial temperature [3]. Such an approach enables us to derive the electron partition function, which can be efficiently used to calculate the probabilities of free and captured electronic states, thereby giving the degree of ionization of the strongly-coupled Rydberg plasma.

[1] T.C. Killian *et al.*, *Phys. Rep.* **449**, 77 (2007).
[2] J.P. Morrison *et al.*, *Phys. Rev. Lett.* **101**, 205005 (2008).
[3] Yu.V. Dumin, *J. Low Temp. Phys.* **119**, 377 (2000).

A 1.4 Mo 12:00 VMP 6 HS-B

**Mesoscopic Rydberg Gate based on Electromagnetically Induced Transparency** — •Markus Müller[1], Igor Lesanovsky[1], Hendrik Weimer[2], Hans-Peter Büchler[2], and Peter Zoller[1] — [1]Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria — [2]Institute for Theoretical Physics III, University of Stuttgart, Germany

We demonstrate theoretically a parallelized CNOT gate which allows to entangle a mesoscopic ensemble of atoms with a single control atom in a single step, with high fidelity and on a microsecond timescale. Our scheme relies on the strong and long-ranged interaction between Rydberg atoms triggering Electromagnetically Induced Transparency. By this we can robustly implement a conditional coherent transfer of all ensemble atoms among two logical states, depending on the state of the control atom. As an application, we outline a many-body interferometer which allows a comparison of two many-body quantum states by performing a measurement of the control atom. Finally, we discuss perspectives of the gate as a building block for quantum simulators of Hamiltonians with few-body interactions.

A 1.5 Mo 12:15 VMP 6 HS-B

**Partial Auto-Ionization Rates of Doubly Excited States in Helium** — •Maximilian Schmidt[1], Celsus Bouri[1], Javier Madronero[2], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Technische Universität München, James-Franck-Strasse, 85747 Garching

The spectrum of helium consists of a complex structure of stable, resonant and single continuum states. All doubly excited states are resonances and coupled to some single continuum channels, to which they decay due to electronic correlations. The Complex Rotation Method is a powerful technique to access resonant energies, widths and wave functions directly by diagonalizing the rotated two electron Hamiltonian in a $\mathcal{L}^2$ basis set. Nevertheless, this method does so far only provide the *total* auto-ionization rate. In this work, the *partial* auto-ionization rates for doubly excited states into different single continuum channels are calculated for the first time within the framework of the Complex Rotation Method. These calculations are obtained for 2D-helium, that mimics the realistic helium atom very well [1].

[1] J. Madroñero, P. Schlagheck, L. Hilico, B. Gremaud, D. Delande, and A. Buchleitner, Europhysics Letters **70**, 183 (2005)

# A 2: Interaction with VUV and X-Ray Light I

Zeit: Montag 10:45–12:30 Raum: VMP 6 HS-E

**Hauptvortrag** A 2.1 Mo 10:45 VMP 6 HS-E

**Angular distributions and continuous intensity behavior in multi-photon processes** — •Markus Braune[1], Axel Reinköster[1], Jens Viefhaus[2], Sanja Korica[1], and Uwe Becker[1] — [1]Fritz-Haber-Insitut der MPG, 14195 Berlin — [2]DESY, 22607 Hamburg

Using angle-resolved photoelectron spectroscopy at the FLASH facility we were able to distinguish various sequential and simultaneous pathways of multi-photon double-ionization of rare gases. The results show that sequential double-ionization is the dominant process if the required photon energy threshold is exceeded. The photoelectron angular distributions of these multi-photon processes differ from a distribution of a dipole transition showing contributions of higher order Legendre polynomials. The corresponding higher order parameters $\beta_4$ could be determined and compared to recent calculations [1,2]. Especially for argon and krypton, these predict a dramatic change in the $\beta_4$-values at a photon energy around 50eV due to the Cooper minimum in the cross section. Surprisingly, this effect depends on the coupling of the ionic final states. A substantial variation of $\beta_4$ is in fact observed in our preliminary data analysis of the sequential double ionization of

krypton.

For very short time delays between the steps of sequential double-ionization a dynamical screening effect is theoretically predicted which should give rise to continuous photoelectron intensity between the pair of photoelectron lines caused by the sequential process. So far, only weak indications of such a screening effect is found in our helium data.

**Fachvortrag** A 2.2 Mo 11:15 VMP 6 HS-E

**Lepton Pair Production in High-Frequency Laser Fields** — •Carsten Müller, Carlus Deneke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg

The production of electron-positron and muon-antimuon pairs in high-frequency laser fields via few-photon absorption is considered. It is assumed that an intense xuv or x-ray laser pulse collides head-on with a relativistic ion beam. We study the generation of free $e^+e^-$ pairs, free $\mu^+\mu^-$ pairs, and bound-free $e^+e^-$ pairs, where in the latter case the electron is born in a low-lying atomic orbit of the projectile nucleus. Effects resulting from the finite nuclear size, the nuclear recoil, excited atomic shells, and the laser's polarization state are examined.

[1] C. Müller, C. Deneke, and C. H. Keitel, Phys. Rev. Lett. 101, 060402 (2008).
[2] C. Deneke and C. Müller, Phys. Rev. A 78, 033431 (2008).
[3] C. Müller, submitted (arXiv:0811.0976)

A 2.3 Mo 11:45 VMP 6 HS-E

**Jitter-compensated time-resolved ion spectrometry at FLASH** — •Maria Krikunova[1], Theophilos Maltezopoulos[1], Armin Azima[1], Moritz Schlie[1], Ulrike Frühling[2], Patrick Rüdiger[1], Harald Redlin[2], Roland Kalms[1], Marek Wieland[1], and Markus Drescher[1] — [1]Institut für Experimentalphysik, Universität Hamburg, Luruper Chausee 149, 22761 Hamburg, Germany — [2]HASYLAB at DESY, Notkestrasse 85, 22607 Hamburg, Germany

Photoionisation of deep atomic shells creates inner vacancies followed by a complex sequence of multi-electron relaxation processes via transient states. Recent XUV-pump/laser-probe ion spectrometry experiments using a HHG source allowed real time studies of electron relaxation dynamics in noble gas atoms. The much higher intensity of XUV pulses from the Free electron LASer in Hamburg (FLASH) holds out the prospect of extending this technique to more dilute species. This, however, calls for an improvement of the temporal resolution. Currently, the XUV/laser timing is subject to a jitter of a few hundred fs. In order to compensate for these fluctuations, we have developed a correlation technique based on XUV-induced reflectivity changes on a semiconductor surface. Applying this tool, we were able to perform a jitter-compensated time resolved ion-spectrometry experiment, identifying intermediate state dynamics in Xe atoms upon excitation of the 4d-shell with 93 eV XUV pulses and probing with 400 nm laser pulses. The results of this study reveal the current temporal resolution limit of pump-probe experiments utilizing XUV- and laser pulses from FLASH.

A 2.4 Mo 12:00 VMP 6 HS-E

**Beobachtung des Tunnelns von Elektronen durch Doppler-Elektronenspektroskopie** — •Rainer Hentges[1,2], Burkhard Langer[3], Oliver Kugeler[4,5], Uwe Hergenhahn[4], Arno Ehresmann[1] und Uwe Becker[2] — [1]Universität Kassel — [2]Fritz-Haber-Institut der MPG — [3]Freie Universität Berlin — [4]Max-Planck-Institut für Plasmaphysik — [5]Helmholtz-Zentrum Berlin

Die Spiegelsymmetrie homonuklearer zweiatomiger Moleküle führt zum periodischen Ladungsdichte-Transfer aller Molekülorbital bildenden Elektronen zwischen den Positionen ihrer ununterscheidbaren Kerne. Dieser symmetrieinduzierte Tunneleffekt ist bisher noch nicht in der Zeit-Domäne nachgewiesen worden, da die Paritätserhaltung der elektromagnetischen Wechselwirkung *quantum beat* Experimente mittels nichtkoinzident nachgewiesener Elektronen ausschließt. Der Nachweis des Elektronen-Tunnelns wurde daher bisher immer über die komplementäre Messung der Aufspaltung der geraden und ungeraden Symmetriezustände geführt. Wir zeigen hier die erste quasi-zeitaufgelöste Messung des Tunnel-Effekts von Elektronen in homonuklearen zweiatomigen Molekül durch den hochaufgelösten Nachweis von Elektronen, die von einem dissoziierenden Molekül dopplerverschoben emittiert werden. Diese rot/blau verschobenen Elektronenlinien werden bezüglich der Achse ihrer Emittermoleküle richtungaufgelöst nachgewiesen. Die Intensität der Elektronen, die mit der falschen Verschiebung in die falsche Richtung fliegen ist ein indirektes Maß für die Tunnelzeit der Elektronen in Form einer „Sanduhr"-Messung.

A 2.5 Mo 12:15 VMP 6 HS-E

**Two photon double ionization of $He^+$: autocorrelation of soft x-ray FEL pulses** — •Björn Siemer[1], Sebastian Roling[1], Rolf Mitzner[1,2], Tino Noll[2], Andrei Sorokin[3], Mathias Richter[3], Kai Tiedtke[4], Wolfgang Eberhardt[2], and Helmut Zacharias[1] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität, 48149 Münster — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Glienicker Straße 100, 14109 Berlin — [3]PTB, Abbe-Str. 2-12, 10578 Berlin — [4]DESY, Notkestr. 85, 22603 Hamburg

In order to perform jitter-free X-ray pump and probe experiments at the Free Electron Laser in Hamburg (FLASH) as well as to characterize the temporal structure of its high power pulses a novel beam splitter and delay unit (autocorrelator) has been designed and constructed. Based on geometrical beam splitting by a mirror edge the apparatus covers the XUV energy range up to photon energies of 200 eV providing a total delay of about 20 picoseconds with sub-femtosecond resolution. As a first test the pulse length of the FEL pulses has been measured at 24 nm. While the nonlinear autocorrelation in the UV and visible regions is a well established method to determine the duration of laser pulse there is a lack of efficient nonlinear detection processes in the soft X-ray regime. In this first experiments the pulse length of the FEL pulses provided at 24 nm are measured by double ionization of He, yielding a duration of $(30 \pm 5)$ fs.

## A 3: Precision Spectroscopy of Atoms and Ions I

Zeit: Montag 14:00–16:00 Raum: VMP 6 HS-B

**Hauptvortrag** A 3.1 Mo 14:00 VMP 6 HS-B

**Laser spectroscopy of highly charged argon at the Heidelberg electron beam ion trap** — •Volkhard Mäckel, Renee Klawitter, Sven Bernitt, Günter Brenner, José Ramon Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernpysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The study of forbidden transitions in highly charged ions opens a broad window for analyzing and diagnosing plasmas found in astronomy and fusion research. Since those plasmas have a low density, excited levels mainly decay to the ground state configuration through magnetic dipole (M1) transitions. Electron beam ion traps (EBIT) are especially suited for the investigation of such transitions, since their monoenergetic electron beam allows for specific charge state selection, while their extremely high vacuum level faciliates the simulation of low density plasmas.

We report a laser fluorescence measurement of such a transition in boron-like $Ar^{13+}$ produced and trapped at the Heidelberg electron beam ion trap. The M1 $1s^22s^22p\ ^3P_2 - ^3P_1$ transition was resonantly excited using a frequency variable pulsed dye laser, while simultaneously monitoring the fluorescence photons. For the first time a forbidden transition has been excited in highly charged ions trapped inside an EBIT. In combination with enhanced ion cooling and two-photon excitation, large gains in accuracy can be expected.

**Fachvortrag** A 3.2 Mo 14:30 VMP 6 HS-B

**Proposed gravity measurement with antihydrogen** — •Carlo Canali, Arne Fischer, Ulrich Warring, and Alban Kellerbauer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The gravitational interaction between matter and antimatter has never been tested experimentally. The AEGIS experiment (Antimatter Experiment: Gravity, Interferometry, Spectroscopy) intends to measure for the first time the gravitational acceleration of antihydrogen. $\overline{\mathrm{H}}$ will be obtained through a charge exchange process between Rydberg positronium atoms and antiprotons. The antiprotons will be delivered by the CERN AD (Antiproton Decelerator). After being captured and confined inside a cylindrical Penning trap, they will be cooled down to $\approx 100$ mK. At the same time, positronium will be produced by bom-

bardment of a nanoporous insulator material with positrons. A double laser pulse will excite the positronium to a Rydberg state immediately before the interaction with the antiprotons, such as to increase the cross-section for the charge exchange process. The produced antihydrogen atoms will be accelerated to form a horizontal beam and projected through a Moiré deflectometer with a velocity of a few 100 m/s along a path of about 1 m length. The deflectometer consists of two gratings and a position-sensitive detector able to measure the vertical displacement and the time of flight of $\overline{\mathrm{H}}$ atoms. With this setup an initial precision on the measurement of $g(\overline{\mathrm{H}})$ of 1% is expected.

A 3.3 Mo 15:00 VMP 6 HS-B

**A temperature stabilization system for the spin-flip detection in the *g*-factor experiment on highly-charged ions** — •Anke Wagner[1], Klaus Blaum[1], Wolfgang Quint[2], Birgit Schabinger[3], and Sven Sturm[3] — [1]MPI für Kernphysik, D-69117 Heidelberg, Germany — [2]GSI Darmstadt, D-64291 Darmstadt, Germany — [3]Institut für Physik, Johannes Gutenberg-University, D-55099 Mainz, Germany

For the high-precision measurement of the magnetic moment of the electron bound in highly-charged calcium ions, the Larmor spin-precession frequency has to be measured [1]. To this end the so called continuous Stern-Gerlach-effect is employed using a magnetic bottle where the axial frequency of an ion stored in a Penning trap depends slightly on its spin orientation, which provides a possibility to detect the spin state [2]. Microwaves are used to induce a spin-flip. By scanning the microwave frequency and measuring the particular spin-flip rate, the Larmor frequency can be determined. To be able to detect the spin-flip, the axial frequency and accordingly the electrode voltage needs to be very stable. To minimize voltage changes due to temperature drifts during the *g*-factor measurement, a temperature stabilization for the whole setup is under construction. Therefore, a Fuzzy Logic controller was implemented. Its principle and first results, as well as the microwave setup and the spin flip detection technique will be presented.

[1] B. Schabinger *et al.*, J. Phys. **58**, 121-124 (2007)
[2] M. Vogel *et al.*, Nucl. Inst. Meth. B **235**, 7-16 (2005)

A 3.4 Mo 15:15 VMP 6 HS-B

**Fundamental constants and tests of theory in Rydberg states of hydrogen-like ions** — Ulrich D. Jentschura[1,2], Peter J. Mohr[3], Joseph N. Tan[3], and •Benedikt J. Wundt[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg — [2]Departement of Physics, Missouri University of Science and Technology, Rolla, MO 65409-0640, USA — [3]National Institue of Standards and Technology, Gaithersburg, MD 20899-8420, USA

Higher-order QED binding corrections constitute an old but still very efficient and successful tool to determine the energy levels in atomic systems to high precision. We will describe here the self-energy contribution to the Lamb shift for highly excited Rydberg states. With the results of a recent calculation of a key QED contribution, the uncertainty in the theory of the energy levels can be greatly reduced. These new results allow for a comparison of precision frequency measurements and quantum electrodynamics prediction for Rydberg states that can lead to an improved value for the Rydberg constant. Experiments at NIST are underway.

A 3.5 Mo 15:30 VMP 6 HS-B

**Preparation of a single proton in a Penning trap experiment for the determination of the *g*-factor of the proton** — •Cricia Rodegheri[1], Klaus Blaum[2,3], Holger Kracke[1], Susanne Kreim[1], Andreas Mooser[1], Christian Mrozik[1], Wolfgang Quint[4], Stefan Ulmer[1,2,4], and Jochen Walz[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [3]Ruprecht-Karls-Universität, 69047 Heidelberg — [4]GSI, 64291 Darmstadt

The determination of the proton *g*-factor results from the accurate measurement of two frequencies of the stored particle in a double Penning trap setup, as it can be calculated as $g = 2\frac{\nu_L}{\nu_c}$. The free cyclotron frequency $\nu_c$ is determined in the homogeneous magnetic field of the precision trap. The Larmor frequency $\nu_L$ will be measured by means of the continuos Stern-Gerlach effect in the analysis trap. The preparation of a single proton from a particle cloud loaded in the precision trap is presented. The undesired species, products of the in-trap ion creation process, are removed by applying a strong dipolar excitation at the axial frequency of the ions and lowering the trap potential. The resulting proton cloud is successively reduced up to one single proton by exciting the cyclotron motion in a detuned trap. In an anharmonic potential the frequency of the ion depends on its energy. Thus, with a broad band excitation one can spread the ion cloud and then remove the protons individually with a stronger discrete excitation. Due to the extremely low background pressure inside the trap chamber the storage time of the isolated proton is longer than several weeks.

A 3.6 Mo 15:45 VMP 6 HS-B

**Laser spectroscopy of highly charged argon at the Heidelberg electron beam ion trap** — •Volkhard Mäckel, Renee Klawitter, Sven Bernitt, Günter Brenner, José Ramon Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The study of forbidden transitions in highly charged ions opens a broad window for analyzing and diagnosing plasmas found in astronomy and fusion research. Since those plasmas have a low density, excited levels mainly decay to the ground state configuration through magnetic dipole (M1) transitions. Electron beam ion traps (EBIT) are especially suited for the investigation of such transitions, since their monoenergetic electron beam allows for specific charge state selection, while their extremely high vacuum level faciliates the simulation of low density plasmas.

We report a laser fluorescence measurement of such a transition in boron-like argon$^{13+}$ produced and trapped at the Heidelberg Electron Beam Ion Trap. The M1 $1s^2 2s^2 2p\ ^3P_2 - {}^3P_1$ transition was resonantly excited using a frequency variable pulsed dye laser while simultaneously monitoring the fluorescence photons. For the first time a forbidden transition has been excited in highly charged ions trapped inside an EBIT. In combination with enhanced ion cooling and two-photon excitation large gains in accuracy can be expected.

## A 4: Electron Scattering and Recombination

Zeit: Montag 14:00–16:00 Raum: VMP 6 HS-E

**Hauptvortrag** A 4.1 Mo 14:00 VMP 6 HS-E

**Relativistic quantum dynamics in extremely strong electromagnetic fields** — •Andrey Surzhykov[1,2], Anton Artemyev[1,2], Stephan Fritzsche[2,3], and Thomas Stöhlker[1,2] — [1]Universität Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Frankfurt Institute for Advanced Studies

Recent progress in theoretical studies of electronic structure and dynamical behaviour of highly–charged, heavy ions is reviewed. These investigations show that high–$Z$ ions provide a unique tool for improving our understanding of the electron–electron and electron–photon interaction in the presence of extremely strong electromagnetic fields. We discuss that strong–filed phenomena can be probed, for instance, by exploring the radiative stabilization of excited ionic states produced by means of radiative and dielectronic recombination [1] as well as Coulomb excitation [2]. Special attention is paid, moreover, to the electron–positron pair production in relativistic collisions of highly–charged projectiles with atomic and electronic targets. For these collisions, we present recent results on the negative continuum dielectronic recombination of (initially) bare ion; the process which leads to a production of a continuum–state positron and a residual helium–like ion and which attracts nowadays much of interest both, in experiment and in theory.

[1] S. Fritzsche *et al.*, PRA **78**, 032703 (2008).
[2] A. Surzhykov *et al.*, PRA **77**, 042722 (2008).

**Fachvortrag** A 4.2 Mo 14:30 VMP 6 HS-E

**Trielectronic Recombination with K-Shell Excitation** — •Christian Beilmann, Octavian Postavaru, Rainer Ginzel, Christoph H. Keitel, Volkhard Mäckel, Paul H. Mokler, Martin C. Simon, Hiro Tawara, Joachim Ullrich, José R. Crespo López-Urrutia, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

We report the first observation of trielectronic recombination with excitation of a K-shell electron, involving three active electrons. It was identified in the x-ray emission spectrum of recombining highly charged Kr ions, together with indications of quadruelectronic recombination linking four active electrons. A resolution three times higher than any reported for this collision energy range around 10 keV resulted in the separation of their features from the stronger dielectronic resonances. For $Kr^{30+}$, contributions of nearly 6% to the total resonant photorecombination rate were found.

**Fachvortrag** A 4.3 Mo 15:00 VMP 6 HS-E

**Trielectronic Recombination with K-Shell Excitation** — •Christian Beilmann, Octavian Postavaru, Rainer Ginzel, Christoph H. Keitel, Volkhard Mäckel, Paul H. Mokler, Martin C. Simon, Hiro Tawara, Joachim Ullrich, José R. Crespo López-Urrutia, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We report the first observation of trielectronic recombination with excitation of a K-shell electron, involving three active electrons. It was identified in the x-ray emission spectrum of recombining highly charged Kr ions, together with indications of quadruelectronic recombination linking four active electrons. A resolution three times higher than any reported for this collision energy range around 10 keV resulted in the separation of their features from the stronger dielectronic resonances. For $Kr^{30+}$, contributions of nearly 6% to the total resonant photorecombination rate were found.

A 4.4 Mo 15:30 VMP 6 HS-E

**Electron-Positron Pair Creation in Relativistic Heavy Ion Collisions Described in a Molecular View** — •Sven Augustin and Werner Scheid — Institut für Theoretische Physik, Justus Liebig Universität, Gießen, Deutschland

Previous calculations of cross sections for electron-positron pair production with electron capture into the target's K shell in relativistic heavy nuclei scattering, for instance those done by Busic et al. [1], faced problems due to difficulties in defining the positron states in a two centre problem.

It is usually assumed that, after the collision, a positron is defined by a hole state in the negative continuum of the target ion. While this approach is true for a single ion, it is not if a second ion, i.e. the projectile, is present. This is indeed independent of their distance.

Thus a projection on the target's negative continuum states causes a "double counting" of the positrons. It should be replaced by a projection on time dependent solutions of the Dirac equation with electromagnetic potentials of two separating ions.

Considering such a molecular-like setting we chose the description in a centre of mass frame rotating with the axis connecting target and projectile.

[1] O. Busic, N. Grün and W. Scheid, Phys. Rev. **A70**, 062707 (2004)

A 4.5 Mo 15:45 VMP 6 HS-E

**Dielectronic recombination by excitation within the $n = 3$ shell for iron ions in astrophysical plasmas** — •Michael Lestinsky[1,2], Nigel R. Badnell[3], Dietrich Bernhardt[4], Manfred Grieser[2], Jens Hoffmann[2], Dragan Lukic[1,5], Alfred Müller[4], Dmitry Orlov[2], Roland Repnow[2], Eike W. Schmidt[4], Michael Schnell[2], Stefan Schippers[4], Deyang Yu[4,6], Andreas Wolf[2], and Daniel W. Savin[1] — [1]Columbia University, New York — [2]Max-Planck-Institut für Kernphysik, Heidelberg — [3]Department of Physics, University Strathclyde, Glasgow — [4]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität, Gießen — [5]Institute of Physics, Belgrade — [6]Institute of Modern Physics, Lanzhou

Line emission and absorption from M-shell iron ions are observed in a wide range of cosmic plasmas. Interpreting these spectroscopic data requires an accurate understanding of the underlying charge balance distribution. Dielectronic recombination (DR) is the dominant electron-ion recombination mechanism for most atomic ions in astrophysical plasmas. We are in the process of carrying out a series of DR measurements for M-shell iron ions at the TSR ion storage ring. Here we compare some of our recent results with previously recommended DR data and recent state-of-the-art results. We find significant deviations between theory and experiment at collision energies from 0 to $\sim$ 50 eV. This range includes all cosmically relevant resonances for these ions. From our experimental data we derive plasma recombination rate coefficients for photoionized and collisionally ionized plasmas and recommend their inclusion into astrophysical codes.

## A 5: Atomic Systems in External Fields I

Zeit: Montag 16:30–18:00 Raum: VMP 6 HS-B

**Hauptvortrag** A 5.1 Mo 16:30 VMP 6 HS-B

**Exceptional points in atomic spectra and Bose-Einstein condensates** — •Holger Cartarius, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

In parameter-dependent open quantum systems exceptional points can appear, at which both the complex energy eigenvalues *and* the wave functions describing two or even more resonances of the system pass through a branch point singularity as functions of the parameters, i.e. become identical. A real physical system which is accessible theoretically and experimentally and which exhibits exceptional points is the hydrogen atom in crossed external electric and magnetic fields. We show how exceptional points can be detected in numerical calculations, how they can be described with low-dimensional matrix models, and propose a method to verify their existence in an experiment with atoms. Important phenomena such as the geometric phase for closed loops around the critical parameter sets are demonstrated and the rare case of a connection between three resonances almost forming a triple-degeneracy in the form of a cubic root branch point is presented.

Furthermore, we extend the concept of exceptional points to the nonlinear Gross-Pitaevskii equation describing the stationary states of Bose-Einstein condensates. Here, they appear as bifurcation points at which two stationary states, a stable ground state and an unstable nodeless excited state, are born together in a tangent bifurcation.

A 5.2 Mo 17:00 VMP 6 HS-B

**Laser-Induced Channeling of Bethe-Heitler Pairs** — •Erik Lötstedt[1], Ulrich D. Jentschura[1,2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg — [2]Department of Physics, Missouri University of Science and Technology, Rolla MO65409, USA

A high-energy photon colliding with a nuclear Coulomb field may decay into an electron-positron pair by the Bethe-Heitler process. We investigate the modification of this process by the addition of an assisting laser field [1]. For a subcritical laser field, the total cross section is almost unchanged compared to the laser-free case. In contrast, there is a drastic enhancement of the differential cross section in a certain direction of emission. The additional momentum transferred by the laser field serves to channel the produced pairs, so that they are preferentially ejected in a direction making a small angle with the propagation direction of the laser field. The laser-induced modification of the cross section can be understood by classical arguments.

[1] E. Lötstedt, U. D. Jentschura, and C. H. Keitel, Phys. Rev. Lett. **101**, 203001 (2008).

A 5.3 Mo 17:15 VMP 6 HS-B

**Charge breeding in SPARC EBIT** — Sabrina Geyer[1], Frank Herfurth[1], Oliver Kester[1], Wolfgang Quint[1], Alexandra Silze[2], •Alexey Sokolov[1], Thomas Stoehlker[1], and Gleb Vorobjev[1] — [1]GSI, Darmstadt, Germany — [2]Institut für Angewandte Physik, Technische Universität Dresden, Germany

Charge breeding experiments are important to increase the variety of elements produced in highly charged ion state by electron beam ion sources/traps (EBIS/T). In our experiment, singly charged ions, created by an external high temperature substrate heater were injected into an EBIT for further ionization. Continuing recent studies using MAXEBIS, charge breeding experiments were performed this time with the new SPARC EBIT. The advantages of this source are it's compact size and application of permanent magnets instead of superconducting coils. In it's low magnetic field of 0.25T on the electron beam axis the singly charged ions could only be trapped due to the electrostatic fields of the drift tube electrodes and the space charge

potential of the electrons. The influence of the electron beam potential on the ion confinement was studied in simulations showing an effective potential well of approximately 30 eV (dependent on electron current and energy) and, thus, a good possibility for trapping. Charged species produced in the EBIT were analysed using X-rays spectroscopy and m/q separation techniques. Experimental results showed that the capture is in fact difficult. The absence of magnetic trapping as well as the small trap region of the source are the main reasons for that. Further attempts are currently in preparation using an advanced setup.

A 5.4 Mo 17:30 VMP 6 HS-B

**A quantum fluid perspective on electron dynamics** — •Mark Thiele and Stephan Kümmel — Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth

The fluid dynamic formulation of quantum mechanics provides an intuitive way to interpret phenomena of many-electron physics. We use this approach to study the dynamics of bound electrons in time-dependent external fields. Comparing exact solutions of the interacting Schrödinger equation and of adiabatic time-dependent density-functional theory, we investigate both nonlinear and linear effects such as strong field excitation and photoabsorption. We find that viscous dissipation is the fluid dynamical mechanism connecting doubly excited states in atoms to the appearance of memory effects in density-functional theory.

A 5.5 Mo 17:45 VMP 6 HS-B

**Resonant Dynamics in Time-Dependent Density Functional Theory ?** — •Michael Ruggenthaler and Dieter Bauer — Max-Planck-Institut für Kernphysik, Heidelberg

Density functional theory (DFT) [1] and the corresponding time dependent theory (TDDFT) [2] are rigorous reformulations of the quantum many-body problem. The associated nonlinear Kohn-Sham (KS) equations give, in principle, the exact probability density. The crucial point is the approximation of the local exchange-correlation potential describing the internal forces. Resonant dynamics are usually not treated within TDDFT as sufficiently accurate approximations for the exchange-correlation potential do not yet exist. It is assumed that adiabatic approximations derived from groundstate DFT will not be able to reproduce resonant behavior. We investigate Rabi oscillations and show that even simple adiabatic approximations reproduce the dipole of the interacting problem quite well although the charge transfer between the two states involved is not properly described. Moreover we explain why the two-level approximation applied to the noninteracting system leads to unphysical results.

[1] R. M. Dreizler and E. K. U Gross, Density Functional Theory (Springer, Heidelberg, 1990)
[2] M. A. L. Marques et al, Time Dependent Density Functional Theory, Lect. Notes Phys. 706 (Springer, Heidelberg, 2006)

## A 6: Scattering Processes

Zeit: Montag 16:30–18:00 Raum: VMP 6 HS-E

**Hauptvortrag** A 6.1 Mo 16:30 VMP 6 HS-E

**Atomic parity violation in one single radium ion** — •Rob Timmermans — KVI, University of Groningen

The photon-Z0 mixing angle is a fundamental parameter of the unified electroweak theory. Its renormalization group "running" from high to low energy is a poorly tested prediction of the Standard Model. A high-precision measurement of the electroweak mixing angle at low momentum scales is possible by monitoring quantum jumps in one single trapped radium ion with precision laser techniques, and observing the coherent weak charge of the quarks via the effects of parity-forbidden transitions. We discuss the particle-physics and atomic theory, and the feasibility of a definitive parity-violation experiment at the TRImP facility at KVI.

**Hauptvortrag** A 6.2 Mo 17:00 VMP 6 HS-E

**Ultracold few-boson systems** — •Sascha Zoellner[1], Hans-Dieter Meyer[1], and Peter Schmelcher[1,2] — [1]Theoretische Chemie, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg — [2]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

Ultracold atoms have openened up the way toward the study of seemingly exotic quantum systems, such as the one-dimensional (1D) Bose gas. This system has the intriguing feature that the bosons behave much like an ideal Fermi gas in the limit of hard-core repulsion (fermionization). This talk deals with the mechanism of the interaction crossover from an ideal Bose gas to the fermionization limit from a few-body perspective.

In the first part, the basic mechanism of this crossover is discussed for the ground state, with a special emphasis on the interplay between two-body interactions and the trapping potential. An extension to the case of attractive bosons and binary mixtures will be discussed.

The second part is devoted to the impact of this crossover on the quantum dynamics, specifically the tunneling dynamics in a double-well trap. The dynamics changes over from Rabi oscillations to multi-band tunneling for increasing repulsion. The tunneling can be controlled by making the wells asymmetric. An outlook to the dynamics in larger multi-well traps is given.

A 6.3 Mo 17:30 VMP 6 HS-E

**High resolution spectroscopy of Rydberg resonances in 2s2-2s2p dielectronic recombination of berylliumlike Ge** — •Dmitry A. Orlov[1], Claude Krantz[1], Eva Lindroth[2], Fabrizio Ferro[2], Anton N. Artemyev[3], Dietrich Bernhardt[4], Carsten Brandau[5], Jens Hoffmann[1], Alfred Müller[4], Ticia Ricsóka[4], Stefan Schippers[4], Andrey Shornikov[1], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany — [2]Stockholm University, AlbaNova University Center, SE-106 91 Stockholm, Sweden — [3]Institute of Physics, Heidelberg University, D-69120 Heidelberg, Germany — [4]Institut für Atom- und Molekülphysik, Universität Giessen, D-35392 Giessen, Germany — [5]Gesellschaft für Schwerionenforschung, D-64291 Darmstadt, Germany

Low-energy dielectronic recombination resonances of beryllium-like $Ge^{28+}$ are studied by electron collision spectroscopy in the TSR ion storage ring using its ultracold photoelectron target [1]. The rich resonance structure below 1.7 eV is observed with resolved peaks appearing also below 100 meV [2], which is mainly due to $(2s2p\ ^1P_1)9l$ and $(2s2p\ ^3P_0)14l$ dielectronic resonances. The calculation of Rydberg binding energies for the two-valence-electron core is challenged by these results (work in progress). Since radiative corrections are negligible in these high Rydberg orbits, the QED contributions are those of the $^1S_0{-}^1P_1$ and $^1S_0{-}^3P_0$ core transitions, which are thus probed by the experiment.

[1] D.A. Orlov, et. al., J.Phys.: Conf. Series 4, 290 (2005)
[2] D.A. Orlov, et. al., J.Phys.: Conf. Series (2008), to be published

A 6.4 Mo 17:45 VMP 6 HS-E

**Coherent electron emission from H2 and Young type interference in swift ion and electron collisions** — D. Misra, S. Chatterjee, and •Lokesh C. Tribedi — Tata Institute of Fundamental Research, Colaba, Mumbai 400005, India

The coherent electron emission from the inversion-symmetric homonuclear diatomic molecule $H_2$, carry the signature of the Young type electron interference [1,2]. In a new approach we have shown that instead of taking $H_2$-to-2H DDCS ratios one can use the forward backward asymmetry in electron emission to obtain the oscillation due to interference. Bare fast C and F available from Pelletron accelerator at TIFR and 8 keV electron beam was used for these experiments. The frequency in 160° was found to be a factor of two higher w.r.t. 20°. The difference in the oscillation frequency for the forward and backward angles causes the oscillation in the asymmetry parameter. A model calculation based on Cohen-Fano model joined together with the frequency difference in forward-backward angles, fits the spectrum well. Since this study does not need any atomic target, can be applied for other diatomic molecular targets: a step forward towards the study of Young type interference in ionizations of molecule. Besides first order interference our data provides a strong support for the evidence of a double frequency component in interference oscillations as predicted earlier by Stolterfoht [2].

[1] H. D. Cohen and U. Fano, Phys. Rev. **150**, 30 (1966).
[2] N. Stolterfoht *et al.*, Phys. Rev. Lett. **87**, 023201 (2001).

[3] D. Misra, Phys. Rev. Lett. **92**, 153201 (2004).
[4] D. Misra, Phys. Rev. A-Rapd comm. **74**, 060701(R) (2006).

## A 7: Ultracold atoms I: Traps and cooling (with Q)

Zeit: Dienstag 10:30–12:30 Raum: Audi-B

A 7.1 Di 10:30 Audi-B

**Sympathetic cooling towards a mixed quantum degenerate Gas of Yb and Rb** — Florian Baumer, •Frank Münchow, Nils Nemitz, and Axel Görlitz — Institut für Experimentalphysik, Universität Düsseldorf

Quantum gases of ultracold polar molecules offer fascinating prospects for the realization of new forms of quantum matter with possible applications to quantum information and to precision measurements. Our approach is photoassociative production of YbRb molecules in a mixture of ultracold atomic Yb and Rb, where the special feature of our particular system is that in the ground state YbRb possesses an electric as well as a magnetic dipole moment.

An important step towards efficient molecule production using photoassociation is the realization of a quantum degenerate mixture of Yb and Rb. In our experimental setup the Yb atoms are held in a bichromatic optical dipole trap designed to have minimal effect on the evaporatively cooled $^{87}$Rb atoms which are held in a Ioffe-Pritchard type magnetic trap. Through interspecies collisions by $^{87}$Rb we have reached temperatures of 1$\mu$K at $^{174}$Yb atom numbers of $2 \cdot 10^5$. While sympathetic cooling works without loss of Yb atoms down into this temperature regime, quantum degeneracy in the mixed system has not yet been observed possibly due to excessive heating of the atoms due to technical noise. Currently, the nature of the heating mechanisms is under investigation and we will report on the latest results.

A 7.2 Di 10:45 Audi-B

**Auf dem Weg zum Calcium-BEC** — •Oliver Appel, Felix Vogt, Uwe Sterr und Fritz Riehle — PTB, Braunschweig

Calcium bietet aufgrund seiner Elektronenstruktur interessante Möglichkeiten zur Untersuchung ultrakalter Stöße und zur Atominterferometrie. Zudem ist es ein aussichtsreicher Kandidat zum Erreichen der Quantenentartung. Aufgrund fehlender magnetischer Substruktur im Grundzustand muss das BEC mit ausschließlich optischen Methoden verwirklicht werden.

Die Calciumatome werden in einer zweistufigen MOT vorgekühlt und in eine eindimensionale oder gekreuzte Dipolfalle umgeladen. Die so erreichten Phasenraumdichten von etwa 0,01 sollen durch Verdampfungskühlung in der Dipolfalle weiter erhöht werden. Die bisherigen Experimente deuten auf starke Dreikörperverluste im Kreuzungsbereich der Dipolfalle hin. Es wird diskutiert welchen Einfluss das Ladeverhalten und die Dreikörperstöße auf eine erfolgreiche Verdampfungskühlung haben.

A 7.3 Di 11:00 Audi-B

**Kalte neutrale Quecksilberatome in einer MOT** — •Patrick Villwock, Arne Schönhut, Mathias Sinther und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, 64289 Darmstadt

Quecksilber hat fünf stabile bosonische und zwei stabile fermionische Isotope. Die fermionischen Isotope eignen sich zur Untersuchung eines neuen optischen Zeitstandards. In einer magneto-optischen Falle gefangene Quecksilberatome bieten zusätzlich die Möglichkeit der Erzeugung translatorisch kalter Moleküle durch Photoassoziation, sowie deren Laserkühlung in den vibratorischen Grundzustand.

Die Sättigungsintensität des Kühlübergangs bei 253,7 nm beträgt 10,2 mW/cm$^2$, bei einer natürlichen Linienbreite von 1,27 MHz. Eine UV-Leistung von über 250 mW wird mit einer zweistufigen externen Frequenzverdopplung eines Yb:YAG Scheibenlasers bei 1014,8 nm bereitgestellt. Zur Frequenzstabilisierung des Lasers wird mit Sättigungsspektroskopie ein entsprechendes Fehlersignal im Lock-In Verfahren generiert.

Erste Ergebnisse zur erfolgreichen Realisierung der magneto-optischen Falle werden diskutiert.

A 7.4 Di 11:15 Audi-B

**Laser cooling by collisional redistribution of fluorescence** — •Ulrich Vogl and Martin Weitz — Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

The general idea that optical radiation may cool matter was put forward by Pringsheim already in 1929. Doppler cooling of dilute atomic gases is an extremely successful application of this concept, and more recently anti-Stokes fluorescence cooling in multilevel systems has been explored, culminating in the optical refrigeration of solids. Collisional redistribution of fluorescence is a proposed different cooling mechanism that involves atomic two-level systems, though experimental investigations in gases with moderate density have so far reached the cooling regime. Here we experimentally demonstrate cooling of an atomic gas based on collisional redistribution of fluorescence, using rubidium atoms subject to several hundreds of bars of buffer gas pressure. The frequent collisions in the ultradense gas transiently shift a far red detuned laser beam into resonance, while spontaneous decay occurs close to the unperturbed atomic resonance frequency. During each excitation cycle, a kinetic energy of order of the thermal energy $k_BT$ is extracted from the dense atomic sample. In a proof of principle experiment with a thermally not isolated sample, we experimentally demonstrate relative cooling by 33 K. The cooled gas has a density of more than 10 orders of magnitude above the typical values in Doppler cooling experiments. Future prospects of the demonstrated technique can include cryocoolers and the study of homogeneous nucleation in saturated vapour.

A 7.5 Di 11:30 Audi-B

**EIT Kühlen von $^{40}Ca^+$ Ketten in einer segmentierten Ionenfalle** — •Johannes F. Eble, G. Schütz, F. Schmidt-Kaler und K. Singer — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

Mittels elektromagnetisch induzierter Transparenz (EIT) können gefangene Ionen bis nahe dem quantenmechanischen Grundzustand abgekühlt werden. Dabei wird eine zusätzliche schmale Absorptionslinie auf der blau verstimmten Seite eines natürlichen Übergangs erzeugt [1]. Ein Vorteil dieser Methode gegenüber anderen Laserkühlverfahren ist, dass mehrere Schwingungsmoden simultan gekühlt werden können und somit besonders für Ionenketten geeignet ist, bei denen verschiedene Schwingungsmoden auftreten.

Wir verwenden die Zeeman Struktur des $S_{1/2}$ - $P_{1/2}$ Dipol Übergangs von $Ca^+$-Ionen um ein EIT Spektrum zu generieren. Um die Linienform spektroskopisch zugänglich machen zu können scannen wir die Resonanz in gepulstem Lasermodus. Dadurch können wir das EIT Profil charakterisieren und bezüglich optimaler Kühleigenschaften formen. Kühlergebnisse mit einzelnen Ionen und Ionenketten werden vorgestellt.

An diesen kalten Ionenketten wollen wir die Wechselwirkung zwischen Phononen studieren. Diese Wechselwirkung wird durch ein anharmonisches optisches Potential erzeugt [2].

[1] C. F. Roos, D. Leibfried, A. Mundt, F. Schmidt-Kaler, J. Eschner, R. Blatt, Phys. Rev. Lett. **85**, 5547 (2000).
[2] X.-L. Deng et al, Phys. Rev. A **77**, 033403 (2008)

A 7.6 Di 11:45 Audi-B

**Quantum Catcher - Stopping Particles of unknown velocities** — •Sönke Schmidt[1], J. Gonzalo Muga[2], and Andreas Ruschhaupt[1] — [1]Institut für Mathematische Physik, TU Braunschweig, Mendelssohnstrasse 3, 38106 Braunschweig — [2]Departamento de Quimica-Fisica, Universidad del Pais Vasco, Apartado 644, 48080 Bilbao, Spain

We propose a method to stop particles of unknown velocities. We present a classical and a quantum mechanical description of the setting. Using numerical simulations with realistic and experimentally accessible parameters, we show the efficiency of the method and discuss its bounds.

A 7.7 Di 12:00 Audi-B

**Trapping neutral Cs-atoms using ultra-thin optical fibres** — •Eugen Vetsch, Daniel Reitz, Guillem Sagué, Regine Schmidt, and Arno Rauschenbeutel — Abteilung QUANTUM, Institut für

Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We present our recent results on trapping cold neutral Caesium atoms close to the surface of an ultra-thin optical fibre. The atoms are captured by a two-colour trap which is based on light-induced dipole forces exerted on the atoms by a blue- and red-detuned evanescent light field, created by launching two co-propagating laser beams through the fibre. This results in a cylindrically symmetric trap around the fibre that exhibits a trapping minimum about two hundred nanometres above the surface. By launching an additional, counter-propagating red-detuned laser beam through the fibre, a red-detuned standing wave is realized, confining the atoms in all three dimensions.

We are currently able to trap more than $10^3$ atoms with a lifetime of about 50 ms. We probe the atoms by measuring the absorption of a weak resonant probe field which is sent through the fibre and which couples to the atoms via the evanescent field. Remarkably, the atomic ensemble is optically dense for this probe field. This opens the route towards non-linear optics applications like electromagnetically induced transparency, slow and stopped light processes, deterministic single photon sources, and quantum memories with fibre-coupled atomic ensembles.

Financial support by the Volkswagen Foundation and the ESF is gratefully acknowledged.

A 7.8 Di 12:15 Audi-B

**Mikrostrukturierte Ionenfalle mit integrierten Magnetfeldspulen** — •Delia Brüser, Thomas Collath, Michael Johanning und Christof Wunderlich — Fachbereich Physik, Universität Siegen, 57072 Siegen, Deutschland

Es wurde eine mikrostrukturierte Ionenfalle (Mikrofalle) entwickelt, gefertigt und gebaut, welche intern einen hohen Magnetfeldgradienten erzeugen kann. Die Mikrofalle ist eine dreidimensionale Paul-Falle mit segmentierten DC-Elektroden. Sie ist sandwichförmig aus drei übereinander plazierten Lagen aufgebaut. Die beiden äußeren Lagen führen dem Fallenschlitz jeweils 33 DC-Elektroden und eine RF-Elektrode zu. Die mittlere Lage ist so geformt, dass durch vergoldete Strukturen effektiv ein Anti-Helmholtz Spulenpaar gebildet wird. Aufgrund der großen Nähe der Spulen zu den Ionen kann so ein Magnetfeldgradient von erwarteten 100 T/m erzeugt werden. Dieser Gradient ist für Adressierung und Kopplung der Ionen von großer Bedeutung [1].

Der Aufbau des Mikrofallensystems wird beschrieben. Es werden zudem erste Ergebnisse präsentiert und mit vorhergegangenen Simulationen verglichen.

[1] M. Johanning, A. Braun, N. Timoney, V. Elman, W. Neuhauser, Chr. Wunderlich, arXiv:0801.0078v1 [quant-ph]

# A 8: Atomic Clusters I

Zeit: Dienstag 10:30–12:30 Raum: VMP 6 HS-B

**Fachvortrag** A 8.1 Di 10:30 VMP 6 HS-B

**Energieabsorption durch resonante Streuprozesse in Metallclustern bei der Wechselwirkung mit sehr kurzen Laserpulsen** — •Jörg Köhn, Thomas Fennel, Karl-Heinz Meiwes-Broer und Ronald Redmer — Institut für Physik, Universitätsplatz 1, Universität Rostock, 18051 Rostock

In Experimenten zur Untersuchung der Wechelwirkung von intensiven fs-Laserpulsen mit Metallclustern lassen sich hohe Absorptionsquerschnitte der Cluster und als Reaktionsprodukte neben hochgeladenen Ionen auch emittierte hochenergetische Elektronen nachweisen. Einen zugrundeliegenden fundamentalen Absorptionsprozess stellt die resonante Anregung von Oberflächenplasmonen dar. Es wird gezeigt, dass dieser Mechanismus selbst in Pulsen, die nur wenige optische Zyklen umfasssen, wirksam ist. Zum Einsatz kommt dabei ein gekoppeltes Verfahren, basierend auf der numerischen Lösung der Vlasovgleichung für das Elektronensystem und der klassischen Bewegungsgleichungen für die Ionen (Thomas-Fermi-Vlasov-Molekulardynamik). Im speziellen wird untersucht, wie die im Plasmon gespeicherte Energie auf einzelne Elektronen übertragen wird. Dazu erfolgt die Analyse der Energieabsorption im Einteilchenbild, das die Dynamik des betrachteten Elektrons im externen Laserfeld und dem Feld der anderen Elektronen und Ionen erfasst. Die erhaltenen Ergebnisse weisen darauf hin, daß für moderate Intensitäten ($I \sim 10^{13}\mathrm{Wcm}^{-2}$) ein resonanter Rückstreuprozess durch die dynamische Änderung des Vielteilchenpotentials der dominierende Mechanismus zu Erzeugung energetischer Elektronen ist.

**Fachvortrag** A 8.2 Di 11:00 VMP 6 HS-B

**Ionization dynamics of embedded Xenon clusters in strong laser fields** — •Christian Peltz and Thomas Fennel — Institute of Physics, University of Rostock, Germany

Efficient energy absorption and the emission of highly charged atomic ions are well known effects emerging from the interaction of ultrashort and intense near-infrared laser pulses with clusters. Besides the many corresponding experiments on free clusters, where the dynamics of heating and ionization is relativly well understood, studies on embedded clusters show comparable or even higher charge states at moderate laser intensities[1]. For a theoretical study of the matrix effects on the absorption and ionization processes, such as an early plasmon resonance[2] or ionization threshold lowering in the cluster medium[3], we use a semiclassical molecular dynamics approach[3]. Results on the spatially resolved energy absorption as well as on final ion charge spectra for dual-pulse excitation of $\mathrm{Xe_N@He_M}$ as function of laser intensity and size of the matrix[4] will be presented.

[1] T. Döppner et al. , to be published
[2] A. Mikaberidze et al. , Phys. Rev. A **77**, 041201 (2008)
[3] T. Fennel et al. , Phys. Rev. Lett. **99**, 233401 (2007)
[4] Ch. Peltz et al. , in preparation

A 8.3 Di 11:30 VMP 6 HS-B

**Probing optical and electronic properties of deposited metal doped silicon clusters** — •Vicente Zamudio-Bayer[1], Konstantin Hirsch[1], Philipp Klar[1], Andreas Langenberg[1], Fabian Lofink[1], Jürgen Probst[1], Robert Richter[1], Jochen Rittman[1], Marlene Vogel[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/FMF, Stefan-Meier-Straße 21, D-79104 Freiburg

Recent experiments have shown how silicon cages can be stabilized by doping them with a transition metal atom. The reactivity and electronic properties of these clusters in the gas-phase are now well known and understood and the next logical step is to deposit them to study their interaction with the surface. For this purpose we have designed a transportable experimental setup with which it will be possible to study the optical and electronic properties of deposited mass-selected clusters at our own lab and at the synchrotron source. The data on these $\mathrm{M@Si}_n$ systems (M = 3d transition metal atom) in the gas-phase will be used as a fingerprint to test the strength of the substrate-cluster interaction. Additional investigations of the optical properties will be made possible due to the increased target density on the surface. An overview of the setup will be given and preliminary results will be presented.

A 8.4 Di 11:45 VMP 6 HS-B

**Kontrolle von Prozessen der Laser-Cluster-Wechselwirkung auf kurzen Zeitskalen** — •Paul Hilse[1], Max Moll[1], Manfred Schlanges[1] und Thomas Bornath[2] — [1]Ernst-Moritz-Arndt-Universität Greifswald — [2]Universität Rostock

Die Wechselwirkung intensiver Laserstrahlung mit Silber- und Edelgasclustern mit Größen im nm-Bereich wird im Rahmen eines modifizierten Nanoplasma-Modells untersucht. Von besonderem Interesse ist die Ionisisationsdynamik im lasererzeugten dichten Plasma.

Ein modernes Instrument bei Laser-Cluster Experimenten ist das sogenannte Pulse-shaping. Mit dieser Methode lässt sich die Dynamik des Systems auf der Skala von Femtosekunden kontrollieren, z.B. kann die Ausbeute an hochgeladenen Ionen gezielt optimiert werden. In unserem theoretischen Zugang benutzen wir einen genetischen Algorithmus, um Pulsformen zu berechnen, die die Produktion von hochgeladenen Ionen maximieren. Es werden Resultate mit optimierten Pulsformen gezeigt und mit Doppel- und Einzelpulsanregungen verglichen.

[1] P. Hilse, M. Moll, M. Schlanges, Th. Bornath, Laser-Cluster Interaction in a Nanoplasma-Model with Inclusion of Lowered Ionization Energies, Laser Physics, accepted (2009); arXiv: 809.3058v1

[2] N.X. Truong, P. Hilse, S. Göde, et al., Femtosecond Optimal Control of the Charge State and Yield of Silver Fragment Ions from Coulomb Explosion of Silver Clusters, submitted (2009).

[3] M. Schlanges, P. Hilse, Th. Bornath, Ionization dynamics in dense nanoplasmas irradiated by intense laser fields. Pulse shaping, Journal of Physics A: Math. and Theor., accepted (2009)

A 8.5 Di 12:00 VMP 6 HS-B

**Erzeugung mehrfach negativ geladener Aluminiumcluster in der Penningfalle** — Noelle Walsh, •Franklin Martinez, Gerrit Marx, Lutz Schweikhard und Falk Ziegler — Institut für Physik, Ernst-Moritz-Arndt Universität, 17487 Greifswald, Deutschland

Die Erzeugung mehrfach negativ geladener Aluminiumcluster in der Penningfalle wurde auf den vierten Ladungszustand erweitert. Einfach geladene Aluminiumcluster werden in einer Penningfalle einem Elektronenbad ausgesetzt und nehmen dabei weitere Elektronen auf, wodurch zweifach, dreifach und vierfach negativ geladene Cluster gebildet werden. Der Transfer in höhere Ladungszustände ist von der Clustergröße abhängig. Insbesondere wird eine Mindestgröße benötigt, um stabile Systeme bei höheren Ladungszuständen zu erzeugen. Die experimentellen Ergebnisse werden mit Abschätzungen aus einfachen Modellansätzen verglichen.

A 8.6 Di 12:15 VMP 6 HS-B

**The temperature dependence of the lifetime of the first excited electronic state in $C_{60}$ anions studied using two color pump-probe photoelectron spectroscopy** — •Mattias Svanqvist, Raphael Kuhnen, and Bernd von Issendorff — University of Freiburg

The electronic valence structure of fullerenes is determined by the delocalized $\pi$-band which can be seen as a spherical two-dimensional electron gas. This makes fullerenes interesting model systems for the study of excitation and relaxation processes in a highly correlated many electron systems.

We have studied the temperature and pump beam intensity dependence on the lifetime of the first excited state ($t_{1g}$) in $C_{60}$ anions in a molecular beam. The lifetime of this state has previously been reported as $2.2 \pm 0.2$[1]. We show that the measured lifetime is dependent on the temperature of the fullerenes and the intensity of the pump laser.

We have used a pump beam wavelength of 800 nm and two different probe beam wavelengths: 400 nm and 266 nm. The 1.55 eV absorbed by the molecule is clearly more than the observed energy gap between the $t_{1u}$ and $t_{1g}$, which has a value of around 1.1 eV. We assume that the energy difference goes into vibrations thus heating the molecule, which means that the observed lifetime of the $t_{1g}$ level also should depend on the pumping beam wavelength.

We conclude that the interpretation of lifetime measurements of excited states in non-adiabatic systems needs to take into consideration at least two parameters: initial temperature and pump beam heating.

## A 9: Interaction with Strong or Short Laser Pulses I

Zeit: Dienstag 10:30–12:30 Raum: VMP 6 HS-C

**Hauptvortrag** A 9.1 Di 10:30 VMP 6 HS-C

**Atomic and molecular ionization dynamics in strong laser fields: Excited neutral fragments after tunneling** — •Ulli Eichmann — Max-Born Institut, Berlin, Germany

Ionization and fragmentation dynamics of atoms and molecules in strong laser fields has been well studied with a strong focus on charged fragments and high harmonic generation. In this talk we report our observation of excited neutral fragments after exposing atoms and molecules to strong laser fields. Our experiments have been made possible by direct detection of excited neutral atoms. An explanation of the creation of excited states of atoms in strong laser fields can be found in an extension of the rescattering model by a process which we call Frustrated Tunnel Ionization (FTI)[1]. It leads to the recapture of those electrons into bound excited states which tunnel within a narrow range of laser field phases that does not allow for a high enough drift energy to escape. Results from semi-classical calculations are in quantitative agreement with full quantum mechanical calculations. More striking appears the extrapolation to molecules, where we observe the appearance of fast excited neutral fragments after exposure of diatomic molecules to a strong laser pulse, an hitherto unobserved fragmentation channel [2]. We show that polarization dependent measurements of the excited neutral fragment yield and correlated measurements of ions and excited neutral atoms together with classical Monte Carlo simulations confirm our assumption on the underlying model.

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

[2] B. Manschwetus et al., PRL, submitted (2008).

**Fachvortrag** A 9.2 Di 11:00 VMP 6 HS-C

**Pikosekunden-Elektronenbeugung von selektiv ausgerichteten Molekülen** — Peter Reckenthäler[1,2], Martin Centurion[1], Werner Fuss[1], Alexander Apolonski[2], Ferenc Krausz[1,2] und •Ernst Fill[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Ludwig-Maximilians-Universität München, Am Coulombwall 1, 85748 Garching

Die Aufklärung der Struktur großer Moleküle ist eine der großen Herausforderungen der strukturellen Biologie und Chemie. Um die Grenzen der gegenwärtigen Technik - Röntgenbeugung von Molekülen in kristalliner Phase - zu überwinden, demonstrieren wir Elektronenbeugung von ausgerichteten Molekülen in der Gasphase.

Der Wirkungsquerschnitt eines parallelen Photodissoziations-Übergangs ist proportional zum Quadrat des Cosinus des Winkels zwischen Polarisationsrichtung und Dissoziationsachse. Aus diesem Grund zeigen die erzeugten Radikale eine transiente Ausrichtung parallel zur Polarisation, während die undissoziierten Moleküle in einer Ebene senkrecht dazu ausgerichtet sind. Wir zeigen dies durch zeitaufgelöste Elektronenbeugung von photodissoziiertem 1,2-Diiodotetrafluoroethan (C2F4I2).

Die Moleküle werden in einem Überschallstrahl durch linear polarisierte UV Laserspulse dissoziiert. Synchron mit den Laserpulsen treffen Pikosekunden-Elektronenpulse auf die Moleküle und werden an diesen gebeugt. Die Bilder zeigen eine deutliche Anisotropie der Beugungsringe. Mit Hilfe der Pump-Abfrage-Technik wird die Dephasierung des erzeugten Rotationswellenpakets verfolgt.

A 9.3 Di 11:30 VMP 6 HS-C

**Coulomb-corrections for strong field ionization using quantum trajectories** — •Dieter Bauer[1] and Sergey Popruzhenko[1,2] — [1]Max-Planck-Institut für Kernphysik, Postfach 103980, 69029 Heidelberg, Germany — [2]Moscow State Engineering Physics Institute, Kashirskoe Shosse 31, 115409, Moscow, Russia

A theory describing above-threshold ionization of atoms and ions in a strong electromagnetic field is presented [1]. It is based on the widely known strong field approximation and incorporates the Coulomb interaction between the photoelectron and the nucleus using the method of complex classical trajectories. By comparing our predictions with the results of *ab initio* numerical solutions we show that the new theory provides a significant improvement over the Coulomb-free strong field approximation [1,2]. Moreover, with the same method a simple, analytical, nonrelativistic ionization rate formula for atoms and positive ions in intense ultraviolet and x-ray electromagnetic fields is derived. The rate is valid at arbitrary values of the Keldysh parameter and confirmed by results from *ab initio* numerical solutions [3]. The proposed rate is particularly relevant for experiments employing the new free electron laser sources.

[1] S.V. Popruzhenko and D. Bauer, J. Mod. Opt. 55, 2573 (2008).

[2] S.V. Popruzhenko, G.G. Paulus, and D. Bauer, Phys. Rev. A 77, 053409 (2008).

[3] S.V. Popruzhenko, V.D. Mur, V.S. Popov, and D. Bauer, Phys. Rev. Lett. 101, 193003 (2008).

A 9.4 Di 11:45 VMP 6 HS-C

**Time resolved two-color scattering experiments on clusters at the FLASH-FEL** — •M. Adolph[1], D. Rupp[1], D. Wolter[1], S. Schorb[1], H. Thomas[1], R. Unterumsberger[1], R. Hartmann[2], N. Kimmel[2], L. Strüder[2], D. Rolles[3], A. Rudenko[3], K.U. Kühnel[4], J. Ullrich[4], T. Feigel[5], H. Wabnitz[6], T. Laarmann[6], R. Treusch[6], T. Möller[1], and C. Bostedt[1] — [1]TU - Berlin, IOAP — [2]MPI Halbleiterlabor — [3]ASG/MPG — [4]MPI Kernphysik — [5]Frauenhofer IOF — [6]DESY

The rapid development of ultra bright soft X-Ray sources (FEL) makes the imaging of nano samples and bio molecules might become feasible. The evolution and interaction of nano scale samples in the X-Ray laser pulses is only scarcely investigated, even though it is critical for the success of the prospective imaging experiments. We are developing an experimental approach for two-color scattering experiments based on the inherently correlated harmonics of the FEL for studying the X-Ray inducted dynamics in clusters. The wavelength separation and pulse delay are realized with multilayer optics. The detector unit is based on three pn-CCD cameras. With this setup first single shot, single wavelength scattering experiments have already been accomplished. The obtained scattering data has been compared with simulations based on Mie's theory. Free parameters for this calculation are the size parameter, describing the ratio of the cluster size and the wavelength, and the complex refractive index. The refractive index is correlated to the electronic structure of the cluster. The experiments shed light on the electron dynamics during the femtosecond X-Ray pulses.

A 9.5 Di 12:00 VMP 6 HS-C

**Interference phenomena in strong field ionization of noble gas dimers** — •Bastian Manschwetus[1], Horst Rottke[1], Günter Steinmeyer[1], Armin Czasch[2], Lutz Foucar[2], Rainhard Dörner[2], Horst Schmidt-Böcking[2], and Wolfgang Sandner[1] — [1]Max-Born-Institute, Max-Born-Str. 2A, D-12489 Berlin — [2]Institut für Kernphysik, Johann-Wolfgang-Goethe- Universität, Max-von-Laue-Str.1, D-60438 Frankfurt am Main

Strong-field photoionization of argon, krypton and xenon dimers by a 30 fs laser pulse ($\lambda = 800nm$) is investigated below the saturation intensity of the respective atom using electron-ion coincidence momentum spectroscopy. The dimers undergo single or double ionization, resulting in either a molecular ion or Coulomb explosion of the dimer.

The momentum distribution of the photoelectrons from single ionization of the dimers shows a prominent feature originating from the two center structure of the dimers. This feature can not be reproduced completely by a SFA based simulation, which incorporates 2-center interference [1]. More complex electron dynamics during the ionization process may be responsible for the observed deviations.

Coulomb explosion allows the investigation of double ionization of the dimers with fixed in space molecular axis. The atomic ions angular distribution is nearly isotropic (see also [2]). Their kinetic energy distribution is very sharp and corresponds to the Coulomb repulsion energy at the equilibrium internuclear separation of the neutral dimer.

[1] Z.Ansari *et al.*, New Jour. of Phys. **10**, 093027 (*2008*)

[2] S. Minemoto and H. Sakai, Phys. Rev. A **75**,033413 (*2007*)

A 9.6 Di 12:15 VMP 6 HS-C

**Acceleration of Electrons in Vacuum with Intense Laser Pulses** — •Stefanie Lourenco, Nicolas Kowarsch, and Werner Scheid — Theoretische Physik, Justus Liebig Universität Gießen, Deutschland

High intense laser pulses can be used in order to achieve high energies ($TeV$) for electrons in future accelerators. We study the acceleration of electrons in the vacuum with short laser pulses which have an extension of roughly a half wave length. For that we consider a three-dimensional laser pulse which approximately solves the Maxwellian's equations. For a laser pulse forming a plane wave in the transversal direction the electron acceleration can be expressed in simple analytical formulas. Next we plan to solve the Maxwell's equations exactly for a three-dimensional short laser pulse. Then we can calculate the electron acceleration more precisely.

## A 10: Ultracold atoms II: Single atoms (with Q)

Zeit: Dienstag 14:00–15:45 Raum: Audi-B

A 10.1 Di 14:00 Audi-B

**Cavity cooling of cesium atoms: experiments in the bad cavity limit** — •Arne Wickenbrock, Piyaphat Phoonthong, Lyubomir Petrov, and Ferruccio Renzoni — Department of Physics and Astronomy, Univerity College London, WC1 5BT London, UK

When an atom is placed in an optical cavity, its scattering properties may be significantly modified [1]. Based on this, new mechanisms of laser cooling were proposed [2-4]. In contrast to the standard laser cooling techniques, cooling by coherent scattering inside an optical resonator does not require a closed optical transition. This might expand the range of ultracold particles to more complex structured atoms and molecules.

We report on a series of experiment exploring cavity cooling in the bad-cavity limit. We prepare a cloud of ultracold cesium atoms in the centre of a leaky, near-confocal cavity. Then we pump the cavity with resonant laser light for a certain time and measure the achieved temperature as a function of atom-cavity detuning and laser intensity. [1]E. M. Purcell, Phys. Rev. 69, 681 [2]Horak P., Hechenblaikner G., Gheri K. M., Stecher H., Ritsch H., Phys. Rev. Lett.79, 4974 [3]Vuletic V., Chu S., Phys. Rev. Lett. 84, 3787 [4]P. Domokos and H. Ritsch, J. Opt. Soc. Am. B 20, 1089 (2003)

A 10.2 Di 14:15 Audi-B

**Towards a guided atom interferometer based on a superconducting atom chip** — Tobias Mueller, Xing Wu, •Anushyam Mohan, Azar Eyvazov, Yu Wu, and Rainer Dumke — Division of Physics & Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore

We evaluate the realization of a novel geometry of a guided atom interferometer based on a high temperature superconducting microstructure [1]. The interferometer type structure is obtained with a guiding potential realized by two current carrying superconducting wires in combination with a closed superconducting loop sustaining a persistent current. We present the layout and realization of our superconducting atom chip. By employing simulations we discuss the critical parameters of the interferometer guide in particular near the splitting regions of the matter waves. In the talk, we present the actual status of the experiment.

[1]: T. Müller et al, New J. Phys.10, 073006, (2008)

**Gruppenbericht** A 10.3 Di 14:30 Audi-B

**Quantum jumps and continuous spin measurement in a strongly coupled atom-cavity system** — •Tobias Kampschulte, Wolfgang Alt, Mkrtych Khudaverdyan, Sebastian Reick, Alexander Thobe, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, D-53115 Bonn

In our experiment we transport a predetermined small number of cold caesium atoms into a high-finesse optical resonator using an optical dipole trap. By monitoring the transmission of a probe laser beam resonant with the cavity we are able to measure the atomic spin continuously and observe quantum jumps between the two hyperfine ground states.

Utilizing this non-destructive method, we measure the single atom vacuum Rabi splitting via detection of the atomic state. Moreover, we experimentally demonstrate conditional dynamics of the internal states of two atoms, simultaneously coupled to the cavity field.

A reduction of the intra-cavity scattering rate would enable a quantum nondemolition measurement of the atom number as is required for probabilistic multi-atom entanglement schemes.

A 10.4 Di 15:00 Audi-B

**Manipulation of atoms with optical tweezers** — Lukas Brandt, Cecilia Muldoon, •Edouard Bains, and Axel Kuhn — Universtiy of Oxdord, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK

The controlling and positioning of single atoms [1,2] has been the dream for the past decades. This is of interest for quantum engineering and quantum computation. The ultimate goal is to position single atoms with nanometric precision, for example for positioning single atoms into optical cavities [3]. Furthermore arbitrary potential landscapes can be created, so the dynamics of individual atoms can be controlled and observed. By realising controlled collision collisions entangled cluster states can be realised as a resource for one-way quantum computing [4]. We present a new scheme which allows to arbitrarily and independently manipulate the positions and motional properties of single trapped atoms. Cold atoms are loaded from a magneto optical surface trap [5] into an array of dipole-force traps, which act like optical tweezers. This array of dipole-force traps is generated by imaging the intensity distribution of a spatial light modulator with an isopla-

natic optical system [6] into the vacuum chamber and is thus forming the optical tweezers.

[1] Miroshnychenko et al, Nature 442, 151 (2006)
[2] Beugnon et al, Nature Physics 3, 696 (2007)
[3] Nußmann et al, PRL 95, 173602 (2005)
[4] Raussendorf and Briegel, Phys. Rev. Lett. 86, 5188 (2001)
[5] Wildermuth et al, Phys. Rev. A 69, 030901 (2004)
[6] Brainis er al, Opt. Com. accepted

A 10.5 Di 15:15 Audi-B

**Efimov states in atom-molecular collisions** — •Maxim A. Efremov[1], Lev Plimak[1], Misha Yu. Ivanov[2], Gora V. Shlyapnikov[3], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm, D-89069, Germany — [2]Steacie Institute for Molecular Sciences, NRC Canada, ON Ottawa, K1A 0R6 Canada — [3]Laboratoire de Physique Theorique et Modeles Statistiques, CNRS, Universite Paris Sud, 91405 Orsay, France

Scattering of a heavy atom off a weakly bound molecule comprising an identical heavy and a light atom is considered. We focus on the experimentally favorable situation in which the heavy atoms are bosons and the light ones are fermions, and the molecules exist in a cold boson-fermion mixture due to an interspecies Feshbach resonance. The total cross section of atom-molecular scattering is calculated in the Born-Oppenheimer approximation. In the limit of slow incident atom the total cross section as a function of the heavy-light $s$-wave scattering length (in experimental terms, as a function of the applied magnetic field) is shown to exhibit a series of resonances, providing a physically clear manifestation of the Efimov states in the three-body collision. Measurement of the cross section can therefore be an efficient and precise tool for scanning the effective potential in the three-body problem.

A 10.6 Di 15:30 Audi-B

**Deterministische ultrakalte Ionenquelle nahe dem Heisenberg Limit** — •Wolfgang Schnitzler, R. Fickler, N. M. Linke, F. Schmidt-Kaler und K. Singer — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

Wir haben mittels einer Ionenfalle eine universelle deterministische Einzelionenquelle realisiert [1,2]. In einer segmentierten Falle werden kalte $^{40}Ca^{+}$ Ionenkristalle gefangen, anschließend deterministisch aus der Falle extrahiert und mit einer Erfolgsquote von 90% in einem Abstand von 29cm detektiert. Die absolute Geschwindigkeitsfluktuation liegt unter 6.3m/s bei einer mittleren Geschwindigkeit von 19.47km/s und einer Strahldivergenz von 600$\mu$rad. Wir zeigen anhand von numerischen Simulationen, dass unsere Quelle in Kombination mit einer elektrostatischen Einzellinse in der Lage sein wird, einzelne Ionen mit nm Auflösung in Festkörper zu implantieren. Diese können dann zur Implantation von P in Si oder zur Erzeugung von NV-Farbzentren in Diamant genutzt werden, welche optisch manipuliert werden können. Solche Systeme stellen Kandidaten zur Realisierung eines skalierbaren Festkörper-Quantencomputers dar [3,4]. Die elektrischen Eigenschaften von Halbleiterbauelementen können durch die deterministische Implantation einzelner Ionen ebenfalls verbessert werden [5].

[1] J. Meijer et al., Appl. Phys. A **83**, 321 (2006)
[2] J. Meijer et al., Appl. Phys. A **91**, 567 (2008)
[3] B. Kane, Nature **393**, 133 (1998)
[4] F. Jelezko et al., Phys. Rev. Lett. **93**, 130501 (2004)
[5] T. Shinada et al., Nature **437**, 1128 (2005)

## A 11: Attosecond Physics I

Zeit: Dienstag 14:00–16:00 Raum: VMP 6 HS-B

**Fachvortrag** A 11.1 Di 14:00 VMP 6 HS-B

**Experimental molecular orbital tomography by attosecond electron wavepackets** — •Stefan Haessler[1], Willem Boutu[1], Cecilia Giovanetti[2], Jeremie Caillat[2], Thierry Ruchon[1], Hamed Merdji[1], Pierre Breger[1], Bertrand Carre[1], Alfred Maquet[2], Richard Taieb[2], and Pascal Salieres[1] — [1]CEA-Saclay, IRAMIS, Service des Photons, Atomes et Molécules, 91191 Gif-sur-Yvette, France — [2]UPMC Université Paris 06, LCPMR, 11 rue Pierre et Marie Curie, 75231 Paris, France

The strong interaction of a molecule with a laser field frees by tunnel ionization an attosecond electron wavepacket that probes its bound state half a laser cycle later as it recollides with the core. The information is encoded in the attosecond XUV burst emitted during recombination. Complete characterization of this observable gives access to the transition dipole moment over a large momentum span. With suitable assumptions on the EWP, the retrieval of the highest occupied molecular orbital (HOMO) as a function of space and time becomes possible.

We measured amplitudes and phases of the recombination dipole as a function of alignment angle for $N_2$ and $CO_2$ molecules by characterizing their attosecond emission with the RABITT technique. With these data, we successfully perform tomographic reconstructions of the HOMOs with a reduced set of assumptions as compared to the first demonstration by Itatani et al. Potentials and limitations of this technique will be discussed based on the deviations of the experimentally determined orbitals from theoretical ones.

**Fachvortrag** A 11.2 Di 14:30 VMP 6 HS-B

**Multi-orbital effects for high harmonic generation 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 (HHG) proceeds in three steps. First, a part of the electron wave function tunnels out of the valence orbital. The liberated electron wave packet accelerates in the laser field and finally coherently recombines with the initially ionized orbital. This leads to emission of harmonics of the driving laser frequency. The harmonic spectrum contains information about the valence orbital [1]. For molecules, the highest occupied molecular orbital (HOMO) is generally thought to be responsible for ionization and recombination during HHG. Molecular electronic states energetically below the HOMO should contribute to HHG, but this behavior has not been observed previously. Utilizing molecular alignment, we obtain experimental evidence that the more deeply bound HOMO-1 with its $\pi_u$ symmetry also contributes to HHG in $N_2$ [2]. Semi-classical simulations of the recombination process to the HOMO and HOMO-1 support our observation. This opens the route to imaging coherent superpositions of electronic orbitals.

[1] J. Itatani et al., Nature **432**, 867 (2004)
[2] B. K. McFarland, J. P. Farrell, P. H. Bucksbaum and M. Gühr, Science **322**, 1232 (2008)

A 11.3 Di 15:00 VMP 6 HS-B

**Strong field Cooper minimum in High Harmonic Generation** — •Markus Gühr, Joseph P. Farrell, Brian K. McFarland, and Philip H. Bucksbaum — Stanford PULSE Institute, SLAC National Accelerator Lab, Menlo Park, CA 94025 and Physics Department, Stanford University, Stanford CA 94305, USA

The so called Cooper minimum is a prominent feature in the VUV photoionization cross section. It results from a cancellation of the transition matrix element from the atomic ground state to the continuum states at certain photon energies and is accompanied by a $\pi$ phase jump in the matrix element [1]. We observe the Cooper minimum in high harmonic generation (HHG) spectrum of argon. In addition to the spectral amplitude modulation we also observe a spectral phase jump of $\pi$ around the Cooper minimum. The recombination step of HHG can be described by the inverse photoionization matrix element and we apply the photoionization theory to simulate our data. In the experiment, we observe a shift of the HHG Cooper minimum with respect to the photoionization Cooper minimum of about 5 eV. We explain this shift by a strong-field mixing of the continuum states during the recombination step in HHG. The results show the opportunity for controlled attosecond pulse shaping.

[1] J. W. Cooper, Physical Review **128**, 681 (1962)

A 11.4 Di 15:15 VMP 6 HS-B

**Monitoring nuclear and electronic dynamics using high-order harmonic radiation** — •Stefanie Gräfe[1], Daniil V. Kartashov[2], and Joachim Burgdörfer[1] — [1]Institut für Theoretische Physik, TU Wien, Österreich — [2]Institut für Photonik, TU Wien, Österreich

We investigate the possibility to simultaneously monitor nuclear and electronic dynamics in diatomic molecules using HHG. Applying a simple two-dimensional model analogously to the hydrogen molecular ion with one nuclear and one electronic coordinate, we demonstrate numerically the possibility to use high-order harmonic spectra as a dynamical structural probe, identifying the traces of nuclear and electronic dynamics in the HHG spectra.

The harmonic spectra contain rich information, e.g. peak broadening due to nuclear motion, the prominent feature of two-center interference minima showing directly the temporal change in the internuclear distance [Lein et al., Phys. Rev. A, 2002]. We can distinguish the contributions of different electronic states leading to additional interferences in high-harmonics radiation. The occurrence of interference structures is a result of inversion symmetry breaking due to localization dynamics; the electron being ionized from one state (or one potential well) may recombine to several other coherently populated states residing in both potential wells. As this process is only efficient in a region where the nuclear autocorrelation function is substantially different from zero, the information on the internuclear coordinate maps onto cross terms in a defined spectral energy region. Support by FWF-SFB ADLIS and the Lise-Meitner program, M1077-N16, is highly acknowledged.

A 11.5 Di 15:30 VMP 6 HS-B

**Molecular orbital tomography using HHG and ATI** — •Elmar van der Zwan, Ciprian Chirila, and Manfred Lein — Institute for Physics, University of Kassel, Germany

In 2004 a revolutionary method to perform tomographic imaging of molecular orbitals using high-harmonic generation (HHG) caught a lot of attention [1]. The method is based on the simplification that the returning electron in the three-step model can be modeled as a plane wave. We have shown that orbitals of arbitrary symmetry can be reconstructed if one uses extremely short laser pulses that ensure the continuum wave packet recombines from one side only [2]. Within the single-active-electron approximation, the challenge of the scheme lies in the accurate determination of the continuum wave packet. For a known orbital, an expression for the continuum wave packet in terms of classical trajectories is derived from the Lewenstein model. We propose an experimentally feasible method to determine the composition of the continuum wave packet using both HHG and angularly resolved above-threshold ionization (ATI) electrons. By incorporating the ATI electrons in the procedure, the instantaneous tunneling rates for electron emission parallel to the applied field can be measured. This avoids one of the major assumptions in the tomographic scheme, namely approximating the tunnel ionization of the molecule by that of the reference.

[1] Itatani *et al.* Nature **432**, 867-871 (2004)
[2] van der Zwan *et al.* Phys. Rev. A **78**, 033410 (2008)

A 11.6 Di 15:45 VMP 6 HS-B

**Probing shake-up states in He by laser controlled rescattering of XUV photoelectrons** — •Renate Pazourek[1], Johannes Feist[1], Stefan Nagele[1], Emil Persson[1], Lee A Collins[2], Barry I Schneider[3], and Joachim Burgdörfer[1] — [1]Inst. for Theor. Physics, Vienna University of Technology, Austria — [2]Theor. Division, Los Alamos National Laboratory, USA — [3]Physics Division, NSF, USA

Recent progress in the generation of ultrashort XUV pulses and few-cycle infrared pulses opens the possibility for various novel pump-probe setups for the study of ultrafast electronic dynamics. We present numerical ab initio simulations where we employ an XUV pulse to singly ionize a helium atom in the presence of an IR field which can induce rescattering of the ionized electron at the parent ion.

For XUV pulses with photon energies slightly above the first ionization potential ($I_1 \approx 24.6\,\mathrm{eV}$) one electron is ionized and the remaining ion relaxes to the $He^+$ ground state. For photon energies $\hbar\omega > 65.4\,\mathrm{eV}$ a second channel, where the bound electron is excited into a shake-up state, opens. In this contribution we present velocity maps, i. e. angularly resolved momentum distributions of the singly ionized electrons, experimentally accessible by a velocity map imaging spectrometer. Insights into two-electron effects, a sine qua non for the shake-up process to occur, can be obtained. We compare our ab initio simulations (without approximations for inter-electron interactions) with single-active electron calculations in order to show to what extent electron-electron interactions account for the observed effects.

## A 12: Precision Spectroscopy of Atoms and Ions II

Zeit: Dienstag 14:00–16:00 Raum: VMP 6 HS-C

**Fachvortrag** A 12.1 Di 14:00 VMP 6 HS-C

**Laser-Microwave Double-Resonance Spectroscopy in a Penning Trap for g-Factor Measurements in Highly Charged Ions** — Nicolaas Petrus Marcus Brantjes[1], •David von Lindenfels[2], Wolfgang Quint[1], and Manuel Vogel[3] — [1]GSI, Darmstadt, Germany — [2]University of Heidelberg, Heidelberg, Germany — [3]Imperial College, London, United Kingdom

Precise determination of bound-electron g-factors in heavy highly-charged ions (e.g. $Bi^{82+}$, $U^{91+}$) provides a stringent test of bound-state QED in extreme fields. The H-like and Li-like heavy ions, produced at GSI and slowed down at the HITRAP facility, will be loaded into a half-open cylindrical Penning trap and confined at cryogenic temperatures. With a laser-microwave double-resonance technique we can then probe microwave transitions between Zeeman sub-levels of the hyperfine structure in such ions. From this the ionic g-factors $g_\mathrm{F}$ can be measured with high accuracy. Both the electronic g-factor $g_J$ and the nuclear g-factor $g_I$ can be determined from a single experiment. This experiment will be a novel method to measure the g-factor of the bound electron.

A 12.2 Di 14:30 VMP 6 HS-C

**Status of the *g*-factor experiment** — •Birgit Schabinger[1], Klaus Blaum[2], Wolfgang Quint[3], Sven Sturm[1], and Anke Wagner[2] — [1]Institute of — [2]MPI für Kernphysik, 69117 Heidelberg, Germany — [3]GSI Darmstadt, 64291 Darmstadt, Germany

Calculations of the bound-state quantum electrodynamic (BS-QED) can be tested by high-precision measurements of the magnetic moment of the electron bound in highly-charged ions. In the past, $g$-factor measurements were done on light ions with relative uncertainties $\delta g/g$ below $10^{-9}$ [1]. Since the influence of the BS-QED increases with the nuclear charge, the current experiment [2] aims for measurements on medium-heavy ions like silicon (Z=14) and calcium (Z=20). The ions are created in-trap by a mini electron-beam ion source [3]. In the experiment the $g$-factor measurement of a single ion will be performed in a double Penning-trap setup employing the "continuous Stern-Gerlach-effect". Here the $g$-factor measurement is reduced to the measurements of the three eigenfrequencies of the ion ($\nu_+, \nu_-$ and $\nu_z$) and the spin precession frequency ($\nu_L$). First results with single ions and the status of the experiment will be presented .

[1] G. Werth *et al.*, Int. J. Mass Spec. **251**, 152 (2006)
[2] M. Vogel *et al.*, Nucl. Inst. Meth. B **235**, 7 (2005)
[3] B. Schabinger *et al.*, J. Phys. Conf. Ser. **58**, 121 (2007)

A 12.3 Di 14:45 VMP 6 HS-C

**Magnetische Wechselfelder zum Spinflip eines Protons** — •Andreas Mooser[1], Klaus Blaum[2], Holger Kracke[1], Susanne Kreim[1], Christian Mrozik[1], Wolfgang Quint[3], Cricia Rodegheri[1], Stefan Ulmer[1,2,3,4] und Jochen Walz[1] — [1]Institut für Physik, Universität Mainz, 55099 Mainz, — [2]MPI für Kernphysik, 69117 Heidelberg — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, — [4]Ruprecht-Karls-Universität, 69047 Heidelberg

In Mainz wird derzeit ein Experiment zur Messung des $g$-Faktors eines einzelnen Protons in einer Penningfalle aufgebaut. Dazu muss die Larmorfrequenz $\nu_L = g\frac{\vec{\mu}}{\hbar}\vec{B}$ des Teilchens im magnetischen Feld der Falle bestimmt werden. Mit einem magnetischen Wechselfeld bei der Larmorfrequenz, welches transversal zum homogenen Magnetfeld orientiert ist, kann der Spin umgeklappt werden. Dabei darf die Amplitude des Wechselfeldes den $\mu$T-Bereich nicht unterschreiten, will man den Spin innerhalb von Sekunden umklappen. In laufenden Versuchen wird untersucht, ob diese Voraussetzung an die Felder über Spulen außerhalb der Falle erfüllt werden kann, oder ob die Wechselfelder von den Kupferelektroden zu stark abgeschirmt werden. Dazu wurde der Durchgriff magnetischer Wechselfelder durch Öffnungen in

metallischen Schirmen unter idealisierten Bedingungen experimentell untersucht und mit analytischen sowie Finite-Elemente Rechnungen verglichen.

A 12.4 Di 15:00 VMP 6 HS-C

**Precision spectroscopy on weakly bound ions** — •Maximilian Herrmann, Valentin Batteiger, Sebastian Knünz, Guido Saathoff, Thomas Udem, and Theodor W. Hänsch — Max-Planck-Institut für Quantenoptik, 85748 Garching, Deutschland

We demonstrate a method for precision spectroscopy on trapped ions in the limit of unresolved motional sidebands. By sympathetic cooling of a chain of crystallized ions we suppress adverse temperature variations induced by the spectroscopy laser that usually lead to a distorted line profile and obtain a Voigt profile with negligible distortions. We applied the method to measure the absolute frequency of the astrophysically relevant D2 transition in single $^{24}Mg^{+}$ ions and find 1 072 082 934.33(16) MHz, a nearly 400fold improvement over previous results. Further, we find the excited state lifetime to be 3.84(10) ns.

A 12.5 Di 15:15 VMP 6 HS-C

**Ion capture and non-destructive detection in the SPECTRAP experiment** — •Zoran Andjelkovic[1,5], Shailen Bharadia[4], Bettina Sommer[2,5], Stefan Stahl[3], Richard Thompson[4], Manuel Vogel[4,5], and Wilfried Nörtershäuser[1,5] — [1]Universität Mainz, Germany — [2]Universität Gießen, Germany — [3]Stahl Electronics, Mettenheim, Germany — [4]Imperial College London, England — [5]GSI Darmstadt, Germany

Several precision experiments are under development within the framework of the new HITRAP facility at GSI Darmstadt. One of them is SPECTRAP, which aims to trap highly charged heavy ions in a Penning trap, cool them to cryogenic temperatures and measure their hyperfine structure by means of laser spectroscopy. This report presents the trapping technique and the methods used for detecting, cooling and manipulating the ions inside the trap before and during their excitation. Here for the first time resistive cooling is going to be applied to a large ion cloud ($\sim 10^5$ particles). Also considered are various problems arising from (non-perfect) vacuum, cryogenic environment, electronic noise, thermal shielding, etc. Finally, the current status and an overview of the planned experiments will be given.

A 12.6 Di 15:30 VMP 6 HS-C

**Vergleich eines neuen kompakten Laser-Induzierten Breakdown Spektrometers mit EDX und ESCA** — •Christian Wagner[1], Johannes Ewald[1], Juri Fedotov[2], Georg Ankerhold[1] und Peter Kohns[1] — [1]RheinAhrCampus Remagen University of Applied Sciences Koblenz, Suedallee 2, 53424 Remagen — [2]Baumann Moscow State Technical University, Moskau, Russland

Laser-Induzierte Breakdown Spektroskopie (LIBS) ist ein berührungsfreies, minimal zerstörendes Verfahren der Materialanalyse, welches das spektrale Leuchten einer lasergenerierten Plasmaquelle auswertet. Es ergeben sich daraus verschiedene Möglichkeiten der Plasmaerzeugung durch Änderung der Laserparameter.

Dieser Vortrag vergleicht ein kommerzielles Lasersystem mit hoher Pulsenergie und niedriger Repetitionsrate mit einem neuen System mit niedriger Pulsenergie und hoher Repetitionsrate.

Zusätzlich wurde das LIBS-System anhand unterschiedlicher Aluminiumlegierungen mit anderen Materialanalyseverfahren wie EDX (Energy Dispersive X-Ray spectroscopy) und ESCA (Electron Spectroscopy for Chemical Analysis) verglichen.

A 12.7 Di 15:45 VMP 6 HS-C

**Identifizierung von Aluminiumlegierungen mittels eines kompakten Laser-Induzierten Breakdown Spektrometers** — •Johannes Ewald[1], Christian Wagner[1], Juri Fedotov[2], Peter Kohns[1] und Georg Ankerhold[1] — [1]RheinAhrCampus Remagen University of Applied Sciences Koblenz, Remagen, Deutschland — [2]Baumann Moscow State Technical University, Moskau, Russland

Laser-Induzierten Breakdown Spektroskopie (LIBS) ist ein berührungsfreies, minimal zerstörendes Verfahren der Materialanalyse, welches das spektrale Leuchten einer lasergenerierten Plasmaquelle auswertet. Die Erstellung von geeigneten Analysealgorithmen, welche eine zuverlässige Identifizierung von Spektrallinien ermöglichen, stellt dabei ein Kernproblem dar.

Dieser Vortrag behandelt die Präparation und Auswertung von Spektraldaten aus LIBS Experimenten. Dies umfasst die Programmierung einer geeigneten Erfassungssoftware mit zuverlässiger Spitzenwerterkennung und Elementzuweisung.

Diese wurde auf ihre Praxistauglichkeit getestet mittels Nachweisuntersuchung an unterschiedlichen Legierungen mit dem Basismaterial Aluminium.

## A 13: Atomic Systems in External Fields II

Zeit: Dienstag 16:30–18:00 Raum: VMP 6 HS-B

**Hauptvortrag** A 13.1 Di 16:30 VMP 6 HS-B

**The total break-up of two-electron atoms: from highly doubly excited states to double ionization of helium** — •Javier Madroñero[1,2], Johannes Eiglsperger[1], and Bernard Piraux[2] — [1]Physik Department, TU München, Germany — [2]PAMO, UC Louvain, Belgium

The complete breakup of an atomic system involving three or more particles is a very complex process, mostly due to the long range nature of the Coulomb interactions between the electrons. Close to the break-up-threshold of two-electron atoms the spectrum is strongly influenced by the underlying classical mixed regular-chaotic dynamics and typical signatures of quantum chaos, e.g., Ericson fluctuations or scaling laws for the fluctuations of the spectrum, are expected to become observable. Under the action of an electromagnetic field, electronic correlations are brought about by the kinematics of the double ionization, i.e., in two-photon processes, or they might manifiest directly in two-electron nondispersive wave packets which are expected to be observed under near-resonant periodic driving of highly doubly excited states localized in stable regions of the classical system.

In this contribution we give a brief review of our most important recent achievments in the understanding of these issues, namely fluctuations in the photoionization cross sections of planar helium up to the 20th ionization threshold, the formation of two-electron nondispersive wave packets by near-resonant driving of highly doubly excited states and the electron dynamics in double ionization of helium by two XUV photons.

**Fachvortrag** A 13.2 Di 17:00 VMP 6 HS-B

**Commissioning of the HITRAP Decelerator using a Single-shot Pepper Pot Emittance Meter: A Status Report** — •Jochen Pfister[1,2], Winfried Barth[2], Ludwig Dahl[2], Peter Forck[2], Frank Herfurth[2], Oliver Kester[3], and Ulrich Ratzinger[1] — [1]Goethe Universität Frankfurt, Institut für Angewandte Physik, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt, Germany — [3]NSCL, Michigan State University, 1 Cyclotron, East Lansing, MI 48824, USA

The Heavy Ion TRAP (HITRAP) project at GSI is in the commissioning phase. Highly charged ions up to $U^{92+}$ provided by the GSI accelerator facility will be decelerated and injected into a large Penning trap for cooling to the meV/u energy level. A combination of an inversely operated IH- and a RFQ-structure combination decelerates the ions from 4MeV/u down to 6keV/u. In front of the decelerator a double drift-buncher-system is provided for phase focusing and a final de-buncher integrated in the RFQ-tank reduces the energy spread in order to improve the efficiency for beam capture in the cooler trap. This contribution concentrates on the beam dynamics simulations and corresponding measurements in the commissioning beam times for bunchers and IH structure. Single-shot emittance measurements, profile measurements as well as longitudinal bunch structure measurements are presented. Especially for low energy, low intensity beams a new single-shot emittance meter using Micro Channel Plate technology is under construction and will be discussed as well.

A 13.3 Di 17:30 VMP 6 HS-B

**Hartree-Fock-Roothaan calculations of bound-bound transi-**

**tions for medium-Z atoms in strong magnetic fields** — •Akin Yildirim, Peter Diemand, and Günter Wunner — 1. Institut für theoretische Physik, Universität Stuttgart, 70550 Stuttgart

We present an enhanced algorithm to compute energy levels and oscillator strenghts of astrophysically relevant atoms and ions in the range Z=2,..,26 at neutron star magnetic field strenghts in different ionization stages. Single-particle orbitals are chosen as products of longitudinal wave functions with linear combinations of up to 8 landau levels, both of which are determined in a doubly self-consistent way solving the appropriate Hartree-Fock-Roothaan equations with the help of finite-element and B-spline techniques. In particular we discuss the problem of choosing "good" initial wave functions for excited orbitals.

A 13.4 Di 17:45 VMP 6 HS-B

**Hartree-Fock-Roothaan calculations of the photoionization of medium-Z atoms in neutron star magnetic fields** — •Peter Diemand, Akin Yildirim, and Günter Wunner — 1. Institut für theoretische Physik, Universität Stuttgart, 70550 Stuttgart

We calculate photoionization cross sections for astrophysically relevant atoms and ions in the range Z=2,...26 at neutron star magnetic field strenghts in different ionization stages. Exact continuum states are determined numerically taking into account the correct boundary conditions. Bound states are calculated by solving the Hartree-Fock-Roothaan equations using finite-element and B-spline techniques. The results are compared with those obtained using Born's approximation.

## A 14: Ultra-Cold Atoms, Ions and BEC I (with Q)

Zeit: Dienstag 16:30–18:00 Raum: VMP 6 HS-C

**Hauptvortrag** A 14.1 Di 16:30 VMP 6 HS-C

**Squeezing and enanglement in a Bose Einstein condensate** — •Markus Oberthaler — Kirchhoff Institut für Physik, University of Heidelberg, Im Neuneheimer Feld 227, 69120 Heidelberg

Generation of spin squeezed states for matter waves is the first step pushing atom interferometry beyond the classical limit due to projection noise. We report on our recent experimental results obtained with a new very stable double well setup combined with high spatial resolution imaging which allows the generation and characterization of number squeezed atomic states. The direct observation of the conjugate variable – the relative phase – allows the experimental confirmation of a successfully generated spin squeezed atomic state. The results show that a many particle quantum state has been produced which can improve the precision of Ramsey type interferometer. Furthermore, with the observed squeezing a sufficient criterion for pairwise entanglement can be constructed confirming that for our experimental parameters pairwise entanglement between the atoms exist even at finite temperature. In the conclusion a short overview of the recent group activities will be given.

**Fachvortrag** A 14.2 Di 17:00 VMP 6 HS-C

**Coherent collapse dynamics of dipolar Bose-Einstein condensates for different trap geometries** — •Jonas Metz, Thierry Lahaye, Bernd Fröhlich, Ashok Mohapatra, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

We present the collapse dynamics of dipolar chromium Bose-Einstein condensates in different harmonic trap geometries, from prolate, via almost spherical to oblate. The evolution of the condensates in the unstable regime are compared to three-dimensional simulations of the Gross-Pitaevskii equation including three-body losses. In order to probe the phase coherence of the collapsed condensates we interfere several copies and observe high fringe contrast.

A 14.3 Di 17:30 VMP 6 HS-C

**A Trapped-Ion Phonon Laser** — •S Knünz[1], V Batteiger[1], M Herrmann[1], T Udem[1], T W Hänsch[1], and K Vahala[2] — [1]MPQ, Hans Kopfermann-Strasse, 85748 Garching — [2]California Institute of Technology, Pasadena, CA 91125

Red-detuned laser pumping is a well known and powerful cooling technique. The opposite regime of blue-detuned pumping widely known as heating is investigated in this talk. A theoretical framework as well as experimental results on a single, laser-cooled Magnesium ion are presented. We show that this regime is stimulated emission of center-of-mass phonons instead, which can lead to coherent vibrational motion in analogy to a laser.

A 14.4 Di 17:45 VMP 6 HS-C

**Atom-Dimer Scattering in Ultracold Gases** — •Kerstin Helfrich and Hans-Werner Hammer — Helmholtz-Institut für Strahlen- und Kernphysik and Bethe Center for Theoretical Physics, Universität Bonn, 53115 Bonn, Germany

Three-body systems with large scattering length display so-called Efimov physics – universal phenomena associated with a discrete scaling symmetry. These phenomena include resonant enhancement of three-body loss rates when an Efimov resonance is at the scattering threshold. In particular, there can be resonant peaks in the atom-dimer relaxation rate for large positive scattering length.

We compute the atom-dimer relaxation rate as a function of temperature using calculations of the atom-dimer scattering phase shifts from effective field theory. A comparison to experimental data is shown.

## A 15: Poster I

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

A 15.1 Di 16:30 VMP 9 Poster

**Frequency comb spectroscopy of Hydrogen 1S-3S** — •Elisabeth Peters[1], Sascha Reinhardt[1], Scott Diddams[2], Thomas Udem[1], and Theodor W. Hänsch[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]National Institute of Standards and Technology

Precise spectroscopy of atomic hydrogen allows us to test fundamental theories as the quantum electro dynamics (QED). Decades of precise comparisons with experiments have established this theory in physics. The comparison of the narrow 1S-2S transition frequency, which has reached the uncertainty of 1.4 parts in $10^{14}$, and determination of the Rydberg constant and the Lamb shift are presently limited by the large uncertainty in the proton charge radius. To overcome this limitation we set up an experiment to measure the absolute frequency of the 1S-3S two photon transition at 205nm.
The required UV light at 205nm is generated by two successive resonant enhanced second harmonic generations (SHG) of a mode locked titanium sapphire laser. The spectrum of such a mode locked laser features equidistant frequency modes, which can be used for the high precision spectroscopy.

A 15.2 Di 16:30 VMP 9 Poster

**Polarization and entanglement studies on the two-photon transitions in hydrogenlike ions** — •Filippo Fratini[1,2], Stephan Fritzsche[2,3], and Andrey Surzhykov[1,2] — [1]Universität Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Frankfurt Institute for Advanced Studies

During the last two decades entanglement and polarization studies on the two–photon emission from few–electron ions and atoms have attracted particular interest both in experiment and theory. While, however, most investigations in the past have dealt with low–$Z$ atomic systems, much of today's interest is focused on the high–$Z$ region. At the GSI facility in Darmstadt, for example, two–photon polarization experiments with highly–charged heavy ions are likely to be carried out in the next few years. In order to provide theoretical support for these experiments, we apply the density matrix formalism based on Dirac's relativistic equation in order to describe the polarization states of two emitted photons. By using such a formalism, we are able to ana-

lyze *correlations* between the linear polarization of the photons in the $2s_{1/2} \to 1s_{1/2}$ and $3d_{5/2} \to 1s_{1/2}$ decay of neutral hydrogen H as well as hydrogen–like $Xe^{53+}$ and $U^{91+}$ ions. For these ions, we analyze the non–dipole contributions to the polarization correlations and compare our results obtained within the fully relativistic and the electric dipole [1] approximations.
[1] T. Radtke, A. Surzhykov, and S. Fritzsche, PRA **77**, 002507 (2008).

A 15.3 Di 16:30 VMP 9 Poster

**Absolute Determination of X-ray Transition Energies in $S^{14+}$ and $Ar^{16+}$Ions** — •Katharina Kubicek, Hjalmar Bruhns, Johannes Braun, José R. Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut for Nuclear Physics, Heidelberg, Germany

We report on relative and absolute high-precision wavelength experiments for H-like and He-like ions, performed at the Heidelberg Electron Beam Ion Trap (EBIT) using a flat crystal (Si-111) X-ray spectrometer. Our measurements resulted in $\lambda_w = 5038.695(74)\,\text{mÅ}$, or $E_w = 2460.641(32)\,\text{eV}$ for the $1s2p\ ^1P_1 \to 1s^2\ ^1S_0$ resonance line ($w$ transition) in $S^{14+}$. The error of only 13 ppm is a factor of $\sim 3$ smaller than the former most precise value for this transition energy. Our result for the $Ar^{16+}$ $w$ transition, $\lambda_w = 3949.066(8)\,\text{mÅ}$, or $E_w = 3139.583(6)\,\text{eV}$, has an even smaller uncertainty of only 2 ppm being 6 times more accurate than the most precise measurement in any He-like ion and to the present day a factor 2.5 better than any X-ray wavelength determinaton in HCIs ever reported. As expected, in both cases excellent agreement with theory is obtained. The Lyman-$\alpha_1$ X-ray transition wavelength was used as calibration line.

A 15.4 Di 16:30 VMP 9 Poster

**Towards Laser Spectroscopy of the Ground State Hyperfine Splitting in Lithium-like $^{209}Bi^{80+}$** — •Matthias Nothhelfer[1,2], Benjamin Botermann[1,2], Andreas Dax[3], Christopher Geppert[2], Volker Hannen[4], Thomas Kühl[2], Rodolfo Sánchez[2], Thomas Stöhlker[2], Christian Weinheimer[4], and Wilfried Nörtershäuser[1,2] — [1]Universität Mainz, Germany — [2]GSI Darmstadt, Germany — [3]CERN, Genève, Switzerland — [4]Universität Münster, Germany

Measurements of the hyperfine splitting (HFS) in H- and Li-like heavy ions can be used to test QED in extremly strong fields. Comparing the transition frequencies, one can eliminate the contribution of the nuclear magnetization distribution (Bohr-Weisskopf effect) and test QED calculations [1]. $^{209}$Bi is the only isotope, which has the ground state hyperfine transitions of both the H-like and the Li-like ion in a range accessible for laser spectroscopy in traps. So far, measurements have been performed with a relative uncertainty of $1.6 \cdot 10^{-4}$ ($^{209}Bi^{82+}$) [2] and $6 \cdot 10^{-3}$ ($^{209}Bi^{80+}$) [P. Beiersdorfer, priv. comm.], respectively. We are preparing a collinear laser spectroscopic measurement of the HFS in $^{209}Bi^{80+}$ at the Experimental Storage Ring at GSI. This experiment tests QED calculations and facilitates measurements on trapped ions [3] with a potential uncertainty below $10^{-6}$, which will test QED calculations on the level of a few percent.
[1] V. M. Shabaev *et al.*, PRL **86**, 3959 (2001)
[2] I. Klaft *et al.*, PRL **73**, 2425 (1993)
[3] W. Quint *et al.*, PRA **78**, 032517 (2008)

A 15.5 Di 16:30 VMP 9 Poster

**Perspektive für ein Experiment zum Test der Speziellen Relativitätstheorie** — •Benjamin Botermann[1], G. Huber[1], S. Karpuk[1], W. Nörtershäuser[1,4], C. Novotny[1], D. Bing[2], D. Schwalm[2], A. Wolf[2], G. Gwinner[3], C. Geppert[1,4], H.-J. Kluge[4], T. Kühl[4], T. Stöhlker[4], T. W. Hänsch[5], S. Reinhardt[5], G. Saathoff[5] und T. Udem[5] — [1]Johannes Gutenberg Universität Mainz — [2]MPI für Kernphysik, Heidelberg — [3]University of Manitoba, Winnipeg, Canada — [4]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [5]MPI für Quantenoptik, Garching

Durch laserspektroskopische Messungen an Ionenstrahlen in modernen Beschleunigeranlagen können die bislang präzisesten Messungen der Zeitdilatation der Speziellen Relativitätstheorie (SRT) realisiert werden. Am Experimentier-Speicherring des Helmholtzzentrums für Schwerionenforschung wurden entsprechende Experimente an metastabilen $^7Li^+$-Ionen durchgeführt. Die Ionen wurden auf 33,8 % der Lichtgeschwindigkeit beschleunigt, in und entgegengesetzt zu ihrer Flugrichtung mit Laserlicht angeregt und das Fluoreszenzlicht analysiert. Bei Vorgängerexperimenten am MPI für Kernphysik [1] konnte die SRT bei niedrigerer Ionengeschwindigkeit mit hoher Präzision bestätigt werden. Mit dem bisherigen Messaufbau für hohe Ionengeschwindigkeiten können Abweichungen von der SRT mit einer Obergrenze von $3 \cdot 10^{-7}$ ausgeschlossen werden. Der hier vorgestellte Aufbau hat das Potential die Empfindlichkeit um etwa zwei Größenordnungen zu verbessern.
[1] S. Reinhardt et.al. *Nat.Phys.* **3** (2007) 861.

A 15.6 Di 16:30 VMP 9 Poster

**Tiefenauslese orts- und zeitauflösender planarer Halbleiterdetektoren zur Untersuchung hochenergetischer Röntgenstrahlung** — •U. Spillmann[1,2], H. Bräuning[1], S. Hess[1,2], Chr. Kozhuharov[1], Th. Krings[3], R. Reuschl[1,2], D. Protic[3], S. Trotsenko[1,2] und Th. Stöhlker[1,4] — [1]AP, GSI, 64291 Darmstadt — [2]IKF, Goethe-Universität, 60438 Frankfurt am Main — [3]Semikon GmbH, 52428 Jülich — [4]PI, Ruprechts-Karls-Universität, 69120 Heidelberg

Strukturierte energieauflösende Halbleiterdetektoren eröffnen neuartige Methoden in der Röntgen-Spektroskopie. Weiterhin ermöglichen diese Systeme unter Ausnutzung des Compton-Effekts Aussagen über den Polarisationsgrad sowie die Lage des Polarisationsvektors von Röntgenstrahlung. Eine weitere wichtige Anwendung ist die hochpräzise Vermessung atomarer Übergangsenergien in Kristallspektrometerexperimenten. Hier wird neben der hervorragenden Energieauflösung eine deutlich gesteigerte Effizienz im Vergleich zu klassischen Schlitzsystemen, die einfache Dioden einsetzen, erreicht. Gegenstand der aktuellen Arbeiten ist die Analyse der geometrischen und elektronischen Responsefunktion eines beidseitig strukturierten 128x48-Streifendetektors aus hochreinen Germanium, mit dem Ziel neben der zweidimenionalen Ortsinformation auch die Tiefe des Wechselwirkungspunkts im Detektorkristall bestimmen zu können. Somit lassen sich einerseits Parallaxefehler beim Imaging korregieren andererseits kann der Nachweis des Compton-Prozesses in Hinblick auf Compton-Imaging optimiert werden.

A 15.7 Di 16:30 VMP 9 Poster

**Solid-state laser systems for photoionization, laser cooling and coherent manipulation of magnesium ions** — •Daniel Nigg[1], Börge Hemmerling[1], Birgit Brandstätter[2], Lukas An der Lan[2], and Piet O. Schmidt[1] — [1]QUEST Institute for Quantum Metrology, Physikalisch-Technische Bundesanstalt and Leibniz University of Hannover, 38116 Braunschweig, Germany — [2]Institut für Experimentalphysik, Universität Innsbruck, Austria

The challenges of performing precision spectroscopy with metal ions such as $Ti^+$ and $Fe^+$ arising from their complex level structure can be overcome by sympathetically cooling such ions and mapping their states via quantum logic methods to a more accessible 'logic' ion.

This contribution focuses on the details of an all-solid state laser system for photoionization, laser cooling and coherent manipulation of magnesium ions, which are used for sympathetic cooling the ions of interest. A single fibre laser, which is frequency quadrupled using LBO and BBO crystals in combination with electro- and acousto-optical modulators provides all laser frequencies required for this task. The photoionization is implemented by frequency quadrupling a diode laser using a MgO-doped PPLN and a BBO crystal. This laser system is selective to the 1S-1P transition of neutral Mg at 285nm. The autoionizing excited state can then be excited into the continuum by the photoionization laser or the Doppler cooling laser for the magnesium ion.

A 15.8 Di 16:30 VMP 9 Poster

**Fluorescence cascades in Xe II after autoionization of doubly excited neutral Xenon** — •Witoslaw Kielich[1], Pascal Kerdelhué[1], Philipp Reiss[1], Irina Haar[1], Rainer Hentges[1], Philipp V. Demekhin[1,2], Ivan D. Petrov[2], Viktor L. Sukhorukov[2], and Arno Ehresmann[1] — [1]Institute of Physics University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Rostov State University of Transport and Communications, 344038 Rostov-on-Don, Russia

Excitation of two-electron states in rare gas atoms with narrowband synchrotron radiation provides information for the analysis of electron interaction in atomic shells. The 5s/5p Xenon valence electrons, at room temperature and with a target cell pressure of 53.3$\mu$bar, were excited to doubly excited states in the energy range between 26.15eV and 26.35eV. They autoionize and populate singly ionized Xenon states which decay through a two step fluorescence cascade with the first decay in the visible spectral range and the second in the vacuum-ultraviolet. The florescence cascades were measured using the photon-induced fluorescence spectroscopy (PIFS) technique after extreme narrowband excitation at the BESSY II U125/2 10m-NIM beamline. The obtained partial fluorescence cross sections are analyzed in respect of

their dependence as function of the exciting-photon energy.

A 15.9 Di 16:30 VMP 9 Poster

**Compact and robust tunable cw narrowband near IR-VIS-UV source for high-resolution spectroscopy** — •Sergey Vasilyev, Hans-Emanuel Gollnick, Alexander Nevsky, and Stephan Schiller — Institut für Experimentalphysik, Universität Düsseldorf, Universitätsstr 1, 40225 Düsseldorf, Germany

Recent advances in high power fiber laser technology and advent of quasi-phase-matched (QPM) nonlinear materials open new opportunities for development of compact and reliable laser sources for high-resolution spectroscopy.

We report on a narrowband tunable multi-wavelength laser source, designed for laser cooling of the Beryllium ions. The source is based on quintupling of narrowband tunable diode laser (ECDL), amplified to 10 W using the Er doped fiber amplifier. A chain of nonlinear crystals (PPLN, PPSLT, BBO) is used for conversion to the fifth harmonic. The source is turnkey and requires a minimum warm-up time and realignment. The unique feature of the source is tunable multi-wavelength output, spanning from IR to UV: 1540-1570 nm (4 W), 770-785 nm (4 W), 513-523 (1 W), 308-314 nm (1 mW). The UV output power can be further increased by a factor of 20-30 using an enhancement cavity or recently announced UV-capable QPM crystals.

We have performed Doppler-free spectroscopy of the hyperfine-structure components of the molecular iodine using the third harmonic output. These lines could serve for absolute frequency stabilization of the source, providing stable UV radiation e.g. for laser cooling of Beryllium ions.

A 15.10 Di 16:30 VMP 9 Poster

**Nuclear Charge Radii Measurements of $^{7,9,10,11}$Be with Laser Spectroscopy** — •Monika Žáková[1], Zoran Andjelkovic[1], Klaus Blaum[4], Mark L. Bissell[5], Gordon W. F. Drake[6], Christopher Geppert[1,2,3], Magdalena Kowalska[8], Jörg Krämer[1], Andreas Krieger[1], Rainer Neugart[1], Rodolfo Sánchez[2], Ferdinand Schmidt-Kaler[7], Dirk Tiedemann[1], Zong Chao Yan[9], Deyan Yordanov[4], Claus Zimmermann[3], and Wilfried Nörtershäuser[1,2] — [1]Institut für Kernchemie, Universität Mainz, 55099 Mainz, Germany — [2]GSI, 64291 Darmstadt, Germany — [3]Institut für Physik, Universität Tübingen, 72076 Tübingen, Germany — [4]MPI für Kernphysik, D-69117 Heidelberg, Germany — [5]Instituut voor Kern- en Stralingsfysica, Katholieke Universiteit Leuven, 3001 Leuven, Belgium — [6]Department of Physics, University of Windsor, Windsor, Ontario, Canada, N9B 3P4 — [7]Institut für Quanteninformationsverarbeitung, Universitä t Ulm, 89081 Ulm, Germany — [8]CERN, CH-1211 Geneva 23, Switzerland — [9]Department of Physics, University of New Brunswick, New Brunswick, Canada E3B 5A3

The rms nuclear charge radii of $^{7,10,11}$Be have been determined for the first time using frequency-comb based collinear laser spectroscopy online. Spectroscopy with two frequency-stabilized dye lasers and combination with recent precise atomic theory calculations allowed us to extract these charge radii. Of particular interest is the nuclear charge radius of $^{11}$Be, where one of the neutrons is loosely bound to the $^{10}$Be core and creates so called 'halo nucleus'. The obtained isotope shifts for the $D_1$ and $D_2$-lines and the corresponding charge radii are presented.

A 15.11 Di 16:30 VMP 9 Poster

**Towards an optical lattice clock with $^{88}$Sr** — •Thomas Middelmann, Joseph Sundar Raaj Vellore Winfred, Christian Lisdat, Thomas Legero, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt and Centre for Quantum Engineering and Space-Time Research QUEST, Bundesallee 100, 38116 Braunschweig, Germany

Optical clocks achieve a higher stability and lower systematic uncertainty than the current microwave clocks using a hyperfine transition of $^{133}$Cs, that defines the SI second. Thus optical clocks might be used to redefine the SI second. A very promising candidate is strontium. The doubly forbidden $^1S_0 - {}^3P_0$ clock transition is weakly allowed in $^{87}$Sr (linewidth $\approx 1.2$ mHz) and can be induced by a magnetic field in $^{88}$Sr. We trap $^{88}$Sr atoms in a horizontal 1-D optical lattice, where the atoms are confined in the Lamb-Dicke regime to suppress motional effects. At present the highest contributions to the uncertainty of strontium lattice clocks are frequency shifts due to the environmental black body radiation and especially for bosonic $^{88}$Sr collisional shifts. We have measured the influence of collisions on the clock transition and discuss implications for the operation of a clock. To precisely evaluate the black body shift, atoms will be transferred to a cryogenic environment. First tests of the mechanical setup will be presented.

A 15.12 Di 16:30 VMP 9 Poster

**Laser source for spectroscopy of trapped highly charged bismuth ions** — •Sebastian Albrecht, Norbert Herschbach, Gerhard Birkl, and the SPECTRAP collaboration — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, D-64289 Darmstadt

Our objective is to investigate the ground state hyperfine splitting of highly charged ions. Unprecedented precision and accuracy will be achieved by applying high resolution laser spectroscopy to ions cooled and stored in a Penning trap. This experiment is carried out as part of the SPECTRAP collaboration at GSI within the HITRAP facility.

For highly charged $^{209}Bi^{82+}$ ions, transitions between hyperfine ground states can be excited using light at 243.9 nm. We prepared a laser source delivering 20 mW for spectroscopy of these transitions. The scheme we developed to control the laser frequency aims at an accuracy of 2 MHz with respect to an atomic transition used as reference.

A 15.13 Di 16:30 VMP 9 Poster

**High-Precision Experiments on a Single Trapped Radium Ion** — O. Boell, G.S. Giri, K. Jungmann, B.K. Sahoo, R.G.E. Timmermans, •O.O. Versolato, L.W. Wansbeek, and L. Willmann — KVI, University of Groningen, The Netherlands

A single, trapped radium ion is an ideal candidate for high precision experiments. Two $Ra^+$ experiments are under construction at KVI. Ultra-narrow transitions in radium ions provide an excellent basis for an all-optical, high-stability frequency standard, i.e. a clock. The off-the-shelf availability of semiconductor lasers for all necessary transitions is highly advantageous. In certain odd isotopes of radium, the nuclear electric quadrupole shift is absent. The same system and experimental hardware will be used to search for physics beyond the Standard Model of particle physics by measuring Atomic Parity Violation. This will serve as a low-energy test of the running of the electroweak mixing angle. Recent calculations have shown $Ra^+$ to be the superior candidate. Recently we have succeeded in the production and efficient slowing down of isotopes around $^{213}$Ra at the AGOR cyclotron and the TRI$\mu$P facility of KVI. Progress has been made in the development of ion traps and in the laser set-up in a dedicated laser laboratory. Laser spectroscopy of the radium ion and the first ever trapping of this particle are planned in the near future.

A 15.14 Di 16:30 VMP 9 Poster

**A high current electron beam ion trap for fast charge breeding** — •Thomas Baumann, José Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

A new high current electron beam ion trap (EBIT) is constructed at the MPIK Heidelberg. This machine will utilize an up to 5 A electron beam, which is strongly confined by a 7 T magnetic field, to produce and trap highly charged ions from almost any stable element. The electron beam energy will be adjustable between 100 eV and up to 200 keV, while the extremely high current density within the trap region will allow for fast charge breeding, which enables this EBIT to produce He-, H-like or bare ions of heavy elements in hundreds of ms. These ions can be studied by experiments using high resolution spectrometers in the visible, soft x-ray and x-ray spectral range. Furthermore the ions will be extracted out of the EBIT into other experiments like ion-surface interaction measurements, a reaction microscope to study collision dynamics or a penning trap for high precision mass spectrometry.

A 15.15 Di 16:30 VMP 9 Poster

**Resonance of Electromagnetically Induced Absorption in Bichromatic Field for Hanle Setup** — •Andrey A. Zhukov[1,2], Sergey A. Zibrov[3], Vladimir L. Velichansky[3], and Valery P. Yakovlev[2] — [1]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany — [2]Departament of Theoretical Physics, Moscow State Engineering and Physics Institute, 115409 Moscow, Russia — [3]P.N. Lebedev Physical Institute RAS, 117924 Moscow, Russia

The analytic description of the electromagnetically inducied absorbtion (EIA) in the Hanle configuration for the atomic transition $F_g = 1 \leftrightarrow F_e = 2$ is given. It is shown that the absorbtion coefficient depends on the coherence between the marginal ground sublevels. The qualitative explanation of the narrow structure of EIA in weak magnetic field is also discussed. In the case of the backward field acting on the

transition $F_g = 1 \leftrightarrow F_{e'} = 1$, the EIA resonance strongly depend on a power of the backward field. Due to the effective Λ-scheme increasing of the backward field magnitude leads to increasing of the absorption coefficient.

A 15.16 Di 16:30 VMP 9 Poster

**Fundamental symmetries in $^{21}$Na decay** — D.J. van der Hoek, R. Hoekstra, K. Jungmann, •W.L. Kruithof, C.J.G. Onderwater, M. Sohani, L. Willmann, and H.W. Wilschut — KVI, University of Groningen, Groningen, The Netherlands

The $\beta$-$\nu$ correlations in $\beta$-decay allows searching for contributions that go beyond the V-A description of the Standard Model for the electroweak interaction. We are developing an experimental setup to measure correlations in the $\beta$-decay of $^{21}$Na. By trapping the radioactive atoms, the recoiling nucleus (kinetic energy $<$ 230 eV) can be measured in a reaction microscope in coincidence with the emitted $\beta$ particle. The first step is to study $\beta$-$\nu$ correlations that allows to set limits on scalar and tensor contributions. By polarizing the parent nucleus it becomes possible to search for time reversal violation. The production and trapping of $^{21}$Na has been accomplished. Details of the setup with a two laser system and the status of this phase of the program will be described.

A 15.17 Di 16:30 VMP 9 Poster

**Laser Spectroscopy of atomic Radium** — Alexander Groot, Klaus Jungmann, •Bodhaditya Santra, Lorenz Willmann, and Hans W. Wilschut — KVI, University of Groningen, The Netherlands

The heavy alkaline earth elements radium (Ra) offers a unique sensitivity to a parity and time reversal violating permanent electric dipole moments (EDM). In particular, Ra exhibits the largest known atomic enhancements factors for EDMs. The intrinsic sensitivity arises from the specific atomic and nuclear structure of Ra. All Ra isotopes with nuclear spin I are radioactive. The lifetimes are shorter than 15d. Several Ra isotopes are available at the TRI$\mu$P facility at KVI. For the exploitation of the sensitivity Ra atoms have to be collected in a neutral atom trap. The main laser cooling will be done on the strong $^1$S$_0$-$^1$P$_1$ transition at 482.7nm, similar to the laser cooling and trapping of the chemical homologue barium. Laser spectroscopy of the strong $^1$S$_0$-$^1$P$_1$ transitions will be presented. The light at this wavelength is provided by frequency doubling of a Ti:sapphire laser in a $KNbO_3$ crystal. Of particular interest is the decay branching of the excited state to the metastable D-states. Such measurements are indispensable input for current atomic structure calculations, which are necessary for the analysis of a EDM measurement using Ra.

A 15.18 Di 16:30 VMP 9 Poster

**Laser excitation and light shifts of highly charged ions** — •Octavian Postavaru, Zoltan Harman, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Recent developments in laser technology allow the probing of highly charged ions in the strong field and in the x-ray domain, providing one new insights into relativistic electron dynamics, nuclear and quantum electrodynamic effects [1,2]. The interaction of ions with the laser field leads to resonant excitation of the bound electrons and to dynamic shifts of the energy levels. We apply a relativistic description of the excitation process and the light shifts by means of the Dirac equation, as necessary in the case of higher nuclear charges and for transitions which are nonrelativistically forbidden. We investigate excitation schemes by which the accuracy of measurements can be significantly improved, leading to new physical findings. The results are relevant for experiments with at present and near-future laser systems like the FLASH [1] and the PHELIX [2] facilities.

[1] S.W. Epp, J.R. Crespo López-Urrutia, G. Brenner *et al.*, Phys. Rev. Lett. 98, 183001 (2007)

[2] P. Neumayer, R. Bock, S. Borneis *et al.*, Laser and Particle Beams 23, 385 (2005)

A 15.19 Di 16:30 VMP 9 Poster

**An Optical Dipole Trap Target for a Reaction Microscope** — •Renate Hubele, Michael Schuricke, Jochen Steinmann, Ganjun Zhu, Alexander Dorn, and Joachim Ullrich — Max Planck Institut für Kernphysik, Heidelberg, Germany

For a thorough understanding of atomic reactions high quality experimental data on fundamental quantum systems are indispensable. One of the most sophisticated tools to study atomic fragmentation processes is the Reaction Microscope (REMI), which allows for a coincident detection of the full vector momenta of all charged final state particles over a solid angle of up to $4\pi$. In recent years the merging of REMI spectrometers with magneto optically trapped targets became popular (MOTRIMS). Among the most important benefits of this combination compared to the conventional setup using gas jets, are lower target temperatures in the mK-regime allowing for a improved momentum resolution and the possibility of accessing target species like lithium that are hardly produced in a supersonic expansion.

However, if electrons are also to be detected, MOTRIMS setups suffer from transient eddy currents induced by the rapid turn-off of the MOT fields, limiting the momentum resolution due to stray magnetic fields in the electron spectrometer.

Therefore, our new setup will combine for the first time a purely optical dipole trap (FORT) with a REMI. Since we are already successfully operating a MOTRIMS experiment, we are now implementing a FORT in order to perform fully differential studies of lithium double and triple ionisation by photon or electron impact.

A 15.20 Di 16:30 VMP 9 Poster

**Towards Laser Spectroscopy on Lithium II** — •Mariusz Semczuk[1,2], Guido Saathoff[1], Valentin Batteiger[1], Maximilian Herrmann[1], Sebastian Knünz[1], Hans Schuessler[3], Thomas Udem[1], and Theodor Hänsch[1] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Institute of Experimental Physics, University of Warsaw — [3]Dept. of Physics, Texas A&M University, Texas

Simple atomic systems like hydrogen and helium have been subject to great interest as they allow for sensitive tests of Quantum Electrodynamics. Helium spectroscopy, in particular, has been considered as one way of determining an accurate value of the fine-structure constant. The constant $\alpha$ can be derived from the fit of a theoretical calculation of the He $2^3$P level fine structure to measured values. While the fine structure has been measured to high accuracy [1], there is still a significant discrepancy between two theoretical calculations [2]. In order to help solve this open problem in bound-state QED, we plan to measure the $2^3$P fine structure in helium-like $Li^+$. The lithium ion provides the advantage that it can be trapped and laser-cooled in an ion trap. Moreover the $Li^+$ fine structure is more sensitive to higher-order QED terms as these scale with large powers of Z. The measurement is complicated by hyperfine structure. We thus aim at a measurement of the complete hyperfine structure multiplet of the $2^3S_1$-$2^3P_{0,1,2}$ optical transition in $^7Li^+$ to extract both the hyperfine and fine structure simultaneously.

[1] T. Zelevinsky, *et al.*, Phys. Rev. Lett. 95, 203001 (2005).
[2] G.W. F. Drake, Can. J. Phys. 80, 1195 (2002); K. Pachucki, Phys. Rev. Lett. 97, 013002 (2006)

A 15.21 Di 16:30 VMP 9 Poster

**Untersuchung von angeregten Zuständen in He-artigem Uran durch Messung des $^3P_0$ Zustands** — •Regina Reuschl[1,2], Heinrich Beyer[2], Dieter Liesen[2], Daniel Thorn[1,2], Danyal Winters[2] und Thomas Stöhlker[2,3] — [1]ExtreMe Matter Institute EMMI, Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]Ruprecht-Karls-Universität, Heidelberg

Helium-artige Ionen sind einfache Systeme, die sich hervorragend zur Untersuchung von Mehrkörpereffekten der atomaren Struktur eignen. Besonders die Beiträge der Quantenelektrodynamik (QED) in starken Feldern sind hier von Interesse. Je schwerer ein Ion ist, desto stärker sind die elektrischen Felder in der Nähe des Kerns und umso größer sind die Beiträge der QED. Aus diesem Grund ist in den vergangenen Jahren sehr stark an der theoretischen Auswertung der Korrekturterme höherer Ordnung gearbeitet worden [1].

Aufgrund geringer Energieunterschiede in den angeregten Niveaus ist es nicht immer möglich, einen direkten Zugang zu den relevanten Übergängen zu finden. Daher möchten wir mit der Beam-Foil-Spektroskopie Lebensdauermessungen des $(1s2p)^3P_0 \rightarrow (1s2s)^3S_1$ Übergangs durchführen. Diese Methode hat bereits in früheren Experimenten erfolgreich Anwendung gefunden [2,3]. Durch die Verwendung neuartiger Detektoren und somit eines verbesserten Aufbaus, möchten wir die Genauigkeit der bisherigen Lebensdauermessungen des $2^3P_0$ Zustands um eine Größenordnung verbessern.

[1] A. Artemyev et al., PRA **71**, 062104 (2005) [2] S. Toleikis et al., PRA **69**, 022507 (2004) [3] S. Toleikis et al., NIM B **235**, 197 (2005)

A 15.22 Di 16:30 VMP 9 Poster

**Methoden zur hochgenauen Laserspektroskopie verbotener Übergänge in hoch geladenen Ionen** — •Manuel Vogel[1],

Wilfried Nörtershäuser[2], Wolfgang Quint[2] und Richard Thompson[1] — [1]Imperial College London, SW7 2BZ London — [2]GSI, 64291 Darmstadt

Wir präsentieren eine Reihe experimenteller Methoden zur hochgenauen spektroskopischen Bestimmung verbotener Übergänge in hoch geladenen Ionen mit relativen Unsicherheiten von etwa $10^{-7}$ bis unter $10^{-10}$. Augenmerk liegt auf Feinstruktur- und Hyperfeinstruktur-Übergängen, die sich im zugänglichen Bereich für Laseranregung befinden. Die Methoden basieren auf der Speicherung extern erzeugter Ionen in einer Penning-Falle bei Temperaturen von 4 K und nutzen die entsprechend niedrige Teilchengeschwindigkeit sowie spezielle Manipulationen der Speicherbewegungen. Der Nachweis der Übergänge erfolgt entweder optisch oder aber rein elektronisch. Kandidaten für Messungen der Feinstruktur sind leichte bor- und kohlenstoff-artige Ionen. Für Hyperfeinstruktur-Übergänge sind schwere wasserstoff- und lithium-artigen Ionen interessant. Derartige Messungen mit den hier möglichen Präzisionen stellen hochempfindliche Tests theoretischer Vorhersagen im Rahmen der QED gebundener Zustände dar. Sie erlauben zugleich Zugriff auf das magnetische Moment des Elektrons, sowie das des Atomkerns in Abwesenheit diamagnetischer Abschirmung. Die zugehörigen Experimente befinden sich im Rahmen des HITRAP-Projekts der GSI, Darmstadt, im Rahmen der SPARC-Kollaboration und des Zukunftsprojektes FAIR im Aufbau.

A 15.23 Di 16:30 VMP 9 Poster

**Mg-Candidate for an optical atomic clock** — •Temmo Wübbena[1], Jan Friebe[1], Matthias Riedmann[1], Andre Pape[1], Osama Terra[2], Gesine Grosche[2], Wolfgang Lipphardt[2], Harald Schnatz[2], Ernst M. Rasel[1], and Wolfgang Ertmer[1] — [1]Institute of Quantum Optics, University of Hanover, Welfengarten 1, 30167 Hannover — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Mg belongs to the small group of the elements suitable for a next generation optical atomic clock. We have recently measured the frequency of the clock transition $(3s^2)^1S_0 \rightarrow (3s3p)^3P_1$ on a thermal atomic beam apparatus with an accuracy on the level of $10^{-12}$. From this measurement we could derive the frequency of the strongly forbidden $(3s^2)^1S_0 \rightarrow (3s3p)^3P_0$ intercombination transition which will be of interest as a clock transition for a future lattice clock. In this poster we present the current status of our work towards the realization of an optical lattice clock with Mg including an improved frequency measurement based on cold Mg atoms via telecom fiber network and a characterization of our new MOT in the triplet system. This metastable MOT serves as an efficient detector for the atoms that were excited in our Ramsey Borde atom interferometer. At the same time it will be the starting point for new cooling approaches since the cooling in the triplet system is not limited by the Doppler theory and we expect to reach temperatures which enable efficient loading an optical dipole trap.

A 15.24 Di 16:30 VMP 9 Poster

**Polarisationsmessungen Radiativer Einfangstrahlung in Uran und Xenon mit neuartigen 2D Halbleiterdetektoren** — Sebastian Hess[1,2], Harald Bräuning[1], Sabrina Geyer[1,2], •Ajay Kumar[1], Renate Märtin[1,2], Regina Reuschl[1,2], Uwe Spillmann[1], Martino Trassinelli[3,1], Sergej Trotsenko[1,2], Siegbert Hagmann[1,2], Günter Weber[1,4] und Thomas Stöhlker[1,4] — [1]GSI, Hemholtzzentrum für Schwerionenforschung GmbH — [2]Institut für Kernphysik, Universität Frankfurt — [3]Universite Pierre et Marie Curie-Paris 6 — [4]Physikalisches Intitut, Universität Heidelberg

Neuartige energie- zeit- und ortsauflösende 2D Halbleiterdetektoren erlauben seit jüngster Zeit die Messung der Polarisation von Röntgenstrahlung aus atomphysikalisch relevanten Prozessen. Am Experimentierspeicherring der GSI, verwendeten wir einen 2D Silizium Detektor als Compton Polarimeter, um die Polarisation der Strahlung des Radiativen Elektroneneinfangs in die K- und erstmals auch in die energetisch partiell aufgelösten L-Schalen von nacktem sowie wasserstoffähnlichem Uran experimentell zu erschließen. Außerdem nutzten wir den Radiativen Einfang in die K-Schale von nacktem Xenon, um die Vorgänge in dem Detektor mit einer aktiven Fläche von 64 x 64 mm und einer Dicke von 7mm sowie einer Aufteilung von jeweils 32 einzeln auslesbaren Streifen auf Vorder- und Rückseite im Detail zu untersuchen.

A 15.25 Di 16:30 VMP 9 Poster

**Improved measurement of the 2S hyperfine splitting in atomic hydrogen and 1S-2S isotopic shift in deuterium** — •Janis Alnis, Arthur Matveev, Nikolay Kolachevsky, and Theodor Hänsch — MPI of Quantum Optics, Garching near Munich

Atomic hydrogen is the simplest atom that can be calculated theoretically with great precision and better experimental data allow to make higher order Quantum Electrodynamics (QED) corrections. In 2008 we have performed a series of measurements allowing to improve the precision of a 2S hyperfine structure (HFS) interval more than two times comparing to the 2004 result [1] and the new value is 177556834.3(6.7) Hz [2]. An important improvement was to perform measurements using two independent stable laser systems simultaneously. The spectroscopy laser was scanned sequentially across the singlet and the triplet 1S-2S two-photon transitions while the reference laser [3] was all the time locked to a stable Fabry-Perot cavity. This method allowed to detect immediately any instabilities in spectroscopy laser frequency during the laser scanning and re-locking. As a next step we propose to remeasure the isotopic shift of the 1S-2S transition between atomic hydrogen and deuterium.

1. N. Kolachevsky, et al., Phys. Rev. Lett. **92**, 033003 (2004)
2. N. Kolachevsky et al., arxiv.org
3. J. Alnis et al. Phys. Rev. A. **77**, 053809 (2008)

A 15.26 Di 16:30 VMP 9 Poster

**A trapped-ion phonon laser** — •S Knünz[1], V Batteiger[1], M Herrmann[1], T Udem[1], T W Hänsch[1], and K Vahala[2] — [1]MPQ, Hans Kopfermann-Strasse, 85748 Garching — [2]California Institute of Technology, Pasadena, CA 91125

A single trapped $Mg^+$ ion is laser-cooled within a Paul trap by a red-detuned laser. Illuminated with a blue-detuned pump laser the ion exhibits oscillatory motion with a well defined threshold. We show that this is not the result of heating but of stimulated emission of center-of-mass phonons, constituting the mechanical analog of a laser.

A 15.27 Di 16:30 VMP 9 Poster

**daming in 2D and 3D dilute Bose gas** — •Ming-Chiang Chung — Academia Sinica Taiwan

Damping in 2D and 3D dilute gases is investigated using both the hydrodynamical approach and the Hartree-Fock-Bogoliubov (HFB) approximation . We found that the both methods are good for the Beliaev damping at zero temperature and Landau damping at very low temperature, however, at high temperature, the hydrodynamical approach overestimates the Landau damping and the HFB gives a better approximation. This result shows that the comparison of the theoretical calculation using the hydrodynamical approach and the experimental data for high temperature done by Vincent Liu (PRL **21** 4056 (1997)) is not proper. For two-dimensional systems, we show that the Beliaev damping rate is proportional to $k^3$ and the Landau damping rate is proportional to $T^2$ for low temperature and to $T$ for high temperature. We also show that in two dimensions the hydrodynamical approach gives the same result for zero temperature and for low temperature as HFB, but overestimates the Landau damping for high temperature.

A 15.28 Di 16:30 VMP 9 Poster

**Matter-wave interference on an atom chip** — •Philipp Wicke, Shannon Whilock, Jan-Joris van Es, Aaldert van Amerongen, and Klaasjan van Druten — University of Amsterdam, The Netherlands

Atom chips are extremely versatile tools for trapping and manipulating quantum gases on a micrometer scale in close proximity to a surface. They can produce tightly confining magnetic potentials and provide unprecedented experimental access to novel low dimensional regimes [1]. Recently we have investigated radio frequency dressed potentials on atom chips, which provide even further control over the associated trapping potentials [2]. In general, the three-dimensional rf-dressed potential forms a connected pair of one-dimensional waveguides, used to coherently split a single Bose condensate in two parts and to observe matter wave interference upon overlap. We study the phase coherence of quasi-condensates from the resulting interference patterns, observed simultaneously in both the transverse and longitudinal directions. These experiments probe the dynamics of quantum-degenerate Bose gases in the one-dimensional regime. Possible future directions include fundamental studies of two-component quantum gases and soliton formation for two coupled condensates.

[1] van Amerongen et al., Phys. Rev. Lett. 100, 090402 (2008)
[2] van Es et al., Phys. Rev. A 77, 063623 (2008)

A 15.29 Di 16:30 VMP 9 Poster

**Superconducting Microtraps for Cold Atom Experiments** — •Florian Jessen, Daniel Cano, Brian Kash, Helge Hattermann, Max Kahmann, Dieter Kölle, Reinhold Kleiner, Claus Zimmermann, and József Fortágh — Center for Collective Quantum Phenomena and their Applications, Auf der Morgenstelle 14, 72076 Tübingen

We report on the realization and characterization of an experimental system to produce Bose-Einstein Condensates in a superconducting chip. Ultracold $^{87}$Rb atomic clouds are produced in a magneto-optical trap and further cooled by evaporative cooling in an Ioffe trap. The atoms are transported from the Ioffe trap to the superconducting chip by means of optical tweezers. The superconducting chip is attached to the cold finger of a Helium-flow cryostat. We show recently-built superconducting chips that have been designed to minimize the impact of the Meissner effect on the magnetic potentials. In general, the Meissner effect reduces the trap depth as this is brought close to the superconducting surface [1]. These chip structures will allow experimental studies on interactions between superconductors and ultracold atom clouds. [1] D. Cano *et al.*, Phys. Rev. A **77**, 063408 (2008)

A 15.30 Di 16:30 VMP 9 Poster

**Towards a Gross-Pitaevskii-Boltzmann Equation** — •Luis Rico Perez and James Anglin — Technische Universität Kaiserslautern

Despite many progresses in the theoretical description of cold atoms have been achieved, the search of a general but at the same time simple formalism explaining nonequilibrium phenomena in cold bosons - as the condensation process, heating or collisions between two of them - is still an interesting problem. We develop a simple description of cold interacting bosons based on the single particle density matrix rather than the macroscopic wave function, which is therefore able to include thermodynamic properties of the gas on an equal footing with Gross-Pitaveskii mean field dynamics. Our theory includes incoherent scattering as well as Gross-Pitaevskii coherent interaction, by adapting Boltzmann's classical *Stosszahlansatz* to time-dependent s-wave scattering of wave packets.

A 15.31 Di 16:30 VMP 9 Poster

**Design and setup of a trap for ultracold lithium atoms as a scattering target for cold atom-molecule collision studies** — •Tim Eichhorn, Matthias Strebel, Marcel Mudrich, and Frank Stienkemeier — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

In order to experimentally investigate reactive and non-reactive collisions we plan to combine a magneto-optical trap and a magnetic trap with a setup for producing slow beams of cold molecules by means of supersonic expansion from a rotating nozzle. Studying scattering processes, e.g. Li + HF -> LiF + H, with collision energies down to 1 meV we expect to get insight into the quantum mechanical nature of cold reaction dynamics.

For trapping lithium atoms at very low temperatures we present calculations and design features for a compact setup consisting of a magneto-optical trap (MOT) and a magnetic trap. The MOT will be loaded from a decreasing field type Zeeman-slower and operated with a high-power diode laser system, which is based on a master-slave scheme.

A 15.32 Di 16:30 VMP 9 Poster

**Local superfluidity in finite 2D helium systems** — •Jens Böning, Alexei Filinov, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts Universität, Kiel, Germany

It was shown previously[1], that the superfluid density vanishes nonhomogeneously upon density induced freezing in harmonically trapped 2D systems of charged bosons. While the total superfluid fraction declines, the radial distribution of the superfluid density becomes localized either in the core or at the boundary of the system. Our investigations revealed that the driving mechanism behind this behavoir is related to the hexagonal ordering in the system. In this work we extend our analysis to 2D systems of trapped helium atoms. We consider two kinds of trapping, firstly a harmonic trap as used in our Coulomb systems, and secondly a hard wall confinement. We employ the path-integral Monte-Carlo method with worm algorithm extension[2] for our simulations which requires no approximations on interaction potentials.

[1] A. Filinov, J. Böning, M. Bonitz, and Yu. Lozovik, *Phys. Rev. B* **77**, 214527 (2008)

[2] M. Boningsegni, N. V. Prokof'ev, and B. V. Svistunov, *Phys. Rev. E* **74**, 036701 (2006)

A 15.33 Di 16:30 VMP 9 Poster

**An ultracold fermion mixture of $^6$Li and $^{40}$K** — •Antje Ludewig, Tobias Tiecke, Sebastian Kraft, Steve Gensemer, and Jook Walraven — University of Amsterdam, The Netherlands

We report on the creation of an ultracold mixture of the fermionic alkali isotopes $^6$Li and $^{40}$K in an optical dipole trap. In the same trap we have realized a three-component degenerate spin mixture of $^{40}$K . To create the mixtures we start by loading a two-species magneto-optical trap (MOT) from two separate 2D-MOT sources. This is the first time a 2D-MOT source is realized for lithium. The source is clean, cold (30 m/s) and yields 3D-MOT loading rates of up to $10^9$ $^6$Li atoms/s. The mixtures are then captured in an optically-plugged magnetic quadrupole trap. The plug is realized with a 10 W Verdi (532nm) focused to a 14 $\mu$m waist. After forced evaporative cooling on the F=9/2-F=7/2 hyperfine transition of $^{40}$K to a temperature of 10 $\mu$K the $^6$Li - $^{40}$K mixture can be loaded in the optical dipole trap. The lithium temperature follows by sympathetic cooling. Thus so far we have realized degenerate spin mixtures of $10^6$ $^{40}$K-atoms at T = 0.3(1)TF. For the dipole trap we use a 5 W IPG fiber laser (1070 nm) focused to a 20 $\mu$m waist. By translating the dipole trap focus we have - without significant losses - transported an ultracold sample of $^{40}$K over a distance of 16 cm into a science cell. We report on our progress investigating many-body phenomena close to a Feshbach resonance using coils designed for high homogeneity.

A 15.34 Di 16:30 VMP 9 Poster

**Berezinskii-Kosterlitz-Thouless transition in two-dimensional dipole systems** — •Alexey Filinov[1,3], Nikolay Prokof'ev[2], Michael Bonitz[1], and Yurii Lozovik[3] — [1]Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität, Leibnizstr. 15, D-24098 Kiel, Germany — [2]Department of Physics, University of Massacusetts, Amherst, Massachusetts 01003, USA — [3]Institute of Spectroscopy of the Russian Academy of Sciences, Troitsk, Russia

Dilute dipole gases of polar molecules and indirect excitons in quantum wells are of increasing interest in recent experimental realizations [1,2], since they allow to realize and control correlations and quantum degeneracy effects. Using path integral Monte Carlo we investigate the normal-superfluid transition in a system of 2D bosonic dipoles which models such experiments in the full temperature-density plane. The critical temperature, superfluid fraction, thermodynamic sound speed and compressibility have been evaluated for different dipole coupling strengths/densities. For indirect excitons at high densities the dipole approximation becomes invalid. We, therefore, take into account the internal exciton structure and derive new effective interaction which crucially effects the phase diagram at high densities.

[1] J.M. Sage *at al.*, Phys. Rev. **94**, 203001 (2005); D. Wang *at al.*, Phys. Rev. **93**, 243005 (2004). [2] Timofeev V *et al* 2007 *J. Phys: Cond. Matt.* **19** 295209.

A 15.35 Di 16:30 VMP 9 Poster

**Efficient guiding of cold atoms through a photonic band gap fiber** — •Stefan Vorrath[1], Sönke Möller[1], Kai Bongs[2], and Klaus Sengstock[1] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]MUARC, School of Physics and Astronomy, University of Birmingham, Edgebaston, Birmingham B15 2TT, UK

We report on the first demonstration of guiding cold atoms through a photonic band gap fiber. The setup consists of a sample of cold atoms from a MOT which is transferred into a red detuned optical dipole trap laser beam which guides the atoms through a 12$\mu$m hole within the photonic fiber.

A very promising environment for further experiments seems to be the nearly perfect 1D optical potential inside the hollow core of the fiber. By measuring the number of atoms transferred through the fiber we have estimated a very high atomic density. This leads to a very high optical depth inside the fiber and can possibly be used for studying nonlinear optical effects in a regime of very low optical power but very strong atom-light interaction.

A 15.36 Di 16:30 VMP 9 Poster

**Density of states for a cold Bose gas in an optical dipole trap** — •Lena Simon and Walter T. Strunz — Institut für theoretische Physik, TU Dresden, 01062 Dresden

Optical dipole traps are frequently employed to provide confining potentials for neutral atoms, as practiced in the Helm group at the university of Freiburg. According to this experiment we study an ultracold Bose gas in an optical dipole trap consisting of one single focused laser beam. An analytical expression for the corresponding density of states beyond the usual harmonic approximation is obtained. We are thus able to determine the critical temperature for Bose-Einstein condensation and find that it depends on a cutoff parameter. Moreover, we study the dynamics of plain and forced evaporative cooling and observe a significant deviation from the well-established harmonic approximation.

A 15.37 Di 16:30 VMP 9 Poster

**EIT and cooling by EIT in an optical dipole trap** — •Andreas Ahlrichs, Carl Basler, Christoph Käfer, Maryam Roghani, and Hanspeter Helm — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

We attempt an experiment in which Rb-atoms which are pre-cooled in a UHV MOT and then transferred into a $CO_2$-laser trap are cooled further by electro-magnetically-induced transparency. The scheme is that predicted to work in a recent publication (MR and HH PRA 77 043418 (2008)) even under conditions far from the Lamb-Dicke limit. In this presentation we discuss the limitations which should appear in EIT-cooling of neutral atoms and the rather stringent experimental conditions required to be met for successful implementation of the scheme. The storage time of 1 minute which we achieved in our single beam $CO_2$-laser trap appear well sufficient to cool over the required millisecond time period. We hope to also present first experimental results on this topic.
Research supported by DFG HE2525/7-1

A 15.38 Di 16:30 VMP 9 Poster

**Spin Struktur von Rb-Spinor-Kondensaten** — •Hosnieh Safaei Katoli und Daniela Phannkuche — I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg, Germany

Spinor-Kondensate sind Modellsysteme, an denen magnetische Strukturenin Reinform untersucht werden können. Ihre magnetischen Phasen resultieren aus der spinabhängigen Wechselwirkung in Bezug auf die Streulängen der Atome eines Bose-Einstein-Kondensats (BEC) und können durch äußere Magnetfelder beeinflusst werden. Wir untersuchen numerisch die Entwicklung der Spin-Strukturen von Rb-Atomen im F = 1 und F = 2-Zustand mit Hilfe der mehrkomponentigen Gross-Pitaevski-Gleichung, die die Eigenschaften von BEC erstaunlich gut beschreibt. Für ein F=1 System unter der Nebenbedingung einer verschwindenden z-Komponente des Gesamtspins führt das Wechselspiel von linearem und quadratischem Zeeman-Effekt zu drei unterschiedlichen magnetischen Phasen, die sich durch die Besetzung der einzelnen Spin-Komponenten charakterisieren lassen. In der ferromagnetischen Phase kann die Fz = 1-Domäne von der Fz = 1-Domäne durch ein Gradienfeld räumlich getrennt werden. In Abwesenheit eines magnetischen Feldes existieren für F = 2-Systeme drei verschiedene Phasen, die sich auf Grund unterschiedlicher spinabhängiger Wechselwirkungen ausbilden.In unserem Beitrag untersuchen wir den Einfluss des Zeeman-Effektes auf diese Phasen.

A 15.39 Di 16:30 VMP 9 Poster

**The thermal Bose gas - a stochastic approach** — •Sigmund Heller and Walter T. Strunz — Institut für Theoretische Physik, Universität Dresden

Temperature dependent quantities like spatial correlation functions [1], density fluctuations [2] and interference contrast [3] are measured in current experiments with ultracold Bose gases. In order to describe these experiments, we present a novel stochastic evolution equation, which enables us to obtain the thermal state of the canonical ensemble. The equation provides a full quantum field description and therefore does not suffer from cutoff problems, which usually occur for classical field equations. Furthermore, it is possible to solve the equation in position space with suitable effort - no knowledge of eigenfunctions or eigenenergies of the external potential is required. The equation is derived for the non interacting case, but drawing on analogies with the classical case, it is more than tempting to include the interaction in a mean field sense. We present numerical simulations for the ideal and for the interacting gas and calculate many different quantities like the ground state occupancy, variance of the ground state occupancy and spatial correlation functions.

[1] I. Bloch, T.W. Hänsch and T. Esslinger, Nature 403, 166 (2000).
[2] J. Esteve, J. B. Trebbia, T. Schumm, A. Apect, C. I. Westbrook, and I. Bouchle, Pyhs. Rev. Lett. 96, 130403 (2006).
[3] R. Gati, B. Hemmerling, J. Fölling, M. Albiez and M. K. Oberthaler, Phys. Rev. Lett. 96, 130404 (2006).

A 15.40 Di 16:30 VMP 9 Poster

**Trapped interacting bosons beyond the Gross-Pitaevskii approximation** — •Martin Heimsoth, Michael Bonitz, and Alexej Filinov — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität Kiel, Leibnitzstraße 15

Systems consisting of cold interacting bosons show interesting collective phenomena such as Bose-Einstein condensation or superfluidity [1,3] and are currently studied in condensed matter and atomic physics. There exist several approximation methods to such systems [2]. Here we analyse the ground-state of a two-dimensional Bose system consisting, with an approximation that was first introduced by Romanovskii [2]. We extend this Method to higher particle numbers and compare the results to quantum Monte Carlo simulations.

Furthermore, an extension to the non-equilibrium regime is developed by analysing the the dynamics of the system following short-pulse laser excitations. The excitation of collective modes, such as the breathing and center-of-mass oscillation, is of particular interest.

[1] A. Filinov, J. Boning, M. Bonitz, and Yu. Lozovik. Controlling the spatial distribution of superfluidity in radially ordered coulomb clusters. Physical Review B (Condensed Matter and Materials Physics), 77(21):214527-5, June 2008.
[2] I. A. Romanovsky. Novel properties of interacting particles in small low-dimensional systems. PhD thesis, September 2006.
[3] M. Heimsoth and M. Bonitz. Physica (2009)

A 15.41 Di 16:30 VMP 9 Poster

**Equilibrium properties of charge-asymmetric quantum-bilayers** — •Lasse Rosenthal, Karsten Balzer, Alexej Filinov, and Michael Bonitz — Institut für Theoretische und Astrophysik, Christian-Albrechts-Uniersität, Leibnitzstraße 15, 24098 Kiel

We present a quantum-statistical treatment of the equilibrium properties of 2-dimensional quantum bilayers with spatially separated electrons and holes[1]. In the regime of intermediate coupling the system is described by solving the self-consistent Hartree-Fock equations[2].

We compute the single-particle spectrum and density profiles of up to $N = 19$ electrons and holes. The influence of different mass ratios of electrons and holes is investigated. Results of spin-polarized calculations are compared to spin unrestricted calculations.

For moderate coupling the description is extended to include correlation effects. This is done by solving Dyson's equation for the equilibrium Matsubara Greens-function.

[1]P.Ludwig, K.Balzer, A.Filinov, H.Stolz and M.Bonitz, New J.Phys.10 083031
[2]M.Bonitz, D.Semkat(Eds.), Introduction to Computational Methods in Many Body Physics, Rinton Press, Princeton (2006)

A 15.42 Di 16:30 VMP 9 Poster

**Few-electron quantum dots within a nonequilibrium Green's functions study** — •Karsten Balzer, David Hochstuhl, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität Kiel, Leibnizstrasse 15, 24098 Kiel, Germany

Carrier-carrier correlations in few-electron quantum dots (QDs)—artificial atoms [1] with parabolic confinement—are studied by means of nonequilibrium Green's functions (NEGF) theory. Starting from an (un)restricted Hartree-Fock reference state, the Dyson equation is solved in the time domain [2] at zero and finite temperatures including 2nd Born and *GW* interaction kernels. We focus on strongly correlated QDs, the electron density in which is tunable by the strength of the confining potential. Considering system sizes with up to 12 electrons in one- and two-dimensional confinements, the computed ground state and equilibrium properties incorporate the self-consistent total energies, the single-carrier densities, the orbital-resolved distribution functions as well as the one-electron spectral functions [2]. The comparison of the results with Configuration Interaction [3,4] and path integral Monte Carlo [4,5] comprises the crossover from Fermi liquid to Wigner molecule or crystal behavior [5] and reveals good agreement with the NEGF approach.

[1] R.C. Ashoori, Nature 379, 413 (1996). [2] K. Balzer et al., submitted to Phys. Rev. B (2008). [3] B. Reusch et al., Phys. Rev. B 63, 113313 (2001). [4] M. Rontani et al., J. Chem. Phys. 124. 11 (2006). [5] A.V. Filinov et al., Phys. Rev. Lett. 86, 17 (2001).

A 15.43 Di 16:30 VMP 9 Poster

**Quantum breathing mode of charged fermions and bosons at arbitrary coupling** — •Sebastian Bauch, Karsten Balzer, Christian Henning, David Hochstuhl, and Michael Bonitz — Christian-Albrechts-Universität Kiel, Institut für Theoretische Physik und Astrophysik, Leibnizstraße 15, 24098 Kiel, Germany

We present a detailed analysis of the quantum breathing behavior of few-particle Coulomb systems in one- and two-dimensional harmonic traps. While the behavior in limiting cases, the *classical* limit and the *ideal* quantum limit, are well-known [e.g. 1, 2], we report a smooth transition behavior in between by variation of the relative interaction strength. We further show, that spin-statistic effects, i.e. the symmetry of the wave function, play an important role. We solve the many particle Schrödinger equation and compare with mean-field Hartree Fock calculations. The numerically obtained results may serve as an experimental tool to probe small interacting quantum systems.

[1] C. Henning, K. Fujioka, P. Ludwig, A. Piel, A. Melzer and M. Bonitz, Phys. Rev. Lett. **101**, 045002 (2008)

[2] M. R. Geller and G. Vignale, Phys. Rev. B **53**, 6979 (1996)

A 15.44 Di 16:30 VMP 9 Poster

**Spin Struktur von Rb-Spinor-Kondensaten** — •Hosnieh Safaei Katoli und Daniela Phannkuche — I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg, Germany

Spinor-Kondensate sind Modellsysteme, an denen magnetische Strukturenin Reinform untersucht werden können. Ihre magnetischen Phasen resultieren aus der spinabhängigen Wechselwirkung in Bezug auf die Streulängen der Atome eines Bose-Einstein-Kondensats (BEC) und können durch äußere Magnetfelder beeinflusst werden. Wir untersuchen numerisch die Entwicklung der Spin-Strukturen von Rb-Atomen im F = 1 und F = 2-Zustand mit Hilfe der mehrkomponentigen Gross-Pitaevskii-Gleichung, die die Eigenschaften von BEC erstaunlich gut beschreibt. Für ein F=1 System unter der Nebenbedingung einer verschwindenden z-Komponente des Gesamtspins führt das Wechselspiel von linearem und quadratischem Zeeman-Effekt zu drei unterschiedlichen magnetischen Phasen, die sich durch die Besetzung der einzelnen Spin-Komponenten charakterisieren lassen. In der ferromagnetischen Phase kann die $F_z$ = 1-Domäne von der $F_z$ = -1-Domäne durch ein Gradienfeld räumlich getrennt werden. In Abwesenheit eines magnetischen Feldes existieren für F = 2-Systeme drei verschiedene Phasen, die sich auf Grund unterschiedlicher spinabhängiger Wechselwirkungen ausbilden. In unserem Beitrag untersuchen wir den Einfluss des Zeeman-Effektes auf diese Phasen.

A 15.45 Di 16:30 VMP 9 Poster

**Experimental observation of oscillating and interacting matter wave dark solitons** — •A Weller[1], J. P. Ronzheimer[1], C. Gross[1], J. Esteve[1], E. Nicklas[1], T. Zibold[1], M. K. Oberthaler[1], D. J. Frantzeskakis[2], G. Theocharis[3], and P. G. Kevrekidis[3] — [1]Kirchhoff Institute for Physics, University of Heidelberg, INF 227, 69120 Heidelberg, Germany — [2]Department of Physics, University of Athens, Panepistimiopolis, Zografos, Athens 157 84, Greece — [3]Department of Mathematics and Statistics, University of Massachusetts, Amherst Massachusetts 01003-4515, USA

We create pairs of stable dark solitons in a Bose-Einstein condensate by means of an interference method. In contrast to the early dark soliton experiments our setup is in the crossover regime between 1D and 3D which enables us to overcome the so called snaking instability. Therefore the created solitons are long-lived which allows the observation of their oscillations for several periods and the determination of their frequencies. During their evolution in the trap the solitons undergo multiple collisions which lead, due to their repulsive interaction, to a measureable increase in the oscillation frequency. Our results are in quantitative agreement with simulations of the Gross-Pitaevski equation and predictions on the basis of effective inter-soliton interaction.

How the interference method can be used to generate single and three solitons will also be presented.

A 15.46 Di 16:30 VMP 9 Poster

**An apparatus for ultracold Fermi gases using sodium and lithium** — •Jens Appmeier, Fabienne Haupert, Bernhard Huber, Raphael Scelle, Tobias Schuster, Valentin Volchkov, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Heidelberg, Germany

We report on the setup of an apparatus for cooling fermionic $^6$Li atoms to quantum degeneracy. As a refrigerant for the fermions, $^{23}$Na is used and standard cooling schemes are applied. By tuning the interactions between $^{23}$Na and $^6$Li via Feshbach resonances it is possible to study different regimes of a mixed system containing both species. The current progress of the experimental setup will be reported.

A 15.47 Di 16:30 VMP 9 Poster

**Interaction of Ultracold Atoms with Carbon Nanotubes** — •Philipp Schneeweiss[1], Michael Gierling[1], Gabriela Visanescu[1], Michael Häffner[2], Dieter Kern[2], Andreas Günther[1], and József Fortágh[1] — [1]Physikalisches Institut, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen — [2]Institut für Angewandte Physik, Universität Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen

We developed an ultracold atom experiment for studying interactions between 87Rb atoms and carbon nanotubes (CNTs). Atomic clouds are loaded in a MOT and transported magnetically to the nanotubes that are placed on the surface of an atom chip. An integrated magnetic conveyor belt facilitates precise 3D positioning of the atoms near the CNTs. We will report on the experimental progress.

A 15.48 Di 16:30 VMP 9 Poster

**A new Experiment for the investigation of ultra-cold Potassium Rubidium Mixtures** — •Johannes Will, Georg Kleine Büning, Bernd Lücke, Mazyar Sabbar, Wolfgang Ertmer, and Jan Arlt — Institut für Quantenoptik, Leibniz Universität Hannover

Over the past few years quantum degenerate mixtures particularly including bosonic and fermionic atoms have enabled a new range of experiments. Especially the use of Feshbach-resonances to tune the interaction between the atoms in these samples has contributed to the success of these experiments. We present an experimental apparatus under construction, which will allow us to investigate mixtures of one isotope of rubidium with all isotopes of potassium and also enable the use of Feshbach-resonances.

In the experimental setup the desired fermionic or bosonic isotopes are collected in a magneto-optical trap from the background vapor. A magnetic quadrupole trap is used to transport the pre-cooled atoms mechanically into a glass cell with better vacuum. There the atoms are transferred into a novel hybrid optical and magnetic trap. This process can be repeated to increase the number of atoms or to collect multiple isotopes. Subsequently sympathetic cooling is used to bring the desired isotopes of rubidium and potassium to quantum degeneracy. Finally a magnetic field can be tuned to the Feshbach resonances to investigate and manipulate the interaction strength or to form molecules.

Particular attention will be given to the design of the laser system and the field coils, which enable the flexibility of the experiment.

A 15.49 Di 16:30 VMP 9 Poster

**Squeezing and entanglement in a Bose-Einstein condensate** — •Christian Gross, Jerome Esteve, Andreas Weller, Stefano Giovanazzi, Eike Nicklas, Tilman Zibold, Jens Philipp Ronzheimer, and Markus Oberthaler — Universität Heidelberg, Heidelberg, Deutschland

We report on the observation of spin squeezing and entanglement in a Bose-Einstein condensate trapped in double well and periodic potential. The measurement of two conjugate variables - atom number difference and relative phase between adjacent sites - allows a direct connection to the presence of entanglement. The observations indeed confirm that entanglement is present even at finite temperature. The observed coherent spin squeezing of 3.8 dB implies that a usable quantum resource has been generated which is directly applicable to overcome the standard quantum limit of atom interferometry. The limitations due to experimental imperfections and finite temperature will be discussed in detail. Latest results on spin squeezing using hamiltonian dynamics of internal states are presented.

A 15.50 Di 16:30 VMP 9 Poster

**Bose Einstein Condensates on the surface of a glass prism** — •Helmar Bender, Phillipe Courteille, Claus Zimmermann, and Sebastian Slama — Physikalisches Institut, Eberhard-Karls-Universität Tübingen, Auf der Morgenstelle 14, D-72070 Tübingen

The main focus of our experiments ist the interaction of ultra cold atoms with a dielectric surface. In our case the surface is the facet of a glass prism. An evanescent wave created by total reflection of a laser beam at this facet allows us to generate a dipole potential acting on atoms close to the surface. This potential makes it possible to compensate for the attractive Casimir-Polder (CP) force which is playing a

dominant role at very small distances from the surface. The sum of the two potentials is able to form a controllable barrier at a distance of only a few hundred nanometers from the surface. By using a magnetic trap we are able to shift a Bose Einstein Condensate (BEC) in a controlled way to this barrier. The atoms overlapping with the evanescent wave of a far detuned laser beam shift the phase of the totally reflected light proportionally to the number of atoms. Monitoring this phase shift as a function of time provides information on number fluctuations in a BEC. Another interesting perspective of our setup is the reflection of matterwaves from the barrier for the measurement of CP-forces. In the long term we plan to deposit nano structured metal layers on the surface. Excitation of surface plasmon polaritons in these layers enhances the evanescent wave intensity and thus the dipole potential locally. We will investigate such systems for tailoring of nanometric surface traps with the perspective of a photonic atom chip.

A 15.51 Di 16:30 VMP 9 Poster

**Observation of ultra long-range Rydberg molecules** — Vera Bendkowsky[1], Björn Butscher[1], •Johannes Nipper[1], Jonathan Balewski[1], James P. Shaffer[1,2], Robert Löw[1], and Tilman Pfau[1] — [1]Universität Stuttgart, Germany — [2]University of Oklahoma, USA

We report on the observation of ultra long-range molecules, first proposed by Greene et. al. [1], bound by low energy scattering of Rydberg electrons from polarisable ground state atoms. The novel binding mechanism leads to well defined internuclear separations of some thousand Bohr radii.

Rydberg states between 34S and 40S are excited in a dense cloud of magnetically trapped Rubidium. The excitation spectra show clear evidence for dimer as well as trimer molecules in the vibrational ground states and excited states. The measured binding energies coincide with theoretical calculations taking into account s- and p-wave scattering. The low energy s-wave electron scattering length could be determined. Lifetime measurements for the pure Rydberg state and the molecular dimer state show a decreased lifetime of the molecular state. The coherent excitation dynamics of the dimer and the Rydberg state are studied in rotary echo experiments.

[1] C.H. Greene et al, Phys. Rev. Lett **85**, 2458 (2000)

A 15.52 Di 16:30 VMP 9 Poster

**Universal scaling in a strongly interacting Rydberg gas** — •Robert Löw[1], Vera Bendkowsky[1], Björn Butscher[1], Johannes Nipper[1], Hendrik Weimer[1], Jonathan Balewski[1], James P. Shaffer[1,2], Hans Peter Büchler[1], and Tilman Pfau[1] — [1]Universität Stuttgart, Germany — [2]University of Oklahoma, USA

Universal scaling near a quantum critical point is theoretically analyzed and experimentally demonstrated in a strongly interacting Rydberg gas.

The experiments are performed in a dense cloud of magnetically trapped Rubidium atoms resonantly driven into a Rydberg state. Due to the strong van-der-Waals interaction of the Rydberg atoms blockade effects occure. The coherent collective excitation dynamics were recently studied [1]. We show that the experimental data show a collapse to a universal scaling function in one single dimensionless parameter.

The system can theoretically be described by a mean field model [2] that show a universal scaling near an experimentally accessable critical point. Numerical simulations as well as the mean field model are in good agreement with the experimentally observed critical exponents.

[1] Heidemann et al, PRL 100, 013002 (2007)
[2] Weimer et al, PRL in press

A 15.53 Di 16:30 VMP 9 Poster

**Signature of long-range-molecules in a dipole blocked degenerate atom gas** — •Weibin Li and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

The low energy scattering from the Rydberg-electron and a surrounding ground-state atom in ultracold gases yields an attractive potential, giving rise to exotic, ultralong range molecules [1], for which experimental evidence has been reported recently [2]. Here, we study the coherent excitation dynamics in dipole blocked mesoscopic ensembles, in which all but a single excitation is inhibited by the strong Rydberg-Rydberg interaction. We develop a large scale Monte-Carlo approach to describe the fully correlated excitation dynamics. In particular we study the effect of the interactions on the coherence properties of collective, many-body Rabi oscillations, which are important for proposed applications in quantum information. Finally, we examine possible approaches to experimentally probe the highly structured molecular potential curves.

[1] C. H. Greene, A. S. Dickinson and H. R. Sadeghpour, Phys. Rev. Lett. 85, 2458 (2000).
[2] V. Bendkowsky, et.al., arxiv:0809.2961 (2008).

A 15.54 Di 16:30 VMP 9 Poster

**Excitation of Rydberg atoms in an ultracold gas by a rotary echo sequence** — •Sebastian Wüster[1], Cenap Ates[1], Thomas Pohl[1], Piotr Deuar[2], Joel Corney[3], and Jan-Michael Rost[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Université Paris-Sud, CNRS, Orsay cedex, France — [3]ARC Centre of Excellence for Quantum-Atom Optics, School of Physical Sciences, University of Queensland, Brisbane, Australia

We model the excitation and subsequent de-excitation of Rydberg states in a Bose-Einstein condensate. Our method, stochastic Gauge-P quantum many-body theory, can in principle provide the complete quantum field dynamics of a many-mode, many-particle problem for a softened long-range interaction potential. Typically intractably large Hilbert-space sizes are tackled by representing quantum correlations numerically through noise correlations. As a trade-off, the amplification of this noise intrinsically limits the possible simulation times.

The aim is to study spatial correlations among the remnant fraction of Rydberg atoms, following an echo sequence. This sequence consists of an excitation pulse, followed by a de-excitation pulse of equal duration that would return all atoms to the ground state if there were no interactions. The long-range dipolar interactions between Rydberg states cause dephasing, resulting in a remnant Rydberg population after the sequence.

A 15.55 Di 16:30 VMP 9 Poster

**Rydberg atom formation in strongly correlated ultracold neutral plasmas** — •Georg Bannasch and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

In plasmas at very low temperatures the recombination into neutral atoms is known to be dominated by three-body recombination, owing to the strong $\sim T^{-9/2}$ scaling with the electron temperature. While this law is well proven at high temperatures, the unphysical divergence as $T \to 0$ clearly suggest a breakdown in the low-temperature regime. Despite ongoing debates about its extension into the low-temperature, and consequently strong coupling regime, a conclusive answer is still missing.

The advent of ultracold neutral plasmas has refocussed interest in recombination under such exotic conditions, and experimental studies of the involved questions may be anticipated.

Here we present a combined molecular dynamics - Monte Carlo study of electron-ion recombination over a wide range of temperatures and densities. Our calculations reach far into the strongly coupled regime, in which the charges may be nearly crystallized. Such unusual neutral plasma states clearly defy common few-particle collision models, and their lifetime and stability is yet to be determined.

A 15.56 Di 16:30 VMP 9 Poster

**Towards single lattice site addressability using ultracold Rydberg atoms** — •Ulrich Raitzsch[1], Richard Abel[1], Ashok Mohapatra[1,2], Mark Bason[1], Jonathan Pritchard[1], Kevin Weatherill[1], and Charles Adams[1] — [1]Atomic & Molecular Physics, Durham, U.K. — [2]5. Physikalisches Institut, Universität Stuttgart, Germany

We present our recent progress towards single lattice site addressability using Rydberg atoms. The large polarisability $\alpha$ of Rydberg states makes it possible to selectively excite atoms at a single lattice site into a Rydberg state using electric field gradients. In our experimental scheme the atoms are loaded from a magneto-optical trap into a one-dimensional lattice with $\sim 600$ nm lattice constant. A Rydberg state with a principal quantum number $n = 70$ can be addressed by a moderate electric field gradient. Using a novel scheme for laser locking to any excited state transition, we demonstrate a combined two-photon excitation linewidth to the Rydberg state of $\leq 200$ kHz [1], which is sufficiently small to exclusively address a single lattice site.

[1] R. Abel et al., arXiv:0811.2183v1 (2008)

A 15.57 Di 16:30 VMP 9 Poster

**Adiabatic energy transfer in Rydberg chains** — •Cenap Ates, Alexander Eisfeld, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

Ultracold Rydberg systems are ideally suited to study excitonic transport through ordered structures. The energy transfer is mediated by the strong transition dipole-dipole interactions between Rydberg atoms. As has been shown recently, the excitonic dynamics is also correlated with the motion of the atoms. The structure of the excitonic eigenfunctions determines how the particles move. We analyze the motion of Rydberg atoms prepared on an equidistant chain, where the regularity of the spacings is broken at one end. It is shown that the irregularity can move adiabatically through the chain. Coupled to this motion is a transfer of electronic excitation localized on the irregularly spaced particles. The energy transfer takes place on a single adiabatic potential surface. It should be stable against effects of dephasing.

A 15.58 Di 16:30 VMP 9 Poster

**Collective modes in ultracold plasma** — •Andrii Liubonko, Thomas Pohl, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany

Ultracold neutral plasmas (UCP) are formed by photoionizing laser cooled atoms near the ionization threshold [1,2]. The electron temperature is from 1-1000K and the ion temperature is around 1K. The fundamental interest in these systems originates in the possibility of creating strongly coupled plasma. Recently, a series of collective modes of an UCP were observed in the experiment [3]. Numerical simulations of this effect within molecular dynamics will be presented. The results show that collective modes in an UCP, previously identified with Tonks-Dattner resonances, have a different nature, which stems from the fact, that UCP is not confined. Existing theory based on cold plasma theory does not provide an explanation of these resonances. We extend the theory to the finite temperature. Possible approaches to cope with this problem will be discussed.

1.T. C. Killian, Science 316, 705 (2007). 2.T.C. Killian, T. Pattard, T. Pohl, J.M. Rost, Phys.Rep. 449 (2007). 3.R. S. Fletcher, X. L. Zhang, and S. L. Rolston, Phys. Rev. Lett., 96:105003 (2006).

## A 16: Atomic Clusters II

Zeit: Mittwoch 14:00–16:00 Raum: VMP 6 HS-B

**Fachvortrag** A 16.1 Mi 14:00 VMP 6 HS-B

**Ion and electron emission from Argon clusters in intense femtosecond XUV laser pulses** — •Mathias Arbeiter and Thomas Fennel — Institute of Physics, University of Rostock, Germany

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 $\lambda = 32\,\mathrm{nm}$ and $\lambda = 13\,\mathrm{nm}$ with intensities of I$\sim 10^{12-14}\mathrm{W/cm^2}$ 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 the XUV regime, in contrast to that, the measured photoemission spectra indicate a series of direct electron emission events in the developing cluster Coulomb field. According to this, nanoplasma formation takes place only if the cluster potential is sufficiently deep to suppress direct electron emission. In our MD analysis we focus on the impact of thermalization and laser heating on the electron and ion emission spectra. Whereas the low-energy tail of the photoemission spectra is severely affected by thermalization for higher intensities, laser heating through inverse Bremsstrahlung turns out to be insignificant[2]. Methodical details and simulation results will be presented and discussed in comparison with experimental results.

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

**Fachvortrag** A 16.2 Mi 14:30 VMP 6 HS-B

**Vibronic coupling and energy transfer on aggregates** — •Alexander Eisfeld — MPI-PKS Dresden, Finite Systems

Self-organised J-aggregates of dye molecules, known for over 60 years, are emerging as remarkably versatile quantum systems with applications in photography, opto-electronics, solar cells, photo-biology and as supra-molecular fibres [1].

The optical properties and the energy transfer dynamics of such molecular aggregates are strongly affected by internal vibrations of the constituting monomers, which couple to the electronic excitation. Detailed features of the aggregate spectra could be explained using the "coherent exciton scattering"approximation [2].

A new approach based on a non-Markovian Schrödinger equation [3] allows to investigate the influence of a continuous structured phonon bath on the energy transfer and to treat uniformly the transition from coherent to incoherent motion.

[1] T. Kobayashi,(ed.) J-Aggregates, World Scientific, 1996
[2] A. Eisfeld, J. S. Briggs, Chem. Phys. 324, (2006) 376
[3] T. Yu, L. Diosi, N. Gisin, W. Strunz, Phys. Rev. A. 60, (1999) 91

A 16.3 Mi 15:00 VMP 6 HS-B

**Electronic and magnetic properties of size selected scandium and manganese doped silicon cluster cations** — •Robert Richter[1], Konstantin Hirsch[1], Philipp Klar[1], Andreas Langenberg[1], Fabian Lofink[1], Jürgen Probst[1], Jochen Rittmann[1], Marlene Vogel[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/FMF, Stefan-Meier-Strasse 21, D-79104 Freiburg

Because of its high abundance in mass spectra and backed by theoretical predictions, $VSi_{16}^+$ is assumed to be a 'magic' transition metal doped silicon cluster with high symmetry and electronic shell closure. Core level spectroscopy on size-selected clusters in an ion trap recently revealed that $TiSi_{16}^+$, $VSi_{16}^+$, and $CrSi_{16}^+$ are indeed highly symmetric cage clusters which can be described in the spherical potential model. Extending our studies to $ScSi_{16}^+$ and $MnSi_{16}^+$, we show that this simple description is no longer valid if the cage geometry and the number of valence electrons deviate strongly from the ideal situation in $VSi_{16}^+$. Instead, the Mn 2p X-ray absorption spectrum indicates that $MnSi_{14}^+$ is a symmetric cluster with a local $d^5$ configuration of the Mn atom, pointing at a high spin state. This is the first experimental evidence of a high magnetic moment in transition metal doped semiconductors clusters. We will discuss these results together with electronic properties and reactivities of $ScSi_n^+$ and $MnSi_n^+$ clusters.

A 16.4 Mi 15:15 VMP 6 HS-B

**Transition metal and silicon 2p photoionization of Ti, V, and Cr doped $Si_n^+$ cages** — •Andreas Langenberg[1], Marlene Vogel[1], Konstantin Hirsch[1], Philipp Klar[1], Fabian Lofink[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, Hardenbergstr. 36, 10623 Berlin — [2]Albert-Ludwigs-Universität Freiburg, Fakultät für Physik/FMF, Stefan-Meier-Str. 21, 79104 Freiburg

Silicon 2p photoionization spectroscopy of titanium, vanadium, and chromium doped $Si_n^+$ cages complements X-ray absorption studies at the transition metal 2p edges. While clusters with lower symmetry show broad bands in resonant silicon 2p photoionization, the highly symmetric $TiSi_{16}^+$, $VSi_{16}^+$, and $CrSi_{16}^+$ clusters are characterized by a rich line structure in their spectra. This is a further indication of a highly degenerate density of states and electronic shells in these clusters. Furthermore, resonant and direct photoionization channels are associated with different fragmentation patterns at the silicon 2p edge and can be separated *ex post* in ion yield spectra. This gives access to the direct photoionization threshold and even to x-ray photoelectron spectra. Compared to $VSi_{15}^+$ and $VSi_{17}^+$, the direct 2p photoionization threshold of magic $VSi_{16}^+$ is shifted by approx. 0.7 eV to higher photon energy because of the large HOMO-LUMO gap. We will discuss our recent results with an outlook at valence band photoionization spectroscopy of cationic clusters.

A 16.5 Mi 15:30 VMP 6 HS-B

**2p-Photoionisation an freien größenselektierten Silizium-Clustern** — •Marlene Vogel[1], Konstantin Hisch[1], Philipp Klar[1], Andreas Langenberg[1], Fabian Lofink[1], Jürgen Probst[1], Robert Richter[1], Jochen Rittmann[1], Vicente Zamudio-Bayer[1],

Bernd von Issendorff[2], Thomas Möller[1] und Tobias Lau[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin — [2]Fakultät für Physik/FMF, Albert-Ludwigs-Universität Freiburg

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 durchzuführen. Dadurch ist die 2p-Schwelle von freien Siliziumclustern erstmals einer Beobachtung zugänglich.

An größenselektierten Clustern $Si_n^+, n \geq 5$ wird der Übergang $2p \rightarrow 3d$ und die direkte 2p-Photoionisation im Energiebereich 90 - 115 eV untersucht. Die Spektren zeigen auf deutliche Weise die Entwicklung des Festkörperspektrums aus den Spektren der kleinen Cluster. Darüber hinaus ist durch diese Messungen erstmals die Lage der 2p-Schwelle experimentell zugänglich. Die größenabhängige Änderung dieser Schwelle läßt sich gut durch das Spiegelladungsprinzip einer Metallkugel beschreiben.

A 16.6 Mi 15:45 VMP 6 HS-B

**X-rays reveal high symmetry and electronic shells in transition metal doped silicon clusters** — •Jochen Rittmann[1], Konstantin Hirsch[1], Philipp Klar[1], Andreas Langenberg[1], Fabian Lofink[1], Jürgen Probst[1], Robert Richter[1], Marlene Vogel[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, Hardenbergstraße 36, 10623 Berlin — [2]Universität Freiburg, Fakultät für Physik/FMF, Stefan-Meier-Str. 21, 79104 Freiburg

Incorporation of a transition metal atom leads to a complete geometric rearrangement of silicon clusters. X-ray absorption spectroscopy at the dopant atom 2p edge unravels a high symmetry of $TiSi_{16}^+$, $VSi_{16}^+$, and $CrSi_{16}^+$ cages. We show that Ti, V, and Cr adopt the same local electronic structure when embedded into $Si_{16}$. Our data can be explained within the spherical potential model, where the electronic shell structure of the cage interacts with the dopant atom orbitals of the same character. Charge transfer to the silicon cage leads to a local $d^0$ configuration of the transition metal dopant, quenching the magnetic moment. Because of its closed electronic shells, $VSi_{16}^+$ can be described as a spherically aromatic system according to the $2(N+1)^2$ rule. Our findings are further corroborated by the fact that the local electronic structure of the dopant is unchanged when replacing the $Si_{16}$ cage by $Ge_{16}$.

## A 17: Atomic Systems in External Fields III

Zeit: Mittwoch 14:00–16:00 Raum: VMP 6 HS-C

**Hauptvortrag** A 17.1 Mi 14:00 VMP 6 HS-C

**Atoms and Clusters in Intense Laser Fields** — •Dieter Bauer — Max-Planck-Institut für Kernphysik, Postfach 103980, 69029 Heidelberg, Germany

Analytical descriptions of intense laser atom interaction are commonly based on the so-called strong field approximation (SFA). In this approach, the effect of the laser field on the electron motion after ionization is treated exactly while the effect of the binding potential is neglected. However, there are several well-documented features in photoelectron spectra which can hardly be explained within the standard SFA approach without taking Coulomb-effects into account. Recently we proposed to use quantum trajectories to incorporate Coulomb-effects into the SFA and demonstrated the power and versatility of this approach in Refs. [1–3]. Many of the interesting phenomena in strong field physics rely on the rescattering of electrons. We have identified two novel recollision pathways, namely the simultaneous recombination of two electrons [4] and the excitation of plasmons in collective multi-electron systems such as $C_{60}$ [5]. New results on the generation of energetic electrons and ions in the interaction of intense laser beams with clusters and droplets will be also discussed.

[1] S.V. Popruzhenko et al., Phys. Rev. A **77**, 053409 (2008), [2] S.V. Popruzhenko, D. Bauer, J. Mod. Opt. **55**, 2573 (2008), [3] S.V. Popruzhenko et al., Phys. Rev. Lett. **101**, 193003 (2008), [4] P. Koval et al., Phys. Rev. Lett. **98**, 043904 (2007), [5] M. Ruggenthaler et al., Phys. Rev. A **78**, 033413 (2008).

A 17.2 Mi 14:30 VMP 6 HS-C

**Parity Violating Berry Phases for Hydrogen in an Atom Interferometer** — •Martin-Isbjörn Trappe, Thomas Gasenzer und Otto Nachtmann — Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg

Wir behandeln geometrische Phasenfaktoren, die in longitudinalen Atomstrahl-Spinecho (lABSE) Experimenten auftreten. Die Propagation von Wasserstoffatomen in statischen elektrischen und magnetischen Feldern führt zu geometrischen (Berry-)Phasen, in denen sich aufgrund ihrer Verbindung zur schwachen Wechselwirkung eine neue Form der Paritäts-(P-)Verletzung in der Atomphysik zeigt. Auf der Grundlage von Berechnungen P-verletzender und P-erhaltender geometrischer Phasen für Atome in Ruhe untersuchen wir das Verhalten der metastabilen 2S Zustände von Wasserstoff in lABSE Experimenten mit analytischen und numerischen Methoden. Hierzu diskutieren wir die an geeignete Feldkonfigurationen gestellten Bedingungen, welche die adiabatische Entwicklung der atomaren Eigenzustände sicherstellen. Wir berechnen abelsche geometrische Phasen in Wasserstoff und konstruieren Observablen, die sensitiv auf P-Verletzung sind und den Erfordernissen von lABSE Experimenten entsprechen. Die entwickelten Methoden liefern die theoretische Basis zur Untersuchung möglicher lABSE Experimente für die Messung von P-Verletzung in Wasserstoff.

A 17.3 Mi 14:45 VMP 6 HS-C

**Heating dynamics in ion traps** — Mathieu Marciante, Annette Calisti, Caroline Champenois, and •Martina Knoop — CNRS/Université de Provence, Centre de St Jerome, Case C21, 13397 Marseille Cedex 20, France

Molecular Dynamics simulations are carried out to evaluate the dynamics of ions in radiofrequency traps of different geometry, using the pseudo-potential approximation or the exact time oscillating description. Doppler laser cooling is taken into account by momentum kicks on absorption and emission of a photon by an ion. This detailed description allows to analyze the efficiency of the laser cooling depending on the direction of propagation of the laser and to quantify the role of Coulomb repulsion for the thermalization of the different degrees of freedom, depending on the number of trapped ions.

A 17.4 Mi 15:00 VMP 6 HS-C

**Correlation function Monte Carlo studies for medium-heavy atoms in neutron star magnetic fields** — •Dirk Meyer, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

We present the correlation function Monte Carlo method and apply it to the calculation of excited state energies and transition probabilities of atoms with nuclear charges up to iron ($Z = 26$) for magnetic field strengths relevant for neutron stars [1].

The method extends the released-phase diffusion quantum Monte Carlo method, which is only suited to the calculation of ground state energies [2], and provides an alternative interpretation of the latter.

The calculations are motivated by the discovery of broad features in the thermal emission spectra of isolated neutron stars, which may be due to transitions in atoms and ions present in the progenitor star. With reliable atomic data for ground and excited states at hand it should be possible to predict spectra of neutron star atmospheres with intense magnetic fields to high accuracy and to compare with the observational results.

[1] M. D. Jones, G. Ortiz, and D. Ceperley, Phys. Rev. E 55, 6202 (1997) [2]S. Bü cheler, D. Engel, J. Main, G. Wunner, Phys. Rev. A 76, 032501 (2007)

A 17.5 Mi 15:15 VMP 6 HS-C

**Semiclassical quantization of the diamagnetic hydrogen atom with near action-degenerate periodic orbit bunches** — •Jan Gehrke, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Gutzwiller's trace formula for the semiclassical quantization of classically chaotic systems suffers from the exponential proliferation of periodic orbits, and it is an important question whether semiclassical

eigenstates can be obtained with reduced classical input data. It has been shown [1] that the periodic orbits of chaotic systems appear in "bunches". Members of each bunch are reconnected differently at self-encounters in phase space but have nearly equal classical action and stability parameters. We show the existence of periodic orbit bunches for the diamagnetic Kepler problem and demonstrate that the orbits can be grouped already on the level of the symbolic dynamics by application of appropriate reconnection rules to the symbolic code in the ternary alphabet. This allows for the use of one or few representatives of a periodic orbit bunch in Gutzwiller's trace formula. For the diamagnetic hydrogen atom semiclassical spectra obtained with the complete set of periodic orbits and the, up to a factor of 20 reduced, set of bunch representatives agree very well.

[1] Sebastian Müller, Stefan Heusler, Petr Braun, Fritz Haake, and Alexander Altland, Phys. Rev. E **72**, 046207 (2005).

A 17.6 Mi 15:30 VMP 6 HS-C

**Entwicklung einer kompakten Anlage für die Polarisation von $^3$He durch metastabiles optisches Pumpen** — •Christopher Hauke, Werner Heil, Sergei Karpuk und Ernst-Wilhelm Otten — Universität Mainz

Durch den Einsatz von kernspinpolarisierten Edelgasen in der Magnetresonanztomografie der Lunge haben sich die neuen nicht-invasiven Methoden zur Diagnose von Schädigungen und zur Lungenfunktionsuntersuchung bereits etabliert. In Mainz wurde schon vor einiger Zeit eine Polarisationsanlage zur Herstellung größerer Mengen $^3$He-Gas, unter anderem zur zentralen Produktion für medizinische Anwendungen, entwickelt. Die Anlage basiert auf dem metastabilen optischen Austauschpumpen von $^3$He-Atomen, welches sehr effizient ist bei niedrigen Gasdrücken um etwa 1 mbar und einer schwachen Gasentladung zur Anregung der für den optischen Pumpprozess benötigten Atome in den metastabilen $^3S_1$-Zustand.Eine kompakte und kostengünstige $^3$He-Produktionsanlage vor Ort bietet Vorteile in der Flexibilität, was die unmittelbare Verfügbarkeit des Gases betrifft. Die Verbesserung der $^3$He-Polarisationstechnik soll durch Einsatz eines schnell laufenden Kleinkompressors für polarisiertes $^3$He sowie die Einhausung des magnetischen Führungsfeldes in eine $\mu$-Metall-Abschirmung geschehen. Dadurch ergibt sich ein deutlich größeres nutzbares Volumen mit der geforderten Homogenität des magnetischen Führungsfeldes. Die Neuentwicklung umfasst auch neue Konzepte zur Realisierung der Optik, der optischen Pumpzellen, sowie eines relaxationsarmen, hochreinen $^3$He-Plasmas. Der Stand der Entwicklung wird vorgestellt.

A 17.7 Mi 15:45 VMP 6 HS-C

**The Cooler Trap of the HITRAP Facility at GSI** — Frank Herfurth[1], Heinz-Jürgen Kluge[1], •Stephen Koszudowski[1], Giancarlo Maero[1], Oliver Kester[1], Wolfgang Quint[1], and Stefan Schwarz[2] — [1]GSI, 64291 Darmstadt — [2]NSCL/MSU, East Lansing, USA

A dedicated Cooler Trap for the HITRAP facility at GSI has been designed and built. Here bunches of $10^5$ heavy, highly charged ions up to $U^{92+}$ can be trapped and cooled for precision experiments in atomic and nuclear physics. The trap is a cryogenic multi-ring cylindrical Penning trap, which enables a nested trap configuration.

Two cooling mechanism are employed: electron and resistive cooling. For the electron cooling $10^{10}$ electrons from a photoelectron source developed at MPIK Heidelberg will be fed into the trap. Recombination losses in the cooling process are small down to 10eV. To go to lower energies, resistive cooling via a resonant circuit at 4K is employed. Simulations of the resistive cooling have shown fast cooling (within 0.1s) of the center of mass motion down to a few eV. The following tail has a cooling constant of about 3.7s.

We detect the ions from the induced signal in the resonant circuit, which is fed out via a cryogenic amplifier. A second resonant circuit is installed to detect the cyclotron frequency of the ions. This can also be used for monitoring the axial frequency of the electrons. First tests of the trap will take place beginning of 2009. Therefore a $H^+$ ion source and an EBIT for highly charged ions were bought and set up. The whole set up will be available for experiments later in 2009.

## A 18: Photoionization I

Zeit: Mittwoch 14:00–16:00 Raum: VMP 8 R208

**Fachvortrag** A 18.1 Mi 14:00 VMP 8 R208

**Vektorkorrelation von Auger- und Photoelektron nach O1s Ionisation von $CO_2$** — •Sophie Kirschner[1], Felix Sturm[1], Markus Schöffler[2], Till Jahnke[1], Reinhard Dörner[1], Nadine Neumann[1], Hong-Keun Kim[1], Benedict Rudek[1], Thorsten Weber[2], Sun Lee[2], Timur Osipov[2], Ali Belkacem[2], Joshua Williams[3], Jacob Daughhetee[3], Allen Landers[3] und Lew Cocke[4] — [1]Institut für Kernphysik, Goethe Universität Frankfurt — [2]Lawrence Berkeley National Laboratory, USA — [3]Department of Physics, Auburn University, USA — [4]Department of Physics, Kansas State University, USA

Es wurde die Vektorkorrelation von Photoelektron, Augerelektron und Molekülachse für Sauerstoff 1s Photoionisation von $CO_2$ mit zirkular polarisiertem Licht bei 555eV, 565eV und 590eV Photonenergie untersucht.

Mittels der COLTRIMS Technik wurden die Impulsvektoren des Photoelektrons, des Augerelektrons und der $CO^+$- und $O^+$- Fragmente in Koinzidenz bestimmt.

Ziele des Experimentes sind, nach einer quantenmechanischen Verschränkung zwischen den beiden Elektronen zu suchen, zweizentren Interferenzen in der Photo- und Augerwinkelverteilung nachzuweisen, sowie eine Aussage über eine mögliche Lokalisierung des Sauerstoff K-Loches zu gewinnen.

**Fachvortrag** A 18.2 Mi 14:30 VMP 8 R208

**Highly doubly excited states of planar helium: Fluctuations in photoionization cross sections** — •Johannes Eiglsperger and Javier Madroñero — Physik Department, TU München, Germany

Close to the break-up-threshold of two-electron atoms the spectrum is strongly influenced by the underlying classical mixed-regular chaotic dynamics and typical signatures of quantum chaos, e.g., Ericson fluctuations or scaling laws for the fluctuations of the photoionization cross section, are expected to become observable. A clear understanding of these issues requires a precise description of individual resonances and of the atomic continuum, which is achieved in our case, for planar helium, through an appropriate representation of the Schrödinger equation in creation and annihilation operators combined with the complex rotation method [1].

Photoionization cross sections calculated up to the 20th single ionization threshold exhibit fluctuations. These are mainly due to a dominant series of resonances which can be associated with an approximate quantum number $F = N - K$ in accordance with 3D full calculations and experimental observations [2]. As the energy increases the dominant role of a single series as sole contributor is apparently lost as new series start to contribute significantly to the cross sections. This would result in an earlier onset of Ericson fluctuations [3] as in the picture of a single dominant series, where the onset is expected around $I_{34}$.

[1] J. Madroñero and A. Buchleitner, Phys. Rev A **77**, 053402 (2008).
[2] Y. H. Jiang *et al.*, Phys. Rev A **78**, 021401 (2008).
[3] J. Eiglsperger and J. Madroñero, in preparation.

**Fachvortrag** A 18.3 Mi 15:00 VMP 8 R208

**Demonstration of Photoionization of Highly Charged Ions by Synchrotron Radiation in an Electron Beam Ion Trap** — •Martin C. Simon[1], Sascha W. Epp[2], Maria Schwarz[1], Thomas M. Baumann[1], Christian Beilmann[1], Rainer Ginzel[1], Renee Klawitter[1], Volkhard Mäckel[1], Benjamin L. Schmitt[1], José R. Crespo López-Urrutia[1], and Joachim Ullrich[1] — [1]Max-Planck Institut für Kernphysik, Heidelberg, Germany — [2]Max Planck Advanced Study Group at CFEL, Hamburg, Germany

Photoionization (PI) experiments can provide deep insight into the structure of electronic systems. The study of PI of highly charged ions (HCI) is of general relevance for astrophysics, plasma physics and atomic theory. A common difficulty in PI experiments with ions is the preparation of a dense and well defined ion target, leaving HCIs inaccessible to established methods. We present a new approach using an electron beam ion trap (EBIT), capable of producing a HCI target of an area density as high as $10^{10}$ cm$^{-2}$ for most HCI, an enhancement of up to four orders of magnitude in comparison with most notable

merged-beam experiments. The successful demonstration was accomplished at the BESSY II synchrotron in Berlin with the transportable Heidelberg FLASH-EBIT in July 2008. Near-threshold PI of $N^{3+}$ ions at the optimal photon energy range of the beamline (≈77 eV) showed high sensitivity, very good resolution. This EBIT-based method aims at higher ion charge states and will be able to prove its full potential in forthcoming experiments at higher photon energies.

A 18.4 Mi 15:30 VMP 8 R208

**Angular resolved photoemission from Xenon and C60** — •Slawomir Skruszewicz, Nguyen Xuan Truong, Johannes Passig, Andreas Przystawik, Thomas Fennel, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universität Rostock, Universitätsplatz 3 18051 Rostock, Deutschland

Angular resolved photoelectron spectroscopy is a key method to gain deeper insight into the strong-field photoionization of complex systems, such as multi-electron atoms, molecules, and clusters. A powerful and direct technique for the simultaneous measurement of the energy and angular distribution of the photoelectrons is offered by Velocity Map Imaging spectroscopy [1]. In order to resolve electrons with up to 1 keV kinetic energy we have developed a modified five-electrode setup. As a system benchmark we have analyzed the emission spectra from Xe atoms for fs laser excitation and find clear signatures from intermediate resonant states involved in the ionization process [2,3]. A detailed analysis of photoelectron spectra enables us to estimate lifetimes of the resonances which are of the order of a few femtoseconds. By systematic investigation of the angular resolved photoemission from C60 as a function of the laser intensity we are able to identify signatures for above-threshold ionization in agreement with earlier study [4].

[1] H. Helm et al., Phys. Rev. Lett. 70, 3221 (1993).
[2] R.R. Freeman et al., Phys. Rev. Lett. 59, 1092 (1987).
[3] V. Schyja et al., Phys. Rev. A 57, 3692 (1998).
[4] E.E.B. Cambpell et al., Phys. Rev. Lett. 84, 2128 (2000).

A 18.5 Mi 15:45 VMP 8 R208

**Spektroskopie an den Aktiniden Th, U und Np** — •Sebastian Raeder[1], Tina Gottwald[1], Sebastian Rothe[1], Nils Stöbener[2], Silke Fies[1], Volker Sonnenschein[3], Christoph Mattolat[1], Norbert Trautmann[2] und Klaus Wendt[1] — [1]Institut für Physik - Universität Mainz — [2]Institut für Kernchemie- Universität Mainz — [3]University of Jyväskylä - Finnland

Die resonante Laserionisation ist die Methode der Wahl für die Untersuchung der interessanten Atom- und Levelstruktur der Aktiniden, bei denen neben mehreren offenen Schalen auch relativistische Effekte zu hochkomplexen Spektren führen. Zusätzlich liefert sie effiziente Anregungs- und Ionisationsschemata für die laserbasierte Ultraspurenanalyse dieser radiotoxischen Spezies. Für die meisten Aktiniden sind nur niedrig liegende Energieniveaus im Bereich von typisch 34 000 $cm-1$ bekannt und dokumentiert, während i.A. nur lückenhafte Informationen zu hochliegenden atomaren Energieniveaus vorliegen. Das hochrepetierende Titan:Saphir-Lasersystem der Universität Mainz ist für entsprechende Messungen zu mehrfach resonanten Ionisationsschemata ideal geeignet, wobei in einem kompakten Quadrupolmassenspektrometer mit hinreichend geringen Probenmengen gearbeitet werden kann. Es werden spektroskopische Untersuchungen an den Aktiniden U, Np und Th vorgestellt, bei denen zahlreiche bisher unbekannte intermediäre Zustände sowie eine Fülle von autoionisierenden Resonanzen bestimmt werden konnten. Dabei konnten auch die Drehimpulsquantenzahl $J$ für etliche Zustände zugewiesen werden, was die Vorarbeit zu einer vollständigen Konfigurationszuordnung darstellt.

## A 19: Ultracold atoms III: Manipulation and detection / Rydbergatoms (with Q)

Zeit: Mittwoch 16:30–18:45 Raum: Audi-B

A 19.1 Mi 16:30 Audi-B

**Effects of Non-Abelian Gauge Potentials** — •Andreas Jacob[1], Luis Santos[1], Michael Merkl[2], Frank Zimmer[2], and Patrik Öhberg[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover — [2]SUPA, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, United Kingdom

Artificial electromagnetism may be created for neutral atoms, e.g. by rotating the gas. Other forms of inducing artificial electromagnetism are possible, including ways of generating non-Abelian vector potentials. In this talk, we will first discuss simple laser setups that allow the creation of non-Abelian gauge potentials for atoms with a tripod level scheme. We will comment on specific experimental implementations in e.g. $^4He^*$ and $^{87}Rb$. In particular we will discuss a simple laser arrangement that generates a non-Abelian vector potential proportional to the Pauli matrices. This gauge potential induces a quasi-relativistic physics for cold gases similar to that in graphene, including the possibility of observation of metamaterial phenomena as Veselago lensing. We shall discuss in particular the effects of this gauge potential in the linear and nonlinear atom optics of condensates, including the possibility of creating regions of negative mass in the dispersion relation which allow for bright solitons in the presence of repulsive interactions.

A 19.2 Mi 16:45 Audi-B

**State-selective microwave near-field potentials on atom chips** — •Pascal Böhi[1,2], Max F. Riedel[1,2], Theodor W. Hänsch[1,2], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München

The spectacular experiments with ultracold neutral atoms are intimately connected with the availability of sophisticated techniques for coherent control of internal and motional degrees of freedom of the atoms. For quantum information processing and quantum simulations, for example, tailored potentials are required which control atomic dynamics, but at the same time, control of internal degrees of freedom is needed. Potentials which are in principle arbitrarily configurable can be realized in static magnetic near-field traps on microfabricated 'atom chips'. However, state-selectivity is limited in these potentials.

In this talk we show how we use on-chip microwave near-fields to generate versatile state-selective potentials varying on a $\mu$m scale and use these potentials for the state-selective coherent manipulation of Bose-Einstein condensates. We entangle atomic spin and motional state in a controlled and reversible way, as required for a quantum phase gate previously proposed [1]. Our system also constitutes a trapped-atom interferometer with internal-state labeling and is furthermore useful for experiments on squeezing and many-particle entanglement in Bose-Einstein condensates [2].

[1] P. Treutlein et al., Phys. Rev. A 74, 022312 (2006)
[2] Y. Li et al., arXiv:0807.1580 (2008)

A 19.3 Mi 17:00 Audi-B

**Light Sheet Fluorescence Imaging of Cold Atoms** — •Robert Bücker[1], Aurélien Perrin[1], Stephanie Manz[1], Thomas Betz[1], Christian Koller[1], Wolfgang Rohringer[1], Martin Göbel[1], Jörg Rottmann[2], Thorsten Schumm[1], and Jörg Schmiedmayer[1] — [1]Atominstitut der Österreichischen Universitäten, TU Wien, Stadionallee 2, A-1020 Vienna, Austria — [2]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg, Germany

Fluorescence imaging with illumination by a light sheet is commonly used in optical microscopy of biological specimen. We transfer this approach to detection of ultracold Bosonic gases in an atom chip experiment. During time of flight, the expanding cloud pierces a thin horizontal sheet of near-resonant light. Scattered photons are collected by an imaging objective and detected by an electron-multiplying CCD. This scheme allows for extremely low background and high sensitivity unattainable with conventional methods. By autocorrelation analysis we confirm the efficient detection of single atoms within dilute clouds at a spatial resolution on the order of 10 $\mu$m, limited by stochastic motion of the atoms during interaction time. Time-of-flight imaging on a single-atom level paves the way for studying second-order correlations in the various regimes of low-dimensional degenerate Bose gases feasible in our experiment.

A 19.4 Mi 17:15 Audi-B

**Quantum resolution limits for imaging Bose gases** — •Antonio Negretti[1,2], Carsten Henkel[3], and Klaus Molmer[2] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm, Germany — [2]Lundbeck Foundation Theoretical Center for Quantum System Research Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus

C, Denmark — [3]Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24/25, D-14476 Potsdam, Germany

We present an analysis of the resolution limits for observables contained in the density profiles for an ultracold Bose gas of atoms. Within the Bogoliubov approximation we compute the density-density correlations by including both quantum and thermal fluctuations. These correlations provide a tool to construct the (approximate) joint counting statistics of atoms in an array of pixels covering the gas. As an example of the general theory, we derive the position uncertainty of a dark soliton in a quasi one dimensional Bose gas. The smallest uncertainty scales with the atomic background density, $n$, as $n^{-3/4}$, beating the classical shot noise limit. Intriguingly, the sensitivity is slightly improved when quantum fluctuations are included.

A 19.5 Mi 17:30 Audi-B

**Image formation in scanning electron microscopy of ultracold quantum gases** — •Peter Würtz, Tatjana Gericke, Andreas Koglbauer, and Herwig Ott — Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz

We review the image formation and reconstruction of our recently developed scanning electron microscope for ultracold atoms. In our experimental setup, a focussed electron beam with a FWHM of 100 nm ionizes atoms, which are subsequentl y accelerated towards an ion detector. Obtaining images from the time resolved signal of ion detection events involves several post-processing methods to account for effects disturbing the imaging process. For applications with optical la ttices, drifts and fluctuations of the lattice potential have to be determined and compensated for. We discuss differen t imaging modes and interaction mechanisnms and show that the microscope is a very versatile tool for the detection and manipulation of ultracold atoms.

A 19.6 Mi 17:45 Audi-B

**Coherent excitation of ultra-long-range Rydberg molecules** — •Björn Butscher[1], Vera Bendkowsky[1], Johannes Nipper[1], Jonathan Balewski[1], James Shaffer[1,2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Deutschland — [2]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, USA

At ultralow temperatures - in so-called frozen Rydberg gases - the scattering of the Rydberg electron and a nearby polarizable ground state atom can generate an attractive potential due to the negative scattering length which is able to bind the ground state atom to the Rydberg atom at a well localized position within the Rydberg electron wave function. The resulting giant molecules can have an internuclear separation of several thousand Bohr radii, which places them among the largest known molecules to date.

Here we present spectroscopic data on the observation of vibrational ground and first excited state of Rubidium dimers Rb(5S)-Rb(nS). We apply a Born-Oppenheimer model to explain the measured binding energies for principal quantum numbers $n$ between 34 and 40 and extract the s-wave scattering length for electron-Rb(5S) scattering in the relevant low energy regime $E_{\mathrm{kin}} < 100\,\mathrm{meV}$. We also determine the lifetimes and the polarizabilities of these molecules [arXiv:0809.2961].

Additionally, we report on the observation of trimer states, where two ground state atoms are bound by a Rydberg atom.

A 19.7 Mi 18:00 Audi-B

**Controlling the pair distribution in an ultracold Rydberg gas** — •Christoph S. Hofmann, Thomas Amthor, Christian Giese, Hanna Schempp, Brett DePaola, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We show that the pair distribution in an ultracold Rydberg gas can be influenced by means of red or blue detuned Rydberg excitations. To demonstrate this the ionization of the Rydberg gas is used as a sensitive probe [1,2]: For attractive interaction potentials, atoms excited to Rydberg states on the red-detuned wing of the resonance are observed to ionize first, since more atom pairs are prepared at small interatomic distances and hence experience strong attractive forces. This excitation scheme is extended by using Autler-Townes-splittings of up to 150 MHz in order to exploit a wider frequency range for the pair distribution control. This allows to address pairs with a 1.6 times smaller pair distance, yielding an increase of the interaction strength by more than one order of magnitude. A Monte Carlo model for the description of such a system is presented and agrees well with experimental observations. The Autler-Townes-splitting moreover allows for rapid frequency chirps across a resonance without actually tuning any of the excitation laser frequencies.

[1] T. Amthor et al., Phys. Rev. Lett. 98, 023004 (2007)
[2] T. Amthor et al., Phys. Rev. A 76, 054702 (2007)

A 19.8 Mi 18:15 Audi-B

**Autler-Townes Splitting in an inverted three-level system using Rydberg gases** — •Hanna Schempp, Christian Giese, Sebastian Saliba, Thomas Amthor, Christoph S. Hofmann, Brett DePaola, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We investigate coherent excitation phenomena in ultracold Rydberg gases. In a three level Rydberg system Autler-Townes (AT) splitting can be seen by coupling the lower transition and probing the excitation to a Rydberg state [1,2]. The long lifetimes of Rydberg atoms permit us to investigate AT splitting in an inverted Rydberg system, i.e. starting with all atoms in the Rydberg state and stimulating them down to the intermediate state which is split by a strong laser field coupling the intermediate and the ground state. We show the first experimental results and discuss the features of our system.

[1] B. K. Teo et al., Phys. Rev. A 68, 053407 (2003)
[2] J. Deiglmayr et al., Opt. Comm. 264, 293 (2006)

A 19.9 Mi 18:30 Audi-B

**Exciton transport in ordered and disordered samples of cold Rydberg atoms** — Torsten Scholak, •Thomas Wellens, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study coherent dipolar energy transfer between resonant levels of Rydberg atoms. We determine the transport properties by examining the spectral structure and the associated eigenfunctions. To highlight the impact of disorder on the Rydberg exciton transport, we introduce a disorder parameter allowing us to switch continuously from an ordered to a completely disordered sample of atoms. Special attention is dedicated to the transition from diffusive to non-diffusive transport, as well as to the metamorphosis of the nearest-neighbor level spacing distribution from Wigner to Poisson.

## A 20: Precision Spectroscopy of Atoms and Ions III

Zeit: Mittwoch 16:30–18:00 Raum: VMP 6 HS-B

**Hauptvortrag** A 20.1 Mi 16:30 VMP 6 HS-B

**Frequenzkammgestütze Laserspektroskopie kurzlebiger Isotope zur Kernladungsradienbestimmung des Halokerns $^{11}$Be** — •Ch. Geppert[1,2], W. Nörtershäuser[1,3], J. Krämer[3], A. Krieger[3], R. Neugart[3], R.M. Sanchez Alarcon[1], D. Tiedemann[3], M. Zakova[3], M.L. Bissell[4,6], D.T. Yordanov[5,6], M. Kowalska[6], F. Schmidt-Kaler[7] und C. Zimmermann[2] — [1]GSI Darmstadt, Germany — [2]Universität Tübingen, Germany — [3]Universität Mainz, Germany — [4]Katholieke Universiteit Leuven, Belgium — [5]MPI f. Kernphysik Heidelberg, Germany — [6]CERN, Genf, Suisse — [7]Universität Ulm, Germany

Durch den Einsatz eines Frequenzkamms konnte die kollineare Laserspektroskopie kurzlebiger Isotope (on-line) erstmals auf sehr leichte Elemente angewendet werden. Dazu wurden die Resonanzfrequenzen simultan in kollinearer und anti-kollinearer Laser-Ionenstrahl-Geometrie vermessen. Dies erlaubte uns die Bestimmung der Isotopieverschiebungen der Isotope $^{7,9,10}$Be und des Halokerns $^{11}$Be im $2s_{1/2} \rightarrow 2p_{1/2}$ Übergang mit einer Genauigkeit von etwa 1 MHz. Durch Kombination mit äußerst präzisen Berechnungen des Masseneffektes in der Isotopieverschiebung ließen sich daraus die Kernladungsradien dieser Isotope mit einem relativen Fehler kleiner 1 % bestimmen. Aus der Änderung des Ladungsradius zwischen $^{10}$Be und $^{11}$Be, ergibt sich ein mittlerer Abstand zwischen dem schwach-gebundenen Neutron und dem $^{10}$Be Rumpfkern von etwa 7 fm. Dies entspricht etwa dem

dreifachen Durchmesser des Rumpfes. Die Messungen erfolgten an der COLLAPS Strahlstrecke an ISOLDE.

**Fachvortrag** A 20.2 Mi 17:00 VMP 6 HS-B

**Doppler-freie Spektroskopie an schnellen Lithium-Ionen am Experimentier-Speicherring der GSI** — •Christian Novotny[1], B. Bernhardt[2], D. Bing[3], B. Botermann[4], G. Ewald[4], C. Geppert[1,4], G. Gwinner[5], T. W. Hänsch[2], R. Holzwarth[2], G. Huber[1], S. Karpuk[1], H.-J. Kluge[4], T. Kühl[4], W. Nörtershäuser[1,4], S. Reinhardt[2], G. Saathoff[2], D. Schwalm[3], T. Stöhlker[4], T. Udem[3] und A. Wolf[3] — [1]Johannes Gutenberg Universität Mainz — [2]MPI für Quantenoptik, Garching — [3]MPI für Kernphysik, Heidelberg — [4]Gesellschaft für Schwerionenforschung, Darmstadt — [5]University of Manitoba, Winnipeg, Canada

Am Experimentier-Speicherring der GSI wurde die relativistische Dopplerverschiebung eines geeigneten Uhrenübergangs im metastabilen Spektrum des $^7Li^+$-Ions exakt in Vorwärts- und Rückwärtsrichtung der Ionenbewegung vermessen. Durch Anwendung von optischer Doppelresonanzspektroskopie wird hierbei die durch die Geschwindigkeitsverteilung verursachte Dopplerverbreiterung erster Ordnung eliminiert. Hieraus lassen sich sowohl die Zeitdilatation als auch die Geschwindigkeit der Ionen mit hoher Genauigkeit bestimmen und so die Vorhersagen der Speziellen Relativitätstheorie (SRT) überprüfen.

Aus den bisher durchgeführten Messungen kann eine Obergrenze für Abweichungen zur SRT mit $\leq 3 \times 10^{-7}$ gefunden werden. In nachfolgenden Untersuchungen soll dieser Wert um etwa zwei Größenordnungen verbessert und somit die bisherige Obergrenze aus dem Vorgängerexperiment [1] am MPK in Heidelberg deutlich übertroffen werden. [1] S. Reinhardt et.al. *Nat.Phys.* **3** (2007) 861.

A 20.3 Mi 17:30 VMP 6 HS-B

**Two Photon Direct Frequency Comb Spectroscopy with Chirped Pulses** — •Sascha Reinhardt, Elisabeth Peters, Theodor W. Hänsch, and Thomas Udem — Max-Planck-Institut für Quantenoptik, 85748 Garching

Spectroscopy with frequency combs offers new ways of investigations of atoms and molecules. The recorded spectrum that is obtained with a frequency comb is influenced by several parameters of the comb like noise of the repetition rate and structure of the pulses. With a Caesium two photon spectroscopy the influence of a chirped pulse on the line strength of the observed transition is measured and compared with a theoretical model. The frequency comb is obtained by a mode locked picoseconds laser and the pulses are chirped with an optical glass fibers. The behaviour of the experimental observation and theoretical model is similar over a large parameter space.

A 20.4 Mi 17:45 VMP 6 HS-B

**An efficient accurate representation of the three-body Coulomb problem: new perspectives for highly doubly excited states of helium** — •Johannes Eiglsperger[1], Javier Madroñero[1,2], and Bernard Piraux[2] — [1]Physik Department, TU München, Germany — [2]Unité de physique atomique, moléculaire et d'optique, UC Louvain, Belgium

A comprehensive understanding of the general structure of the energy spectrum and eigenstates of two-electron atoms at and near the double ionization threshold requires sophisticated theoretical approaches.

We present a spectral method of configuration interaction type for 3D helium [1] which combines the complex rotation method with an appropriate expansion of the atom wave function in a basis of products of Coulomb-Sturmian functions of the electron radial coordinates with *independent* dilation parameters for the two electrons and bipolar harmonics of the angular coordinates. The freedom on the choice of the dilation parameters permits us to access highly excited states with rather small sizes of the basis. The associated eigenvalue problem is represented by full matrices. The computation of the matrix elements of $1/r_{12}$ is by far the most time-consuming part in our calculations. A combination of Gauss-Laguerre integration techniques with the generalized Wigner-Eckart theorem and recurrence relations [2] allows an efficient and stable calculation of these matrix elements [3].

[1] E. Foumouo *et al.*, Phys. Rev. A **74**, 063409 (2006).
[2] J. Zamastil *et al.*, Phys. Rev. A **75**, 022506 (2007).
[3] J. Eiglsperger *et al.*, in preparation.

## A 21: Interaction with Strong or Short Laser Pulses II

Zeit: Mittwoch 16:30–18:00 Raum: VMP 6 HS-C

**Fachvortrag** A 21.1 Mi 16:30 VMP 6 HS-C

**Spin effects in purely laser-induced pair creation** — •Matthias Ruf, Carsten Müller, Karen Z. Hatsagortsyan, Guido R. Mocken, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

Electron-positron pair creation is investigated in an oscillating electric field, which can be formed by two counter-propagating laser fields. A numerical ansatz is employed to propagate the corresponding Dirac equation on a 2+1 dimensional space-time grid. This enables us to obtain the momentum distribution of the created particles in a single computation. It is found that for linear laser polarization the spin state of the electron is not relevant for the process, whereas for circular polarization a strong asymmetry occurs between the two spin orientations. This effect can be explained in the context of a quasi-classical approach by an additional spin term of the classical Hamiltonian. The process is in principle of interest for experimental studies in upcoming intense x-ray laser facilities.

A 21.2 Mi 17:00 VMP 6 HS-C

**Study of multiple ionization of Xe induced by intense XUV femtosecond laser pulse** — •Roland Guichard, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

Recently, an experiment performed at the FLASH source of Hamburg showed that xenon atoms irradiated with intense XUV femtosecond laser pulses can be ionized up to $Xe^{21+}$ [1]. Contrary to an experiment performed with a conventional IR laser [2] where multiple ionization is understood within tunneling and rescattering framework, the previous can neither be interpreted within the perturbative nor the non-perturbative theories of laser-atom interaction. Furthermore, the XUV frequency is in the range of the well-known giant resonance of the Xe $4d$ shell [3,4] which renders the dynamics of the very first ionization steps unclear. To shed more light onto these processes, we develop a multielectronic treatment based on time-dependent density functional theory. First results and computational issues will be presented in the talk.

[1] A.A. Sorokin, S.V. Bobashev, T. Fiegl, K. Tiedtke, H. Wabnitz, and M. Richter. *Phys. Rev. Lett.*, **99** (2007)
[2] K. Yamakawa, Y.Akahane, Y. Fukuda, M. Aoyama, N. Inoue, H. Ueda, and T. Utsumi. *Phys. Rev. Lett.*, **92** (2004)
[3] R. Haensel, G. Keitel, P. Schreiber, and C. Kunz. *Phys. Rev.*, **188** (1969)
[4] A. Zangwill and P. Soven. *Phys. Rev. A*, **21** (1980)

A 21.3 Mi 17:15 VMP 6 HS-C

**Bestimmung der H2 bzw. He - Clustergrössenverteilung für Experimente in straken Laserfeldern** — •Rui Alexandre Costa Fraga und Robert Grisenti — Institut für Kernphysik Goethe Universität, Frankfurt am Main, Deutschland

Mit Hilfe der Rayleigh-Gans-Theorie für Lichtstreuung an sphärischen Partikel wird die Clustergrössenverteilung unserer Clusterquelle bestimmt. Diese Clusterquelle wird dann verwendet um H2 und He-Cluster zu erzeugen, die dann mit einem starken Laserfeld (1e16 $W/cm^2$) wechselwirken sollen. Die daraus entstehenden Ionen werden mit einem MCP-Detektor untersucht.

A 21.4 Mi 17:30 VMP 6 HS-C

**Electronic Wavepackets in Lithium** — •Michael Schuricke, Jochen Steinmann, Ganjun Zhu, Manuel Kremer, Bettina Fischer, Robert Moshammer, Alexander Dorn, and Joachim Ullrich — Max Planck Institut für Kernphysik, Heidelberg, Germany

Whenever an excitation process coherently transfers population from an initial state to several final states a wavepacket is created. Its dynamics will be determined by the number of excited states, their energy differences and their spatial wavefunctions. The creation of a wavepacket can be achieved with a single photon or as in this case

with several photons, as long as the final states lie within the coherence bandwidth of the laser pulse.
In our experiment a superposition of 4p and 4f states was excited by three-photon absorption from a Ti:Sa laser pulse with 800 nm wavelength and 20 fs duration. The peak intensity of the pulses was kept moderate and therefore the ionization rate for a single pulse was negligible. The evolution of the wave packet was probed by a variable delayed probe pulse ionizing the atoms and determining the momenta of the ejected electrons. As result, dramatic changes in the momentum distribution as a function of delay time were observed.
By shaping the spectral profile of the laser, it was also possible to excite superpositions of the 9p,f and 10p,f states via three photon excitation. The measurements allow to deduce the multiphoton excitation amplitudes and their relative phases with respect to the different intermediate states.

A 21.5 Mi 17:45 VMP 6 HS-C

**High-quality laser-accelerated ion beams for medical applications** — •Zoltan Harman[1], Yousef I. Salamin[1,2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]American University of Sharjah, POB 26666, Sharjah, United Arab Emirates

Cancer radiation therapy requires accelerated ion beams of high energy sharpness and a narrow spatial profile. As shown recently [1], linearly and radially polarized, tightly focused and thus extremely strong laser beams should permit the direct acceleration of light atomic nuclei up to energies that may offer the potentiality for medical applications. Radially polarized beams have better emittance than their linearly polarized counterparts. We put forward the direct laser acceleration of ions, once the refocusing of ion beams by external fields is solved or radially polarized laser pulses of sufficient power can be generated.

[1] Y. I. Salamin, Z. Harman, C. H. Keitel, Phys. Rev. Lett. 100, 155004 (2008)

## A 22: Attosecond Physics II

Zeit: Mittwoch 16:30–17:30 Raum: VMP 8 R208

**Fachvortrag** A 22.1 Mi 16:30 VMP 8 R208

**Attosecond pump-probe electron interferometry** — •Kathrin Klünder[1], Thomas Remetter[1], Marko Swoboda[1], Johan Mauritsson[1], Anne L'Huillier[1], Kenneth J. Schafer[2], Freek Kelkenberg[3], Wing-Kiu Siu[3], Per Johnsson[2,3], Marc Vrakking[3], Franck Lépine[4], Matthias F. Kling[5], Irina Znakovskaya[5], Thorsten Uphues[5], Enrico Benedetti[6], Federico Ferrari[6], Giuseppe Sansone[6], and Mauro Nisoli[6] — [1]Department of Physics, Lund University, Lund, Sweden — [2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana, USA — [3]FOM Institute for Atomic and Molecular Physics, Amsterdam, The Netherlands — [4]Université Lyon 1, CNRS,Villeurbanne, France — [5]Max-Planck-Institut für Quantenoptik, Garching, Germany — [6]CUSBO, ULTRAS-INFM, Department of Physics, Politecnico, Milano, Italy

We present an interferometric pump-probe experiment to characterize ultrafast bound electron dynamics using isolated attosecond pulses generated from an ultrashort, carrier-envelope-phase stabilized infrared laser with a time-dependent polarization. These attosecond pulses have sufficient photon energy and are broad enough to excite coherently all the p-states in Helium and a fraction of the continuum. The wave packets created in Helium, partly trapped in the atomic potential, are further probed by a 7 fs infrared laser field. From the observed interference between the different ionization pathways we show that it is possible to extract the amplitudes and phase evolutions of the bound, excited states.

A 22.2 Mi 17:00 VMP 8 R208

**Laser-Assisted Photoemission from surface/adsorbate systems** — •Guido Saathoff[1], Luis Miaja-Avila[2], Stefan Mathias[3], Jing Yin[2], Chan La-o-vorakiat[2], Michael Bauer[4], Martin Aeschlimann[3], Margaret Murnane[2], and Henry Kapteyn[2] — [1]MPI für Quantenoptik, Garching — [2]Jila and University of Colorado, Boulder, CO — [3]TU Kaiserslautern — [4]Universität Kiel

Laser-assisted photoemission (LAPE) and Auger decay (LAAD) have evolved into a powerful tool for time-resolved studies of the femtosecond-to-attosecond dynamics of highly-excited states in atoms. Recently we have extended LAPE to clean solid surfaces [1] and a detailed study has allowed the discrimination of surface-LAPE against adverse above-threshold photoemission (ATP) caused by the high laser intensities required for dressing [2]. This has led to the first direct time-resolved observation of the lifetime of a core-excited state of an atom adsorbed onto a surface. By combining LAPE with LAAD, we measured the $4d^{-1}$ core level lifetime of Xenon on Pt(111) to be 7±1 fs [3]. We also show that using longer laser wavelengths enhances LAPE and LAAD while ATP is strongly suppressed. This will allow for time-resolved measurements on low-energy Auger electrons, which are usually buried by ATP. Our results open up time domain measurements of electronic processes in surface/adsorbate systems, which are fundamental to the understanding of surface chemistry.

[1] L. Miaja-Avila et al.,Phys Rev. Lett. 97, 113604 (2006)
[2] G. Saathoff et al., Phys. Rev. A, 77, 022903 (2008)
[3] L. Miaja-Avila et al., Phys.Rev. Lett., 101, 046101 (2008)

A 22.3 Mi 17:15 VMP 8 R208

**Attosecond Pump-Probe Experiments with a Reaction Microscope** — •Helga Rietz, Konstantinos Simeonidis, Ram Gopal, and Joachim Ullrich — Max-Planck-Insitut für Kernphysik, Heidelberg

An experiment combining an attosecond light source based on high harmonic generation (HHG) in Argon with an electron and recoil ion spectrometer, a so called reaction microscope, is presented. The experiment aims at performing pump-probe-measurements with attosecond time resolution on atoms and small molecules. One future goal is to take previous work from our insitute, where the vibrational motion of the nuclear wave packet in $H_2^+$ and $D_2^+$ was observed with femtosecond resolution, to the next level.

The harmonics are generated with a commercially available Ti:Sapphire amplifier delivering laser pulses with 25 fs duration at a wavelength of 800 nm and approximately 1 mJ pulse energy. The repetition rate can be varied between 3 and 10 kHz. Further compression of the pulses is achieved via spectral broadening through self phase modulation (SPM). The HHG-source yields photon fluxes of typically $10^9$ photons per second and harmonic order for the plateau region of the VUV-spectrum, where the cutoff is observed at approximately 40 eV for Argon. The whole setup including pump-probe optics and the HHG-target is housed in a novel vacuum chamber to meet the challenging demands for stability set by the goal to achieve attosecond time resolution.

## A 23: Interaction of Matter with Ions

Zeit: Donnerstag 10:30–12:30 Raum: VMP 6 HS-B

**Fachvortrag** A 23.1 Do 10:30 VMP 6 HS-B

**A simple parameter-free one-center one-electron description of $H_2$ molecules** — •Armin Lühr, Yulian V. Vanne, and Alejandro Saenz — Institut für Physik, AG Moderne Optik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, D-10117 Berlin, Germany.

A peculiarity in quantum mechanics is the fact that in the case of hydrogen most experimental efforts were done for *molecules* while the theoretical description concentrates mainly on *atomic* hydrogen. This discrepancy is motivated experimentally by the reactivity of atomic hydrogen and theoretically with the complexity of the full description of the molecular systems including, e.g., two electrons as well as rota-

tional and vibrational degrees of freedom. A direct comparison — if possible — of results obtained with a full molecular and a model description can yield the importance of two-electron or molecular effects, like the deviation from a spherical symmetric charge distribution.

A simple one-electron, single-centered model potential was proposed recently [1] and applied to various physical problems [2]. The model potential is designed to agree in the ionization potential and long-range Coulomb potential with the $H_2$ molecule. Thereby, the model potential can be used for arbitrary internuclear distances. By comparison of excitation energies, transition moments, photo-electron spectra and collisional cross sections for $H_2$ with those determined with the model its applicability shall be examined.

[1] Y. V. Vanne and A. Saenz, J. Mod. Opt. **55**, 2665 (2008)
[2] A. Lühr *et al.*, Phys. Rev. A **78**, 042510 (2008)

**Fachvortrag** A 23.2 Do 11:00 VMP 6 HS-B

**Dynamik des Elektroneneinfangs in Stößen von hochgeladenen Ionen mit Atomen** — •D. Fischer[1], Y. Xue[1], S. Knoop[2], M. Zapukhlyak[3], T. Kirchner[3], K.-U. Kühnel[1], R. Ginzel[1], S. Hagmann[4], R. Hoekstra[2], J. R. Crespo López-Urrutia[1], R. Moshammer[1] und J. Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]KVI, Groningen, Holland — [3]Institut für theoretische Physik, TU Clausthal-Zellerfeld — [4]GSI, Darmstadt

Mit Hilfe der COLTRIMS-Technik ("cold target recoil ion momentum spectroscopy") wurde Elektroneneinfang in Stößen zwischen hochgeladenen Ionen und Atomen im Bereich von einigen keV/amu bis hin zu MeV/amu differentiell untersucht. Für den Einfachelektroneneinfang in langsamen Stößen zwischen $Ar^{q+}$-Ionen (q>14) und Atomen wurden zustandsaufgelöste, winkeldifferentielle Wirkungsquerschnitte gewonnen. Neueste Gekoppelte-Kanäle-Rechnungen zeigen gute Übereinstimmung mit den experimentellen Daten. Beim Mehrfachelektroneneinfang wurde nicht nur der Zustand, in den die Elektronen eingefangen wurden, bestimmt, sondern auch die durch Autoionisation des Projektils emittierten Elektronen wurden koinzident detektiert. Diese Resultate bieten Einblicke in die Relaxationsprozesse hochangeregter Ionen. Bei schnellen Stößen stellt die Vermessung des Einfangs, aufgrund der sehr kleinen Querschnitte, eine große Herausforderung dar. In einem Pilotexperiment am Speicherring ESR der GSI konnte erstmals der Einfang in ein schnelles $U^{92+}$-Projektil differentiell untersucht werden. Weitere Experimente sind geplant, bei denen insbesondere radiative Transferreaktionen beobachtet werden sollen.

**Fachvortrag** A 23.3 Do 11:30 VMP 6 HS-B

**ECC und Elektronenkontinua in Ion-Atomstößen mit $q/v \gg 1$** — •Siegbert Hagmann — Inst. f. Kernphysik, Univ. Frankfurt und GSI Darmstadt

Wir haben doppelt-differentielle Wirkungsquerschnitte (DDCS) für einfache und doppelte Elektronenemission für die Stoßsysteme $F^{8+,9+}$ und $I^{23+,25+}$ + He über Elektron-Recoil Koinzidenzen gemessen. Dabei wurde erstmals der gesamte wesentliche Phasenraum $0^0 \leq \Theta_e \leq 360^0$ und $0 < v_e/v_{proj} \leq 2$ abgedeckt. Wir beobachten, daß der $v_e = v_{proj}$ Cusp bei großem $q_{proj}/v_{proj}$ überwiegend aus der Doppelionisation des Targets stammt. Das Projektilkontinuum dominiert ganz deutlich über das Targetkontinuum. Wir diskutieren die auffälligen Strukturen der koinzidenten DDCS.

A 23.4 Do 12:00 VMP 6 HS-B

**Impulsspektroskopische Untersuchung des Elektroneneinfangs in Proton-Helium Stößen** — •Hong-Keun Kim — Institut für Kernphysik, Goethe Universität Frankfurt am Main

Bei $H^+$-Helium Stößen wurde der streuwinkel differenzielle Wirkungsquerschnitt des Einelektronentransfers (single capture, SC) bestimmt. Bei Projektilenergien zwischen 600 und 1200 keV/u wurden sowohl der Einfluss großer bzw. sehr kleiner Störungen abgedeckt. Zur experimentellen Untersuchung kam die Technologie der Rückstossionenimpulsspektroskopie (COLTRIMS) zum Einsatz. Bei den höchsten untersuchten Einschussenergien gab es Evidenzen für Prozesse höherer Ordnung wie den Elektron-Kern-Thomas-Prozess. Die experimentell erfassten Daten stehen in guter Übereinstimmung mit neuen theoretischen Ergebnissen der four-body one-channel distorted wave Modelle (CDW-BFS,CDW-BIS und BDW).

A 23.5 Do 12:15 VMP 6 HS-B

**Anwendung eines kryogenischen Mikrojets als internes Target am ESR der GSI** — •Nikolaos Petridis, Matthias Kühnel und Robert Grisenti — Institut für Kernphysik Frankfurt

Am experimentellen Speicherring an der GSI in Darmstadt wurde ein neuartiges System zur Erzeugung von Clusterstrahlen als Anwendung für ein internes Target installiert. Durch Expansion eines kryogenisch gekühlten Gases durch eine wenige Mikrometer große Düse werden Flächendichten in der Interaktionszone mit dem Ionenstrahl des ESR erreicht, die um Größenordnungen höher liegen als diejenigen, die mit dem alten Aufbau des internen Targets erreicht werden konnten. Während der Testphase des Aufbaus wurden einige Eigenschaften des neuen Targets ermittelt. Das Augenmerk lag auf den erreichbaren Flächendichten, dem Einfluss auf das Vakuum im Speicherring und mögliche Verbesserungen für einen Einsatz im zukünftigen neuen Speicherring der GSI, dem NESR. In diesem Vortrag wird über die Ergebnisse der Teststrahlzeiten und die Eigenschaften des neuen Targets berichtet.

## A 24: Ultra-Cold Atoms, Ions and BEC II (with Q)

Zeit: Donnerstag 10:30–12:15 Raum: VMP 6 HS-C

**Fachvortrag** A 24.1 Do 10:30 VMP 6 HS-C

**Towards surface quantum optics with Bose-Einstein condensates in evanescent waves** — Helmar Bender, Philippe Courteille, Claus Zimmermann, and •Sebastian Slama — Physikalisches Institut, Eberhard-Karls-Universität Tübingen, Auf der Morgenstelle 14, D-72070 Tübingen

I will speak about the interaction of ultracold atoms with surfaces. This topic is very interesting for several reasons, for example from a fundamental point of view for the measurement of van der Waals like surface potentials and the understanding of surface effects like adsorption. From a quantum optical point of view it is interesting to coherently couple atomic matter waves with evanescent light waves for nondestructive atom detection with the prospect of QND measurements of atom numbers. Evanescent light waves are also interesting for technological reasons because by the use of surface plasmons it might be possible to produce nanostructured surface traps. In Tübingen we have made a first step towards these goals and have set up an experiment in which we bring Bose-Einstein condensates very close to the surface of a glass prism. We are able to position the atoms in a controlled way to distances from the surface below one micrometer by loading them into a combined magnetic and evanescent wave surface trap. I will present first measurements with our setup and discuss our plans for the future.

A 24.2 Do 11:00 VMP 6 HS-C

**Dissipative processes of a trapped atom approaching conditions of electromagnetically induced transparency** — •Maryam Roghani, Heinz-Peter Breuer, and Hanspeter Helm — University of Freiburg, Hermann-Herderstr. 3,D-79104 Freiburg, Germany

We study a three-level atom trapped in a one-dimensional quantum mechanical harmonic oscillator, interacting with two counterpropagating laser beams. Atom-light interaction leads to an entangled state of electronic and vibrational degrees of freedom. We show that by prudent choice of experimental parameters the atom approaches EIT-like (Electromagnetically Induced Transparency) conditions as it is cooled down to the lowest level of the trap [1], even beyond the Lamb-Dicke limit. Solving numerically the master equation gives us the opportunity to derive from the time-dependent density matrix elements the evolution of transparency and entanglement, together with the force and dissipation terms which are active in the removal of translational energy from the trapped atom. This scheme may find application in the purely optical preparation of Bose-Einstein condensates without evaporative cooling and also in the laser-cooling of macroscopic objects of crystalline matter. [1]. Trapped-Atom Cooling Beyond The Lamb-Dicke Limit Using Electromagnetically-Induced Transparency, M. Roghani and H. Helm , Physical Review A 77, 043418 (2008).

A 24.3 Do 11:15 VMP 6 HS-C

**dynamical structure factor and spin-density separation for a weakly-interacting two-component Bose gas** — •Ming-Chiang Chung — Academia Sinica Taiwan

We show that spin-density separation in a Bose gas is not restricted to 1D but also occurs in higher dimension. The ratio ($\alpha$) of the intra-species atom-atom interaction strength to the inter-species interaction strength, strongly influences the dynamics of spin-density separation and the elementary excitations. The density wave is phonon-like for all values of $\alpha$. For $\alpha < 1$, spin wave is also phonon-like. The spin waves have a quadratic dispersion in the $\alpha = 1$ coupling regime, while in the phase separated regime ($\alpha > 1$) the spin waves are found to be damped. The dynamical structure factor (DSF) reveals two distinct peaks corresponding to the density and spin waves for $\alpha \leq 1$. For $\alpha > 1$ there is only one DSF peak corresponding to the density wave.

A 24.4 Do 11:30 VMP 6 HS-C

**Coherent control and matter wave interference of single atoms** — •Andreas Steffen, Michał Karski, Leonid Förster, Jai-Min Choi, Tan Wang, Artur Widera, and Dieter Meschede — Institut für angewandte Physik, Bonn, Deutschland

We report on recent progress for coherent spin-dependent transport of neutral atoms, paving the way to creating entanglement via controlled collisions.

We store a small number of ultracold caesium atoms in a state-selective 1D optical lattice. We are able to manipulate and detect atoms with close to nearest-neighbor precision. By displacing the potentials for two spin states, vibrational sidebands appear in the microwave spectrum, which we have employed to cool the atoms to the vibrational ground state in the axial direction. We have also achieved coherent state-selective transport over multiple lattice sites. This opens up a number of applications, such as the single trapped atom interferometer and the quantum walk with a single atom.

We will present latest experimental results.

A 24.5 Do 11:45 VMP 6 HS-C

**Ultracold Atoms in Superconducting Microtraps** — •Helge Hattermann, Daniel Cano, Brian Kasch, Florian Jessen, Max Kahmann, Dieter Kölle, Reinhold Kleiner, Claus Zimmermann, and József Fortágh — Center for Collective Quantum Phenomena and their Applications, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen

We present recent measurements on ultracold atoms in a superconducting magnetic mictrotrap. It is shown that the Meissner effect plays a critical role in determining the near field trap shape. Our experimental setup consists of a $^{87}$Rb BEC apparatus and an optical tweezers for transporting an ultracold atom cloud 44mm to the surface of a helium flow cryostat at 4 K. Here, the atoms are loaded into a magnetic microtrap formed by a 125 micron diameter superconducting niobium wire. The influence of the Meissner effect on the trap geometry has been evaluated both theoretically [1] and experimentally [2]. The Meissner effect shortens the distance between the trap and the superconductor, reduces the magnetic field gradients and lowers the trap depth. We also observed a temperature dependence of the magnetic field exclusion from the superconducting wire. Based on our measurements, we discuss future strategies for the manipulation of ultracold atoms in superconducting traps.

[1] D. Cano *et al.*, Phys. Rev. A 77, 063408 (2008)
[2] D. Cano *et al.*, Phys. Rev. Lett. 101, 183006 (2008)

A 24.6 Do 12:00 VMP 6 HS-C

**Towards a finite system of degenerate fermions** — Timo B. Ottenstein, Thomas Lompe, Andre N. Wenz, •Gerhard Zürn, and Selim Jochim — Max Planck Institut für Kernphysik, Heidelberg, Germany

We report on our approach towards a finite ensemble of degenerate fermionic $^6$Li atoms. In this system it will be possible to study the crossover from mesoscopic physics to the thermodynamic limit. One of the first phenomena to study is the formation of shell structures in a two component mixture with tunable interactions. $^6$Li is especially well suited due to the easy tunability of the interparticle interaction by means of Feshbach resonances.

The starting point of such experiments will be our BEC of $^6$Li Feshbach molecules in an optical dipole trap. For preparing an ensemble of few atoms a precise control of the particle number is essential. This requirement can be fullfilled by transferring the sample into a micrometer sized trap with high trapping frequencies which is realized by a tightly focused laser beam. So far we have determined the parameters of our micro trap in an external test setup with satisfying results.

The next step will be the integration of the micro trap into the existing setup and testing its performance.

## A 25: Interaction with Strong or Short Laser Pulses III

Zeit: Donnerstag 10:30–11:15 Raum: VMP 8 R208

A 25.1 Do 10:30 VMP 8 R208

**Strong field dynamics of the hydrogen molecular ion under full Coulomb interaction** — •Frank Grossmann[1], Alexander Kästner[1], Anatole Kenfack[2], and Jan-Michael Rost[3] — [1]Institut für Theoretische Physik, TU Dresden, 01062 Dresden — [2]Freie Universität Berlin, Institut für Chemie und Biochemie, Takustr. 3, D-14195 Berlin — [3]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38 . D-01187 Dresden

In strong field physics the use of the so called soft core potential, which smoothes the Coulomb singularity at the nucleus, is a well accepted approximation. It facilitates the numerical solution of the time-dependent Schroedinger equation considerably. Here, we study the dissociation and ionization of the hydrogen molecular ion under the influence of a strong pulsed laser field and in dependence on the initial vibrational excitation. We compare our calculations using the full Coulomb potential with those of Feuerstein and Thumm using a soft core potential [1]. We conclude that the soft-core calculations severely underestimate the dissociation probability and give reasons for this discrepancy.

[1] B. Feuerstein and U. Thumm, Phys. Rev. A 67, 043405 (2003).

A 25.2 Do 10:45 VMP 8 R208

**Non-collinear high harmonic generation** — •Andreas Vernaleken, Akira Ozawa, Igor Gotlibovych, Waldemar Schneider, Thomas Udem, and Theodor W. Hänsch — Max-Planck-Insitut für Quantenoptik, Garching

We present the results of our investigation of non-collinear high harmonic generation (NCHHG). In conventional high harmonic generation (HHG), the generated harmonic radiation is emitted collinearly with the fundamental beam. In contrast, when focusing two infrared (IR) beams into a xenon gas jet at a small angle, we observe collimated high harmonic radiation of up to 21st order in a direction which is non-collinear with respect to the driving IR beams.

We have systematically investigated the dependence of NCHHG on experimental parameters such as the delay between the driving pulses for different harmonic orders and will compare our experimental results to a numerical simulation based on a simple model.

The potential application of NCHHG as a combined method for efficient generation and outcoupling of extreme ultraviolet radiation in the next generation of cavity-assisted HHG experiments will be discussed.

A 25.3 Do 11:00 VMP 8 R208

**Shaping and application of picosecond-length laser pulses** — •Terry Mullins[1], Simone Goetz[1], Magnus Albert[2], Wenzel Salzmann[3], Brett DePaola[4], Roland Wester[5], and Matthias Weidemueller[1] — [1]Universitaet Heidelberg — [2]Aarhus Universitet — [3]Fraunhofer IPM Freiburg — [4]Kansas State University — [5]Universitaet Freiburg

Picosecond-length pulses have a bandwidth which is well suited to study processes taking place over an energy range of a few tens of wavenumbers, while concurrently offering time resolution in the picosecond range. While suitably high-resolution pulse-shapers exist for femtosecond-length pulses [1,2], and are relatively straightforward to build, designing and building a pulse-shaper with suitably high resolution for picosecond pulses is more difficult. The smaller bandwidth means longer path-lengths through the shaper optics are usually required, leading to large devices. We have overcome these problems and developed a compact, suitably high-resolution shaper. One example of a process well-suited to picosecond pulses is the photoassocia-

tion of ultracold atoms [3,4], which is most efficient within a few tens of wavenumbers from the dissociation limit, and typically having vibrational dynamics in the tens of picoseconds range. We discuss the application of shaped picosecond pulses to this process.

[1] J. Weiner et al., IEEE J. Quant. Elec. 28, 908 (1992)
[2] F. Verluise et al., J. Opt. Soc. Am. B 17, 138 (2000)
[3] W. Salzmann et al., Phys. Rev. Lett. 100, 233003 (2008)
[4] C. Koch et al., Phys. Rev. A, 70, 013402 (2004)

## A 26: Atomic Clusters III

Zeit: Donnerstag 14:00–16:00 Raum: VMP 6 HS-B

**Hauptvortrag** A 26.1 Do 14:00 VMP 6 HS-B

**X-ray spectroscopy in an ion trap: doped semiconductor cages, transition metal molecules, and water clusters** — •Tobias Lau[1], Konstantin Hirsch[1], Philipp Klar[1], Andreas Langenberg[1], Fabian Lofink[1], Jürgen Probst[1], Robert Richter[1], Jochen Rittmann[1], Marlene Vogel[1], Vicente Zamudio-Bayer[1], Bernd von Issendorff[2], and Thomas Möller[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

With the development of ion traps for core level excitation, X-ray absorption spectroscopy on size-selected gas phase clusters has come into reach. For the first time, local electronic properties of isolated clusters and nanoparticles can be accessed with element specificity. For doped semiconductor clusters, XAS provides the key to understanding the electronic structure and the nature of bonding, elucidating electronic shells in highly symmetric cages. In transition metal dimers, core level excitation revealed atomic localization of 3d valence electrons in $Cr_2^+$, $Mn_2^+$, and $CrMn^+$ dimers. In protonated water clusters, hydrogen bonding is studied via oxygen 1s excitation. Very recently, even direct core-level photoionization could be accessed in silicon and aluminum clusters. We will give an overview of the experimental technique and present highlights from recent results.

**Hauptvortrag** A 26.2 Do 14:30 VMP 6 HS-B

**Electron and ion emission from clusters in intense laser pulses** — •Thomas Fennel — Institute of Physics, University of Rostock, Germany

A fascinating aspect of the interaction of intense laser pulses with atomic clusters is the creation of transient nanoplasmas. Whereas the efficient energy absorption by clusters, i.e. through collective electron excitations, is well understood these days, detailed insight into the nanoplasma dynamics underlying the generation of highly charged ions and energetic electron remains a challenge. Recently, electron rescattering in clusters, which can be driven by dynamic polarization fields as well as by the laser field itself, has been identified as the central mechanism for high energy electron generation [1,2]. Corresponding experimental and simulation results on metal and rare-gas clusters as well as perspectives for future experiments with few-cycle pulses will be discussed. The prediction of ion charge spectra requires the modelling of ionization and recombination processes [3]. New data on the intensity dependent charging of rare-gas clusters will be presented, revealing signatures of cluster avalanche ionization near the threshold for atomic barrier suppression [4].

[1] Th. Fennel et al., Phys. Rev. Lett. **98**, 143401, 2007
[2] U. Saalmann et al. Phys. Rev. Lett. **100**, 133006, 2008
[3] Th. Fennel et al., Phys. Rev. Lett. **99**, 233401, 2007
[4] T. Döppner et al., in preparation

**Hauptvortrag** A 26.3 Do 15:00 VMP 6 HS-B

**Helium-embedded clusters exposed to intense laser pulses: From "local ignition" to "global cooling"** — •Ulf Saalmann — MPI-PKS, Nöthnitzer Str. 38, 01187 Dresden

As well known intense-laser interaction with matter strongly depends on the laser frequency. For atoms and molecules the famous Keldysh parameter is used in order to quantify the transition from tunneling to multi-photon ionization, which occurs for a fixed intensity by increasing the frequency.

In clusters, where a strong laser quickly creates a nano-plasma inside the cluster, we will show that the response is better characterized by the quiver amplitude $x_{\mathrm{quiv}} = F/\omega^2$, the amplitude of a free electron oscillating in the field of a laser with strength $F$ and frequency $\omega$. This amplitude has to be compared to the cluster radius $r$. Whereas for large amplitudes $x_{\mathrm{quiv}} \geq r$ collective plasma oscillations dominate, electronic charge migration occurs when the quiver amplitude is small or neglible $x_{\mathrm{quiv}} \ll r$. Since $x_{\mathrm{quiv}}$ shrinks quadratically with $\omega$, samples exposed to free-electron laser radiation (either UV or X-ray) will, despite the high field strengths available, show charge migration, as has recently been seen in experiments at FLASH.

We present microscopic calculations for clusters embedded in helium nano-droplets where both mechanism — collective excitations and charge migration — can be clearly identified. They have profound consequences like igniting a helium droplet with a handful of xenon atoms or slowing down the Coulomb explosion of a highly-charged sample.

**Hauptvortrag** A 26.4 Do 15:30 VMP 6 HS-B

**Resonant amplification of quantum fluctuations with a spinor gas** — Carsten Klempt[1], Oliver Topic[1], Manuel Scherer[1], Thorsten Henniger[1], Garu Gebreyesus[1], Philipp Hyllus[2], Wolfgang Ertmer[1], Luis Santos[2], and •Jan Arlt[1] — [1]Institut für Quantenoptik — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, D-30167 Hannover

Bose-Einstein condensates of atoms with non-zero spin constitute not only an optimal scenario to investigate fundamental properties of magnetic superfluids, but also an ideal system to study amplification of quantum and classical fluctuations. This is strikingly manifested in a sample initially prepared in the $m = 0$ state, where spin-changing collisions triggered by quantum fluctuations may lead to the creation of correlated pairs in $m = \pm 1$. We show that the pair creation efficiency is strongly influenced by the interplay between the external trapping potential and the Zeeman effect and reflects the confinement-induced magnetic-field dependence of elementary spin excitations of the trapped condensate. Remarkably, pair creation in our experiments is characterized by a multi-resonant dependence on the magnetic field. Pair creation at these resonances acts as strong parametric matter-wave amplifier. Depending on the resonance condition, this amplification can be extremely sensitive or insensitive to the presence of seed atoms. We show that pair creation at a resonance which is insensitive to the presence of seed atoms is triggered by quantum fluctuations and thus the system acts as a matter-wave amplifier for the vacuum state.

## A 27: Ultra-Cold Atoms, Ions and BEC III (with Q)

Zeit: Donnerstag 14:00–16:00 Raum: VMP 6 HS-C

**Hauptvortrag** A 27.1 Do 14:00 VMP 6 HS-C

**Quantum gases of ultracold polar molecules** — •Silke Ospelkaus — JILA, NIST and University of Colorado, Boulder, CO, USA

Polar molecules, molecules exhibiting a permanent electric dipole moment, have bright perspectives as systems with long-range and anisotropic interactions. These interactions form the basis for numerous exciting theoretical proposals ranging from ultra-cold chemistry, precision measurements, quantum phase transitions, to novel systems for quantum information processing and quantum control with external magnetic and electric fields. We will present our recent work on the creation and characterization of a near quantum degenerate gas of rovibrational ground state polar $^{40}K^{87}Rb$ molecules. Using a single step of two photon coherent transfer, we convert weakly bound

KRb Feshbach molecules to the rovibrational ground state of the singlet electronic ground molecular potential. The polar molecules have a permanent electric dipole moment, which we measure with Stark spectroscopy to be 0.566(17) Debye.

Work done in collaboration with K.-K. Ni, M. H. G. de Miranda, A. Peer, B. Neyenhuis, J. J. Zirbel, P. S. Julienne, S. Kotochigova, D. S. Jin and J. Ye

**Fachvortrag** A 27.2 Do 14:30 VMP 6 HS-C

**Quantum Gases under Electron Bombardment** — •Herwig Ott, Tatjana Gericke, Peter Würtz, Tim Langen, and Andreas Koglbauer — Institut für Physik, Johannes Gutenberg-Universität, Mainz

Scanning electron microscopy is routinely used to study solid objects on a nanometer scale. Applied to ultracold quantum gases it constitutes a powerful imaging and manipulation technique that combines single atom sensitivity with high spatial resolution.

We have adapted a scanning electron microscope for the study of Bose-Einstein condensates of rubidium atoms. The focussed electron beam ionizes the atoms which are subsequently detected. Loading the condensate in a two-dimensional optical lattice with 600 nm period we demonstrate single site addressability and show that one can produce arbitrary patterns of occupied lattice sites. Such micro-engineered quantum gases might become an important resource for future applications in quantum simulation and quantum information processing.

Ultimately, we want to employ this technique to make snapshots of the many-body wave function and to get *in situ* access to the quantum correlations of bulk, lattice and low-dimensional quantum systems.

A 27.3 Do 15:00 VMP 6 HS-C

**Trap assisted creation of giant molecules and Rydberg-mediated coherent charge transfer in a Penning trap** — •Igor Lesanovsky[1,2], Markus Müller[1], and Peter Zoller[1] — [1]Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria — [2]School of Physics and Astronomy, University of Nottingham, Nottinhgham, UK

We study two ions confined in a Penning trap. We show that electronically highly excited states exist in which an electron is delocalized among the two ions forming a giant molecule of several micrometer size. At energies close to the top of the Coulomb barrier these molecular states can be regarded as superpositions of Rydberg states of individual ions. We illuminate the possibility to observe coherent charge transfer between the ions. Beyond a critical principal quantum number the electron can coherently tunnel through the Coulomb barrier to an adjacent doubly charged ion. The tunneling occurs on timescales on which the dynamics of the nuclei can be considered frozen and radiative decay can be neglected. The present study can be regarded as a first step towards the implementation of electronic Hubbard models in an ion trap setup.

[1] I. Lesanovsky, M. Müller and P. Zoller, arXiv:0809.3213 (2008)

A 27.4 Do 15:15 VMP 6 HS-C

**Collective effects in ultracold atomic clouds interacting with a high-finesse resonator** — •Simone Bux, Gordon Krenz, Sebastian Slama, Philippe Courteille, and Claus Zimmermann — Physikalisches Institut, Universität Tübingen

We study the coupled dynamics of ultracold or Bose-condensed atomic clouds or interacting with the modes of an optical high-finesse ring resonator. Our interest is focused on collective effects taking place in such systems, like Collective Atomic Recoil Lasing or superradiant Rayleigh scattering. We load ultracold atomic clouds into the light field supported by a laser-pumped ring resonator. Density fluctuations in the atomic cloud lead to strong transient backscattering of light, which is recorded in real time. The scattering couples and populates several quantized momentum states resolved in time-of-flight absorption images. Both, the optical and the matter wave signals are studied as a function of collective gain and detuning of the pump laser from the cavity resonance. We particularly focus our attention to the emergence of signatures of quantized motion in the gain profile and the threshold behaviour of the collective instability.

A 27.5 Do 15:30 VMP 6 HS-C

**Scattering of ultra-cold atoms by nano-cylinders** — •Andrés Naranjo, Javier Madroñero, and Harald Friedrich — Physik Department, TU München, Germany

Different scattering properties, like quantum reflection, are studied for the interaction between an ultra cold atom and a grounded perfectly conducting cylinder. For this, an expression for the interaction potential of a cylinder-dipole configuration is derived for the non retarded regime. This is an acceptable model which assumes that the atom interacts via its dipole polarizability. The calculation uses the traditional Green's function method in cylindrical coordinates imposing Dirichlet boundary conditions [1]. For large separations the potential exhibits explicitly the contribution of each of the dipole components to the interaction. It is shown that the radial and axial components share the same dependence on the separation $r$ and cylinder radius $R$, namely $1/\left(r^3 \log(r/R)\right)$, while the component perpendicular to these two has the form $1/r^5$ with a proportionality constant depending on the cross section area of the cylinder. The validity of this asymptotic behavior is numerically verified against the exact potential for realistic situations, e.g. helium atoms interacting with nanowires [2].

[1] J.A. Hernandes and A.K.T. Assis, *J. Electrostatics* **63**, 1115 (2005).
[2] A. Naranjo *et al.*, in preparation.

A 27.6 Do 15:45 VMP 6 HS-C

**Oscillation and stability of Dark-Bright solitons in cigar-shaped BECs** — •Stephan Middelkamp[1], Panayotis Kevrekidis[2], and Peter Schmelcher[1,3] — [1]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, INF 229, 69120 Heidelberg, Germany — [2]Department of Mathematics and Statistics, University of Massachusetts, Amherst MA 01003-4515, USA — [3]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany

We derive effective 1D vector equations that govern the axial dynamics of mean-field cigar-shaped condensates consisting of atoms in two different internal states with repulsive interactions. These coupled equations take into account the contributions of the transverse degree of freedom accuratley. We apply the equations to predict the oscillation frequency of dark-bright solitons in cigar-shaped traps and investigate their stability using a Bogoliubov-de-Gennes analysis.

## A 28: Precision Spectroscopy of Atoms and Ions IV, Interaction with VUV and X-Ray Light III

Zeit: Donnerstag 14:00–15:00 Raum: VMP 6 HS-E

A 28.1 Do 14:00 VMP 6 HS-E

**Das SPECTRAP-Experiment und erste Tests mit einer Offline-Ionenquelle** — •Bettina Sommer[1], Zoran Andjelkovic[1], Manuel Vogel[2] und Wilfried Nörtershäuser[1] — [1]GSI, Planckstrasse 1, 64291 Darmstadt — [2]Imperial College London, SW7 2BW London

Ziel des Experiments ist die laserspektroskopische Messung der Hyperfeinstruktur hochgeladener Ionen mit einer relativen Genauigkeit von etwa $10^{-7}$. Dazu werden extern erzeugte Ionen in einer kryogene Penningfalle eingefangen, gespeichert und laserspektroskopisch untersucht. Derartige Messungen erlauben stringente Tests der QED gebundener Zustände in extremen Feldern. Bereits vor der Verfügbarkeit schwerer, hochgeladener Ionen können Tests mit einfach geladenen und leichten, hochgeladenen Ionen aus Offline-Quellen durchgeführt werden. Dieser Vortrag beschäftigt sich mit der Produktion, dem Ionentransport und dem Einfang der Ionen in die Falle. Hierzu wurde der Gesamtaufbau mit SIMION simuliert und der Ionentransport systematisch untersucht. Korrespondierende Probemessungen wurden mit Hilfe einer Argon-Ionenquelle durchgeführt. Im zweiten Schritt wird eine kommerzielle Ionenquelle für mittlere Ladungszustände eingesetzt werden. Schließlich werden entschleunigte, hochgeladene Ionen aus der HITRAP-Anlage der GSI verwendet werden. Unsere Simulationen und offline-Tests dienen u.a. der Ermittlung der korrekten ionenoptischen Parameter für den effizienten Einfang solcher Ionen.

A 28.2 Do 14:15 VMP 6 HS-E

**Untersuchungen der Hyperfeinstruktur von La-Atomen mit**

**Hilfe hochaufgelöster Fourier-Transformations-Spektren** — Markus Raith[1], Yasmin Nighat[1], •Laurentius Windholz[1], Andrey Jarmola[2], Rubin Ferber[2], Sophie Kröger[3] und Gönül Basar[4] — [1]Inst. f. Experimentalphysik, Techn. Univ. Graz, Petersgasse 16, A-8010 Graz, Österreich — [2]University of Latvia, Laser Centre, 19 Rainis Blvd., LV-1586 Riga, Latvia — [3]Inst. f. Optik und Atomare Physik, Techn. Univ. Berlin, Hardenbergstr. 36, D-10623 Berlin — [4]Istanbul University, Physics Departement, TR-34134 Vezneciler, Istanbul, Turkey

Für das Element La sind für die meisten Energieniveaus die zugehörigen A- und B-Faktoren zur Beschreibung der Hyperfeinstruktur noch unbekannt. Mit Hilfe hochaufgelöster Fourier-Transformations-Spektren kann die Klassifizierung von La-Spektrallinien unter Zuhilfenahme der Hyperfeinstruktur überprüft werden bzw. - wenn die A- und B-Werte für eines der an einem Übergang beteiligten Niveaus bekannt sind - die Hyperfeinkonstanten des anderen Nivaus mit guter Genauigkeit ermittelt werden. Die laserspektroskopische Untersuchung von Übergängen liefert noch genauere Werte für A und B. Die Laseranregung nicht klassifizierbarer La-Linien ermöglicht durch Analyse der registrierten Hyperfeinstruktur sowie der Anregungs- und Fluoreszenzwellenlängen das Auffinden bislang unbekannter Energieniveaus.

A 28.3 Do 14:30 VMP 6 HS-E

**Neue Energieniveaus des Pr-Atoms** — Shamim Khan, Tanweer Iqbal, Imran Siddiqui, Bettina Gamper, Michaela Ellmeier, Günter H. Guthöhrlein und •Laurentius Windholz — Inst. f. Experimentalphysik, Techn. Univ. Graz, Petersgasse 16, A-8010 Graz, Österreich

Die Untersuchung der Hyperfeinstruktur nicht klassifizierbarer Pr-Spektrallinien erfolgt mittels Laseranregung und Beobachtung der laserinduzierten Fluoreszenz. Aus der beobachteten Hyperfeinstruktur können die Drehimpulse und die Hyperfeinkonstanten A der am Übergang beteiligten Niveaus ermittelt werden. In der Regel ist das untere der beteiligten Niveaus bekannt. Die Addition der Anregungswellenzahl zur Wellenzahl eines Niveaus mit passendem A-Faktor liefert die Wellenzahl des unbekannten oberen Niveaus. Dessen Zerfall muß wiederum die beobachteten Fluoreszenzwellenlängen erklären. Die Existenz des neuen Niveaus wird durch weitere Laseranregungen bestätigt. Auf diese Weise konnten im letzen Jahr mehr als hundert bislang unbekannte Energieniveaus aufgespürt werden.

A 28.4 Do 14:45 VMP 6 HS-E

**Photoionization Processes in $H_3O^+$** — •Brandon Jordon-Thaden[1], Henrik Pedersen[2], Simon Altevogt[1], Oded Heber[3], Lutz Lammich[2], Michael Rappaport[3], Dirk Schwalm[1], Joachim Ullrich[1], Daniel Zajfman[3], Rolf Treusch[4], Natalia Guerassimova[4], Michael Martins[5], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany — [2]Department of Physics and Astronomy, University of Aarhus, Aarhus, DK-8000 Aarhus C, Denmark — [3]Department of Particle Physics, Weizmann Institute of Science, Rehovot, 76100, Israel — [4]HASYLAB at DESY, D-22607 Hamburg, Germany — [5]Institut für Experimentalphysik, Universtität Hamburg, D-22671 Hamburg, Germany

The fragmentation of the hydronium ion $H_3O^+$ after photoionization by high energy radiation plays a significant role in the chemistry in interstellar environments. In measurements performed at the Free-ELectron LASer in Hamburg (FLASH), the photoionization and subsequent dissociation of fast $H_3O^+$ ions with VUV photons in a cross-beam setup was measured where the photodissociating fragments were position and time analyzed by two detectors arranged in a serial geometry. An analysis of the coincidence and fragmentation patterns between the measured events yields the branching ratios between the multitude of possible channels with absolute cross-sections. Furthermore the kinetic energy release distribution for the two-body channels returns detailed information about the $H_3O^{2+}$ states after inner-valence ionization and the atomic and molecular photofragment states.

## A 29: Photoionization II

Zeit: Donnerstag 14:00–15:30 Raum: VMP 8 R208

**Hauptvortrag** A 29.1 Do 14:00 VMP 8 R208

**Radiometry and the nature of light** — •Mathias Richter[1], Andrei A. Sorokin[1], and Kai Tiedtke[2] — [1]Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, 10587 Berlin, Germany — [2]Deutsches Elektronen-Synchrotron, Notkestraße 85, 22603 Hamburg, Germany

At the Free-electron LASer in Hamburg FLASH, the non-linear photoionization of rare gases in the vacuum and extreme ultra-violet (VUV, EUV) was investigated by ion spectroscopy [1, 2]. Our quantitative experiments relied on different radiometric methods and tools of X-ray laser diagnostics to measure pulse energy and duration and focus size in absolute terms [3-6]. Thus, the behaviour of the different targets could be compared under equivalent conditions at irradiances from $10^{12}$ to $10^{16}$ W/cm$^2$. It came out that, in contrast to optical radiation, the degree of atomic perturbation and the nature of the VUV and EUV light on the interaction strongly depends on the respective target and the excitation of inner-shell resonances.

[1] A. A. Sorokin et al., Phys. Rev. A 75, 051402(R) (2007).
[2] A. A. Sorokin et al., Phys. Rev. Lett. 99, 213002 (2007).
[3] M. Richter et al., Appl. Phys. Lett. 83, 2970 (2003).
[4] A. Sorokin et al., Appl. Phys. Lett. 89, 221114 (2006).
[5] K. Tiedtke et al., J. Appl. Phys. 103, 094511 (2008).

**Hauptvortrag** A 29.2 Do 14:30 VMP 8 R208

**Threshold Fragmentation of Simple Atoms by Electron Impact and FLASH VUV Light** — •Alexander Dorn — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

Double ionization (DI) of an atom by electron impact (e,3e) or by absorption of one photon ($\gamma$,2e) is a process purely mediated by electron correlation and, therefore, is a very fundamental and intriguing problem in physics. Using many-particle imaging spectrometers (reaction microscopes) we have measured the momentum vectors of all final state continuum particles close to the DI threshold. Here, due to the vanishing kinetic energy the Coulomb-interaction among all particles should lead to highly symmetric electron emission patterns. For the three-electron final continuum state resulting from the (e,3e) reaction on helium at 5 eV excess energy the symmetric emission of the ejected electrons with 120° relative angles was observed settling a long standing issue between various theories and rising new questions on whether the emission configuration depends on the target structure.

In order to enable kinematically complete ($\gamma$,3e) studies on the fundamental three-electron atom lithium we have implemented a magneto-optical trap into a reaction microscope. Due to the small cross section in the order of 1 barn this process can be studied only at high flux photon sources as the Free Electron Laser at Hamburg (FLASH). In a recent pilot experiment at FLASH we studied DI of optically pumped Li(2p). It turns out that the dynamic correlation between a photoionized 1s-electron and the ejected 2p-electron strongly depends on the spatial alignment of the 2p-orbital.

**Hauptvortrag** A 29.3 Do 15:00 VMP 8 R208

**Ring molecules as tunable light sources** — •Andrey Moskalenko and Jamal Berakdar — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany

We analyze the emission properties of molecular and nanostructured rings [1] excited by ultrafast light pulses. Application of an appropriate sequence of light pulses allows for the control of the charge polarization dynamics in such driven quantum rings. As a consequence, the spectral and polarization properties of the emitted radiation can be controlled on ultrafast time scales. This we conclude from the theory of the time-dependent spectrum and its generalization to the time-dependent detection of Stokes parameters and the polarization degrees of polychromatic radiations, valid for time scales comparable to the reciprocal of characteristic emission frequencies [2].

[1] A. S. Moskalenko, A. Matos-Abiague, J. Berakdar, Phys. Rev. B 74, 161303(R) (2006); EPL 78, 57001 (2007).
[2] A. S. Moskalenko and J. Berakdar, Phys. Rev. A 78, 051804(R) (2008).

## A 30: Precision Spectroscopy of Atoms and Ions V

Zeit: Donnerstag 16:30–17:45 Raum: VMP 6 HS-B

**Fachvortrag** A 30.1 Do 16:30 VMP 6 HS-B

**Accurate absolute frequency and isotope shift measurements of the 3s-3p doublet in $^{24-26}Mg^+$** — •Valentin Batteiger[1], Sebastian Knünz[1], Maximilian Herrmann[1], Guido Saathoff[1], Thomas Udem[1], and Theodor W. Hänsch[1,2] — [1]Max–Planck–Institut für Quantenoptik, 85748 Garching, Germany — [2]Ludwig–Maximilians–Universität München, 80539 München, Germany

We present an isotopically resolved absolute frequency measurement of both fine structure components of the 3s-3p transition near 280nm in $Mg^+$. When red-shifted into the transparency range of our atmosphere, the doublet is frequently observed in astronomical spectra. Thus the transitions are good probes of physics at early epochs. Together with other strong UV transitions both lines where requested for improved measurement on the quest for a possible space-time variation of the fine structure constant 7-11 billion years ago. We performed a series of absolute frequency measurements on single trapped magnesium ions. Owing to a new spectroscopy method we could improve the values of the transition frequencies, fine structure splitting and isotope shifts by more than two orders of magnitude.

A 30.2 Do 17:00 VMP 6 HS-B

**Direct Frequency Comb Spectroscopy of Metal Ions using Quantum Logic** — •Boerge Hemmerling[1], Daniel Nigg[1], Lukas An der Lan[2], Birgit Brandstätter[2], and Piet O. Schmidt[1] — [1]QUEST Institute for Quantum Metrology, Physikalisch-Technische Bundesanstalt, Leibniz Universität Hannover, Braunschweig, Germany — [2]Institut für Experimentalphysik, Universität Innsbruck, Austria

Improving the interpretation of quasar absorption spectra for the search of a possible temporal variation of the fine-structure constant on cosmological time scales requires more precise frequency measurements of certain transitions in metal ions such as $Ca^+$, $Ti^+$ and $Fe^+$ [1].

We are developing a versatile setup for precision spectroscopy of these ions with a complex level structure. The ions are sympathetically cooled by $^{25}Mg^+$ in a linear Paul trap. A femto-second optical frequency comb will be used as a tunable spectroscopy probe, ideally covering the whole spectrum of interest. Quantum logic techniques will be employed for efficient state preparation, ground state cooling and detection of the spectroscopy signal. We will present the latest results of our experiments and a detailed theoretical analysis of the interrogation scheme for $Ca^+$. We expect that direct frequency comb spectroscopy produces a maximum fluorescence rate of ($\sim 100$ photons/s), which will be detected by measuring the increase of the vibrational quantum number of the ion crystal due to photon scattering.

[1] J. C. Berengut, V. A. Dzuba, V. V. Flambaum, M. V. Marchenko and J. K. Webb, arXiv:physics/0408017 (2006)

A 30.3 Do 17:15 VMP 6 HS-B

**Detektion der Bewegungsfrequenzen eines Protons in der Mainzer $g$-Faktor Apparatur** — •Holger Kracke[1], Klaus Blaum[2], Susanne Kreim[1], Andreas Mooser[1], Christian Mrozik[1], Wolfgang Quint[3], C. C. Rodegheri[1], Stefan Stahl[5], Stefan Ulmer[1,2,3,4] und Jochen Walz[1] — [1]Institut fürPhysik, Universität Mainz, 55128 Mainz, — [2]MPI für Kernphysik, 69117 Heidelberg, — [3]GSI,64291 Darmstadt, — [4]Ruprecht-Karls-Universität,69047 Heidelberg, — [5]Stahl-Electronics, 67582 Mettenheim

Der $g$-Faktor des Protons soll aus dem Verhältnis der freien Zyklotronfrequenz $\nu_c$ und der Larmorfrequenz $\nu_L$ bestimmt werden. Um eine hohe Messgenauigkeit zu erzielen, wird die Messung an einem einzelnen Proton durchgeführt. Dies setzt die zerstörungsfreie Detektion der Eigenfrequenzen des Teilchens in der Penning-Falle voraus. Dabei werden die vom Teilchen in den Fallenelektroden induzierten Spiegelströme als Spannungsabfall über einem externen Schwingkreis nachgewiesen. Die kryogene Umgebung erlaubt die Verwendung supraleitender Materialien und rauscharmer Elektronik. Die somit erreichte hohe Güte des axialen Schwingkreises von $Q \approx 5000$ ermöglicht eine Detektion der axialen Mode eines einzelnen Protons im thermischen Gleichgewicht über den Dip im Rauschspektrum des Schwingkreises. Die Magnetronfrequenz $\nu_-$ wird anhand eines "Avoided Crossings*"gemessen. Ausserdem wird die reduzierte Zyklotronfrequenz $\nu_+$ über eine Kühlkurve detektiert und somit kann die freie Zyklotronfrequenz über $\nu_c^2 = \nu_-^2 + \nu_z^2 + \nu_+^2$ bestimmt werden.

A 30.4 Do 17:30 VMP 6 HS-B

**Precision measurement of decay branching ratios in a single trapped $Ca^+$ ion** — •Rene Gerritsma[1], Gerhard Kirchmair[1,2], Florian Zähringer[1,2], Jan Benhelm[1,2], Rainer Blatt[1,2], and Christian Roos[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria — [2]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria

We report on precision measurements of the $4P_{3/2}$ decay branching ratios in $Ca^+$ [R. Gerritsma et al., Eur. Phys. J. D 50, 13 (2008)]. Absorption and emission lines in $Ca^+$ have been used in many astrophysical observations, such as of galaxies, interstellar clouds and dust disks surrounding stars. Here, an accurate knowledge of transition frequencies and oscillator strengths is desired. On the theoretical side considerable effort is devoted to precise structure calculations of singly charged alkali earth ions such as $Ca^+$. For comparison to theory precise measurements of branching ratios and lifetimes are needed. Measurements of these quantities in literature are often based on experiments in ion beams or trapped clouds of ions. In our approach, the use of a single trapped ion eliminates errors due to depolarizing collisions while allowing high fidelity state preparation and detection. Furthermore, we improve the precision by a new technique based on repetitive pumping to the $4P_{3/2}$ state. In this way we determine the branching fractions with sub-precent precision and a forty-fold improvement with respect to the previously best known values.

## A 31: Ultra-Cold Atoms, Ions and BEC IV (with Q)

Zeit: Donnerstag 16:30–18:00 Raum: VMP 6 HS-C

**Fachvortrag** A 31.1 Do 16:30 VMP 6 HS-C

**Novel phases of spinor fermions in 1D optical lattices** — •Karen Rodriguez, Arturo Argüelles, and Luis Santos — Leibniz Universität Hannover, Hannover, Deutschland

The Hubbard Hamiltonian model shows two different phases namely Mott insulator and superfluid. When internal degrees of freedom like spin is added to the system, new phases can appear. By means of numerical simulations using Matrix Product State algorithms combined with an effective Hamiltonian which allows up to one particle per site, we found that the ground state of the system inside the Mott region shows the presence of spin-Peierls ordering. Furthermore, we showed that adding a magnetic field, the quadratic Zeeman effect allows us to drive the spin ordering into a Neel state.

**Fachvortrag** A 31.2 Do 17:00 VMP 6 HS-C

**Ultracold chaos – strongly coupled bosons** — •Sandro Wimberger — Institut für Theoretische Physik, Universität Heidelberg — Heidelberger Graduiertenschule für Fundamentale Physik

Modern atom-optics experiments allow one an unprecedented control of atomic degrees of freedom and, as a consequence, the clean realization of toy models used to explain transport phenomena in condensed matter physics. We present recent results on extended Bose-Hubbard systems. For reasonable lattice sizes, this model gives access to the full quantum spectrum, which allows us a complete characterization of "horizontal" (spatially) and "vertical" (energetic) quantum transport. Various dynamical regimes can be prepared, using atom-atom interactions, disorder, and external forces as control parameters. We show that the interband transport of atoms – confined to a periodic lattice and subject to an additional tilting force – is strongly dependent on the dynamics of the ground-state band. Analogies between Stark local-

isation and Anderson localisation are discussed, as well as predictions for experiments to observe signatures of complex interband dynamics with ultracold atoms.

A 31.3 Do 17:30 VMP 6 HS-C

**Few-body physics in a three-component Fermi gas** — •Timo Ottenstein[1], Thomas Lompe[1], Andre Wenz[1], Gerhard Zürn[1], and Selim Jochim[1,2] — [1]Max-Planck Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Ruprecht-Karls-Universität Heidelberg

Here we report on our experiments studying a three-component Fermi gas in thermal equilibrium consisting of atoms in the three lowest magnetic substates of $^6$Li. Our first experiments analyzed the collisional stability of the gas in dependence of the two-body interaction strength, which can be tuned by means of Feshbach resonances [1]. Three body-collisions lead to strong variation of the stablility as a function of the applied magnetic field, including a strongly enhanced trap loss at 127 G. It turns out that the behaviour of three-body loss over the adressed magnetic field range can be explained by the presence of a trimer state consisting of one atom in each of the three states, which crosses the continuum twice at different magnetic field values [2]. The physics of this trimer state is comparable to Efimov's scenario in bosonic systems.

Furthermore, the interaction properties of this three-component Fermi gas resemble SU(3) symmetry, making it a promising candidate to study phenomena related to QCD and baryon formation. By addition of an optical lattice, the SU(3) Hubbard model can be studied, in which new and interesting quantum phases are predicted.

[1] T.B. Ottenstein et al., Phys. Rev. Lett. 101, 203202 (2008)
[2] E. Braaten et al., arXiv 0811.3578 (2008)

A 31.4 Do 17:45 VMP 6 HS-C

**Towards Single Impurities in a Bose-Einstein Condensate** — •Stefan Palzer, Christoph Zipkes, Carlo Sias, and Michael Köhl — Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom

We are currently working on an experimental setup to combine a single trapped Ytterbium ion with a Bose-Einstein Condensate (BEC) of Rubidium (Rb) atoms. Once the ion trap is implemented inside the BEC chamber this experiment will open the path to investigate ultracold atom-ion collisions and to study single impurities in superfluid systems. Moreover, this experiment could provide a new approach to cool trapped ions sympathetically thus prolonging the coherence time for quantum operations. To produce the Bose-Einstein Condensate (BEC) we trap and cool about $10^9$ Rb atoms in a magneto-optical trap (MOT). The atomic cloud then is magnetically transported into the ultrahigh-vacuum ($10^{-11}$ mbar) interaction chamber. We cool the atoms well below the BEC transition temperature by evaporative cooling and create a BEC of about $10^6$ atoms. A single trapped Ytterbium ion will be used as impurity. A linear Paul trap is loaded with one (or more) Yb ion(s) using resonance enhanced isotope-selective photoionionisation. Both systems are currently characterized independently.

## A 32: Attosecond Physics III

Zeit: Donnerstag 16:30–18:00 Raum: VMP 6 HS-E

**Hauptvortrag** A 32.1 Do 16:30 VMP 6 HS-E

**"And, action!"- Video clips of electron motion in molecules** — •Matthias Kling — Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

The control of the electric field waveform $E(t) = E_0(t)\cos(\omega t+\phi)$, with envelope $E_0(t)$, frequency $\omega$, by the carrier envelope phase (CEP) $\phi$ constitutes a new paradigm of coherent control. This control became accessible with CEP-stabilization and opened the door for the direct manipulation of electron dynamics in atomic and molecular systems [1]. For frequencies in the range of visible light the electric field waveform changes on an attosecond time-scale. Waveform controlled few-cycle pulses have been used to control electron localization in the dissociative ionization of the prototype molecules $D_2$ and HD [2].

These experiments will be introduced together with recent efforts to record movies of the electron localization dynamics on attosecond timescales using attosecond XUV light pulses. The important question arises, whether the steering of electrons in more complex systems is feasible and — if yes — can we understand the role of the strong-field coupling of the various potential energy surfaces that follows an initial ionization / excitation and leads to the observed control? New results on the control of electron dynamics in a multi-electron molecule, carbon monoxide (CO), will be presented to shed light on these topics.

[1] Kling, M.F. and Vrakking, M.J.J., *Annu.Rev.Phys.Chem.* **59** (2008) 463.
[2] Kling, M.F. *et al.*, *Science* **312** (2006) 246; Kling, M.F. *et al.*, *Mol.Phys.* **106** (2008) 455.

**Fachvortrag** A 32.2 Do 17:00 VMP 6 HS-E

**Anomalous quasi-elastic electron scattering and neutron Compton scattering from single nuclei of H2, D2 and HD molecules** — C. Aris C.-Dreismann[1], Glyn Cooper[2], and •Adam P. Hitchcock[2] — [1]Institute of Chemistry, Technical University of Berlin, D-10623 Berlin — [2]Brockhouse Institute for Materials Research, McMaster University, Hamilton, ON, Canada L8S 4M1

Quasi-elastic electron scattering from gaseous H2, D2, a 50:50 mixture of H2 and D2 and HD is investigated with 2.25 keV impact energy, at a momentum transfer $q$ of 19.7 a.u. [1]. The spectral positions of the H and D recoil peaks follow Rutherford scattering theory. Surprisingly, in the spectrum of the 50:50 H2-D2 mixture, the integrated intensity of the H peak is about 30 percent lower (as compared to that of D) than predicted by Rutherford scattering, despite equal screening of nuclear charges by the electrons in all molecules. In contrast, the ratio of scattering intensities from HD agrees with the predictions of Rutherford scattering. This result was recently confirmed with a second experiment (M. Vos, ANU) applyiing 6 keV electrons. Comparison is made with neutron Compton scattering (NCS) results, which showed the same anomaly in H2-D2 and HD (about 30 percent in both systems). This anomalous effect is proposed to be due to attosecond scattering dynamics from entangled particles, and can be understood with the aid of the Quantum Zeno Effect.

[1] G. Cooper, A. P. Hitchcock, C. A. Chatzidimitriou-Dreismann, PRL 100, 043204 (2008)

A 32.3 Do 17:30 VMP 6 HS-E

**Strong field dynamics with electron wave packet replicas** — •Paula Riviere, Olaf Uhden, Ulf Saalmann, and Jan-Michael Rost — MPI PKS, Dresden

We investigate theoretically the electron dynamics under a train of attosecond pulses (APT) and in the presence of a strong infrared (IR) laser field. Such a combined light field, where the phase of the APT with respect to the IR field can be controlled, has been experimentally realized [1]. Here, we are interested in the process where electron wave packet (EWP) replicas are created at a well defined phase in every cycle or half cycle of the IR field. Each EWP can then interfere with the others and, additionally, suffers a streaking due to the IR field. This process can be studied analytically.

As a function of the delay between APT and IR field we obtain the kinetic energy distribution of the electron as well as the ionization probability. We analyze their dependence on the number of replicas, the main attosecond pulse frequency and the IR field intensity, both for one or two attosecond pulses per IR period. The expression for the final wavepacket can be split into two factors: one that depends on the phase shift, and one that depends on the number of replicas. The ionization probability shows strong modulations as a function of the phase shift between APT and IR pulse for small mean energies of the continuum wave packets, while for higher energies the ionization probability does not depend on the shift, in line with the experimental observations for He and Ar, respectively [1].

[1] P. Johnsson *et al.*, *Phys. Rev. Lett.* **99**, 233001 (2007).

A 32.4 Do 17:45 VMP 6 HS-E

**Higher-Order Effects in Attosecond Pulse Train Measurements** — •Marko Swoboda[1], Thierry Ruchon[2], J. Marcus Dahlström[1], Johan Mauritsson[1], and Anne L'Huillier[1] — [1]Department of Physics, Lund University, P.O. Box 118, 221 00 Lund, Sweden — [2]Centre d'Etudes de Saclay, CEA/DRECAM/SPAM, 91191 Gif-sur-Yvette, France

Multiphoton processes are at the heart of most attosecond pulse characterization schemes. Due to the low availability of intense attosecond pulse sources, the combination of a single or train of attosecond pulses with a probing infrared field in an interferometric setup is the one most often employed. Using this scheme to characterize attosecond pulse trains generated in Argon, we study the influence of the probe field intensity on the measured phase of the final photo electron wave packet. We find that in the transition from RABBITT-like intensities to the range of attosecond streaking higher and higher orders of perturbation and photon numbers contribute to the final photo electron state until the classical limit is reached. A Fourier-type analysis attributes the each individual frequency to an additional perturbative order.

## A 33: Interaction with VUV and X-Ray Light II

Zeit: Donnerstag 16:30–18:30 Raum: VMP 8 R208

**Fachvortrag** A 33.1 Do 16:30 VMP 8 R208

**Lichtfeldgetriebene Röntgen-Streak-Kamera zur Messung der Zeitstruktur einzelner XUV-Pulse am FLASH** — •Ulrike Frühling[1], Marek Wieland[2], Michael Gensch[1], Thomas Gebert[2], Bernd Schütte[2], Maria Krikunova[2], Roland Kalms[2], Filip Budzyn[2], Oliver Grimm[2,3], Jörg Rossbach[2], Elke Plönjes[1] und Markus Drescher[2] — [1]Desy, Hamburg — [2]Uni HH, Hamburg — [3]ETH Zürich, Institut für Teilchenphysik

Der Freie-Elektronen-Laser in Hamburg (FLASH) erzeugt durch selbstverstärkte spontane Emission (SASE) hochintensive kurze XUV-Pulse. Dieses Prinzip führt zu merklichen Schuss-zu-Schuss Fluktuationen von Pulsenergie, Wellenlänge und Zeitstruktur. Ziel unseres Experimentes ist daher eine Einzelschussmessung des XUV Zeitprofils. Dazu werden die XUV-Pulse ($\lambda = 13\,\mathrm{nm}$) mit in einem speziellen THz-Undulator erzeugten THz-Pulsen ($\lambda = 100\,\mu\mathrm{m}$) überlagert. Die verwendete Technik überträgt ein in der Attosekunden-Metrologie verwendetes Konzept auf Zeitmessungen im Femtosekundenbereich. Anders als bei einer konventionellen Streak-Kamera wird die Festkörper-Photokathode durch freie Edelgasatome gebildet, die durch die XUV-Pulse ionisiert werden. Die entstehenden Photoelektronen werden durch das zeitabhängige elektrische Feld der THz-Pulse beschleunigt, wobei die Energieänderung vom elektrischen Feld zum Ionisationszeitpunkt abhängt. Durch Messung der Photoelektronenenergien konnte das THz-Lichtfeld abgetastet werden und es wurden erste Einzelschuss-Spektren gemessen, die Informationen über die Zeitstruktur der einzelnen XUV-Pulse liefern.

**Fachvortrag** A 33.2 Do 17:00 VMP 8 R208

**Time evolution of photon emission from the quark-gluon plasma** — •Andreas Ipp, Jörg Evers, and Christoph H. Keitel — Max Planck Institut für Kernphysik, Heidelberg

Photons emitted from the quark gluon plasma (QGP) carry information directly from the interior of the strongly interacting plasma, since they are likely to leave the QGP without further interaction. They can for example provide information about a global quark polarization that can be created in non-central heavy ion collisions. Such a global quark polarization is transferred efficiently to the circular polarization of photons for various emission energies and momentum anisotropies [1].

In this work, we analyze the time evolution of the photon production in the QGP. For this, we fold the photon production with a model of the time evolution of temperature and momentum anisotropy [2]. The evolution is based on Bjorken's one-dimensional expansion model [3]. The photon production rate locally depends on the temperature and the momentum anisotropy. It is boosted from the expanding frame into the laboratory frame to obtain the time-dependent signal in the detector. We find that a strongly varying momentum anisotropy could lead to particular emission envelopes, like a double-peak structure on the zepto-second scale. A detection of the emission shape could lead to experimental insight into the isotropization process within the QGP.

[1] A. Ipp, A. Di Piazza, J. Evers, and C. H. Keitel, Phys. Lett. B 666, 315 (2008).
[2] M. Martinez, M. Strickland, Phys. Rev. C 78, 034917 (2008).
[3] J. D. Bjorken, Phys. Rev., D 27, 140 (1983).

**Fachvortrag** A 33.3 Do 17:30 VMP 8 R208

**A New Endstation for Imaging and Photon-Particle Coincidence Experiments at VUV and X-Ray Free Electron Lasers** — Sascha Epp[1], Heinz Graafsma[2], Robert Hartmann[3], Helmut Hirsemann[2], Faton Krasniqi[1], Kai-Uwe Kühnel[4], Robert Moshammer[4], •Daniel Rolles[1], Artem Rudenko[1], Ilme Schlichting[1,5], Lothar Strüder[1,3], Simone Techert[1,6], Joachim Ullrich[1,4], and Christopher Youngman[2] — [1]Max Planck Advanced Study Group at CFEL, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [3]Max Planck Halbleiterlabor, München, Germany — [4]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [5]Max-Planck-Institut für medizinische Forschung, Heidelberg, Germany — [6]Max-Planck-Institut für biophysikalische Chemie, Göttingen, Germany

We are building a new endstation to explore the interaction of intense VUV and soft x-ray radiation with various targets of increasing complexity and size, ranging from atoms and (laser-aligned) molecules to nano-particles such as clusters and biological targets, by measuring fluorescent or scattered photons in coincidence with ions and electrons. The endstation is equipped with two large-area, single-photon counting pnCCD detectors and specially-designed ion and electron spectrometers (VMI or reaction microscope), which can detect all charged particles with a large solid angle and measure their kinetic energies and emission directions, while still providing an unrestricted line-of-sight from the interaction region to the photon detectors. Proposed applications of the endstation at FLASH and LCLS are presented.

A 33.4 Do 18:00 VMP 8 R208

**Threshold behavior of quantum oscillations in spatially integrated and directionally fixed in space systems** — •Sanja Korica[1], Axel Reinköster[1], Markus Braune[1], Daniel Rolles[2], Burkhard Langer[3], and Uwe Becker[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft Berlin — [2]CFEL Hamburg — [3]Frei Universität Berlin

Oscillatory behavior of particle breakup processes is the result of quantum interference between different emission pathways. Prominent examples are the partial cross section oscillations in the ionization of fullerenes and homonuclear diatomic molecules. This behavior may be described in the simplest way by a 'ripple tank' simulation. Such a simulation predicts a cosine-like threshold behavior of these oscillations. New near threshold measurements of the photoionization of $C_{60}$ and $N_2$ corroborate these predictions. They are, however, in contrast to corresponding measurements and theoretical calculations of the photoionization probability for fixed in space $N_2$ molecules along the molecular axis [1]. The threshold behavior of the quantum oscillations of this system points more to a sine-like function. The 'ripple tank' simulation exhibits also a difference between the two kinds of measurements, however much less pronounced. This may be due to the different periodical functions employed in this simulation compared to the real photoionization process.

[1] Zimmermann *et al.* Nature Physics, Vol.**4**, 649, 2008.

A 33.5 Do 18:15 VMP 8 R208

**Double Photoionization of Optically Pumped Lithium Atoms at FLASH** — •Ganjun Zhu, Jochen Steinmann, Johannes Albrecht, Michael Schuricke, Alexander Dorn, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg

The combination of intense FEL radiation with modern spectroscopy technique of MOTRIMS (Magneto Optical Trap Recoil Ion Momentum Spectroscopy) will pave the way to numbers of unprecedented experiments in atomic, optical and plasma physics as well as on ultra cold ensembles. For instance, the "multi-electron ejection from light atoms via single-photon absorption"process lies in the very focus of atomic physics, which is the most fundamental few-body reaction.

Here we report on a pilot experiment performed at Flash (FEL LASER at Hamburg), investigating double-photoionization (DPI) phenomena. For the first time, initial target preparation by optical pumping ($\lambda$= 671nm , linear polarization) was applied to control the DPI dynamics. It is demonstrated that the $Li^{2+}$ recoil ion momentum distribution changes dramatically as the initial $Li(1s^22s)$ $^2S_{1/2}$ ground

state is excited to Li($1s^2 2p$) $^2P_{3/2}$; and the DPI cross section strongly depends on the spatial alignment of the excited electron wave function. One intuitive interpretation to this new observation could be related with the different overlap of the ionized 1s-electron dipole emission lobes with the aligned 2p-wave function. Thus, the collision probability of both electrons and therefore the DPI cross section differs.

## 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 $\beta$. 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 description 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.
[1] C. Townsend et al., PRA 53, 1702 (1996)
[2] J. Ullrich et al., J Phys. B 30, 2971 (1997)

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 gleichzeitig 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 $\alpha$ decay is an obvious candidate for the study of possible effects due to the interaction with intense laser fields.

Motivated by this, we calculate $\alpha$ tunneling widths in the framework of the WKB approximation, and investigate its validity in differ-

ent approaches of the tunneling problem[2]. Furthermore, the process of laser-assisted tunneling in $\alpha$ 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 $\alpha$ 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 Atom-

are 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 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 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 $\pi$, the expected Lorentzian dip at the resonance frequency increases with the light intensity. At pulse areas above $\pi$, 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 $\lambda_{central}$ = 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)

A 34.49 Do 16:30 VMP 9 Poster

**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.

A 34.50 Do 16:30 VMP 9 Poster

**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.

A 34.51 Do 16:30 VMP 9 Poster

**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.

A 34.52 Do 16:30 VMP 9 Poster

**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).

A 34.53 Do 16:30 VMP 9 Poster

**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.

A 34.56 Do 16:30 VMP 9 Poster

**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 $\pi$. 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.

## A 35: Precision Spectroscopy of Atoms and Ions VI

Zeit: Freitag 10:30–12:30 Raum: VMP 6 HS-B

**Fachvortrag** A 35.1 Fr 10:30 VMP 6 HS-B

**Precision Measurement of the K-Shell Spectrum from Highly Charged Xenon With a Quantum Microcalorimeter** — •Daniel B. Thorn[1,2], F. Scott Porter[4], Ming F. Gu[3], Gregory V. Brown[3], Peter Beiersdorfer[3], Caroline A. Kilbourne[4], and Richard L. Kelley[4] — [1]ExterMe Matter Institute EMMI, 64291 Darmstadt, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]Lawrence Livermore National Laboratory, Livermore, CA 94550, USA — [4]Goddard Space Flight Center, NASA, MD 20771, USA

We present a measurement of the K-shell spectrum from highly charged xenon ions recorded with a high-energy microcalorimeter array that can distinguish between various theories for the atomic structure of the two electron system. The array was designed to provide high quantum efficiency in the 10-60 keV x-ray range. A resolution of 34 eV at 31 keV is achieved, which is an order of magnitude better than previous measurements. This allows for a $\leq 2$ eV measurement of the $Xe^{52+}$ and $Xe^{53+}$ K-shell transitions without the uncertainty of unresolved blends that afflicted previous measurements. This work was performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-C52-07NA27344 and was supported by NASA grants to LLNL and GSFC.

**Fachvortrag** A 35.2 Fr 11:00 VMP 6 HS-B

**Design einer asymmetrischen zylindrischen Penningfalle für *g*-Faktor-Messungen mit hochgeladenen Ionen** — Nicolaas P. M. Brantjes[1], •David von Lindenfels[2], Wolfgang Quint[1] und Manuel Vogel[1] — [1]GSI Darmstadt, Deutschland — [2]Universität Heidelberg, Deutschland

Die präzise Bestimmung von *g*-Faktoren gebundener Elektronen in schweren hochgeladenen Ionen ermöglicht einen genauen Test der QED gebundener Teilchen in starken Feldern. Für die Laser-Mikrowellen Doppelresonanztechnik wird eine halboffene zylindrische Penningfalle benötigt. Simulationen dienen der Optimierung des elektrostatischen Speicherpotentials in einer solchen Falle. Dazu gehen wir von einer geschlossenen, elektrisch kompensierten Falle aus. Dann ersetzen wir eine der Endkappen durch weitere röhrenförmige Elektroden.

A 35.3 Fr 11:30 VMP 6 HS-B

**Decoherence and losses by collisions in $^{88}$Sr lattice clocks** — •Joseph Sundar Raaj Vellore Winfred, Christian Lisdat, Thomas Middelmann, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt and Centre for Quantum Engineering and Space-Time Research QUEST,Bundesallee 100, 38116 Braunschweig,Germany.

Recent advancement in optical frequency metrology has enabled optical lattice clocks with neutral atoms to surpass Cesium fountain clock's stability and accuracy. Such precise measurement of time is very important in technological and scientific endeavors. High atom number induces collisional effects in neutral atom clocks. In case of the $^{87}$Sr fermionic isotope, collision induced frequency shift is suppressed while in $^{88}$Sr bosonic isotope the shift is present due to s-wave collisions. Due to its higher natural abundance, a $^{88}$Sr optical clock can offer better signal-to-noise ratio and therefore higher stability. We report our study of collision induced losses in a $^{88}$Sr optical lattice clock. Around $1\times10^6$ $^{88}$Sr atoms are loaded into a 1-D optical lattice operated at the magic wavelength. The atoms are interrogated on the doubly forbidden $^1S_0$-$^3P_0$ transition which is made possible by applying static magnetic field that mixes the $^3P_1$ state to $^3P_0$ state. The investigations of density dependent losses and of line broadening give estimates for the loss coefficients which would determine the operational parameters of an $^{88}$Sr optical lattice clock.

A 35.4 Fr 11:45 VMP 6 HS-B

**Messung der Vibrationsamplituden von Pulsrohrkühlerstufen und deren Effekt auf die Zyklotronfrequenz eines Protons in der Penning-Falle** — •Christian Mrozik[1], Klaus Blaum[2], Holger Kracke[1], Susanne Kreim[1], Andreas Mooser[1], Wolfgang Quint[3,4], Cricia de Carvalho Rodegheri[1], Stefan Stahl[5], Stefan Ulmer[1,2,3,4] und Jochen Walz[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]MPI für Kernphysik, 69117 Heidelberg — [3]GSI, 64291 Darmstadt — [4]Ruprecht-Karls-Universität, 69047 Heidelberg, — [5]Stahl-Electronics, 67582 Mettenheim

Das neue Mainzer Experiment zur Bestimmung des $g-$Faktors des freien Protons wird mit Hilfe eines zweistufigen Pulsrohrkühlers auf die erforderliche Temperatur von etwa 4 K gebracht. Als nachteilig erweist sich hierbei die Tatsache, dass sich die Stufen des Kühlers mit jedem Pulszyklus bewegen. Diese Vibrationen können auf die Falle übertragen werden. Wir haben bei der reduzierten Zyklotronfrequenz $\nu_+$ eines Protons in der vibrierenden Falle Schwankungen beobachtet, die mit den Kühlervibrationen korreliert sind. Diese Schwankungen begrenzen derzeit die relative Genauigkeit für die Bestimmung von $\nu_+$ auf $10^{-6}$. Die Vibrationsamplituden der Kühlerstufen sind daraufhin unabhängig mit Hilfe einer positionssensitiven Photodiode in allen drei Raumrichtungen gemessen worden. Eine Dämpfung der Fallenvibrationen kann über eine Modifikation der Kopplung zwischen Kühler und Falle erreicht werden.

A 35.5 Fr 12:00 VMP 6 HS-B

**Development of improved detection electronics for the g-factor experiment on highly-charged ions** — •Sven Sturm[1], Klaus Blaum[2], Wolfgang Quint[3], Birgit Schabinger[1], and Anke Wagner[2] — [1]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [3]GSI Darmstadt, 64291 Darmstadt, Germany

For the high-precision measurement of the magnetic moment of the electron bound in highly-charged calcium ions [1] extremely sensitive detection electronics are needed. The cryogenic amplifier systems used in former experiments [2] was shown to limit the accessible measurement accuracy for the $g$-factor by raising the necessity to increase the ion temperature to $\sim$ 200 K. Therefore, a novel cryogenic ultra low noise amplifier was developed, realizing previously unmatched noise performance and detection sensitivity for the axial motion of medium-heavy ions in Penning traps. The noise performance especially in the interesting range from 100 kHz - 1 MHz and the negligible feedback even on tank circuits with very high quality factors will allow for a considerably decreased axial ion temperature and thus for an improved measurement accuracy. Exploiting the extremely low noise temperature (<1K) of the amplifier, ion temperatures far below the trap ambient temperature of 4.2 K might become accessible. The design and setup of the amplifier system will be presented and first results will be shown.

[1] M. Vogel *et al.*, Nucl. Inst. Meth. B **235**, 7 (2005)
[2] G. Werth *et al.*, Int. J. Mass Spec. **251**, 152 (2006)

A 35.6 Fr 12:15 VMP 6 HS-B

**Relativistic theory of trielectronic recombination with K-shell excitation** — •Octavian Postavaru, Christian Beilmann, Christoph H. Keitel, Joachim Ullrich, José R. Crespo López-Urrutia, and Zoltan Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

In the dielectronic recombination (DR) process involving two interacting electrons, the kinetic energy of the recombined electron is transferred to a single bound electron by excitation to an intermediate autoionizing state. Beyond the simple DR, resonant recombination processes involving higher-order correlations may also occur. Two bound electrons can be simultaneously excited in trielectronic recombination (TR). We performed calculations of cross sections for TR with excitation of a K-shell electron in the framework of the multiconfiguration Dirac-Fock (MCDF) method. Our theoretical predictions have been verified by recent high-resolution emission spectroscopy experiments at the Heidelberg electron beam ion trap [1]. For $Kr^{30+}$, TR contributions of nearly 6% to the total resonant photorecombination rate were found. This effect has to be considered in the quantitative modelling of fusion and other hot, e. g., astrophysical plasmas.

[1] C. Beilmann, O. Postavaru, R. Ginzel, et al., submitted (2008)

## A 36: Ultra-Cold Atoms, Ions and BEC V (with Q)

Zeit: Freitag 10:30–12:30 Raum: VMP 6 HS-C

**Fachvortrag** A 36.1 Fr 10:30 VMP 6 HS-C

**Supersolidity in a commensurate mixture of one-dimensional hardcore bosons with mass imbalance** — •Tassilo Keilmann[1], Ignacio Cirac[1], and Tommaso Roscilde[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ecole Normale Supérieure de Lyon, Lyon, France

We propose two methods to create a **superfluid solid phase** of an attractive mixture of mass-imbalanced hardcore bosons in a 1D optical lattice. At a commensurate filling with 2-to-1 filling ratio, we observe the formation of a crystal of *trimers* (made of two heavy and one light particle) which shows quasi-condensation and superfluidity for *both* particle species at the same time - hence a two-species supersolid. Supersolidity is observed both in the ground state of the system, as well as out of equilibrium in the stationary state that the system attains in the Hamiltonian evolution, that starts off initially from a crystal of trimers. These two situations correspond to two different preparation protocols (simple adiabatic loading into an optical lattice, and release from a superlattice) which can both lead to the direct observation of **supersolidity in optical lattices** using present experimental techniques.

**Fachvortrag** A 36.2 Fr 11:00 VMP 6 HS-C

**Laser Cooling and Trapping of Barium** — •Lorenz Willmann — KVI, University of Groningen, The Netherlands

The heavy alkaline earth element barium (Ba) offers no single closed optical transition. The strong $6s^2\ ^1S_0$ - $6s6p\ ^1P_1$ cooling transition at 553.7nm branches with 0.3% into three metastable states. This loss is 100 times larger than for the corresponding transition in the lighter earth-alkali strontium. Repumping was accomplished via the $6s6p\ ^1P_1$ state at the wavelengths 1108nm, 1130nm and 1500nm. A Ba atomic beam was slowed by light at the cooling and the repump wavelengths and then captured in a magneto optical trap (MOT). A collection efficiency of 1% from the atomic beam was achieved. The capture velocity of the MOT was 30(5) m/s. Three-photon photoionization from the ground state limited the trap lifetimes at higher cooling laser intensities. The multi-laser approach lead to coherent Raman transitions and a large fraction of 0.5(2) of the population in the metastable states. Several branching ratios and lifetimes of highly excited states have been determined, which provide input for atomic structure calculations.

The atomic level scheme of radium (Ra) is similar to Ba and the laser cooling and trapping approach can be transferred. Atomic Ra exhibits large enhancement factors for time reversal and parity violating effects, i.e permanent electric dipole moments (EDMs). The enhancements of up to four orders of magnitude are due to near degenerate states of opposite parity in the atomic and nuclear level structure. An experimental search for EDMs is underway at the TRI$\mu$P facility at KVI where short-lived Ra isotopes are available.

A 36.3 Fr 11:30 VMP 6 HS-C

**Magnetism and Phase Transitions in High Temperature Superfluids** — •Thomas Judd, Robin Scott, and Mark Fromhold — School of Physics and Astronomy, University of Nottingham, University Park, Nottingham, NG7 2RD, UK

Magnetism and strong inter-particle interactions are believed to play a significant role in high temperature superconductors but not in conventional BCS superconductors. Many unanswered questions remain about the nature of their influence. However, recent advances in cold atom physics allow us to investigate these long standing issues from a new angle by studying superfluidity in strongly interacting atomic Fermi gases. It is also possible to consider how long range magnetic interactions affect the superfluid state. Theoretical work on such systems is limited by their complexity - conventional computer resources struggle to model three-dimensional Fermi gases at finite temperature with strong interactions which can undergo phase transitions and ex-

hibit coherence. However, by exploiting high performance computing resources, these difficulties can be overcome and new insights gained. Here we present progress towards simulations of high temperature superflow in fermionic systems with magnetic interactions and optical lattices. We use a beyond-mean-field wave-mechanical model which includes fluctuations and second-order scattering terms. The model reproduces unanticipated results observed in recent BEC-BCS crossover experiments and also temperature phase transitions. We have begun work investigating how magnetic dipolar interactions affect the dynamics of rotating Bose gases and the formation of vortex lattices.

A 36.4 Fr 11:45 VMP 6 HS-C

**Temperature gradients in superfluid Bose-Hubbard systems** — •Lukas Gilz and James Anglin — Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern

While the interaction of Bose-Einstein-Condensates (BEC) with homogeneous thermal environments has been studied extensively, and phenomena such as condensate growth and decoherence have been well understood, little attention has been payed to the interaction of BECs with inhomogeneous environments. We examine non-equilibrium steady states of cold bosons tunneling between a finite series of potential wells, while interacting at opposite ends of the series with two distinct particle reservoirs, characterized by different temperatures and chemical potentials. We describe the coherent dynamics of the system with a Bose-Hubbard Hamiltonian, and model the interaction with the thermal reservoirs using a quantum kinetic master equation. We derive expressions for the temperature gradient and heat current in the system, in various dynamical regimes.

A 36.5 Fr 12:00 VMP 6 HS-C

**Cooling and Trapping of metastable Magnesium** — •Matthias Riedmann, Jan Friebe, André Pape, Temmo Wübbena, Ernst M. Rasel, and Wolfgang Ertmer — Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover

Magnesium is one of the few elements suitable for a neutral atom optical lattice clock. The magic wavelength is predicted between 430 and 470 nm and magnesium offers interesting features like low sensitivity to room temperature blackbody radiation, one of the main uncertainty contributions of state-of-the-art lattice clocks. Up to now, cooling of Mg atoms within the singlet system is limited to the mK regime.

We report on first results with a magneto-optical trap based on transitions in the triplet system. On this transition, the cooling is not limited by the Doppler theory and we expect to reach temperatures in the *K range which are necessary for efficient loading of optical dipole traps. We also use this MOT as an efficient, state-selective detector of atoms in a frequency-sensitive Ramsey-Borde interferometer.

A 36.6 Fr 12:15 VMP 6 HS-C

**Optical traps for ultracold metastable helium atoms** — •Juliette Simonet — LKB ENS, Paris, France

One of the main characteristics of metastable helium atoms is their high internal energy (20 eV). This energy can be released when a metastable atom hits a surface, ejecting one electron. Therefore, using a Channeltron Electron Multiplier (CEM), one can detect atoms with a time resolution of up to 5 ns. However, this high internal energy raises the problem of inelastic Penning ionizations, following: He*+ He* -¿ He + He+ + e*. This process has a rate of the order of 10*10cm3.s*1 but is reduced by four orders of magnitude if the atoms are spin polarized due to total spin conservation.

We report on the progess of the set up of a dipole trap for ultracold metastable helium using a red detuned fiber laser at 1560nm. One of the aims of this optical trap is to release the constraint on the magnetic field value. We plan to measure the magnetic field dependance of inelastic collision rates initially calculated by P. O. Fedichev1, for temperatures smaller than $10\mu$K. In a spin polarized gas of helium, the spin-spin interaction produces spin relaxation and relaxation induced Penning ionization if the polarization condition is no longer maintained.

We also present the development of a optical lattices in 1D and later in 3D. We intend to monitor the Penning ionization rate in order to follow the real-time dynamics of the Superfluid-Mott insulator quantum phase transition.

## A 37: Precision Spectroscopy of Atoms and Ions VII

Zeit: Freitag 14:00–16:00 Raum: VMP 6 HS-B

**Fachvortrag** A 37.1 Fr 14:00 VMP 6 HS-B

**Hochgeladene Ionen in Ruhe - Die HITRAP Anlage** — •Frank Herfurth[1], Ludwig Dahl[1], Oliver Kester[1,2], H.-Jürgen Kluge[1], Christophor Kozhuharov[1], Wolfgang Quint[1], Thomas Stöhlker[1] und die HITRAP Kollaboration[1] — [1]GSI Helmholtzzentrum für Ionenforschung, Darmstadt — [2]NSCL/MSU, East Lansing, USA

HITRAP ist eine Anlage zum Abbremsen und Kühlen schwerer, hochgeladener Ionen wie z.B. wasserstoffähnliches Uran $U^{91+}$. Etwa $10^4$ Ionen können pro Sekunde für Präzisionsexperimente in Atom- und Kernphysik bereitgestellt werden. Das sind zum Beispiel Präzisionsmassenmessungen, Messungen des g-Faktors des gebundenen Elektrons oder kinematisch komplette Reaktionsstudien. Produziert werden die hochgeladenen Ionen im GSI Beschleunigerkomplex bei relativistischen Energien. Für höchste Präzision müssen die Ionen dann bis auf 4 Kelvin abgebremst werden; eine Reduktion der kinetischen Energie um 14 Größenordnungen! Dies geschieht zuerst im Experimentierspeicherring der GSI (ESR), in dem sie von 400 MeV/u auf 4 MeV/u abgebremst und gleichzeitig mit Elektronen gekühlt werden. Danach werden sie aus dem ESR ausgeschossen, in zwei, umgekehrt betriebenen, linearen Beschleunigerstrukturen von 4 MeV/u auf 6 keV/u abgebremst und in eine Penningfalle eingefangen, wo sie erst mit Elektronen auf 10 eV und dann mit Widerstandskühlen auf 4K abgekühlt werden. Die erste Hälfte des linearen Abbremsers wurde kürzlich in Betrieb genommen und hochgeladene Ionen auf 0,5 MeV/u abgebremst.

**Fachvortrag** A 37.2 Fr 14:30 VMP 6 HS-B

**Optical Hyperfine Structure and Isotope Shift Measurements on $Os^-$** — •Arne Fischer, Carlo Canali, Ulrich Warring, and Alban Kellerbauer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

In 1999 the first bound–bound electric-dipole transition in a negative ion was observed in the transition metal osmium. Within the UNIC project (Ultracold Negative Ions by indirect laser Cooling) we studied this transition and performed measurements of the isotope shift for all naturally occurring isotopes and the hyperfine structure in $^{187}Os^-$ and $^{189}Os^-$. The hyperfine constants of the ground and the bound excited state of $^{187}Os^-$ and $^{189}Os^-$ were determined. For the spectroscopy a mass-separated beam of negative osmium ions was collinearly superimposed with a tunable narrow-bandwidth laser. Due to the velocity-bunching effect in a fast beam this geometry allows precise measurents with linewidths of some MHz and hence sufficient resolving power to resolve the hyperfine structure.

A 37.3 Fr 15:00 VMP 6 HS-B

**High-resolution collinear laser spectroscopy as a tool for precise high-voltage determination** — •R. Sánchez[1], A. Krieger[2], Z. Andjelkovic[2], R. Cazan[2], K. Blaum[3], M.L. Bissell[4], G.W.F. Drake[5], Ch. Geppert[1], M. Kowalska[4], J. Krämer[2], R. Neugart[2], F. Schmidt-Kaler[6], D. Tiedemann[2], Z.-C. Yan[7], D. Yordanov[4], M. Žáková[2], C. Zimmermann[8], and W. Nörtershäuser[1,2] — [1]GSI Helmholtzzentrum für Schwerionenförschung GmbH, Darmstadt, Germany — [2]Institut für Kernchiemie, Universität Mainz, Germany — [3]Max-Planck Institut für Kernphysik, Heidelberg, Germany — [4]Physics Department, CERN, Geneva, Switzerland — [5]Department of Physics, University of Windsor, Canada — [6]Quanteninformationsverarbeitung, Universität Ulm, Germany — [7]Department of Physics, University of New Brunswick, Canada — [8]Physikalisches Institut, Universität Tübingen, Germany

For more that 25 years collinear laser spectroscopy has provided outstanding results of ground-state nuclear structure properties. This technique has been successfully applied to measure isotope shifts (IS) of long chains of mid-$Z$ isotopes at ISOL facilities. However IS measurements performed on low-$Z$ do not reach the required accuracy mainly because the large uncertainty introduced in the determination of the high-voltage applied to the extraction electrodes at the target region.

We have now found a way to determine precisely this parameter by measuring the transition frequencies via high-resolution collinear laser spectroscopy. In this contribution we report on the technique and the results we obtained at COLLAPS, ISOLDE-CERN.

A 37.4 Fr 15:15 VMP 6 HS-B

**Spectroscopy of $Os^-$ and a Route to Laser-Cooled Negative Ions** — •Ulrich Warring, Carlo Canali, Arne Fischer, and Alban Kellerbauer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Typical binding energies of negative ions are in the range of 1–2 eV, hence at least one order of magnitude lower than in positive ions or atoms. Furthermore the potential experienced by the valence electron is short-ranged and thus only supports a finite number of bound states. Often these bound states are different fine-structure levels of the same configuration. An exceptional case can be found in the negative osmium ion. It has the unique property of a bound excited state with opposite parity with respect to the ground state – so far the only known electric-dipole transition in a negative ion. This fact enables the use of standard atomic-physics techniques, such as laser cooling. The goal of the UNIC project (Ultracold Negative Ions by indirect laser Cooling) is to demonstrate this method to work. As a first milestone we conducted high-resolution laser spectroscopy of the relevant transition on a $Os^-$ beam. In this presentation we will report on the experimental results and outline the next steps towards trapping and laser cooling negative osmium ions.

A 37.5 Fr 15:30 VMP 6 HS-B

**Mg frequency measurement via telecom fibre network** — •Andre Pape[1], Jan Friebe[1], Matthias Riedmann[1], Temmo Wübbena[1], Ernst M. Rasel[1], Wolfgang Ertmer[1], Osama Terra[2], Gesine Grosche[2], Katharina Predehl[2,3], Thorsten Feldmann[2], Burghard Lipphardt[2], and Harald Schnatz[2] — [1]Institut für Quantenoptik, Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

The alkaline earth magnesium (Mg) is an interesting candidate for a future optical clock based on ensembles of neutral atoms. We report on a recently performed characterization of the Mg frequency standard at the Institute of Quantum Optics (IQ) in Hanover via a telecom fibre network connecting IQ with the optical frequency standards at the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig. The stability of PTB's Ca clock laser is transferred via an actively stabilized 73 km long telecom fibre for direct optical comparison to the Mg frequency standard by means of a telecom fibre laser and two fs frequency combs. The investigated clock transition $^1S_0 \rightarrow {}^3P_1$ in cold free falling Mg atoms is probed in a Ramsey-Bordé interferometer with subsequent detection of the excited atoms in a MOT in the triplet system. To enable long term stability and accuracy a passive hydrogen maser at IQ is used and compared to a Cs fountain clock at PTB. We present the results of the measurement of the Mg clock lasers' short term stability and the characterization of the Mg frequency standard.

A 37.6 Fr 15:45 VMP 6 HS-B

**Experimental study of two-photon decay in He-like tin** — •Sergiy Trotsenko[1,2], Ajay Kumar[2], Andrey Volotka[3], Dariusz Banas[4], Heinrich Beyer[2], Harald Bräuning[2], Alexandre Gumberidze[5], Siegbert Hagmann[1,2], Sebastian Hess[1,2], Christophor Kozhuharov[2], Regina Reuschl[1,2], Uwe Spillmann[1,2], Martino Trassinelli[2,5], Günter Weber[2,6], and Thomas Stöhlker[2,6] — [1]IKF, University of Frankfurt, Germany — [2]GSI, Darmstadt, Germany — [3]TU Dresden, Germany — [4]Swietokrzyska Academy, Kielce, Poland — [5]Institut des NanoSciences de Paris, France — [6]University of Heidelberg, Germany

The study of two-photon transitions (2E1) in the He-like heavy ions is of particular interest due to the sensitivity of its spectral shape to electron correlation and quantum electrodynamical effects. Numerous experimental and theoretical attempts to explore the process have been done in the past proving the high interest and importance of this rare decay mode. In the present investigation an alternative approach for studying the two-photon transitions in few-electron high-Z ions was applied. Here, relativistic collisions of the Li-like projectiles with a gaseous target were used to form the desired initial state allowing to measure the undistorted two-photon spectral shape. The decay of the [1s2s] singlet state in He-like tin (Z=50) was examined and the continuum shape of the two-photon energy distribution was compared with fully relativistic spectral distributions, which in turn are predicted to be Z-dependent. The technique has allowed to confirm for the first time fully relativistic calculations.

## A 38: Atomic Clusters IV

Zeit: Freitag 14:00–15:15 Raum: VMP 6 HS-C

A 38.1 Fr 14:00 VMP 6 HS-C

**Collision frequency of electrons in laser excited expanding small clusters** — •Thomas Raitza, Heidi Reinholz, and Gerd Röpke — Universität Rostock

One of the fundamental quantities in the physics of strongly coupled Coulomb systems is the dynamical collision frequency. Collisions are of relevance for emission, absorption, reflection and scattering of light. Analytical as well as MD simulation techniques have been applied to evaluate the dynamical collision frequency for homogeneous systems, with special application to optical properties. Recently, clusters at nearly solid densities are more accessible to experimental investigations using laser intensities of $10^{13} - 10^{16}\mathrm{Wcm}^{-2}$. Here, we present theoretical results for finite Coulomb systems. In particular, we are interested in the cluster size dependence of the collisional damping rates in comparison to bulk systems.

Properties of laser excited small metallic clusters are calculated using a classical MD simulations code. Results for the electron phase space distribution are analyzed, comparing the simulated profiles with predictions from equilibrium statistical physics. We are interested in time dependent density and temperature profiles as well as optical properties. The question of local thermodynamic equilibrium (LTE) is addressed, and size effects are considered. For this, a restricted MD simulation scheme has been developed, where the ion positions are frozen at given times, and the electrons are treated as an equilibrated subsystem. Collective modes of the excited electron system have been investigated in order to deduct the dynamical collision frequency.

A 38.2 Fr 14:15 VMP 6 HS-C

**Optimal Control of the Ionization of embedded Silver Clusters in Strong Femtosecond Laser Fields** — •Nguyen Xuan Truong[1], Paul Hilse[2], Sebastian Göde[1], Andreas Przystawik[1], Tilo Döppner[1], Thomas Fennel[1], Thomas Bornath[1], Josef Tiggesbäumker[1], Manfred Schlanges[2], Gustav Gerber[3], and Karl Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock, D-18051 Rostock — [2]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, D-17489 Greifswald — [3]Physikalisches Institut, Universität Würzburg, D-97074 Würzburg

Optimal control techniques combined with femtosecond laser pulse shaping are applied to enhance the strong-field induced emission of highly charged atomic ions from silver clusters isolated in helium nanodroplets. We report on a substantial increase of the yield of $Ag^{z+}$ ($z \geq 10$) with the optmized pulses when comparing to single bandwidth-limited or down-chirped pulses at constant fluence. A remarkable simple double-pulse structure containing a low-intensity prepulse and a stronger post-pulse turns out to produce the highest atomic charge states up to $z = 20$. A numerical control experiment based on a modified version of the nanoplasma model converge to a similar pulse envelope, underlining the leading role of plasmons in the generation of highly charged ions from intense laser-cluster interaction.

A 38.3 Fr 14:30 VMP 6 HS-C

**Local ignition and anisotropic nanoplasma growth in laser-driven composite clusters** — •Alexey Mikaberidze, Ulf Saalmann, and Jan M. Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Doping a helium nanodroplet with a tiny xenon cluster of a few atoms only, sparks complete ionization of the droplet at laser intensities below the ionization threshold of helium atoms. As a result, the intrinsically

inert and transparent droplet turns into a fast and strong absorber of infrared light.

Microscopic calculations reveal a two-step mechanism to be responsible for the dramatic change: Avalanche-like ionization of the helium atoms on a femtosecond time scale, driven by field ionization due to the quickly charged xenon core is followed by resonant absorption enabled by an unusual cigar-shaped nanoplasma within the droplet [1]. In contrast to the well known resonant absorption during the Coulomb explosion of both homogeneous [2] and composite [3] clusters, the resonance here occurs on an *electronic* time scale. We have indications that similar effects can be found in composite clusters of other species.

[1] A. Mikaberidze, U. Saalmann, and J. M. Rost, submitted, 2008.
[2] U. Saalmann and J. M. Rost, Phys. Rev. Lett. 91, 223401 (2003).
[3] A. Mikaberidze, U. Saalmann, and J. M. Rost, Phys. Rev. A **77**, 041201(R) (2008).

A 38.4 Fr 14:45 VMP 6 HS-C

**Directed Electron Emission from Resonantly Excited Metal Nanoparticles** — •Johannes Passig, Thomas Fennel, Xuan Truong Nguyen, Slawomir Skruszewicz, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Institut für Physik, Universität Rostock, www.physik.uni-rostock.de\cluster

Experiments on metal particles exposed to intense ultrashort dual laser pulses reveal a strong asymmetric electron emission giving electron kinetic energies of up to 1.3 keV in the direction of the laser polarization axis. Conventional hydrodynamical or purely coulomb driven expansion processes fail to explain the kinetic energy values and the asymmetry in the electron emission. The energy transfer from the laser field to the fast electrons can be assigned to rescattering processes of weakly bound electrons in the resonant driven plasmon field, called SPARC [1]. Recently, the scattering of electrons in the mean field potential was identified as an alternative mechanism for the electron acceleration, particularly in Xe-clusters [2]. The influence of the particle size, laser intensity and pulse delay time on the observed electron emission is discussed in the context of both theoretical models.

[1] T. Fennel et al., Phys. Rev. Lett. 98(14), 2007 [2] U. Saalmann et al., Phys. Rev. Lett. 100(13), 2008

A 38.5 Fr 15:00 VMP 6 HS-C

**Observation of giant dipole plasmon resonance in electron spectrum from $C_{60}$ in fast ion-impact** — Aditya Kelkar, D. Misra, and •Lokesh C. Tribedi — Tata Institute of Fundamental Research, Colaba, Mumbai 400005, India

Fullerenes are known to exhibit collective excitation i.e., the giant dipole plasmon resonance (GDPR). The GDPR has been observed earlier in photoionization through the detection of photoions. Its effect on multiple ionization and electron capture have also been reported [1,2]. However, a direct evidence of this process in fast ion-collisions is awaited. The GDPR de-excites through the emission of electrons with a characteristic energy. This presents a unique possibility of observing the GDPR state directly in the low energy electron spectrum of $C_{60}$. We measured the low energy (1-300 eV) $e^-$ DDCS spectrum from $C_{60}$ in collisions with 4 MeV/u bare F ions at various angles. A careful measurement shows a broad peak like structure near the expected GDPR peak position (i.e. $\hbar\omega - I_p \sim 10$ eV) in all the electron spectra taken for different angles. The distribution shows a dip around 90°, which is in contrary to the expected behaviour in case of ion-atom collisions. The angular distribution suggests that the dipole oscillations are induced preferably along the projectile beam direction.

[1] U. Kadhane et al. Phys. Rev. Lett. **90**, 093401 (2003).
[2] U. Kadhane et al. Phys. Rev. A (Rapd comm.) **75**, 041201 (R) (2007).