Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(lecture rooms V7.02, V47.02, V47.03, V57.03, V57.05, and V55.01; Poster.V)

Invited Talks

A 1.1	Mon	10:30–11:00	V55.01	**Atoms and ions in intense ultrashort laser pulses: entering the relativistic regime** — •Alejandro Saenz
A 3.1	Mon	10:30–11:00	V47.03	**Many-electron dynamics triggered by strong FEL pulse** — •Ulf Saalmann
A 3.2	Mon	11:00–11:30	V47.03	**Ignition and dynamics of doped He nanodroplets in intense few-cycle IR pulses** — Siva Krishnan, Lutz Fechner, Robert Moshammer, Joachim Ullrich, Frank Stienkemeier, •Marcel Mudrich, Alexey Mikaberidze, Ulf Saalmann, Jan-Michael Rost, Christian Peltz, Thomas Fennel
A 3.3	Mon	11:30–12:00	V47.03	**Quantum and classical measures of molecular ultracold plasma dynamics** — Jonathan Morrison, Hossein Sadeghi, Markus Schulz-Weiling, Donald Kelloway, Nicolas Saquet, •Edward Grant
A 11.1	Mon	16:30–17:00	V47.03	**Tracing ultrafast light-induced dynamics in small organic molecules** — •Artem Rudenko
A 11.2	Mon	17:00–17:30	V47.03	**Rydberg atoms in strong laser fields** — •Ulli Eichmann
A 12.1	Tue	10:30–11:00	V47.03	**Two-color photoionization studies at XUV and X-ray Free Electron Lasers** — •Michael Meyer
A 16.1	Tue	14:00–14:30	V7.02	**Macroscopic Quantum Tunneling of Solitons in Bose-Einstein Condensates** — •Lincoln D. Carr, Joseph A. Glick
A 17.1	Tue	14:00–14:30	V55.01	**Single-photon interference experiments with single ions** — •Gabriel Hétet, Lukas Slodicka, Nadia Rock, Markus Hennrich, Rainer Blatt
A 18.1	Tue	14:00–14:30	V47.03	**Ultrafast Quantum Photonics** — •Alfred Leitenstorfer
A 18.2	Tue	14:30–15:00	V47.03	**Attosecond dynamics in laser-driver metal clusters** — Johannes Passig, Sergey Zherebtsov, Robert Irsig, Slawomir Skruszewicz, Josef Tiggesbäumker, Matthias Kling, Karl-Heinz Meiwes-Broer, •Thomas Fennel
A 30.1	Thu	10:30–11:00	V47.03	**X-ray laser spectroscopy at the free-electron laser LCLS** — •José R. Crespo López-Urrutia
A 30.2	Thu	11:00–11:30	V47.03	**Test of fundamental physics with highly charged ions** — •Z. Harman, C. Beilmann, J. R. Crespo López-Urrutia, S. Sturm, V. Yerokhin, J. Zatorski, K. Blaum, J. Ullrich, C. H. Keitel
A 31.1	Thu	10:30–11:00	V57.05	**Coulomb potential effect on the tunneling electron from molecules** — •Jian Wu, Reinhard Dörner
A 37.1	Thu	14:00–14:30	V57.05	**X-ray magnetic circular dichroism spectroscopy of size-selected free cluster ions: spin coupling, orbital angular momentum quenching, and magnetic dopants** — •Tobias Lau
A 37.2	Thu	14:30–15:00	V57.05	**Autoionization of clusters: Energy transfer vs. electron transfer** — •Uwe Hergenhahn
A 42.1	Fri	10:30–11:00	V57.03	**Quantum reflection and matter-wave optics with helium atoms and molecules** — •Wieland Schöllkopf
A 44.1	Fri	10:30–11:00	V57.05	**Attosecond control and tracing of collective electron dynamics in nanoparticles** — •Matthias Kling

Invited talks of the joint symposium SYRA

See SYRA for the full program of the Symposium.

SYRA 1.1	Tue	10:30–11:00	V47.01	**Quantum optics and quantum information with Rydberg excited atoms.** — •Klaus Molmer
SYRA 1.2	Tue	11:00–11:30	V47.01	**Cooperative non-linear optics using Rydberg atoms** — •Charles Adams
SYRA 2.1	Tue	14:00–14:30	V47.01	**Ultralong-range Rydberg molecules** — •Thomas Pohl
SYRA 2.2	Tue	14:30–15:00	V47.01	**Quantum Information Processing with Rydberg Atoms** — •Philippe Grangier

Invited talks of the joint symposium SYIB

See SYIB for the full program of the Symposium.

SYIB 1.1	Tue	10:30–11:00	V55.22	**Nuclear physics with stored highly-charged radioactive ions** — •Yuri Litvinov
SYIB 1.2	Tue	11:00–11:30	V55.22	**High Precision Laser Spectroscopy at the Storage Ring ESR** — •Wilfried Nörtershäuser
SYIB 1.3	Tue	11:30–12:00	V55.22	**Storage-ring measurements of hyperfine-induced one-photon transitions in highly charged ions** — •Stefan Schippers
SYIB 1.4	Tue	12:00–12:30	V55.22	**Low-Temperature Molecular Recombination from fast Electron and Ion Beams** — •Oldrich Novotny
SYIB 2.1	Tue	14:00–14:30	V55.22	**Ion induced fragmentation of large (bio)molecules** — •Thomas Schlathölter
SYIB 2.2	Tue	14:30–15:00	V55.22	**Using femtosecond lasers for determining the structure and dynamics of complex molecules** — •Jason Greenwood
SYIB 2.3	Tue	15:00–15:30	V55.22	**Fast beam momentum spectroscopy on XUV excited molecular ions** — •Henrik Pedersen
SYIB 2.4	Tue	15:30–16:00	V55.22	**Electron Emission from Hot Stored Molecular and Cluster Anions** — •Michael Lange, Klaus Blaum, Christian Breitenfeldt, Michael Froese, Sebastian Menk, Andreas Wolf, Swarup Das, Manas Mukherjee

Invited talks of the joint symposium SYPC

See SYPC for the full program of the Symposium.

SYPC 1.1	Thu	10:30–11:00	V47.01	**Quantum Communication: real-world applications and academic research** — •Nicolas Gisin
SYPC 1.2	Thu	11:00–11:30	V47.01	**Trapping and Interfacing Cold Neutral Atoms Using Optical Nanofibers** — •Arno Rauschenbeutel
SYPC 2.1	Thu	14:00–14:30	V47.01	**Coherent population trapping in quantum dot molecules** — Katharina Weiss, Jeroen Elzerman, •Atac Imamoglu
SYPC 2.2	Thu	14:30–15:00	V47.01	**Nanophotonic Interconnection Networks for Performance-Energy Optimized Computing** — •Keren Bergman

Invited talks of the joint symposium SYQM

See SYQM for the full program of the Symposium.

SYQM 1.1	Fri	10:30–11:00	V47.01	**Overview of some recent "atomic-physics" experiments with nitrogen-vacancy centers in diamond** — •Dmitry Budker
SYQM 1.2	Fri	11:00–11:30	V47.01	**Quantum Limits and Quantum Enhancement in Magnetometry** — Federica Beduini, Naeimeh Behbood, Yannick de Icaza, Brice Dubost, Marco Koschorreck, Mario Napolitano, Ana Predojevic, Robert Sewell, Florian Wolfgramm, •Morgan Mitchell
SYQM 2.1	Fri	14:00–14:30	V47.01	**Nanoscale magnetic resonance imaging: Progress and challenges** — •Daniel Rugar

SYQM 2.2	Fri	14:30–15:00	V47.01	**Optical Far-Field Addressing of Single Spins Beyond the Diffraction Limit at Enhanced Collection Efficency** — •Dominik Wildanger, Jero Maze, Benno Koberstein-Schwarz, Jan Meijer, Sébastien Pezzagna, Brian Patton, Jason Smith, Stefan Hell

Sessions

A 1.1–1.7	Mon	10:30–12:30	V55.01	**Interaction with strong or short laser pulses I**
A 2.1–2.7	Mon	10:30–12:15	V57.05	**Atomic systems in external fields I**
A 3.1–3.3	Mon	10:30–12:00	V47.03	**Correlation dynamics in plasmas and clusters I**
A 4.1–4.8	Mon	10:30–12:30	V47.02	**Präzisionsmessungen und Metrologie 1**
A 5.1–5.4	Mon	14:00–16:00	V47.01	**SAMOP Dissertation Prize Symposium**
A 6.1–6.6	Mon	14:00–16:15	V57.01	**Correlation dynamics in plasmas and clusters II**
A 7.1–7.10	Mon	16:30–19:00	V7.03	**Präzisionsmessungen und Metrologie 3**
A 8.1–8.10	Mon	16:30–19:00	V7.02	**Kalte Atome: Fallen und Kühlung**
A 9.1–9.6	Mon	16:30–18:00	V57.05	**Electron scattering and recombination**
A 10.1–10.8	Mon	16:30–18:30	V55.01	**Interaction with strong or short laser pulses II**
A 11.1–11.8	Mon	16:30–19:00	V47.03	**Interaction with VUV and X-ray light I**
A 12.1–12.7	Tue	10:30–12:30	V47.03	**Interaction with strong or short laser pulses III**
A 13.1–13.7	Tue	10:30–12:15	V55.01	**Photoionization**
A 14.1–14.8	Tue	10:30–12:30	V57.05	**Interaction with VUV and X-ray light II**
A 15.1–15.6	Tue	10:30–12:30	V47.01	**SYRA 1: Ultracold Rydberg Atoms and Molecules 1**
A 16.1–16.7	Tue	14:00–16:00	V7.02	**Ultra-cold atoms, ions and BEC I**
A 17.1–17.7	Tue	14:00–16:00	V55.01	**Precision spectroscopy of atoms and ions I**
A 18.1–18.6	Tue	14:00–16:00	V47.03	**Attosecond physics I**
A 19.1–19.5	Tue	14:00–15:15	V57.05	**Atomic systems in external fields II**
A 20.1–20.6	Tue	14:00–16:00	V47.01	**SYRA 2: Ultracold Rydberg Atoms and Molecules 2**
A 21.1–21.22	Tue	16:30–19:00	Poster.V	**Poster: Precision spectroscopy of atoms and ions**
A 22.1–22.16	Tue	16:30–19:00	Poster.V	**Poster: Interaction with strong or short laser pulses**
A 23.1–23.6	Tue	16:30–19:00	Poster.V	**Poster: Electron scattering and recombination**
A 24.1–24.15	Wed	16:30–19:00	Poster.V	**Poster: Interaction with VUV and X-ray light**
A 25.1–25.4	Wed	16:30–19:00	Poster.V	**Poster: Attosecond physics**
A 26.1–26.16	Wed	16:30–19:00	Poster.V	**Poster: Atomic systems in external fields**
A 27.1–27.7	Wed	16:30–19:00	Poster.V	**Poster: Photoionization**
A 28.1–28.7	Wed	16:30–19:00	Poster.V	**Poster: Interaction of matter with ions**
A 29.1–29.8	Thu	10:30–12:30	V47.02	**Ultra-cold atoms, ions and BEC II**
A 30.1–30.6	Thu	10:30–12:30	V47.03	**Precision spectroscopy of atoms and ions II**
A 31.1–31.7	Thu	10:30–12:30	V57.05	**Interaction with strong or short laser pulses IV**
A 32.1–32.6	Thu	10:30–12:30	V47.01	**SYPC 1: From Atoms to Photonic Circuits 1**
A 33.1–33.10	Thu	10:30–13:00	V7.03	**SYRA 3: Ultracold Rydberg Atoms and Molecules 3**
A 34.1–34.8	Thu	14:00–16:00	V7.03	**Kalte Atome: Manipulation und Detektion**
A 35.1–35.8	Thu	14:00–16:00	V47.02	**Ultra-cold atoms, ions and BEC III**
A 36.1–36.8	Thu	14:00–16:00	V47.03	**Precision spectroscopy of atoms and ions III**
A 37.1–37.6	Thu	14:00–16:00	V57.05	**Atomic clusters**
A 38.1–38.6	Thu	14:00–16:00	V47.01	**SYPC 2: From Atoms to Photonic Circuits 2**
A 39.1–39.8	Thu	16:30–19:00	Poster.V	**Poster: Atomic clusters**
A 40.1–40.34	Thu	16:30–19:00	Poster.V	**Poster: Ultra-cold atoms, ions and BEC**
A 41.1–41.11	Thu	16:30–19:00	Poster.V	**Poster: Ultra-cold plasmas and Rydberg systems**
A 42.1–42.7	Fri	10:30–12:30	V57.03	**Ultra-cold atoms, ions and BEC IV**
A 43.1–43.7	Fri	10:30–12:15	V47.03	**Precision spectroscopy of atoms and ions IV**
A 44.1–44.7	Fri	10:30–12:30	V57.05	**Attosecond physics II**
A 45.1–45.7	Fri	10:30–12:30	V7.02	**Kalte Atome**
A 46.1–46.6	Fri	10:30–12:00	V38.02	**Cluster**
A 47.1–47.8	Fri	10:30–12:30	V47.02	**SYPC 3: From Atoms to Photonic Circuits 3**
A 48.1–48.7	Fri	10:30–12:45	V47.01	**SYQM 1: Quantum limited measurement applications 1**
A 49.1–49.6	Fri	14:00–15:30	V57.03	**Ultra-cold plasmas and Rydberg systems**
A 50.1–50.6	Fri	14:00–15:30	V57.05	**Interaction of matter with ions**
A 51.1–51.8	Fri	14:00–16:00	V53.01	**Materiewellenoptik**
A 52.1–52.7	Fri	14:00–16:15	V47.01	**SYQM 2: Quantum limited measurement applications 2**

Mitgliederversammlung Fachverband Atomphysik

Donnerstag 13:30–14:00 Raum: V57.05

- Bericht
- Wahl
- Verschiedenes

A 1: Interaction with strong or short laser pulses I

Time: Monday 10:30–12:30 Location: V55.01

Invited Talk A 1.1 Mon 10:30 V55.01

Atoms and ions in intense ultrashort laser pulses: entering the relativistic regime — •Alejandro Saenz — Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin

The experimental availability of ultrashort laser pulses with extreme peak intensities above 10^{20}W cm^{-2} opens an mostly unexplored field of laser-matter interaction. At these intensities the influence of the magnetic field cannot longer be ignored. This demands a treatment beyond the usual non-relativistic description within the dipole approximation. A further reason for abandoning the dipole approximation is that short wavelengths are often adopted which requires to consider the spatial variation of the electric (and magnetic) fields within the laser pulse. Most importantly, the outer electrons of atoms or molecules are blown away already during the rising edge of the laser pulse, long before the peak intensity is reached. Therefore, one has to deal with deeply bound core electrons. They may be produced in the same laser pulse or separately by, e. g., using an EBIT. The description of the deeply bound electrons requires a fully relativistic treatment. Therefore, the proper theoretical description of atomic systems at those extreme intensities requires to solve the time-dependent Dirac equation (TDDE) in which the coupling with the field is fully taken into account beyond the dipole approximation. We have recently developed such a solver for (effective) one-electron systems in full dimensions and first results, including a newly found scaling law, will be presented.

A 1.2 Mon 11:00 V55.01

Preparation and measurement of nuclear wave packets with ultrashort laser pulses: "Lochfraß" and the inversion motion of NH_3 — •Johann Förster and Alejandro Saenz — Humboldt-Universität zu Berlin, Germany

Time-resolved imaging of the dynamics of electrons and nuclei is a prerequisite to understand chemical processes and, therefore, a great challenge for theory and experiment. Preparing and measuring nuclear wave packets describable within the promising pump-probe sheme "Lochfraß" was so far discussed theoretically [1] and experimentally [2] for diatomic molecules. The vibration of the molecule D_2 was monitored experimentally with subfemtosecond and sub-Ångstrom resolution in real time. This became possible using two identical but delayed intense ultrashort laser pulses. While so far only diatomic molecules were considered, the Lochfraß effect should be observable for larger molecules as well. The challenge for theory consists in describing this higher dimensional coupled vibrational problem and suggesting pulse parameters for the experiment. For NH_3, we expect a significant Lochfraß effect which can be understood within a simple one-dimensional double-well picture describing the inversion motion of the molecule. In addition to Lochfraß itself, also the tunneling problem in the double-well potential is of interest since a coordinate-dependent ionization rate allows the study of the wave packet traversing the inversion barrier, and thus to investigate quantum-mechanical tunneling.

[1] Goll *et al.*, *Phys. Rev. Lett.* **97**, 103003 (2006).
[2] Ergler *et al.*, *Phys. Rev. Lett.* **97**, 103004 (2006).

A 1.3 Mon 11:15 V55.01

Trajectory-based Coulomb-corrected strong field approximation — •Tian-Min Yan[1,2], Sergey Popruzhenko[3], and Dieter Bauer[1] — [1]Institut für Physik, Universität Rostock, 18051 Rostock, Germany — [2]Max-Planck-Institut für Kernphysik, Postfach 103980, 69029 Heidelberg, Germany — [3]Moscow Engineering Physics Institute, National Research Nuclear University, Kashirskoe Shosse 31, 115409 Moscow, Russia

We present a semi-classical theory for atoms in strong laser fields, the trajectory-based Coulomb-corrected strong field approximation (TCSFA). The method relies on the widely-used strong field approximation (SFA). Using the saddle point approximation, the concept of quantum orbits—inherent in the SFA—allows for an incorporation of the long-range Coulomb interaction with the emitted electron. By comparisons with *ab initio* solutions of the time-dependent Schrödinger equation we show that the Coulomb interaction significantly alters the electron dynamics. The TCSFA method is used to calculate doubly-differential momentum distributions of photo-electrons, especially for the low-energy regime where the plain SFA fails. The TCSFA is particularly convenient for a detailed analysis of the ionization dynamics at relatively low computational demand. In fact, the understanding of spectral features in terms of interfering quantum orbits yields the maximum insight possible in nonperturbative quantum dynamics. The applicability of the method for different laser parameters is discussed.

A 1.4 Mon 11:30 V55.01

The Impact of Multichannel and Multipole Effects on the Cooper Minimum in the High-Harmonics Spectrum of Argon — •Stefan Pabst[1,2], Loren Greenman[3], David A. Mazziotti[3], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Germany — [3]Department of Chemistry and The James Franck Institute, The University of Chicago, Chicago, USA

We investigate the relevance of multiple-orbital and multipole effects during high-harmonic generation (HHG). The time-dependent configuration-interaction singles (TDCIS) approach is used to study the impact of the detailed description of the residual electron-ion interaction on the HHG spectrum. We find that the shape and position of the Cooper minimum in the HHG spectrum of argon changes significantly whether or not interchannel interactions are taken into account. We show that the argument of low ionization probability is not sufficient to justify ignoring multiple-orbital contributions. When additionally the tensorial character of the electron-ion interaction is neglected and a spherically symmetric electron-ion interaction is assumed, we find that the HHG yield is underestimated by up to 2 orders of magnitude in the energy range of 20-40 eV, thus modifying the shape of the Cooper minimum significantly.

A 1.5 Mon 11:45 V55.01

The lateral momentum distribution after strong-field ionization — •Ingo Dreissigacker[1], Jost Henkel[1,2], and Manfred Lein[1] — [1]Institut für Theoretische Physik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Institut für Physikalische und Theoretische Chemie and Röntgen Research Center for Complex Material Systems, Am Hubland, 97074 Würzburg, Germany

Motivated by recent measurements of the lateral electron momentum distribution from ionization with circularly polarized laser pulses [1], we model these distributions using both numerical and analytical methods. We demonstrate that in contrast to the momentum distribution in field direction, the width of the lateral distribution follows the instantaneous electric field on an attosecond timescale. This applies even in case of large fields, where substantial depletion occurs. We review the derivation of the tunneling formula, which predicts lateral distributions of approximately Gaussian shape. We demonstrate that the pre-exponential factor in the saddle-point approximation cannot be neglected if quantitative results are desired. We calculate the widths for hydrogen as well as for argon and neon atoms. We compare to results from the time-dependent Schrödinger equation and to the experimental results from [1]. We find significant improvement of our approach over the previously used tunneling formula.

[1] Arissian et al., PRL 105, 133002 (2010)

A 1.6 Mon 12:00 V55.01

Coulomb interaction in multiphoton ionization of iodine-containing molecules — •Nils Gerken, Stephan Klumpp, Martina Dell'Angela, Florian Sorgenfrei, Florian Hieke, Wilfried Wirth, and Michael Martins — Institut für Experimentalphysik, 22761 Hamburg, Germany

We present multi-ionization processes of Iodine-containing molecules and Xenon in the region of the giant resonance measured with ion mass-to-charge spectroscopy at ultrahigh intensities. In our experiment at the free-electron laser facility FLASH we reached photon intensities of up to $10^{12} - 10^{14} W/cm^2$ at pulse lengths of a few hundred femtoseconds. We observed different Coulomb interaction schemes due to different charge state distributions at two different molecular types of halides. Especially at Ion TOF - peaks belonging to higher charged Iodine atoms we can clearly observe asymmetries in our Ion time-of-flight spectra caused by Coulomb interaction. Differences of ion charge state yields for two different molecules are only observed when exposing to high photon intensities, this can be an indication for double core hole excitations. We also report on time dependent patterns of atomic xenon which is also caused by resonance excitation behavior.

A 1.7 Mon 12:15 V55.01

Electron temperature in laser-solid interaction — •Thomas Kluge, Huang Lingen, Alexander Debus, Karl Zeil, Bhuvanesh Ramakrishna, Ulrich Schramm, and Thomas E. Cowan — Helmholtz-Zentrum Dresden-Rossendorf

Recent theoretical results have led to a new understanding of how to derive the temperature of hot electrons generated in laser-solid interactions from the laser intensity.

We present new scaling laws for electron temperature with laser intensity. We then focus on the implications of our findings for applications such as laser-driven ion acceleration and laser-driven fusion using buried-layer targets.

A 2: Atomic systems in external fields I

Time: Monday 10:30–12:15 Location: V57.05

A 2.1 Mon 10:30 V57.05

Parity Violation in Hydrogen — •Martin-Isbjörn Trappe, Thomas Gasenzer, and Otto Nachtmann — Institute for Theoretical Physics, University of Heidelberg

We discuss the propagation of hydrogen atoms in static electric and magnetic fields in a longitudinal atomic beam spin echo (lABSE) Interferometer. The atoms acquire geometric (Berry) phases that exhibit a manifestation of parity-(P-)violation effects arising from electroweak Z-boson exchange between electron and nucleus. We provide analytical as well as numerical calculations of the behaviour of the metastable n=2 states of hydrogen. We are able to systematically search for Berry phases with tailored properties. Besides maximizing P-violating geometric phases emerging for the respective states we also find the possibility to modify their decay rates, nearly at the order of a percent, solely through P-conserving geometric phases.

A 2.2 Mon 10:45 V57.05

Ionisation Dynamics and Ion Heating Processes of low-Z Ions in EBIS/T — •Erik Ritter and Günter Zschornack — Institute of Solid State Physics, Technische Universität Dresden, Germany

In the past 40 years, EBIS/T were primarily used in basic research to produce highly charged heavy ions. Hence the production of low-Z ions in EBIS/T has not been well investigated. It is well known, that there exist some difficulties in the physics of low-Z ion production, which have to be covered for the optimal operation conditions of EBIS/T systems. The interest in producing low-Z ions in EBIS/T permanently increase because, EBIS/T are expected to be an alternative approach for the ion production in medical particle therapy facilities.

This work presents investigations on the ionisation dynamics of H^+ and H_2^+ ions but can also be applied for other low-Z ions. The ion losses from the ion trap are dominated by energy transfer processes of the produced low-Z ions from residual gas ions or heating by the electron beam. In order to examine these processes measurements of the ionisation dynamics and the energy spread of the extracted ions were done for different ionisation times/trap times (time resolved ion extraction). Thereby the dependence of fundamental ion source parameters such as gas pressure, electron beam current and electron energies were investigated. The results from a room temperature EBIS (B = 600 mT) and a super conductive EBIS (B = 6 T) are compared for proofing the effects on the electron beam current density.

This work is supported by the Federal Ministry of Economics and Technology (Project ZIM-KOOP KF2561301AB0).

A 2.3 Mon 11:00 V57.05

Numerical time-dependent quantum dynamics at relativistic laser intensities — •Heiko Bauke, Matthias Ruf, Frederick Blumenthal, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The quantum dynamics of high intensity laser-matter interactions necessitate a relativistic treatment. The derivation of analytical solutions of the Dirac equation or the Klein-Gordon equation, however, is possible for very few highly symmetric systems only. Many setups of ultrashort laser matter interactions at relativistic intensities require numerical approaches. In this contribution, we survey the challenges of numerical time-dependent relativistic quantum dynamics and present approaches to master these challenges by smart numerical algorithms [1, 2], high-performance implementations on parallel architectures [1, 3] and casting a quantum system's mathematical description by physical insights into a form that is beneficial for numerical methods [4]. Some applications of numerical relativistic time-dependent quantum dynamics will be highlighted.

[1] Matthias Ruf, Heiko Bauke and Christoph H. Keitel, Journal of Computational Physics, **228**, pp. 9092–9106 (2009)
[2] Frederick Blumenthal and Heiko Bauke, Journal of Computational Physics, **231**, pp. 454–464 (2012)
[3] Heiko Bauke and Christoph H. Keitel, Computer Physics Communications, **182**, pp. 2454–2463 (2011)
[4] Heiko Bauke and Christoph H. Keitel, Physical Review E, **80**, article 016706 (2009)

A 2.4 Mon 11:15 V57.05

The time-dependent two-centre Dirac equation: Beyond the monopole approximation — •Sean McConnell[1,2], Anton Artemyev[1,2], Manuel Mai[1,2], and Andrey Surzhykov[1,2] — [1]Universität Heidelberg — [2]GSI, Darmstadt

The realisation of the extreme fields generated by heavy quasimolecules has been of great interest since at least the early 1970's. As such, solutions to the two-centre time-dependent Dirac equation is of utmost importance. A number of approaches have already been made, particularly by the group of Greiner, using the coupled channel equation, to generate solutions to this challenging theoretical problem. In spite of the progress made in the spherically symmetric coordinate system, solutions to the time-*independent* equation using the coupled channel approach have only been performed for the monopole approximation to the two centre potential. Although the monopole approximation indeed provides very good results for small internuclear distances, its applicability at larger internuclear distances is questionable. Therefore, we present in this contribution, an extension of the work already performed toward the use of higher multipoles in the potential expansion. We have calculated, using the B-Spline method in a dual kinetically balanced basis, cross sections for the collision of two U^{+91} U^{92} atoms. To prove the value of our approach we have also determined cross sections of ionisation using this method with those procured using perturbation theory as implemented elsewhere [1]. Applications to laser assisted collisions will also be discussed.

[1] S R McConnell, J. Phys. B: At., Mol., Phys. **44** (2011) 145204

A 2.5 Mon 11:30 V57.05

Decay of hollow states in time-dependent density functional theory — •Varun Kapoor and Dieter Bauer — Institut für Physik, Wismarsche Str. 43-45, Universität Rostock, Rostock-18051, Germany

Hollow or multiply excited states are inaccessible in time dependent density functional theory (TDDFT) using adiabatic Kohn-Sham potentials. We determine the exact Kohn Sham (KS) potential for doubly excited states in an exactly solvable model Helium atom . The exact single-particle density corresponds to the energetically lowest quasi-stationary state in the exact KS potential. We describe how this exact potential controls the decay by a barrier whose origin is traced back to phase of the exact KS orbital. The potential controls the barrier height and width in order for the density to tunnel out and decay with the same rate as the doubly excited state in the ab initio time-dependent Schrödinger calculation. Instead, adiabatic KS potentials only show direct photoionization but no autoionization. A frequency-dependent linear response kernel would be necessary in order to capture the decay of autoionizing states.

A 2.6 Mon 11:45 V57.05

Observation of local temporal correlations in trapped quantum gases — •Vera Guarrera, Ralf Labouvie, Andreas Vogler, Peter Wurtz, Giovanni Barontini, and Herwig Ott

— Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We measure the temporal pair correlation function of a 3-dimensional trapped gas of bosons above and below the critical temperature for Bose-Einstein condensation. The measurement is performed in situ using a local, time-resolved single-atom sensitive probing technique, based on scanning electron microscopy. Third and fourth order correlation functions are also extracted from the same data. We further extend this diagnostics to samples of few 1-dimensional tubes of ultracold bosons in the quasi-condensate and strongly interacting regimes, obtaining, in the second case, clear antibunching signal as a consequence of interaction induced "fermionization". Our results promote temporal correlations as new observables to study the dynamical evolution of ultracold quantum gases.

A 2.7 Mon 12:00 V57.05

^{3}He magnetometer for ultra-sensitive measurements of high magnetic fields — •Anna Nikiel[1,2], Peter Blümler[1], Werner Heil[1], Sergei Karpuk[1], Ernst Otten[1], Andrea Amar[3], Kerstin Münnemann[3], and Maxim Terekhov[4] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]MPI für Polymerforschung, Mainz — [4]Universitätmedizin Mainz

NMR methods are usually used as on-line monitor to measure magnetic fields > 1 Tesla and to trace possible fluctuations. In cases where a very high sensitivity is required an excellent signal to noise ratio (SNR) as well as a long transverse relaxation time T_2^* of the free induction decay (FID) following an NMR excitation is demanded. For example, in Penning trap mass spectroscopy the envisaged resolution of 1 part in 10^{11} or better, requires keeping the magnetic field and its time dependence under control at the same level.

Our approach for an ultra-sensitive measurement of high magnetic fields is to use a gaseous, nuclear spin-polarized ^{3}He spin sample which can reach transverse relaxation times of several seconds, that is far beyond the typical millisecond FID time of a thermally polarized water sample.

We will report on first results obtained in the 1.5 Tesla field of a commercial medical NMR scanner. The ^{3}He gas is spin-polarized in-situ using a new, non-standard variant of Metastability Exchange Optical Pumping (MEOP).

A 3: Correlation dynamics in plasmas and clusters I

Time: Monday 10:30–12:00 Location: V47.03

Invited Talk A 3.1 Mon 10:30 V47.03

Many-electron dynamics triggered by strong FEL pulse — •Ulf Saalmann — Max-Planck-Institut für Physik komplexer Systeme · Dresden

Intense pulses at extreme-ultraviolet or Xray wavelengths — as available from short-wavelength free-electron laser sources like FLASH in Hamburg/Germany, SACLA at Spring8/Japan or LCLS in Stanford/California — couple a large numbers of photons into clusters or bio-molecules, or more generally, extended systems. Within femtoseconds many electrons are released through single-photon absorption. The induced many-electron dynamics depends critically on the photon frequency and the pulse duration. We discuss the various regimes, ranging from nano-plasma termalization [1] to massively parallel ionization [2]. The dynamics can be studied experimentally by measuring electron spectra. We present spectra as obtained by means of a generic model, called Coulomb complexes [3], and from simple analytical considerations.

[1] U Saalmann, I Georgescu, J-M Rost, New J. Phys. 10, 025014 (2008).
[2] Ch Gnodtke, U Saalmann, J-M Rost, arxiv.org/abs/1111.6888
[3] Ch Gnodtke, U Saalmann, J-M Rost, New J. Phys. 13 013028 (2011).

Invited Talk A 3.2 Mon 11:00 V47.03

Ignition and dynamics of doped He nanodroplets in intense few-cycle IR pulses — Siva Krishnan[1], Lutz Fechner[1], Robert Moshammer[1], Joachim Ullrich[1], Frank Stienkemeier[2], •Marcel Mudrich[2], Alexey Mikaberidze[3], Ulf Saalmann[3], Jan-Michael Rost[3], Christian Peltz[4], and Thomas Fennel[4] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisches Institut, Uni Freiburg, Germany — [3]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [4]Physics Institute, University of Rostock, Germany

Doped He nanodroplets are widely used as inert, transparent, and cold matrix for spectroscopy of embedded molecules and clusters [1]. When exposed to strong laser fields, however, a few dopant atoms are sufficient to ”ignite” avalanche-like ionization that turns the whole droplet into a strongly absorbing nanoplasma [2,3]. We present experiments and model calculations on the ignition and dynamics of rare gas-doped He nanodroplets illuminated by few-cycle laser pulses.

[1] J. P. Toennies and A. Vilesov, Angew. Chem. Int. Ed. 43, 2622 (2004)
[2] A. Mikaberidze, U. Saalmann, and J. M. Rost, Phys. Rev. Lett. 102, 128102 (2009)
[3] S. R. Krishnan et al., Phys. Rev. Lett. 107, 173402 (2011)

Invited Talk A 3.3 Mon 11:30 V47.03

Quantum and classical measures of molecular ultracold plasma dynamics — Jonathan Morrison, Hossein Sadeghi, Markus Schulz-Weiling, Donald Kelloway, Nicolas Saquet, and •Edward Grant — University of British Columbia, Vancouver, Canada

Ultracold plasmas offer laboratory access to an important regime of ionized gases in which moderate densities combine with very low ion and electron temperatures to approach conditions of strong Coulomb coupling. Many examples have been studied in atomic systems under conditions of laser cooling in magneto-optical traps. Work in our laboratory has developed an alternative approach using samples cooled in a seeded supersonic molecular beam. This method yields much higher charged particle densities, and appears to attain comparable or even lower electron and ion temperatures, elevating the prospect of strong coupling. Using a beam, we can readily form plasmas composed of molecular ions. Experiments together with model calculations show that molecular effects play a significant role in plasma evolution. For example, ultracold plasmas show promise as bright sources of electrons. Such utility depends on their properties of expansion and decay. This talk presents new results on the ultracold plasma formed by exciting NO in a molecular beam. Aided by model calculations, we show how molecular processes, including dissociative recombination and collision-induced internal conversion, act to effect the spatial and energetic relaxation of the plasma.

A 4: Präzisionsmessungen und Metrologie 1

Time: Monday 10:30–12:30 Location: V47.02

A 4.1 Mon 10:30 V47.02

Detecting the single photon recoil of a single ion — •Cornelius Hempel[1,2], Benjamin P. Lanyon[1,2], René Gerritsma[1,3], Petar Jurcevic[1,2], Florian Zähringer[1,2], Rainer Blatt[1,2], and Christian F. Roos[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstr. 21a, 6020 Innsbruck, Austria — [2]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

I will report on our current work to measure the recoil due to a single photon scattering from a single ion. For this experiment two ions are loaded into a linear ion trap: one well characterized 'measurement' ion and one, possibly unknown, 'spectroscopy ion' on which the photon scattering event is to be detected. The photon recoil energy excites the common vibrational mode shared by both ions. In order to detect this extremely small vibration, we make use of a very sensitive highly non-classical motional state. Our technique could have interesting applications in performing spectroscopy of atoms or molecules at the single photon / single atom level.

A 4.2 Mon 10:45 V47.02

First gravity measurements using the mobile atom interferometer GAIN — •Christian Freier, Malte Schmidt, Alexander Senger, Matthias Hauth, Vladimir Schkolnik, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile gravimeter, based on interfering ensembles of laser cooled ^{87}Rb atoms in an atomic fountain configuration. After introducing the working principle of the interferometer, we present the results of the latest laboratory gravity measurement and progress made in controlling systematic effects.

The high-precision interferometer has reached a sensitivity of $2 \times 10^{-8}\mathrm{g}/\sqrt{\mathrm{Hz}}$ in its first measurement and is designed for a target accuracy of a few parts in 10^{10}g. Finally, we report on the next steps towards a mobile gravimeter for field use.

A 4.3 Mon 11:00 V47.02

Detection and manipulation of nuclear spins coupled weakly to Nitrogen-Vacancy centers — •Jan Honert[1], Helmut Fedder[1], Nan Zhao[1], Michael Klas[1], Junichi Isoya[2], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, 70550 Stuttgart, Germany — [2]University of Tsukuba, Tsukuba, Japan

The ability to investigate weakly coupled nuclear spins via electron spin ancillae offers great potential for novel quantum sensing applications. Nitrogen-Vacancy centers in diamond with long spin coherence times (several ms) are promising solid state systems for quantum information processing and detection at room temperature.

In high magnetic fields single shot readout schemes promise sensing below the Heisenberg limit. Here, we present recent results of nuclear spins coupled weakly to Nitrogen-Vacancy centers in low magnetic fields using dynamical decoupling techniques and isotopically enriched diamonds. Details on detection schemes and robust manipulation of ^{13}C spins are discussed.

A 4.4 Mon 11:15 V47.02

Moving optical lattice for long range transport embedded in an optical clock — •Thomas Middelmann, Stephan Falke, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Optical clocks have surpassed cesium microwave clocks in stability and systematic uncertainty. A major concern for optical clocks is the frequency shift due to ambient thermal radiation. It is currently limiting the systematic uncertainty of Sr optical lattice clocks to $1 \cdot 10^{-16}$ [1]. This blackbody shift can be described to high accuracy as a dc Stark shift from the rms electric field of the ambient blackbody radiation. Thus a dc Stark shift measurement allows a determination of the atomic response to a thermal radiation field. For this measurement ultracold Sr atoms need to be interrogated in the field of a precision capacitor [2]. Therefore a transport of ultracold atoms between the optical access region (MOT, detection) and the dc field (interrogation) is required in each clock cycle. Due to these spatial constrains and optical lattice requirements, we move the optical lattice by moving all its optics. We transport the atoms for 5 cm within 240 ms, with negligible heating, less than 4 % atom loss (back and forth), and maintain a clock stability of better than $3 \cdot 10^{-15}$ $\mathrm{s}^{-1/2}$.

The work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and the ERA-NET Plus Programme.

[1] Falke *et al.* Metrologia **48**, 399 (2011).
[2] Middelmann *et al.* IEEE Trans. Instrum. Meas. **60**, 2550 (2011).

A 4.5 Mon 11:30 V47.02

Interrogation laser with 5×10^{-16} instability for a magnesium optical lattice clock — •Andre Pape, Steffen Rühmann, Temmo Wübbena, André Kulosa, Hrishikesh Kelkar, Dominika Fim, Klaus Zipfel, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Optical clocks revolutionized the field of time and frequency metrology and are outperforming today's best microwave clocks. Magnesium (Mg) is an attractive candidate for a neutral atom optical clock, due to its low sensitivity to blackbody radiation. For interrogation of the narrow atomic transitions in optical clocks, lasers with typically subhertz linewidths are essential. We present an ultrastable laser system with 5×10^{-16} instability for the future spectroscopy of the narrow $^1\mathrm{S}_0 \rightarrow {}^3\mathrm{P}_0$ clock transition at 458 nm on an ensemble of ^{24}Mg atoms confined to an optical lattice at the magic wavelength. The laser system is based on a diode laser at 916 nm stabilized to an ultrastable optical resonator exhibiting a thermal noise floor of 3×10^{-16}. For atomic spectroscopy, the light is resonantly frequency doubled (SHG). We give a detailed presentation of our clock laser system and discuss relevant noise sources, especially the influence of the SHG on laser stability.

A 4.6 Mon 11:45 V47.02

Comparison of reference cavities for an optical clock with improved short-term stability — •Jonas Keller[1], Stepan Ignatovich[2], Maksim Okhapkin[1,2], Stephen Webster[3], David-M. Meier[1], Karsten Pyka[1], and Tanja E. Mehlstäubler[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig — [2]Institute of Laser Physics, 630090 Novosibirsk — [3]National Physical Laboratory, Hampton Road, Teddington

Our work is targeted on the development of an optical frequency standard with a relative short term stability below 10^{-15} in 1s based on Coulomb crystals of $^{115}\mathrm{In}^+$ and $^{172}\mathrm{Yb}^+$ ions in a linear segmented Paul trap. This requires two highly stable lasers for interrogating the $^1\mathrm{S}_0 \leftrightarrow {}^3\mathrm{P}_0$ clock transition in $^{115}\mathrm{In}^+$ and the $^2\mathrm{S}_{1/2} \leftrightarrow {}^2\mathrm{D}_{5/2}$ transition in $^{172}\mathrm{Yb}^+$ for studying and controlling the dynamics of the ion crystals. To achieve these stabilities, we are experimentally comparing two different designs for reference cavities with ULE® spacers and fused silica mirrors. A simple setup using a horizontally mounted cavity of 12 cm length yielded a thermal time constant of 44 h and allowed the stabilization of a diode laser to a relative frequency instability of $6 \cdot 10^{-16}$. The second cavity has a length of 30 cm, giving a thermal noise limit of $1 \cdot 10^{-16}$. Its spacer design is based on FEM calculations to ensure a sufficiently low vibration sensitivity. In order to refine this experimentally, the support points can be moved freely along the optical axis. For this adjustment, the short cavity can act as a reference.

A 4.7 Mon 12:00 V47.02

Strontium in an Optical Lattice as a Mobile Frequency Reference — •Ole Kock, Steven Johnson, Yeshpal Singh, and Kai Bongs — University of Birmingham, Birmingham, UK

Using the higher frequencies (10^{15} Hz) of optical atomic transitions for clocks enable a greater accuracy than the current microwave frequency (10^{10} Hz) standard. Optical clocks have now achieved a performance significantly beyond that of the best microwave clocks. With the rapidly improving performance of optical clocks, in the future, most applications requiring the highest accuracy will require optical clocks. We are setting up an experiment aimed at a mobile frequency standard based on strontium (Sr) in a blue detuned optical lattice. Sr is an alkaline-earth element. The dipole transitions in Sr from the singlet state to the triplet state is forbidden, which results in a long meta-stable lifetime and as narrow line widths as one mHz. Compared to other Strontium experiments with Zeeman Slowers our setup implements the first 2D-MOT for pre cooling the atoms. An up to date progress on the 3D-MOT of this compact and robust frequency standard will be given. For the emerging field of optical clocks in space, this project is developing technologies for the Space Optical Clock (SOC2) project.

A 4.8 Mon 12:15 V47.02

Towards spectroscopy of the clock transition of Yb in a magic wavelength optical lattice — •Gregor Mura, Charbel Abou Jaoudeh, Tobias Franzen, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Optical clocks using neutral atoms hold the promise to eventually reach an inaccuracy at a level of 10^{-18}. So far optical lattice clocks have been demonstrated for Yb, Sr and Hg. Here we report on loading an 1D magic wavelength optical lattice with Yb which is a crucial step towards the realization of a compact and transportable Yb lattice clock. After precooling in a MOT operating at 399 nm a few 10^6 atoms are loaded into a postcooling MOT at 556 nm where a temperature of $\sim 50\,\mu$K is reached. More than 5 % of the atoms can then be transferred into a resonator-based optical lattice. We have achieved a lifetime of a few 100 ms which is sufficient for the operation of an optical clock. The next step will be spectroscopy of the clock transition $6^1S_0 \rightarrow 6^3P_0$ of Yb at 578 nm.

A 5: SAMOP Dissertation Prize Symposium

Time: Monday 14:00–16:00 Location: V47.01

Invited Talk A 5.1 Mon 14:00 V47.01

A Quantum Information approach to Statistical Mechanics — •Gemma De las Cuevas — Max-Planck-Institut fuer Quantenoptik, Garching, Germany

The field of quantum information and computation harnesses and exploits the properties of quantum mechanics to perform tasks more efficiently than their classical counterparts, or that may uniquely be possible in the quantum world. Its findings and techniques have been applied to a number of fields, such as the study of entanglement in strongly correlated systems, new simulation techniques for many-body physics or, generally, to quantum optics. We aim at broadening the scope of quantum information theory by applying it to problems in statistical mechanics. We focus on classical spin models, which are toy models used in a variety of systems, ranging from magnetism, neural networks, to quantum gravity, and we tackle them from three different angles. First, we show how the partition function of a class of widely different classical spin models (models in different dimensions, different types of many-body interactions, different symmetries, etc) can be mapped to the partition function of a single model. Second, we give efficient quantum algorithms to estimate the partition function of various classical spin models, such as the Ising or the Potts model. Finally, we outline the possibility of applying quantum information concepts and tools to certain models of discrete quantum gravity.

Invited Talk A 5.2 Mon 14:30 V47.01

Bose-Einstein condensation of photons — •Jan Klärs — Institut für Angewandte Physik, Universität Bonn, Germany

Does a photon gas condense at low temperatures? Black-body radiation, presumably the most omnipresent Bose gas at all, does not show a phase transition at low temperatures. Here, temperature and photon number cannot be tuned independently. If the temperature of the photon gas is lowered, then also the photon number will decrease (Stefan-Boltzmann law). Under these conditions, a condensation, i.e. a macroscopic occupation of the cavity ground mode, will not occur.

Here, I report on experiments with a two-dimensional photon gas in a dye-filled optical microcavity. In this system, the two transversal motional degrees of freedom of the photons are thermally coupled to the cavity environment by multiple absorption-emission cycles in the dye medium. The cavity mirrors provide an effective photon mass and a confining potential, making the system formally equivalent to a two-dimensional gas of trapped, massive bosons. For such a system, a Bose-Einstein condensation is expected to set in at low temperatures or high photon densities. I will discuss experiments that demonstrate both the thermalization and the condensation process.

Invited Talk A 5.3 Mon 15:00 V47.01

Broadband Optical Quantum Memory at Room Temperature — •Klaus Reim — Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, United Kingdom — Department of Physics, ETH Zurich, CH-8093 Zurich, Switzerland

The quest for upgrading our current, classical information technology architecture with quantum technology is on. Imagine a global quantum network where quantum information is generated and processed in local nodes using future quantum computers and then shared with people on different continents via completely secure quantum channels. Such a quantum network does require several components to function properly, and a quantum memory must certainly be one of them!

In my talk I am going to present our ensemble-based, far off-resonant Raman-approach to quantum memories and explain what distinguishes it from other quantum memories. Furthermore, I will discuss the experimental challenges we faced, e.g. the generation of the 9.2 GHz frequency-shifted single-photon-level signal field or its separation from the co-propagating, 10 orders of magnitude stronger control field. I will explain how we managed to implement this broadband and robust quantum memory scheme and point out its potential for future quantum applications.

Invited Talk A 5.4 Mon 15:30 V47.01

First Spin-Flips Ever Observed with a Single Trapped Proton — •Stefan Ulmer[1,2], Cricia Rodegheri[2,3], Klaus Blaum[2,4], Holger Kracke[3], Andreas Mooser[3], Wolfgang Quint[3,5], and Jochen Walz[3] — [1]RIKEN Advanced Science Institue, Wako, Japan — [2]Max-Planck Institute for Nuclear Research, Heidelberg, Germany — [3]Johannes-Gutenberg Universität, Mainz, Germany — [4]Ruprecht-Karls Universität, Heidelberg, Germany — [5]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Proton spin-flips were observed for the first time using a single isolated particle stored in a cryogenic Penning trap. The spin quantum jumps are detected via the continuous Stern-Gerlach effect. This experimental principle has already been applied to compare the magnetic moments of the electron and the positron, or to measure the g-factor of the electron bound to hydrogen-like ions. These experiments involved magnetic moments on the level of the Bohr-magneton. However, the magnetic moment of the proton is about three orders of magnitude smaller and spin-flips are much harder to detect. We demonstrated for the first time that spin quantum jumps of a single trapped proton can be detected, which is a major step towards a high-precision measurement of the particle's magnetic moment at the level of 10^{-9} or better. Since the techniques developed for the proton can be directly transferred to the antiproton, this is a crucial milestone towards a million-fold improved test of matter-antimatter-symmetry on the baryon-sector.

A 6: Correlation dynamics in plasmas and clusters II

Time: Monday 14:00–16:15 Location: V57.01

Invited Talk A 6.1 Mon 14:00 V57.01

Equilibration of Strongly Coupled Ultracold Plasmas — •Thomas Killian — Rice University, Houston, Texas, USA

Ultracold neutral plasmas provide a powerful platform for studying collisional equilibration in strongly coupled systems. They are created by photoionizing laser-cooled atoms at the ionization threshold, and the resulting ion and electron temperatures are orders of magnitude colder than in traditional neutral plasmas. The ions are strongly coupled and equilibrate with Coulomb coupling constant $1 < \Gamma_i < 4$. Because the density is relatively low compared to high-density strongly coupled plasmas, all relevant timescales are much longer, which provides great advantages for experiments.

The creation of the plasma involves a rapid hardening, or quench of the particle interactions. This leads to an exchange of potential and kinetic energy during subsequent thermalization called correlation induced heating. This is followed by oscillations of the kinetic energy at the ion plasma oscillation frequency. It is also possible to perturb the velocity distribution in an equilibrium plasma and observe the relaxation to a Maxwell-Boltzmann distribution. This allows a measurement of the collision rate in the strongly coupled regime, beyond the point where standard Landau-Spitzer theory becomes invalid. Both experiments probe general features of equilibrating strongly coupled systems and can be related to dynamics in other laser-produced plasmas.

Invited Talk A 6.2 Mon 14:30 V57.01

Short-Time Dynamics of Dust Clusters in Plasmas — •Andre Melzer[1], Tobias Miksch[1], Andre Schella[1], Jan Schablinski[2], Dietmar Block[2], and Alexander Piel[2] — [1]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald — [2]IEAP, Christian-Albrechts-Universität Kiel

Dust clusters show a wide variety of fascinating dynamic properties which strongly depend on the exact particle number. For example, they can be heated from an ordered, solid state to a fluid state or perform normal mode oscillations. Moreover, magic number configurations show high structural and dynamical stability.

Dust clusters consist of a small number of microspheres (dust) trapped in a gaseous discharge plasma. There, the particles attain high negative charges due to the inflow of plasma electrons and ions.These dust clusters can be confined in 2D or 3D arrangements depending on the plasma conditions. They are ideally suited to measure the dynamical properties on the kinetic level of individual particles by (stereoscopic) video microscopy.

Here, we like to address the question of solid-liquid phase transitions in these finite systems in both 2D and 3D as well as their normal modes. These allow a detailed insight into the physical mechanisms of dust systems in particular and charged clusters in general.

This work is supported by DFG under SFB-TR24 and DLR under 50WM1138.

Invited Talk A 6.3 Mon 15:00 V57.01

Shell Formation Dynamics of a Spherical Yukawa Plasma — •Hanno Kählert[1,2] and Michael Bonitz[1] — [1]Christian-Albrechts-Universität zu Kiel — [2]Heinrich-Heine Universität Düsseldorf

Dusty plasmas allow for a fully kinetic investigation of various processes in strongly coupled plasmas—including their dynamics on short time scales. Here, we focus on the time-dependent correlation buildup in spherical dust clusters ('Yukawa Balls'). Starting from a laser-heated initial state, we investigate the time evolution of the dust cloud by Langevin dynamics simulations [1,2]. Due to friction with the neutral gas, the dust particles reach a strongly coupled state in the long-time limit with a well-defined radial shell structure [3]. For short and intermediate times, the simulations show that the cooling process is accompanied by a breathing oscillation of the plasma which manifests itself as a periodic modulation of the dust density. Special attention is paid to the influence of the screening parameter on the order of shell formation, and comparisons are made between closely related processes in ultracold neutral plasmas [4] and confined ion plasmas.

[1] H. Kählert and M. Bonitz, Phys. Rev. Lett. **104**, 015001 (2010)
[2] H. Kählert and M. Bonitz, Contrib. Plasma Phys. **51**, 519 (2011)
[3] M. Bonitz, C. Henning, and D. Block, Rep. Prog. Phys. **73**, 066501 (2010)
[4] T. Pohl, T. Pattard, and J. M. Rost, Phys. Rev. Lett. **92**, 155003 (2004)

A 6.4 Mon 15:30 V57.01

Plasma formation and ionization dynamics in laser-irradiated droplets — •Tatyana Liseykina and Dieter Bauer — Universität Rostock, Deutschland

We present our recent results on ionization dynamics and plasma formation in intense laser-droplet interaction using three-dimensional, relativistic PIC simulations with ionization included. The numerical simulations show that there exists a broad laser intensity regime for which wavelength-sized targets are not fully ionized. For higher-Z material this applies even to ultra-high intensities. Moreover, the results reveal that there exists an angle of incidence at which oscillating electric fields penetrate into the droplet, ionizing its interior. This leads to the formation of a highly asymmetric density distribution, concentrated mostly in the polarization plane, with the higher charge states not only within the skin layer on the surface but also around a focal point in the droplet interior.

A 6.5 Mon 15:45 V57.01

A collisional-radiative model for ns-pulsed laser ablation of metals — •David Autrique and Baerbel Rethfeld — TU Kaiserslautern, 67663 Kaiserslautern, Germany

Laser ablation is nowadays used in a growing number of applications, such as chemical analysis and pulsed laser deposition. Despite the many applications, the technique is still poorly understood. Therefore a model, describing the time dependent material evolution after short pulse laser irradiation, can be a helpful tool during the research quest. The transient behavior in and above a ns-laser irradiated copper target is modeled. Ultrafast phase transitions occur in the liquid, overheated layer. Subsequently a dense mixture of liquid and vapor is ejected above the target. Here a collisional-radiative model accounts for the laser-produced plasma kinetics. Stepwise collisional excitation, ionization, as well as photo processes result in plasma formation in the dense, expanding vapor plume. Calculated transmission profiles are compared with experimental results and similar trends are found.

A 6.6 Mon 16:00 V57.01

Multiscale Approach to Strongly Correlated Two-component Quantum Plasmas in Nonequilibrium — •Michael Bonitz[1], Patrick Ludwig[1], and James W. Dufty[2] — [1]Universität Kiel — [2]University of Florida

A key problem in the description of nonideal, multi-component plasmas is the drastic difference in the r,t-scales which prohibits first-principle simulations, in particular in nonequilibrium. We, therefore, develop a multiscale approach for dense quantum plasmas such as partially ionized Warm Dense Matter, where a full dynamic treatment of the pair correlations of the heavy particles is crucial. To this end the ions are treated exactly by classical Langevin Dynamcis simulations, whereas the electrons are treated fully quantum-mechanically on the basis of a quantum kinetic equation. The coupling of the two is performed in linear response and fully includes the dynamical screening of the ion-ion interaction on the basis of a nonequilibrium extension of the Mermin formula extending our recent results [1,2].

[1] P. Ludwig, M. Bonitz, H. Kählert, and J.W. Dufty, J. Phys. Conf. Series **220**, 012003 (2010) [2] P. Ludwig, H. Kählert, and M. Bonitz, submitted for publication in Plasma Physics and Controlled Fusion (2011)

A 7: Präzisionsmessungen und Metrologie 3

Time: Monday 16:30–19:00 Location: V7.03

A 7.1 Mon 16:30 V7.03

Precision spectroscopy of the $2S_{1/2} - 4P_{1/2}$ transition in atomic hydrogen — •Axel Beyer[1], Arthur Matveev[1], Christian G. Pathey[1], Janis Alnis[1], Randolf Pohl[1], Nikolai Kolachevsky[1], Thomas Udem[1], and Theodor W. Hänsch[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Ludwig-Maximilians-Universität, 80799 München

The comparison between measured and calculated transition frequencies in atomic hydrogen can provide stringent tests of bound state QED. For the last decade, this comparison has been limited by the proton charge radius determined by electron-proton scattering. Recently, laser spectroscopy of muonic hydrogen provided a value, which is ten times more accurate than any previous measurement (Pohl *et al.*, Nature **466**(7303), 2010). But this value differs from the CODATA 2010 value, obtained by a global adjustment of fundamental constants using data from electron-proton scattering and hydrogen experiments for the proton charge radius, by seven standard deviations. The muonic hydrogen result led to a comprehensive search for the cause of this discrepancy, but no convincing argument could be found so far. Because the current CODATA value is mainly based on observations in atomic hydrogen, transition frequency measurements with improved accuracy can help to solve this puzzle or at least to rule out hydrogen experiments as a possible source for the discrepancy. Here we report on the setup which has been developed for the measurement of the one-photon $2S_{1/2}$-$4P_{1/2}$ transition frequency in atomic hydrogen along with the results and conclusions of our first measurement runs.

A 7.2 Mon 16:45 V7.03

A sub-40 mHz linewidth laser based on a single-crystal silicon optical cavity — •Christian Hagemann[1], Thomas Kessler[1], Thomas Legero[1], Uwe Sterr[1], Fritz Riehle[1], Michael J. Martin[2], Lisheng Chen[2], and Jun Ye[2] — [1]Physikalisch-Technische Bundesanstalt (PTB) and Centre for Quantum Engineering and Space-Time Research (QUEST), Bundesallee 100, 38116 Braunschweig, Germany — [2]JILA, NIST and University of Colorado, 440 UCB, Boulder, CO 80309-0440, USA

State-of-the-art ultra-stable lasers achieve fractional frequency stabilities of a few times 10^{-16}, limited by the thermal noise of the high-finesse optical cavities used as reference.

We present a novel optical cavity machined from single-crystal silicon with the potential to push this limitation by one order of magnitude. Various key advantages of silicon as resonator material compared to conventionally used ultra-low expansion (ULE) glass will be discussed. To minimize the impact of thermal instabilities we operate the cavity at its minimum of thermal expansion at a temperature of 124 K in a low-vibration cryostat with nitrogen gas as coolant. In a three-cornered hat frequency comparison with two ULE glass reference cavities we show that the laser frequency-stabilized to the silicon cavity reaches a world-record instability of 10^{-16} and a linewidth of below 40 mHz, the lowest linewidth observed for any laser systems.

We give an outlook on possible applications enabled by dissemination and frequency transfer of this ultra-stable laser light via fiber networks and optical frequency combs.

A 7.3 Mon 17:00 V7.03

Optical Frequency Transfer via 920 km Fiber Link with 10^{-19} Relative Accuracy — •Stefan Droste[1], Katharina Predehl[1,2], Janis Alnis[1], Theodor W. Hänsch[1], Thomas Udem[1], Ronald Holzwarth[1], Sebastian M. F. Raupach[2], Osama Terra[2], Thomas Legero[2], Harald Schnatz[2], and Gesine Grosche[2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Since optical clocks have surpassed the performance of the best microwave clocks they are considered for a possible redefinition of the second. One prerequisite for a future redefinition is the ability to com-pare optical frequencies at a high level of stability and accuracy. Optical fiber links have been investigated and considered to serve this purpose. We established a fiber connection between the two institutes Max-Planck-Institute of Quantum Optics (MPQ) in Garching and the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig. We measured the stability of the frequency transfer to 3.8 x 10^{-14} at 1 s reaching 4 x 10^{-18} after 10^3 s of integration time. We further calculated the deviation of the expected value and the statistical uncertainty to (0.7 ± 3.6) x 10^{-19}. We can therefore constrain any possible frequency deviation between the local and the far end of the fiber link to be smaller than 3.6 x 10^{-19}. The demonstrated frequency transfer over an optical fiber link exceeds the requirements for a comparison of todays most accurate clocks by more than one order of magnitude.

A 7.4 Mon 17:15 V7.03

Precision phase measurement of an optical resonator with a high FSR squeezer — •Timo Denker, Maximilian Wimmer, Dirk Schütte, and Michèle Heurs — Albert-Einstein Institut Hannover: Max-Planck-Institut für Gravitationsphysik, 30167 Hannover

For many applications using optical resonators (e.g. cavity spectroscopy) good frequency stability is required. To achieve this it is necessary to measure the phase shift of the optical resonator with high accuracy. The quality of this measurement depends on the Signal-to-noise-ratio (SNR). For the shot-noise-limited case the SNR can be increased either by increasing the signal or reducing the noise. We present an experimental scheme that makes use of the output of an optical parametric oscillator, a so-called squeezer. The cavity enhanced squeezed signal of a high free spectral range (FSR) squeezer provides a reduced noise-floor for a precision phase measurement of an optical resonator with high finesse. The phase quadrature variance is measured directly at the homodyne detector and yields a suitable error signal for frequency stabilisation.

A 7.5 Mon 17:30 V7.03

An Ultra-Stable Iodine-Based Frequency Reference for Space Applications — •Anja Keetman[1], Thilo Schuldt[1], Klaus Döringshoff[2], Matthias Reggentin[2], Evgeny V. Kovalchuk[2], Moritz Nagel[2], Achim Peters[2], and Claus Braxmaier[1] — [1]University of Applied Sciences Konstanz, Germany — [2]Humboldt-University Berlin, Germany

We present the further development of an iodine-based optical frequency reference on elegant breadboard (EBB) level for future application in space. A frequency-doubled Nd:YAG laser is stabilized to a transition in molecular iodine using modulation transfer spectroscopy near 532 nm. For improving the frequency stability (by a higher pointing stability of the two counter-propagating laser beams in the iodine cell), and also for its future application in space, the optical setup for spectroscopy is realized on a thermally and mechanically ultra-stable baseplate made of a specific glass ceramics (Clearceram by OHARA). The optical components are fixed to the baseplate using adhesive bonding technology, which was already successfully demonstrated in the realization of a highly stable heterodyne interferometer, developed as a prototype demonstrator in the context of the LISA space mission. With the EBB setup, we aim for a frequency stability of $3 * 10^{-15}$ at an integration time of 1000 s, comparable to state-of-the-art iodine-based frequency references realized on laboratory level, e.g. at the Humboldt-University Berlin. This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50 QT 1102.

A 7.6 Mon 17:45 V7.03

Interferometry-Based CTE Measurement Facility with Demonstrated 10 ppb/K Accuracy — •Ruven Spannagel[1], Martin Gohlke[2,3], Thilo Schuldt[1], Ulrich Johann[2], Dennis Weise[2], and Claus Braxmaier[1] — [1]University of Applied Sciences Konstanz, Germany — [2]Astrium GmbH, Friedrichshafen, Germany — [3]Humboldt-University, Berlin, Germany

Structural materials with extremely low coefficient of thermal expansion (CTE) are crucial to enable ultimate accuracy in terrestrial as well as in space-based optical metrology due to minimized temperature dependency. Typical materials, in particular in the context of space-based instrumentation are carbon-fiber reinforced plastics (CFRP), C/SiC, and glass ceramics, e.g. Zerodur, ULE or Clearceram. To determine the CTE of various samples with high accuracy we utilize a highly symmetric heterodyne interferometer with a noise level below 2 $\mathrm{pm}/\sqrt{\mathrm{Hz}}$ at frequencies above 0.1 Hz in our measurement facility. A sample tube made out of the material under investigation is vertically mounted in an ultra-stable support made of Zerodur. Measurement and reference mirrors of the interferometer are supported inside the tube using thermally compensated mounts made of Invar36. For determination of the CTE, a sinusoidal temperature variation is radiatively applied to the tube. One of the essential systematic limitations is a tilt of the entire tube as a result of temperature variation. Using a Zerodur tube as a reference, it is shown that this effect can be reduced in post processing to achieve a minimum CTE measurement sensitivity < 10 ppb/K.

A 7.7 Mon 18:00 V7.03

A rigidly mounted and vibration insensitive optical reference cavity — •Sebastian Häfner, Stefan Vogt, Stephan Falke, Christian Lisdat, and Uwe Sterr — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We report on the development of a sub-Hertz laser system for a transportable optical clock based on an ultra-narrow transition in strontium at 698 nm. A challenge is that its optical reference cavity should withstand transportation shocks. This clock will enable direct comparisons with stationary set-ups and is a predecessor to optical clocks for space missions. This talk will focus on the crucial element of the laser system, namely the reference cavity whose mechanical stability is transferred to frequency stability through Pound-Drever-Hall lock. The spacer of the cavity is made from Ultra-Low-Expansion-glass (ULE), with optical contacted, high finesse fused silica mirrors. It shows a finesse of 460 000 and a theoretical thermal noise floor of $\Delta\nu/\nu = 2.3 \cdot 10^{-16}$.

In this work, we followed a new approach to mount the cavity in a way that its length has a small sensitivity to accelerations ($\Delta l/l = 10.7 \cdot 10^{-10}/g$). We used a rigidly and defined mounting that withstands accelerations of up to 50 g (design): the cylindrical cavity is mounted in its symmetry planes by using a wire-bar mounting system. We measured the performance of this clock laser system by a comparison with two independent sub-Hertz laser systems using a frequency comb. We achieve a relative frequency stability of $\Delta\nu/\nu = 6 \cdot 10^{-16}$ at 10 s. This work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST).

A 7.8 Mon 18:15 V7.03

Towards Testing General Relativity with a dual species interferometer — •Jonas Hartwig, Dennis Schlippert, Ulrich Velte, Daniel Tiarks, Sven Ganske, Olga Lysov, Ernst Maria Rasel, and Wolfgang Ertmer — Institut für Quantenoptik, Hannover, Germany

We report on our work directed towards a dual species matter-wave interferometer for performing a differential measurement of the acceleration of free falling ^{87}Rb and ^{39}K atoms to test Einstein's equivalence principle (universality of free fall). Based on minimal Standard Model Extension calculations this combination of elements is very sensitive for composition based equivalence principle violating effects.

During free fall, a Mach-Zehnder type interferometry sequence employing stimulated Raman transitions is applied synchronously for both species, achieving high common noise rejection. With an expected single shot resolution of $\sim 5\times 10^{-8}g$ the apparatus will allow for studying systematics at a level of few parts in $10^9 g$ after 100 s integration time.

To guarantee well defined starting conditions the two species will be trapped in an optical dipole trap formed by an Fiber Laser of 1960 nm wavelength. The special properties of this dipole trap allow for fast and efficient cooling. Also, use of evaporative and/or sympathetic cooling techniques is possible.

We will show the enviromental noise limited performance of the single species Rubidium gravimeter and the progress in the implementation of the Potassium Interferometer.

A 7.9 Mon 18:30 V7.03

A hybrid on-chip optonanomechanical transducer for ultrasensitive force measurements — •Emanuel Gavartin[1], Pierre Verlot[1], and Tobias J. Kippenberg[1,2] — [1]Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Nanomechanical oscillators have been employed as transducers to measure force, mass and charge with high sensitivity. They are also used in opto- or electromechanical experiments with the goal of quantum control and phenomena of mechanical systems. Here, we report the realization and operation of a hybrid monolithically integrated transducer system consisting of a high-Q nanomechanical oscillator with modes in the MHz regime coupled to the near-field of a high-Q optical whispering-gallery-mode microresonator. The transducer system enables a sensitive resolution of the nanomechanical beam's thermal motion with a signal-to-noise of five orders of magnitude and has a force sensitivity of $74\,\mathrm{aN\,Hz^{-1/2}}$ at room temperature. Energy averaging, required to retrieve incoherent signals, converges only very slowly with the fourth root of the averaging time. We propose and explicitly demonstrate by detecting a weak incoherent force that this constraint can be significantly relaxed by use of dissipative feedback. We achieve a more than 30-fold reduction in averaging time with our hybrid transducer and are able to detect an incoherent force having a force spectral density as small as $15\,\mathrm{aN\,Hz^{-1/2}}$ within 35 s of averaging. This corresponds to a signal which is 25 times smaller than the thermal noise and would otherwise remain out of reach.

A 7.10 Mon 18:45 V7.03

A membrane in a Michelson-Sagnac interferometer with balanced homodyne detection readout — •Andreas Sawadsky, Henning Kaufer, Ramon Moghadas, Daniel Friedrich, Tobias Westphal, and Roman Schnabel — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) and Institut für Gravitationsphysik, Leibniz Universität Hannover, Hannover, Germany.

Using a balanced homodyne detector we measure a broadband shot noise limited displacement of a silicon nitride membrane with a mechanical Q-factor of $6 \cdot 10^5$ in a Michelson-Sagnac interferometer. Thereby we achieved a displacement sensitivity of $2 \cdot 10^{-16}\,\mathrm{m}/\sqrt{\mathrm{Hz}}$ above 50 kHz. We showed that, as expected, thermal noise is only present in amplitude quadrature by performing a zero-span measurement exactly at resonance and varying the homodyne readout phase. By implementing a signal recycling mirror in the interferometer output port we could enhance the displacement sensitivity by a factor of 50 at an input power of 1 mW.

A 8: Kalte Atome: Fallen und Kühlung

Time: Monday 16:30–19:00 Location: V7.02

A 8.1 Mon 16:30 V7.02

Towards a two-species quantum degenerate gas of ^{6}Li and ^{133}Cs atoms and molecules — •Marc Repp, Rico Pires, Juris Ulmanis, Robert Heck, Romain Müller, Stefan Schmidt, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg

The ability to precisely control the interactions of a Bose-Fermi mixture of ^{133}Cs and ^{6}Li at phase-space densities close to quantum degeneracy allows one to study many different aspects of few- and many-body physics in the most extreme alkali atom combination. The extremely large mass-difference of Li and Cs results in the smallest scaling factor of all alkali combinations for the appearance of universal Efimov states [1,2] of 4.88 for ^{133}Cs$_2$^{6}Li [3] (cf. to 22.7 for homonuclear mixtures). The talk will present the design and the current status of our experimental apparatus for achieving higher phase-space densities. The scheme of a double-species Zeeman slower that allows to subsequently decelerate Cs and Li atoms from an atomic oven to the capture velocities of the MOTs will be shown. After further cooling the Cs atoms via Raman side band cooling, both species are transferred into dipole traps where forced evaporative cooling will bring the samples to quantum degeneracy. The possibility of tuning interaction strengths via magnetic fields would enable the study of interspecies Efimov states of Li and Cs.

[1] V. Efimov, Sov. J. Nuc. Phys. 12, 589 (1971)
[2] E. Braaten & H.-W. Hammer, Annals of Physics 322, 120 (2007)
[3] J. P. D'Incao & B. D. Esry, Phys. Rev. A 73, 030703 (2006)

A 8.2 Mon 16:45 V7.02

Microwave guiding of electrons in planar quadrupole guides — •Johannes Hoffrogge, Jakob Hammer, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

We study the guiding of free space electrons in an AC quadrupole guide [1]. Combining the electrode pattern of a surface electrode Paul trap with microwave transmission line structures on a planar substrate leads to exceptionally tight transverse confinement. With microwave driving frequencies, radial trap frequencies in the gigahertz range can be realized. This allows for the precise control of the trajectories of slow electrons with kinetic energies of a few electron volts by means of purely electric fields. We provide a detailed study, both experimentally and numerically, of the kinematics of the electrons and its dependence on the driving parameters of the guide. We also discuss more complex electrode structures like beam splitting elements for guided electrons as well as elements with longitudinal extensions larger than the driving wavelength. These require to consider traveling wave effects in the electrode layout [2]. The combination of a quadrupole electron guide with a single atom tip field emitter as an electron source should allow for the direct preparation of electrons in low lying quantum states of the transverse harmonic oscillator potential. This would enable new guided matter-wave experiments with electrons.

[1] J. Hoffrogge, R. Fröhlich, M. A. Kasevich and P. Hommelhoff, *Phys. Rev. Lett.* **106**, 193001 (2011)
[2] J. Hoffrogge and P. Hommelhoff, *New J. Phys.* **13**, 095012 (2011)

A 8.3 Mon 17:00 V7.02

Shaping the evanescent field of an optical nano-fiber for cold atom trapping — •Ciaran Phelan, Tara Hennessy, and Thomas Busch — Physics Department, University College Cork, Cork, Ireland / Quantum Systems Unit, OIST, Okinawa, Japan

Optical nano-fibers have a number of striking properties which have recently led to their use as a means of trapping neutral atoms. The small diameter of the fiber results in most of the power transmitted in the fiber being contained in the evanescent field. Furthermore, the confinement of the guided fiber modes means that the fiber mode can maintain its profile over a much greater distance than the Rayleigh range of the equivalent free space mode.

Recently, a number of schemes for trapping neutral atoms in the evanescent field have been proposed. One of these involves combining the effect of a red detuned (with respect to the trapped atom's transition frequency) attractive field and a blue detuned repulsive field to form a cylindrical potential minimum surrounding the fiber.

By counter-propagating two red detuned fiber modes with opposite helical phase terms, an interference pattern is formed in the evanescent field. This, when combined with a repulsive fundamental mode, causes the splitting of the circularly symmetric ring trap into an array of traps located on a circle surrounding the fiber. This one dimensional array of traps, with sub-wavelength spacing between the traps has the potential to form a Mott insulator on a ring surrounding the fiber.

A 8.4 Mon 17:15 V7.02

Creating atom-number states around tapered optical fibres by loading from an optical lattice — •Tara Hennessy and Thomas Busch — University College Cork, Republic of Ireland

We present a scheme where the evanescent field around a sub-wavelength diameter tapered nanofibre is combined with the periodic potential of an optical lattice. We show that when the fibre is aligned perpendicularly to the transverse plane of a two-dimensional optical lattice the evanescent field around the fibre can be used to create a time-dependent potential which locally melts the lattice potential.

We first describe the disturbance of the lattice due to scattering of the lattice beams on the fibre, then show how the attractive van der Waals potential close to the surface can be compensated by a blue-detuned evanescent field and finally characterise the resulting atomic samples in the melted part of the lattice. This scheme allows access to a regime in which a small number of particles can be addressed locally without disturbing the rest of the lattice. Furthermore, if the environment around the fibre is given by a well ordered Mott-Insulator state, the melting of the lattice transfers a controllable and well-defined number of atoms from the individual lattice sites around the fibre into the fibre potential. The resulting state is therefore number squeezed and can be used for applications in quantum information or metrology.

A 8.5 Mon 17:30 V7.02

Interplay of cavity and EIT-cooling with neutral atoms in an optical resonator — •René Reimann, Wolfgang Alt, Tobias Kampschulte, Sebastian Manz, Seokchan Yoon, and Dieter Meschede — Institutfür Angewandte Physik der Universität Bonn, Wegelerstr. 8,53115 Bonn

The motional properties of single atoms inside an optical resonator can be changed significantly by the simultaneous interaction with a near-resonant control light field and a weak probing field coupled to the resonator. Following our findings in the case of electromagnetically induced transparency (EIT) with a single neutral atom [1] we investigate the roles of EIT cooling and cavity cooling within our system. We identify cooling and heating regions associated with the EIT-dark state or the atom-cavity dressed states [2]. By this the dressed states of the system and their dependency on the single- and two-photon-detunings can be investigated experimentally.

Further we show a qualitative difference in the cooling dynamics between one and two atoms coupled to the optical resonator.

[1] T. Kampschulte *et al.*, Phys. Rev. Lett. **105**, 153603 (2010)
[2] M. Bienert *et al.*, arXiv, 1109.1666v1 (2011)

A 8.6 Mon 17:45 V7.02

Cooling of a trapped atomic two-level system in a driven optical resonator — •Marc Bienert and Giovanna Morigi — Universität des Saarlandes, Theoretische Physik, D-66041 Saarbrücken, Germany

We investigate the cooling dynamics of the motional degree of freedom of a single atom which is trapped inside an optical resonator in the limit of small mechanical coupling. The atomic dipole interacts with a single mode of the cavity, which is weakly pumped by an external laser. Such a configuration shows several parameter regions, where interference between motional and cavity degrees of freedom can occur. We identify the parameter regions where efficient cooling can be found, identify the underlying physical processes, and present the cooling rate and final temperature for optimal choices of the parameters.

A 8.7 Mon 18:00 V7.02

Cavity cooling below the recoil limit — •Matthias Wolke, Hans Kessler, Jens Klinder, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg, Germany

We study the controlled excitation of a Bose-Einstein-condensate (BEC) into momentum states of $\pm 2\hbar k$ and the cooling back to zero momentum. In our system a BEC of ^{87}Rb is dispersively coupled to the mode of an ultra-high-finesse standing wave cavity with narrow linewidth ($\approx 9\,$kHz). Exploiting the cavity enhanced scattering we deposit energy ($4E_{recoil} \approx h \cdot 14\,$kHz) into the BEC by illuminating it with a laser blue detuned to the cavity resonance. This can be reversed by switching the detuning to the red flank of the cavity and thereby cool the atoms efficiently down to zero momentum.

A 8.8 Mon 18:15 V7.02

Realization of a two-species ^{40}K and ^{87}Rb 2D+MOT — •Tracy Li[1,2], Lucia Duca[1], Monika Schleier-Smith[1,2], Martin Boll[2], Martin Reitter[1], Jens Philipp Ronzheimer[1], Ulrich Schneider[1], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Confining quantum degenerate fermions in an optical lattice realizes a highly tunable system for simulating condensed matter phenomena that are difficult to probe in real solids. The evaporative cooling process used to produce quantum degenerate fermions is facilitated by capturing a large number of atoms in the preceding magneto-optical trap (MOT). Optimizing the evaporative cooling process is essential to reaching the low entropies needed to approach, for example, antiferromagnetically ordered states in the fermionic Hubbard model. To this end, we have realized a two-species 2D+MOT and two-species 3D-MOT for fermionic ^{40}K and bosonic ^{87}Rb in our experiment [1, 2]. The 2D+MOT is a pre-cooling stage and generates a collimated, continuous beam of atoms for more efficient loading into the two-species 3D-MOT. We present the implementation and characterization of the two-species 2D+MOT. We observe collisional losses in the two-species 3D-MOT and ameliorate these losses using a dark SPOT MOT for ^{40}K. With this setup, we achieve atom numbers of 1x10^8 ^{40}K and 7x10^{10} ^{87}Rb in the two-species 3D-MOT.

[1] Dieckmann et.al., PRA 58, 3891 (1998).
[2] Ridinger et.al., Eur. Phys. J. D 65, 223-242 (2011).

A 8.9 Mon 18:30 V7.02

Realization of a magneto-optical trap for erbium atoms — •Jens Ulitzsch, Henning Brammer, Riad Bourouis, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn

The erbium atom has a $4f^{12}6s^2\ ^3H_6$ electronic ground state with a large angular momentum of $L = 5$. So far, most atomic quantum gases have been realized with a spericall symmetric ($L = 0$) s-ground state configuration, for which in far detuned laser fields with detuning above the upper state fine structure splitting the trapping potential is determined by the scalar electronic polarizability. For an erbium quantum gas with its $L > 0$ ground state, the trapping potential also for far detuned dissipation-less trapping laser fields becomes dependent on the internal atomic state (i.e. spin).

We report on progress in an ongoing experiment directed at the generation of an atomic erbium Bose-Einstein condensate by evaporative cooling in a far detuned optical dipole trap. In the present stage of the experiment, a magneto optical trap (MOT) for this rare earth metal atom has been realized, loaded from a Zeeman-slowed atomic beam. The experiment uses a single laser frequency tuned to the red of the $400,91nm$ cooling transition. No repumping radiation is required for the MOT operation, despite the complex energy level structure of the erbium atom.

A 8.10 Mon 18:45 V7.02

Zeeman slower with permanent magnets — •Stefan Vogt, Stephan Falke, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

A Zeeman slower offers a high flux of cold atoms and thus is a useful tool for many experimental setups. Especially for experiments that require atom trapping with a high repetition rate, such as neutral atom clocks, a Zeeman slower is the best choice. However, the high power consumption caused by the field coils of a typical slower design is a drawback in terms of thermal management and transportability.

Not only transportable setups for clock comparisons between laboratories but also the operation of optical clocks in space [1] call for compact setups with low power consumption, e.g., by using permanent magnets instead of field coils [2,3]. In our approach, we use a pattern of standard-size NdFeB magnet blocks to create a field identical to that of the Zeeman slower of our stationary strontium lattice clock.

By allowing both radial displacement and angular tilt of the blocks, we achieve a magnetic field that is oriented parallel to the atomic beam throughout the slower. The tilt reduces the magnetic field behind the slower.

The work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and the EU through the Space Optical Clocks (SOC2) project.

[1] S. Schiller *et al.*, Exp. Astron. 23, 573 (2009).
[2] Y. Ovchinikov, Optics Communications 276, 261 (2007).
[3] P. Cheiney *et al.*, Rev. Sci. Instrum. 82, 063115 (2011).

A 9: Electron scattering and recombination

Time: Monday 16:30–18:00 Location: V57.05

A 9.1 Mon 16:30 V57.05

Parity violation in the radiative electron capture of H-like heavy ions — •Jonas Gunst[1,2] and Andrey Surzhykov[1,2] — [1]Universität Heidelberg — [2]GSI Helmholtzzentrum, Darmstadt

Measurements of parity-violation (PV) effects in atomic systems attract considerable attention as a valuable tool for testing of the Standard Model in the low-energy regime. In the past, however, most of these PV experiments have dealt with neutral atoms. Much less attention was paid to highly-charged heavy ions which are alternative and very promising candidates for atomic PV studies. Most of the proposals for PV-experiments with such heavy few-electron species still require the application of spin-polarized ion beams and/or of circular polarization x-ray measurements. These experimental tasks, however, cannot be easily accomplished today. In this contribution, therefore, we propose and discuss a new method for observing the PV effects in highly-charged ions. The method employs the measurement of a *linear* polarization of the photons emitted due to the radiative electron capture (REC) into the $1s2p\,^3P_0$ state of unpolarized helium-like heavy ions. For such a scenario, significant mixing of opposite-parity levels 2^3P_0 and 2^1S_0 may manifest itself in the rotation of the polarization out of the reaction plane that can be observed by the present-day solid-state detectors. In order to describe this PV-induced rotation, a theoretical model has been developed within the framework of the density matrix approach and relativistic Dirac equation. Detailed calculations have been performed for relativistic collisions of unpolarized (initially) hydrogen-like Gadolinium ions with an electronic target.

A 9.2 Mon 16:45 V57.05

Angular correlations in radiative cascades following resonant electron capture — •Oliver Matula[1,2], Stephan Fritzsche[2,3], and Andrey Surzhykov[1,2] — [1]Physikalisches Institut, Universität Heidelberg, D-69120 Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt — [3]Department of Physical Sciences, University of Oulu, FI-90014 Oulu

Dielectronic recombination (DR) into highly charged ions has been studied intensively in the last decades, both in experiment and theory. Whereas in the past these studies dealt mainly with the total DR rates, much of today's interest is focused on the angular properties of the characteristic x-ray photons. The angle-resolved investigations provide a unique tool to probe relativistic, many-body and QED effects in heavy atoms. For example, a strong E1-M2 multipole mixing in the radiative cascades following K-LL DR of U^{91+} has been recently identified by analyzing the angular distribution of the emitted hypersatellite (HS) photons. Apart from the *individual* HS and satellite (S) transitions, mixing phenomena may also significantly affect the angular correlations *between* the characteristic photons. In this contribution, we present a theoretical study of the γ-γ angular correlations for DR of highly charged ions, based on a density matrix approach and relativistic Dirac's theory. Within this framework, we pay special attention to nondipole effects in the expansion of the electron-photon interaction. To illustrate these effects, detailed calculations will be presented for K-LL DR of (initially) hydrogenlike Xe, Au and U ions. Work is supported by the Helmholtz Gemeinschaft (Nachwuchsgruppe VH-NG-421).

A 9.3 Mon 17:00 V57.05

Dissociative recombination of NH^+: collision energy dependence of atomic product states — •Bian Yang[1,2,4], Oldřich Novotný[1,3], Max Berg[1], Dennis Bing[1], Henrik Buhr[1,6], Christian Domesle[1], Wolf D. Geppert[5], Florian Grussie[1], Claude Krantz[1], Mario Mendes[1], Christian Nordhorn[1], Daniel Wolf Savin[3], Dirk Schwalm[1,6], and Andreas Wolf[1] — [1]MPI, MPIK, D-69117 Heidelberg, Germany — [2]IMP, CAS, Lanzhou 730000, People's Republic of China — [3]Columbia Astrophysics Laboratory, Columbia University, New York 10027, USA — [4]Graduate University of CAS, Beijing 100049, People's Republic of China — [5]Molecular Physics, Stockholm University, SE-10691 Stockholm, Sweden — [6]Weizmann Institute of Science, 76100 Rehovot, Israel

The dissociative recombination (DR) of NH^+ has been experimentally investigated at the storage ring TSR of the MPIK in Heidelberg, using fast merged ion and electron beams. A newly developed mass sensitive imaging detector enabled us to map the branching ratios over collision energies E_d = 0 - 12 eV showing unprecedented detail. Fragment ground states, $N(^4S^o) + H(^2S)$, are almost not populated at all collision energies covered. At $E_d < 0.02$ eV, product channels $N(^2D^o) + H(^2S)$ and $N(^2P^o) + H(^2S)$ dominate at nearly equal fractions. For $E_d > 0.02$ eV additional product channels become energetically accessible. Their branching ratios display rich structure highly sensitive to collision energy. We combine the branching ratios with an independently measured total absolute DR rate coefficient, providing partial rate coefficients towards particular atomic product states.

A 9.4 Mon 17:15 V57.05

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

The prediction of the Kapitza-Dirac effect [1], which is the diffraction of electrons by a standing wave of light, has been confirmed experimentally in recent years [2, 3]. The laser intensities, which were used in these experiments, are far below the highest intensities attainable with modern laser facilities and laser pulses with shorter wavelength are available today. These new developments call for a relativistic treatment of the Kapitza-Dirac effect, also accounting for spin effects. We determine the time-evolution of the electron wavefunction by solving the Dirac equation. The relativistic dynamics is compared with corresponding results of the Pauli equation.

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

A 9.5 Mon 17:30 V57.05

Polarimetry of electron beams by means of bremsstrahlung — •Stanislav Tashenov[1], Torbjörn Bäck[2], Roman Barday[3], Bo Cederwall[2], Joachim Enders[3], Anton Khaplanov[2], Yulia Poltoratska[3], Kai-Uwe Schässburger[2], and Andrey Surzhykov[1,4] — [1]Physikalisches Institut Universität Heidelberg, Germany — [2]Royal Institute of Technology, Stockholm, Sweden — [3]Institut für Kernphysik, Technische Universität Darmstadt, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

The dominant photon emission process in electron-atom collisions, bremsstrahlung has long been considered to be sensitive to the spin of the electron [1]. However only recently experimental studies in this direction became possible. The first measurement of the correlation between the orientation of the electron spin and photon linear polarization in bremsstrahlung will be presented [2]. The particular attention will be given to the applications of this technique for polarimetry of electron beams. The results of the proof-of-principle measurement will be presented.

[1] H.K. Tseng and R.H. Pratt PRA 7 (1973) 1502
[2] S. Tashenov et al., PRL 107 (2011) 173201

A 9.6 Mon 17:45 V57.05

Overlapping resonances and interference in nuclei coupling to the atomic shell — Srinivas K. Arigapudi[1,2] and •Adriana Pálffy[2] — [1]Indian Institute of Technology Delhi, New Delhi, India — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany

A new aspect of electron recombination into highly charged ions (HCI) involving the coupling of the atomic shell to the nucleus in the process of nuclear excitation by electron transition (NEET) is investigated. In NEET, a bound electronic decay transition occurs with the simultaneous excitation of the nucleus, provided that the energies of the atomic and nuclear transition match [1]. Our scenario involves the resonant process of dielectronic capture (DC) into HCI to create the electronic hole needed for NEET. HCI present the advantage that the atomic level energies are very sensitive to the ion charge state and offer the possibility to optimize the match between atomic and nuclear transition energies. The NEET probability can thus be enhanced by several orders of magnitude compared to neutral atoms. The total and interference cross section terms for the processes of radiative and dielectronic recombination, DC followed by NEET and γ decay and nuclear excitation by electron capture (NEEC) followed by γ decay were deduced and their magnitude investigated for the case of ^{237}Np [2]. Our results show that NEEC may be the most important contribution to the total recombination cross sections in HCI and that the interference terms, although small, are still larger than the NEET cross section.

[1] S. Kishimoto *et al.*, Phys. Rev. Lett. 85, 1831 (2000).
[2] S. K. Arigapudi and A. Pálffy, arXiv:1109.2894 (2011).

A 10: Interaction with strong or short laser pulses II

Time: Monday 16:30–18:30 Location: V55.01

A 10.1 Mon 16:30 V55.01

Above threshold ionization of atomic hydrogen by an IR pulse using the time-scaled coordinate approach — •Johannes Eiglsperger[1], Ana Laura Frapiccini[2], Aliou Hamido[2], Javier Madroñero[3], Francisca Mota-Furtado[4], Patrick O'Mahony[4], and Bernard Piraux[2] — [1]Universität Regensburg, Germany — [2]Université catholique de Louvain, Berlgium — [3]Technische Universität München, Germany — [4]University of London, UK

The development of intense, ultrafast laser sources in the mid infrared (IR) region provides new opportunities in strong-filed physics. In recent experiments to study the electronic dynamics of atoms and molecules on time scale of the electronic motion, these sources play an essential role. Deep understanding of the IR-electron interaction poses a challenge: the simple semi-classical recollision model allows to understand basic mechanisms, the use of the strong field approximation is dubious, and currently available techniques for the solution of associated time-dependent Schrödinger equation are not efficient enough. In this contribution, we study the above threshold ionization spectrum resulting from the interaction of H with an intense very low frequency field. We draw our attention to the low-energy part of the spectrum and discuss the possible role of tunneling in this process. For that purpose, we use a highly efficient *ab initio* approach for solving the time-dependent Schrödinger equation which combines a high-order time propagator based on a parallelizable predictor-corrector scheme with the time-scaled coordinate method [1].

[1] A. Hamido *et al.*, Phys. Rev. A **84**, 013422 (2011).

A 10.2 Mon 16:45 V55.01

Complete dynamics of H_2^+ in strong laser fields — •Michael Fischer[1,2], Jan Handt[1], Sebastian Krause[3], Jan-Michael Rost[2], Frank Grossmann[1], and Rüdiger Schmidt[1] — [1]Institut für Theoretische Physik, Technische Universitaet Dresden, D-01062 Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Noethnitzer Strasse 38, D-01187 Dresden, Germany — [3]Institute for Theoretical Physics, University of Bremen, Otto-Hahn-Allee, D-28359 Bremen

We present a complete study of the strong field dynamics of H_2^+, i.e. including all nuclear and electronic degrees of freedom as well as dissociation and ionization, based on a mixed quantum-classical treatment. We find that full-dimensional calculations are necessary to obtain qualitatively correct results for angularly resolved as well as for angularly integrated fragmentation probability densities respectively probabilities. Complementing recent results for the dissociation, we work out in detail the effect of nuclear rotation on ionization. It is found, that rotation generally increases the ionization probability, even up to an order of magnitude, due to dynamical alignment.

A 10.3 Mon 17:00 V55.01

Erzeugung harmonischer Strahlung in Femtosekunden-Laserfilamenten — •Tobias Vockerodt[1,2], Martin Kretschmar[1], Emilia Schulz[1,2], Daniel Steingrube[1,2], Uwe Morgner[1,2] und Milutin Kovacev[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST Centre of Quantum Engineering and Space-Time Research, Hannover

Der Kerr-Effekt in nichtlinearen optischen Medien führt bei intensiven, ultrakurzen Laserpulsen zu räumlicher (Selbstfokussierung) und zeitlicher (Selbstphasenmodulation) Veränderung des Laserpulses. Dabei führt die Kerr-Selbstfokussierung zur Erhöhung der Intensität, bis defokussierende Effekte wie Plasmabildung in einem dynamischen Gleichgewicht zur Selbstführung des Lichts in einem Filament führt. Dieses erstreckt sich über deutlich größere Distanzen als die Rayleigh-Länge.

Durch ein Pinhole wird das Filament an verschiedenen Positionen entlang der Propagationsachse beendet und die Strahlung extrahiert. Dabei wird neben der durch Selbstphasenmodulation verbreiterten fundamentalen Laserstrahlung auch die dritte Harmonische und hohe harmonische Ordnungen bis 25 beobachtet. Die ultraviolette Strahlung in der dritten Harmonischen besitzt eine spektrale Breite von 40 nm und ein Fourier-Limit unterhalb von 5 fs.

A 10.4 Mon 17:15 V55.01

Higher order Kerr terms vs. plasma: Saturation of the nonlinear refractive index — •Christian Köhler[1], Roland Guichard[2], Emmanuel Lorin[3], Szczepan Chelkowski[4], André D. Bandrauk[4], Luc Bergé[5], and Stefan Skupin[1,6] — [1]Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [2]CNRS, UMR 7614, LCPMR, 75231 Paris Cedex 05, France — [3]University of Montréal, Montréal (Québec) H3T 1J4, Canada — [4]Département de chimie, Université de Sherbrooke, Sherbrooke (Québec) J1K 2R1, Canada — [5]CEA-DAM, DIF, F-91297 Arpajon, France — [6]Friedrich-Schiller-University, Institute of Condensed Matter Theory and Solid State Optics, 07743 Jena, Germany

We numerically study the susceptibility of atomic hydrogen and several noble gases in a strong laser field. The susceptibility enters the laser pulse propagation equation via the effective refractive index, whose nonlinear part is found to saturate for intensities where the medium is partially ionized. This saturation can be due to either negatively-valued higher order Kerr terms [1] or plasma contributions [2]. In order to clarify the mechanism of saturation, we calculate the electronic dipole from numerical solutions of the time dependent Schrödinger equation. This non-perturbative method allows us to separate the optical responses from bound electrons and ionized contributions, and to clearly identify the mechanism responsible for saturation.

[1] V. Loriot et al., *Opt. Express* **17**, 13429 (2009).
[2] L. Bergé et al., *Reports on Progress in Physics* **70**, 1633 (2007).

A 10.5 Mon 17:30 V55.01

Low-energy directional asymmetry in CEP-dependent strong-field photoemission — •Martin Laux, Andreas Kaldun, Christian Ott, Philipp Raith, Kristina Meyer, Claus Dieter Schröter, Robert Moshammer, Joachim Ullrich, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The experimental setup of a newly-built Cold Target Recoil Ion Momentum Spectrometer (COLTRIMS), also termed as 'Reaction Microscope' (ReMi), together with first experimental data and simulations, will be presented. The COLTRIMS method has been in use for more than a decade and is a well established technique to completely resolve the kinematics of ionization reactions by interaction of atoms or molecules in a supersonic gas jet with an electronic, ionic or photonic projectile beam. The single ionization of xenon atoms by a few-femtosecond laser pulse was simulated in dependence on the carrier-envelope phase (CEP) using a model based on the strong-field approximation (SFA). The CEP- and electron-energy-dependent asymmetry of the emission direction strongly depends on pulse duration and intensity of the strong-field laser pulse. The calculated electron momentum distributions are compared to measurements carried out with the new setup. In particular, we focus on the measurement of low-energy photoelectron asymmetry, as it may carry important information about the atomic structure and should be most strongly affected by the Coulomb potential and structure of the remaining ion.

A 10.6 Mon 17:45 V55.01

Decoherence and energy increase in attosecond neutron-atom collisions — •C. Aris Dreismann[1], Evan MacA. Gray[2,3], and Tom P. Blach[2,3] — [1]Institute of Chemistry, TU Berlin — [2]Griffith University, Brisbane, Australia — [3]Queensland Micro- and Nanotechnology Centre, Australia

Due to the prevailing interactions, nuclei and electrons in condensed matter or molecules are usually entangled. However the "environment" of a microscopic system (e.g. a proton in a H2 molecule) may cause an ultrafast decoherence thus making atomic and/or nuclear entanglement effects not directly accessible to experiments. For neutron Compton scattering (NCS) in the energy transfer range of ca. 1-100 eV, the neutron-H scattering time lies in the attosecond time range. Results of recent and current NCS experiments [1] from H2 and D2 in the gas (at 40 K), liquid and solid state are reported, showing that the neutron-atom collision exhibits a striking increased energy transfer which stands in blatant contradiction to conventional theory. The experimental NCS setup is shortly introduced. The theoretical frame of "attosecond scattering from open quantum systems" is discussed", with particular focus on the decoherence process as described by the standard Lindblad equation and recent modern theoretical models [2,3].

[1] C. A. Chatzidimitriou-Dreismann, E. MacA. Gray and T. P. Blach, AIP Advances 1 (2011) 022118. [2] L. S. Schulman and B. Gaveau, Phys. Rev. Lett. 97 (2006) 240405. [3] N. Erez et al. Nature 452 (2008) 724.

A 10.7 Mon 18:00 V55.01

Laser-assisted α decay — •Héctor Mauricio Castañeda Cortés[1], Sergey Popruzhenko[2], Adriana Pálffy[1], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Moscow State Engineering Physics Institute, Russia

The spontaneous emission of alpha particles by unstable nuclei was one of the first physical processes to be described by quantum tunneling of a quasistationary state, i.e. a long-lived state. The development of new powerful coherent light sources opens the possibility to study the direct interaction between strong laser fields and atomic nuclei, assisting the tunneling of the α particle through the nuclear barrier.

In this work we investigate for the first time the effect of strong laser fields on the tunneling and α particle emission of several medium-mass and heavy nuclei. To this end we make use of the formalism we have developed starting from the well-known Strong-Field Approximation and its complex trajectories formulation to describe the laser-assisted decay of quasistationary states [1]. The effect of a static as well as optical and x-ray monochromatic fields on the α decay lifetimes and α particle emission spectra is determined. We find that even at strong intensities, the laser-induced acceleration of the α decay is negligible, and only the spectra are significantly changed by the laser field. In particular, for optical fields, high laser intensities can lead to rescattering of the α particle off the daughter nucleus.

[1] H. M. Castañeda Cortés, S. V. Popruzhenko, D. Bauer and A. Pálffy, New J. Phys. 13, 063007 (2011).

A 10.8 Mon 18:15 V55.01

Electroweak Processes in Laser-Boosted Lepton Collisions — •Sarah J. Müller, Carsten Müller, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The advent of powerful laser facilities such as the ltra-high field project of ELI opens new prospect in many physics applications, in particular in high-energy physics. We study the possibility of utilizing strong laser fields for enhancing the center-of-mass energy of lepton collisions. It is shown that an addditional laser post-acceleration of relativistic lepton beams provided by conventional particle accelerators can in principle lead to higher collision energies in e.g. electronpositron colliders. We investigate this with theoretical means and find that laser post-acceleration might become an interesting complement to the existing methods in high-energy physics.

A 11: Interaction with VUV and X-ray light I

Time: Monday 16:30–19:00 Location: V47.03

Invited Talk A 11.1 Mon 16:30 V47.03

Tracing ultrafast light-induced dynamics in small organic molecules — •Artem Rudenko — Max Planck Advanced Study Group at CFEL, Hamburg — Max Planck Institute for Nuclear Physics, Heidelberg

One of the main driving forces behind the development of novel intense short-pulsed light sources is a dream to "watch" chemical reactions in real time and to define properties of the transition states. The basic idea is that one short laser pulse (the 'pump') triggers the reaction, i.e., launches molecular wave packet, which is than "filmed" at different times by a second ('probe') pulse. The availability of ultrashort light bursts in a broad range of wavelengths, from the infrared and visible to XUV and X-ray domains opens exiting new possibilities for both, initiating different types of molecular dynamics and taking snapshots of molecular structure. In this contribution several illustrative examples of all optical, XUV-XUV and two-color pump-probe experiments on small organic molecules (e.g., CH4, C2H2, C2H4 etc.) will be presented, with a focus on mapping dissociation, isomerization, and H2/H3 elimination reactions. Current status and perspectives for different probe schemes, such as Coulomb explosion imaging, photoelectron diffraction and holography will be discussed.

Invited Talk A 11.2 Mon 17:00 V47.03

Rydberg atoms in strong laser fields — •Ulli Eichmann — Max-Born-Institute, D-12489 Berlin, Germany

The widely accepted and very successful concept of tunneling ionization of atoms in strong laser fields fails to describe the ionization of Rydberg atoms in these fields. This is despite the fact that the Keldysh-parameter, typically used to separate the tunneling from the multiphoton scenario, suggests just tunneling. Instead, one might be tempted to assume that the loosely bound Rydberg electron, which temporarily gains kinetic energy exceeding its binding energy by several orders of magnitude is easily removed from the atom. On the other hand, if one considers the loosely bound Rydberg electron as a free electron, absorption of photons is not possible.

We will present results on the ionization dynamics of Rydberg atoms in strong laser fields with intensities up to 5 10^{15}W/cm^2. We are able to prepare Rydberg atoms in a wide range of principal quantum numbers and more importantly, also in a wide range of angular momentum states. In the experiments we find a large percentage of Rydberg atoms surviving the very strong laser field. Moreover, direct position sensitive measurement of neutral atoms allows for the observation of deflection of surviving Rydberg atoms indicating unambiguously their interaction with the strong focused laser field. We will discuss the underlying physical mechanisms, particularly in the context of strong field stabilization of atoms.

A 11.3 Mon 17:30 V47.03

Multiwavelength anomalous diffraction at high x-ray intensity — •Sang-Kil Son[1], Henry N. Chapman[1,2], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Germany — [2]Department of Physics, University of Hamburg, Germany

The multi-wavelength anomalous diffraction (MAD) method is widely used in x-ray crystallography with synchrotron radiation to determine phase information by employing dispersion corrections from heavy atoms on coherent x-ray scattering. X-ray free-electron lasers (FELs) show promise for revealing the structure of single molecules or nanocrystals within femtoseconds, but the phase problem remains largely unsolved. Because of the extremely high fluence of FELs, samples experience severe and unavoidable electronic radiation damage, especially to heavy atoms, which hinders direct implementation of the MAD method with x-ray FELs. We propose a generalized version of the MAD phasing method at high x-ray intensity. We demonstrate the existence of a Karle–Hendrickson-type equation for the MAD method in the high-intensity regime and calculate relevant coefficients with electronic damage dynamics and accompanying changes of the dispersion correction. Here we present the xatom toolkit to simulate detailed electronic damage dynamics and discuss how the proposed method is applicable to the phase problem in femtosecond x-ray nanocrystallography.

A 11.4 Mon 17:45 V47.03

Enhanced nonlinear response of Ne^{8+} to intense ultrafast X-rays — •Arina Sytcheva[1], Stefan Pabst[1,2], Sang-Kil Son[1], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Germany — [2]Department of Physics, University of Hamburg, Germany

We report on the possible reasons for the discrepancy between the theoretical two-photon ionization cross section (TPICS), $\sim 4 \cdot 10^{-56}$ cm^{4}s, of Ne^{8+} obtained within the lowest nonvanishing order of perturbation theory (LOPT) for continuous light and the experimental value, 7×10^{-54} cm^{4}s, reported in [Phys. Rev. Lett. **106**, 083002 (2011)] at a photon energy of 1110 eV and pulse bandwidth of 11 eV. We consider Ne^{8+} exposed to coherent and chaotic ensembles of intense X-ray pulses using the time-dependent configuration-interaction singles (TDCIS) method and LOPT, respectively. A coherent ensemble of pulses of 11-eV bandwidth centered at 1110 eV yields a TPICS enhanced by a factor of ~ 1.25 with respect to the continuous-light TPICS, while a chaotic ensemble yields an enhancement factor of ~ 40. This enhancement is due to the presence of the one-photon $1s^2$–$1s4p$ resonance located at 1127 eV and the finite bandwidth of the X-ray pulse. Using the TDCIS approach, we also show that, for currently available radiation intensities, two-photon ionization of a $1s$ electron in neutral neon is much less probable than one-photon ionization of a valence electron.

A 11.5 Mon 18:00 V47.03

Resonance-Enhanced X-ray Multiple Ionization of Heavy Atoms at LCLS — •Benedikt Rudek[1,2], Daniel Rolles[1,3], Artem Rudenko[1,2], Sang-Kil Son[5], Lutz Foucar[1,2], Benjamin Erk[1,3], Sascha Epp[1,3], Robert Hartmann[4], Lothar Strüder[1,4], Robin Santra[5,6], Joachim Ullrich[1,3], and the CAMP collaboration[5,7] — [1]Max Planck Advanced Study Group at CFEL, Hamburg — [2]MPI für medizinische Forschung, Heidelberg — [3]MPI für Kernphysik, Heidelberg — [4]MPI Halbleiterlabor, München — [5]Center for Free-Electron Laser Science (CFEL), DESY, Hamburg — [6]Universität Hamburg — [7]LCLS, SLAC, Menlo Park

The interaction of ultra-intense X-rays with rare gas atoms was studied at LCLS, where series of inner shell ionizations yield unprecedentedly high charge states within a single shot. Xenon, in particular, was ionized up to 36+, which requires ionization energies far exceeding the photon energy. Combined experimental and theoretical analysis of ion charge state distributions and simultaneously recorded fluorescence spectra showed that resonant excitations are responsibele for the enhanced ionization. This resonantly enhanced X-ray multi-ionization process (REXMI) is predicted to boost ionization in certain ranges of photon energy and thus enhance radiation damage in the vicinity of heavy atoms.

A 11.6 Mon 18:15 V47.03

Terahertz streaking reveals chirped Auger electron emission — •Bernd Schütte[1,3], Sebastian Bauch[2], Ulrike Frühling[1], Marek Wieland[1], Michael Gensch[4,5], Elke Plönjes[4], Thomas Gaumnitz[1], Armin Azima[1], Michael Bonitz[2], and Markus Drescher[1] — [1]Universität Hamburg — [2]Christian-Albrechts-Universität, Kiel — [3]Max-Born-Institut, Berlin — [4]Deutsches Elektronen-Synchrotron DESY, Hamburg — [5]Helmholtz-Zentrum Dresden Rossendorf

We have investigated the Auger decay in xenon and krypton atoms in the presence of a strong terahertz field. The experiments were performed at two different light sources, namely the free-electron laser in Hamburg (FLASH) and a source of high-order harmonic generation (HHG). By measuring at different phases of the terahertz streaking field and from different observation directions, a time-dependent energetic chirp of the Auger electrons was observed. The origin of this behavior was found to be an energy transfer between the Auger electron and the earlier emitted photoelectron in the laser field. This interaction alters the Auger electron energy depending on its emission time with respect to the photoelectron. The experimentally obtained data agree well with theoretical calculations, thereby facilitating the proposed model. Thus, terahertz streaking proves to be an excellent tool for recording electron dynamics in the femtosecond range.

A 11.7 Mon 18:30 V47.03

Nuclear excitation and collective effects with coherent x-ray light — Andre Junker, Christoph H. Keitel, and •Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

With present and upcoming x-ray light sources such as the X-ray Free Electron Laser (XFEL), the direct interaction between nuclei and super-intense laser fields has become feasible, opening the new field of nuclear quantum optics [1]. One of the main difficulties with driving nuclear transitions arises from the weak coupling between nuclei and the electromagnetic field leading to very narrow bandwidths. In solid state targets that allow recoilless nuclear excitation and decay, the excitation caused by a single photon may be shared by a large number of nuclei, forming a collective excited state with a sometimes significantly larger decay width than that of a single nucleus.

Following this line, in this work we investigate theoretically the direct laser-nucleus interaction taking into account for the first time the line broadening due to collective effects. Furthermore, we update former estimates [2] considering the experimental advances of the XFEL regarding photon frequency, focus and intensity. Our results show an enhancement by several orders of magnitude of the excited state population compared to previously reported values [2].

[1] T. J. Bürvenich, J. Evers and C. H. Keitel, Phys. Rev. Lett. **96** 142501 (2006).
[2] A. Pálffy, J. Evers and C. H. Keitel, Phys. Rev. C **77** 044602 (2008), A. Pálffy, J. Mod. Opt. 55, 2603 (2008).

A 11.8 Mon 18:45 V47.03

Imaging electronic quantum motion with light — •Gopal Dixit[1], Oriol Vendrell[1], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Notkestrasse 85, D-22607 Hamburg, Germany — [2]Department of Physics, University of Hamburg, D-20355 Hamburg, Germany

Imaging the quantum motion of electrons not only in real time, but also in real space is essential to understand for example bond breaking and formation in molecules, and charge migration in peptides and biological systems. Time-resolved imaging (TRI) interrogates the unfolding electronic motion in such systems. We show that scattering patterns, obtained by X-ray TRI from an electronic wavepacket, encode spatial and temporal correlations that deviate from the common notion of the instantaneous electronic density as the key quantity being probed. X-ray TRI can be realized with the advent of novel light sources such as X-ray free electron lasers. Surprisingly, the patterns provide an unusually visual manifestation of the quantum nature of light. This quantum nature becomes central only for non-stationary electronic states. The illustrative example used here as a proof of principle lies in the time and energy range of interest corresponding to the dynamics of valence electrons in more complex molecular and biological systems.

A 12: Interaction with strong or short laser pulses III

Time: Tuesday 10:30–12:30 Location: V47.03

Invited Talk A 12.1 Tue 10:30 V47.03

Two-color photoionization studies at XUV and X-ray Free Electron Lasers — •Michael Meyer — European XFEL GmbH, Albert-Einstein-Ring 19, D-22761 Hamburg, Germany

The combination of intense femtosecond X-ray and NIR pulses produced by Free Electron Lasers (FEL) and synchronized optical lasers, respectively, offers various new opportunities to investigate the dynamics of atomic photoionization. Some recent results obtained at the XUV-FEL FLASH in Hamburg and the first X-ray FEL, the LCLS in Stanford, will be presented. In the experiments at FLASH, the optical dressing field gives rise to the so-called two-color Above Threshold Ionization, which could be studied for the first time in a regime free from unwanted interference effects. For resonant excitations, e.g. 3d –> 5p in atomic Kr, the NIR field causes a strong modification of the decay dynamics, which was experimentally investigated via the intensity-dependent shift of the resonance position and via the competition between resonant and direct Auger processes. Recent experiments at LCLS have taken advantage of the very short (2-5 fs) pulse duration, which coincides with the lifetime of the Ne 1s core hole and with the temporal width of one optical cycle of the NIR (800 nm) dressing laser. As a direct consequence, the angle-resolved KLL Auger spectra reveal strong intensity modulations induced by sub-cycle interferences, i.e. by the coherent emission of electrons produced during one cycle of the superimposed optical field.

A 12.2 Tue 11:00 V47.03

Attosecond Two-Electron Dynamics in Non-Sequential Dou-

ble Ionization of Argon using Ultra-short Laser Pulses — •Nicolas Camus[1], Bettina Fischer[1], Manuel Kremer[1], Vandana Sharma[1], Artem Rudenko[1,2], Boris Bergues[3], Mathias Kübel[3], Nora G. Johnson[3], Mathias F. Kling[3], Thomas Pfeifer[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max-Planck Advanced Study Group at CFEL, Hamburg — [3]Max-Planck-Institut für Quantenoptik, Garching

We report on a kinematically complete experiment on non-sequential double ionization (NSDI) of argon using CEP characerized 6 fs laser pulses in combination with a reaction microscope. In NSDI the first ionized electron is driven back to the parent ion causing ionization of the second electron. In this study we choose a rather low intensity where the energy of the re-colliding electron is too small for impact ionization but large enough to excite the remaining Ar^+ ion. Loosing almost all of its kinetic energy during re-collision, the re-colliding electron gets recaptured such that a doubly-excited state is formed. Within a classical simulation we demonstrate that this highly excited complex has lost memory of its creation. We consistently relate measured momentum differences between the two electrons to time differences and, thus, follow the ionization of the doubly excited state in the laser field on a sub-fs time scale. A striking agreement between experimental and simulated distributions is observed with a most likely time difference between the two electrons for leaving the atom of 200 ± 100 as.

A 12.3 Tue 11:15 V47.03

Noisy pulses enhance temporal resolution in pump–probe spectroscopy — •Kristina Meyer, Christian Ott, Philipp Raith, Andreas Kaldun, Yuhai Jiang, Arne Senftleben, Moritz Kurka, Robert Moshammer, Joachim Ullrich, and Thomas Pfeifer — Max-Planck Institut für Kernphysik, Heidelberg

Observing dynamical processes relies on the availability of timing-controlled events (e.g. laser pulses) that are shorter in duration than the typical time scale of the dynamics to be measured. The production of ultra-short pulses is nowadays typically based on the exceptional coherence properties of laser light, hiding the fact that noisy, only partially coherent, light sources could have benefits. The development of Free-Electron Laser (FEL) sources has led to a reevaluation of temporal noise since self-amplified spontaneous emission (SASE) FEL pulse shapes vary widely from shot to shot. Here, we show that such noisy electric fields can be used to resolve temporal features of quantum dynamics with high precision that would be inaccessible using fully coherent pulses of the same average pulse duration. Our concept of noise-enhanced pump–probe spectroscopy is demonstrated for the example of a recently performed experiment investigating the two-photon double ionization of D_2 [1]. The method enables the measurement of dynamics on time scales that are shorter than the average pulse duration by more than a factor of 10. This finding does not only have important consequences for FEL science, but can lead to general paradigm shifts in ultrafast physics, including attosecond spectroscopy.

[1] Y. H. Jiang et al., Phys. Rev. A 81, 051402 (2010)

A 12.4 Tue 11:30 V47.03

Time-Resolved Photoelectron Diffraction in Laser-Aligned Molecules at Free-Electron Lasers — •Denis Anielski[1,2], Alaa Al-Shemmary[3], Rebecca Boll[1,2], Lauge Christensen[4], Sankar De[4], Siarhei Dziarzhytski[3], Benjamin Erk[1,2], Jochen Küpper[5,6], Terence Mullins[5], Harald Redlin[3], Daniel Rolles[1,7], Artem Rudenko[1,2], Kirsten Schnorr[2], Henrik Stapelfeldt[4], Stephan Stern[5,6], Sebastian Trippel[5], and Joachim Ullrich[1,2] — [1]Max Planck Advanced Study Group, CFEL, Hamburg — [2]MPI für Kernphysik, Heidelberg — [3]DESY, Hamburg — [4]University of Aarhus, Denmark — [5]CFEL, DESY, Hamburg — [6]Universität Hamburg — [7]MPI für medizinische Forschung, Heidelberg

The possibility to obtain femtosecond time-resolved information on single molecules with Angstrom spatial resolution is one of the driving forces for the development of short-pulse VUV and X-ray sources such as FELs. Time-resolved photoelectron diffraction allows to investigate fundamental chemical reaction dynamics in small to medium-sized organic molecules. At FLASH, OCS molecules were adiabatically aligned using a ns Nd:YAG laser ($\langle\cos^2(\theta)\rangle_{2D} = 0.82$), dissociated with a fs Ti:Sa laser and then photoionized by the FEL for different delays between Ti:Sa and FEL. A velocity map imaging spectrometer recorded the angular distributions of the photoelectrons. By comparing these distributions with multiple scattering calculations, the changing geometric structure of the molecule can be made visible.

A 12.5 Tue 11:45 V47.03

Photoelectron Diffraction in Laser-Aligned p-Fluorophenylacetylene (p-FAB) at LCLS — •Rebecca Boll[1,2], Denis Anielski[1,2], Christoph Bostedt[3], Lauge Christensen[4], Ryan Coffee[3], Sankar De[4], Sascha Epp[1,2], Benjamin Erk[1,2], Lutz Foucar[1,5], Jochen Küpper[6,7], Daniel Rolles[1,5], Arnaud Rouzee[8], Benedikt Rudek[1,2], Artem Rudenko[1,2], Henrik Stapelfeldt[4], Stephan Stern[6], Sebastian Trippel[6], and Joachim Ullrich[1,2] — [1]Max Planck Advanced Study Group at CFEL, Hamburg, Germany — [2]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [3]SLAC National Accelerator Laboratory, Stanford, USA — [4]Aarhus University, Denmark — [5]Max Planck Institute for Medical Research, Heidelberg, Germany — [6]CFEL, Hamburg, Germany — [7]University of Hamburg, Germany — [8]Max Born Institute, Berlin, Germany

Photoelectron diffraction patterns of adiabatically laser-aligned and mixed-field oriented p-FAB molecules were measured using femtosecond FEL-pulses at different photon energies at LCLS. Ions and electrons were recorded simultaneously in a double-sided velocity map imaging spectrometer installed in the CFEL-ASG MultiPurpose (CAMP) chamber. From the obtained angular distributions of the photoelectrons that are emitted and scattered within a single molecule, it is possible to retrieve information on the molecular structure on an Angstrom length scale.

A 12.6 Tue 12:00 V47.03

Coulomb explosion imaging of small organic molecules at LCLS — •Benjamin Erk[1,2], Artem Rudenko[1,2], Daniel Rolles[1,3], Benedikt Rudek[1,2], Lutz Foucar[1,3], Sascha Epp[1,2], Max Cryle[3], Ilme Schlichting[1,3], Arnaud Rouzee[4], Axel Hundertmark[4], Tatiana Marchenko[5], Mark Simon[5], Christoph Bostedt[6], Sebastian Schorb[6], Kiyoshi Ueda[7], Claus Dieter Schroeter[2], and Joachim Ullrich[1,2] — [1]Max-Planck ASG at CFEL, DESY, Hamburg, Germany — [2]MPI für Kernphysik, Heidelberg, Germany — [3]MPI für Medizinische Forschung, Heidelberg, Germany — [4]MBI, Berlin, Germany — [5]LCPMR, Paris, France — [6]LCLS, SLAC National Accelerator Laboratory, Menlo Park, USA — [7]IMRAM, Tohoku University, Sendai, Japan

Fragmentation of small organic molecules by intense few-fs soft X-ray FEL-pulses has been studied using Coulomb explosion imaging. To increase and localize X-ray absorption, we studied methylselenol and ethylselenol compounds containing one high-Z atom, selenium. The experiment was conducted in the CFEL-ASG Multi-Purpose (CAMP) end station installed at the AMO beamline of the LCLS at Stanford. By measuring kinetic energies and emission angles of few ionic fragments in coincidence as a function of FEL intensity, we study sequential multi-photon absorption and reconstruct fragmentation pathways as well as molecular geometry at the moment of explosion. The results yield unique information on structural rearrangement and charge redistribution in the molecule, which has direct implications for radiation damage induced by intense X-ray pulses.

A 12.7 Tue 12:15 V47.03

Molecular dynamics studied with XUV pump–probe experiments — Yuhai Jiang[1], •Arne Senftleben[1], Moritz Kurka[1], Artem Rudenko[2], Kirsten Schnorr[1], Georg Schmid[1], Kristina Meyer[1], Thomas Pfeifer[1], Lutz Foucar[2], Oliver Herrwerth[3], Matthias Kübel[3], Matthias Kling[3], Joachim Ullrich[1], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Insitut f. Kernphysik, Heidelberg — [2]Max-Planck Advanced Study Group, Hamburh — [3]Max-Planck-Institut f. Quantenoptik, Garching

Present free-electron lasers deliver pulses of extreme ultra-violet (XUV) radiation as short tens of femtoseconds. This enables to study molecular dynamics in real time using the pump–probe technique: Here, one pulse ionizes the molecule and initiates changes to its structure, while a time-delayed second pulsed induced Coulomb explosion. By measuring the momenta of the resulting fragment ions with a reaction microscope, we can reconstruct the molecular structure at the time of the second pulse. Through variation of the time-delay from shot to shot, a "molecular movie" is taken. We will show results from our recent investigations of dissociating diatomic molecules (D_2, N_2, I_2) and isomerization reactions in acetylene and ethylene.

A 13: Photoionization

Time: Tuesday 10:30–12:15 Location: V55.01

A 13.1 Tue 10:30 V55.01

One- and two-photon single ionization of 1D helium: resolving the role of individual decay channels and resonance states — •Vera Neimanns[1], Pierre Lugan[2], Klaus Zimmermann[1], Felix Joerder[1], and Andreas Buchleitner[1] — [1]Quantum Optics and Statistics, Physikalisches Institut, Universitaet Freiburg, Germany — [2]Laboratory of Theoretical Physics of Nanosystems, Institute of Theoretical Physics, EPF Lausanne, Switzerland

We combine the method of complex rotation and Floquet theory to analyze the multiphoton ionization of helium atoms in strong laser fields. We focus on 1D $Z^{2+}e^-e^-$ helium to highlight the methods that allow us to extract the partial decay rates associated with various decay channels. In the regime of one-photon single ionization, we study the dependence of the partial rates associated with the singly ionized $He^+(N)$ states on the field frequency. We show that the electron-electron interaction provides couplings to higher single-ionization continua. Finally, we examine two-photon single-ionization processes, and analyze the role of the internal electronic structure of the atom, specifically the signature of resonant coupling to intermediate bound states on the decay rates.

A 13.2 Tue 10:45 V55.01

Anderson-like localization effects in electromagnetically driven helium — •Felix Jörder[1], Klaus Zimmermann[1], Vera Neimanns[1], Alberto Rodriguez[1], Pierre Lugan[2], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg i.Br., Deutschland — [2]EPFL, Lausanne, Schweiz

The driven helium atom defines a paradigmatic scenario of a fragmenting quantum system, characterized by high spectral densities and decay channels into multiple continua. A powerful tool to access the spectral structure underlying the field-induced excitation and fragmentation process is provided by complex dilation of the Hamiltonian, which uncovers the pole structure of the resolvent operator and provides insight into the dynamics of the system. The microwave-induced excitation process of helium Rydberg atoms is retarded by Anderson-like (dynamical) localization effects, leading to strongly reduced multiphoton decay rates. We present numerical simulations of this process and study the impact of the interelectronic Coulomb repulsion on the localization behavior.

A 13.3 Tue 11:00 V55.01

Evidence for anisotropic final state interactions in the two-photon ionization of He — •Gregor Hartmann[1], Markus Braune[2], Toralf Lischke[1], Andre Meissner[1], and Uwe Becker[1] — [1]Fritz-Haber-Institut der Max-Planck Gesellschaft, Faradayweg 4-6, 14195, Germany — [2]DESY, Notkestr. 85, 22067 Hamburg, Germany

The photoelectron angular distribution of single photoionization is described by Legendre Polynomial of second order $P_2(\cos\theta)$. Two-photon ionization however, gives rise to a second term being a Legendre Polynomial of fourth order$P_4(\cos\theta)$. This Term for sequential two-photon ionization has a weighting factor given by the alignment of the ionic core left by the first ionization step. If this first step leaves an isotropic core this alignment is zero and the corresponding P_4 term should have no actual effect on the photoelectron angular distribution. In order to prove this theoretical prediction we have performed two-photon ionization experiments at Helium. At higher photon energies the angular distribution of the second step photoelectron followed indeed a P_2-distribution as expected. However, at lower photon energies the photoelectron angular distribution showed small P_4 behavior. We interpret this unexpected result as evidence for anisotropic final state interaction due to a first step final state consisting of a combined system of ionic core and outgoing photoelectron.

A 13.4 Tue 11:15 V55.01

High-resolution time-resolved transient-absorption spectroscopy with continuous VUV spectrum around the first ionisation threshold of helium — •Andreas Kaldun, Christian Ott, Philipp Raith, Kristina Meyer, Martin Laux, Yizhu Zhang, and Thomas Pfeifer — Max-Planck Institut für Kernphysik, Heidelberg

Attosecond time-resolved spectroscopy on helium in the energy range around the first ionization threshold has been performed (see e.g. [1, 2]) however without simultaneous access to a broad energy range at high spectral resolution. In our work, we use a continuous coherent vacuum-ultra-violet (VUV) high-harmonic generation (HHG) spectrum together with our high-resolution VUV spectrometer to resolve the helium absorption lines of the transitions corresponding to the $1s^2 \leftrightarrow 1snp$ states with n ranging from 2 up to 9. By spatially and temporally superimposing the VUV-pulse at variable time delays with a moderately intense few-cycle near-visible (VIS) pulse (precission measured interferometrically to be 10 as) we observe a switching from absorption to emission in the measured spectra. The Data were recorded by scanning the time delay in steps of 170 as and for different VIS laser intensities. Characteristic energy shifts of the resonance lines in the temporal overlap region of VUV and VIS pulse are identified and provide information about the dipole coupling of these excited states with surrounding bound as well as continuum states.

[1] Holler *et al.* PRL **106** , 123601 (2011)
[2] Mauritsson *et al.*PRL **105** , 053001 (2010)

A 13.5 Tue 11:30 V55.01

Precise determination of the ionization potential of astatine by in-source laser spectroscopy — •Sebastian Rothe[1,2], Valentin Fedosseev[1], Nobuaki Imai[1], Bruce Marsh[1], Marica Sjödin[3], Maxim Seliverstov[1], and Klaus Wendt[2] — [1]CERN, Geneva, Switzerland — [2]Institut für Physik, Uni Mainz, Germany — [3]GANIL, Caen, France

On-line in-source laser resonance ionization spectroscopy of the exclusively radioactive element astatine was performed at CERN/ISOLDE, representing the first ever laser spectroscopy on that heaviest halogen element. An efficient ionization scheme was developed and the first precise determination of the ionization potential of astatine atoms was carried out. Due to the absence of long lived isotopes of astatine, on-line production at the ISOLDE isotope separator facility at CERN was required. During a first measurement campaign, the ionization potential was located within a range of 100 cm^{-1} by photoionization threshold spectroscopy. This work was a prerequisite for the precision spectroscopy of high lying Rydberg states which was performed by scanning one of the RILIS lasers across the corresponding wavelength range. The observed Rydberg levels converge towards the ionization potential which was determined as 75151(1) cm^{-1}. The efficient ionization scheme for astatine will also enable further precision in-source spectroscopy of isotope shifts and hyperfine structure as well as the study of beta delayed fission of the isotopes $^{194-199}$At.

A 13.6 Tue 11:45 V55.01

Phase Dependence of the β-Oscillations in N_2 and O_2 — •Markus Ilchen[1], Markus Braune[1,2], Sascha Deinert[1], Leif Glaser[1], André Meissner[2], Frank Scholz[1], Lokesh Tribedi[2,3], Peter Walter[1], Jens Viefhaus[1], and Uwe Becker[2] — [1]DESY, Hamburg, Germany — [2]Fritz-Haber-Institut, Berlin, Germany — [3]Tara Institute of Fundamental Research, Mumbai, India

Oscillations in the partial photoionization cross sections of homonuclear diatomic molecules have been described by Cohen and Fano more than 40 years ago as an interference phenomenon analogous to a double slit experiment. These cross section oscillations have been verified by several experiments in the meantime. In addition to the cross section however, also the angular distribution asymmetry parameter β and most likely all spin parameters are showing oscillations. The physical reason of these oscillations has not necessarily to be only the partial cross section and such effects could also be caused by phase shifts of the outgoing photoelectron partial waves. Photoionization of homonuclear diatomic molecules such as H_2, N_2 and O_2 should show non-vanishing oscillating spin polarization in this respect. A persisting oscillation after multiplication of the oscillations of β and $\sigma_{partial}$ indicates a dependence on the phase shift of the photoelectron partial waves. In the light of a double slit experiment this is unexpected and has to be discussed by theory more deeply.

A 13.7 Tue 12:00 V55.01

Spektroskopische Untersuchungen an Uranisotopen mittels hochauflösender Resonanzionisationsspektroskopie — •Amin Hakimi[1], Thomas Fischbach[1], Sebastian Raeder[3], Norbert Trautmann[2] und Klaus Wendt[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz — [2]Institut für Kernchemie, Johannes-

Gutenberg-Universität Mainz — [3]TRIUMF, Vancouver, Canada

Im Rahmen der nuklearen Forensik besteht die Notwendigkeit der präzisen Bestimmung des Isotopenverhältnis $^{236}U/^{238}U$, welches Hinweise auf die Herkunft einer uranhaltigen Probe liefert. Da das Isotopenverhältnis zumindest bis hinab zu 10^{-10} gemessen werden muss, um die Signatur einer anthropogenen Kontamination vom natürlichen Untergrund unterscheiden zu können, muss eine Messmethode höchster Isotopenselektivität eingesetzt werden. Hier bietet sich neben der aufwändigen AMS die hochauflösende Resonanzionisations-Massenspektrometrie (HR-RIMS) als kompaktes Verfahren an. Für eine nachhaltige Verfügbarkeit dieser Methode sollen zur optischen Besetzung erster Schritte der dreistufigen optischen Anregungs- und Ionisationsleiter blaue Laserdioden um 405 nm (BluRay) eingesetzt werden. Ausgehend von diesem Energiebereich sind nur wenige hochliegende gebundene Zwischenzustände und autoionisierende Resonanzen charakterisiert. Der aktuelle Entwicklungsstand der HR-RIMS an Uran wird präsentiert und ihre analytische Anwendung erläutert. Als Vorarbeit für eine nachhaltige Methodensicherung werden die notwendigen spektroskopischen Untersuchungen vorgestellt.

A 14: Interaction with VUV and X-ray light II

Time: Tuesday 10:30–12:30 Location: V57.05

A 14.1 Tue 10:30 V57.05

Atomic photoionization in combined intense XUV free-electron and infrared laser fields — •Mathias Arbeiter and Thomas Fennel — Institute of Physics, University of Rostock

The electron emission process of noble gas atoms exposed simultaneously to ultrashort monochromatic extreme ultraviolet (XUV) and to intense near infrared (NIR) laser pulses can be seen as a two-step process consisting of XUV photoionization and subsequent electron-NIR-field interaction. Experiments at the free electron laser in Hamburg (FLASH) have shown that already at modest intensities of the NIR dressing field, the XUV induced photoionization lines are split into a sequence of peaks due to the emission or absorption of several additional infrared photons [1]. A systematic study reveals that this sequence of sidebands forms a plateau-shaped structure, which broadens with increasing field strength. We present a theoretical study of the electron emission based on the Simpleman's model and a fully quantum mechanical TDSE description in single-active-electron-approximation. We find that the quantum calculation well reproduces the formation of individual sidebands, the AC Stark shifts, and the overall shape of the sideband envelope [1]. Furthermore the intensity-dependent cut-off energies of the sideband plateau are in good agreement with the classical trajectory model. The results are compared to the experimental data.

[1] P. Radcliffe, M. Arbeiter, W. B. Li, S. Düsterer, H. Redlin, P. Hayden, P. Hough, V. Richardson, J. T. Costello, T. Fennel, M. Meyer, submitted 2011

A 14.2 Tue 10:45 V57.05

Coincident imaging and ion spectroscopy of single gas-phase clusters — •D Rupp[1], M Adolph[1], T Gorkhover[1], L Flückiger[1], M Krikunova[1], Y Ovcharenko[1], M Sauppe[1], S Schorb[1,2], D Wolter[1], M Harmand[3], S Toleikis[3], R Treusch[3], C Bostedt[1,2], T Möller[1], and Authors as in Ref. 1[1] — [1]TU Berlin — [2]LCLS @ SLAC — [3]HASYLAB @ DESY

Gas-phase clusters are an ideal target to study the fundamental mechanisms of the interaction between matter and strong light pulses. Novel Free-Electron Lasers (FELs) as FLASH and LCLS deliver highly intense ultrashort pulses in the high energy range. They provide the possibility of imaging single nanosized structures, enabling a completely new type of experiment. From the scattering patterns of an individual gas-phase cluster hit by an FEL pulse, we can extract its shape, size, the actual power density and even information on transient charge states in the developing nanoplasma. The imaging measurement is further combined in coincidence with additional detectors for reaction products as ions, electrons and fluorescent light. We overcome conventional averaging of cluster size distribution and power density profiles by sorting the single shots with the information from the scattering patterns. An unprecedented contrast is gained, for example in the ion spectra of single clusters hit by different intensities. In most recent experiments the setup was extended with pump-probe techniques to explore the timescales of cluster disintegration processes from the femtosecond to pico- and nanosecond range.

Ref.1: L Strueder et al. Nuc. Instr. and Meth. 614(3):483-496.

A 14.3 Tue 11:00 V57.05

XUV-fluorescence of a FEL pulse created nano plasma in rare gas clusters — •M. Müller[1], L. Schroedter[2], M. Adolph[1], D. Rupp[1], T. Oelze[1], L. Nösel[1], L. Flückiger[1], T. Gorkhover[1], M. Krikunova[1], A. Przystawik[2], A. Kickermann[2], T. Laarmann[2], and T. Möller[1] — [1]TU-Berlin IOAP, Hardenbergstr 36, 10623 Berlin — [2]HASYLAB at DESY, Notkestr. 85, 22607 Hamburg

FLASH, the first free electron laser operating at short wavelength (4nm-47nm) and intense pulses ($10^{16} W/cm^2$), has opened up many new fields of research in the last decade [1]. Nonlinear laser-matter processes, in particular the nonlinear response of nanosized systems to FEL pulses became a field of considerable interest.

We investigate the formation of the FEL induced nanoplasma within rare gas clusters. Fluorescence spectroscopy is used as a promising approach to study the heating and relaxation dynamics, before the radiation damage leads to total destruction of the clusters. Thus we can complement the disciption obtained by ion spectroscopy and light scattering [2]. Xenon clusters excited with 90eV photons exhibit a variety of fluorescence lines between 10 and 100 eV, which show a clear dependence on the excitation power density and cluster size. For the highest power densities fluorescence lines occure even above the excitation energy.

1 Bostedt, C. et al. (2009) Nucl. Instrum. Methods Phys. Res. A 601 108-22
2 Bostedt, C. et al. (2010) J. Phys. B: At. Mol. Opt. Phys. 43 194011

A 14.4 Tue 11:15 V57.05

Seeded Multi-electron Ionization of Xenon Doped Helium Droplets — •Michael Kelbg[1], Sebastian Göde[1], Truong Nguyen Xuan[2], Josef Tiggesbäumker[1], and Karl-Heinz Meiwes-Broer[1] — [1]Universität Rostock, Institut für Physik, Universitätsplatz 3, Rostock, Germany — [2]Max-Born Institute, Max-Born-Strasse 2A, 12489 Berlin, Germany

Ionization process of minimally Xenon-doped helium nanodroplets is studied using ultrashort shaped laser pulses. With the technique of colored double pulse fitness landscape the dependencies on delay and energy distribution of the double pulse is systematically determined. As a result the transparent helium droplet turns into a strong absorber of infrared light and is avalanche-like ionized in a two step process due to the initially charged xenon core followed by resonant absorption of the second pulse. Furthermore dependencies on the amount of xenon doping and resonance conditions for xenon charge states are discussed.

A 14.5 Tue 11:30 V57.05

Autoionization dynamics of H2 and D2 molecules using XUV pulses — •Alexander Sperl, Andreas Fischer, Michael Schönwald, Helga Rietz, Philipp Cörlin, Arne Senftleben, Thomas Pfeifer, Robert Moshammer, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg

Wave packet dynamics in molecules are studied by combining an XUV pulse source together with a Reaction Microscope detection system, which allows for coincident measurements of ions and electrons. Furthermore, it is capable of measuring the three dimensional momentum of each charged particle involved in the ionization process.

We used this technique to study the autoionization of doubly excited H2 and D2 molecules, a process with occurs on a timescale of a few femtoseconds [1]. Since this reaction time is of the order of the molecular motion, the nuclei can no longer be regarded stationary. The coupling of the dissociation dynamics of H2+ and D2+ to the corresponding electron, which is ionized through the autoionization channel, leads to a symmetry breaking in the dissociation. In order to study the temporal dynamics of these processes we probed the molecules with XUV pulses of different durations.

[1] J. Fernandez, F. Martin, New J Phys 11, 043020 (2009)

A 14.6 Tue 11:45 V57.05

Gas-Based Photoemission Spectrometer for Online Shot-to-Shot Photon Beam Diagnostics at the European XFEL — •Jens Buck, Jan Grünert, Cigdem Ozkan, Bin Li, Wolfgang Freund, and Serguei Molodtsov — European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany

At free-electron laser facilities, non-invasive beam diagnostics on the basis of photoionization of rare gases has found broad applications in the past and is also under development at the future European X-ray Free Electron Laser (XFEL.EU) facility [1,2]. The Self-Amplified Spontaneous Emission (SASE) process utilized here is known to produce pulses with significant statistical variations of essential pulse properties such as energy, spectrum, temporal profile etc. Single-pulse resolved diagnostics data is therefore required as an essential reference for user experiments. The specifications of XFEL.EU, especially the high intra-bunch repetition rate of 4.5 MHz and the vast energy range between 280 eV and 25 keV pose particular challenges for the design of gas-based devices.

We report on our conceptual design [3] and our recent developments of a photoelectron time-of-flight spectrometer for spectroscopy of single SASE pulses and give a first assessment of the expected performance of the device as derived from detailed simulations in a realistic environment and first commissioning experiments with synchrotron radiation.

[1] M. Altarelli et. al.,*The European XFEL Technical Design Report* (2006). [2] J. Grünert, Proc. FEL09, Liverpool (2009). [3] J. Buck, *Conceptual Design Report: Photoemission Spectrometer*, in prep.

A 14.7 Tue 12:00 V57.05

X-ray Photon Beam Diagnostics Devices for the Commissioning and User Operation of the Multi-Undulator facility European XFEL — •Jan Grünert, Cigdem Ozkan, Bin Li, Wolfgang Freund, Jens Buck, and Serguei Molodtsov — European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany

The X-ray Free-Electron-Lasers (XFELs) LCLS [1], SACLA [2], and the European XFEL [3] open new opportunities in the research of very small structures and at the same time extremely fast phenomena (Ångström and femtosecond resolution). Unlike pulses from a conventional laser radiation is here created by Self-Amplified Spontaneous Emission when electron bunches pass through very long segmented undulators. Shot noise at the origin of this process leads to pulse-to-pulse variations of intensity, spectrum, wavefront, etc. Any XFEL diagnostics is susceptible to single-shot damage due to the extreme brilliance. Apart from the large facility energy range (280eV to 25keV), the particular challenge for the European XFEL diagnostics is the 4.5 MHz intra-bunchtrain repetition rate, causing additional damage by high heatloads and making shot-to-shot diagnostics very demanding [3]. We report on concepts [4,5], developments, and compromises between resolution/accuracy and energy range / shot-to-shot capabilities.

[1] P. Emma et. al.,Nature Photonics, vol. 4, pp. 641 (2010). [2] T. Ishikawa et. al., *XFEL/SPring-8 Beamline TDR* (2010). [3] M. Altarelli et. al.,*The European XFEL TDR* (2006). [4] J. Grünert, Proc. FEL09, Liverpool (2009). [5] J. Buck, *CDR Photoemission Spectrometer*, in prep. [6] C. Ozkan, *CDR Imagers*, in prep.

A 14.8 Tue 12:15 V57.05

Charakterisierung eines Iod-Überschallgasjets für ein Reaktionsmikroskop am Freie-Elektronen-Laser in Hamburg — •Georg Schmid[1], Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Artem Rudenko[2], Joachim Ullrich[1], Claus-Dieter Schröter[1] und Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max-Planck-Advanced Study Group, Hamburg

Unter Ausnutzung des thermodynamischen Effekts der Überschallexpansion lassen sich kalte und gerichtete Gasstrahlen erzeugen, die u.a. zur Impulsspektroskopie in Reaktionsmikroskopen verwendet werden. Hier wurde der Betrieb eines Überschallgasjets mit Iod charakterisiert. Dabei wurden sowohl die Abhängigkeit der Targetdichte als auch der Targettemperatur als Funktion der wesentlichen Betriebsparameter des Jets (Temperatur des Iodreservoirs, verwendetes Trägergas und Vordruck des Trägergases) untersucht.

In ultraschnellen IR/XUV-Pump-Probe-Experimenten am Freie-Elektronen-Laser in Hamburg wurde die Dissoziationsdynamik von Iodmolekülen bei Photonenenergien von 88 eV untersucht. Dabei zeigte sich eine Abhängigkeit sowohl der Ausbeute als auch der Winkelverteilung der Iodionen als Funktion der Zeitverzögerung des IR-und des FEL-XUV-Pulses.

A 15: SYRA 1: Ultracold Rydberg Atoms and Molecules 1

Time: Tuesday 10:30–12:30 Location: V47.01

Invited Talk A 15.1 Tue 10:30 V47.01

Quantum optics and quantum information with Rydberg excited atoms. — •Klaus Molmer — Aarhus University, Aarhus, Denmark

The significant dipole-dipole interaction between Rydberg excited atoms provides an on/off controllable interaction with promising applications for entanglement operations and quantum computing with neutral atoms. The blockade interaction may be used to carry out quantum gate operations between individually addressed atomic qubits, and in small ensembles, the Rydberg blockade may simultaneously couple all atoms and thus enable quantum control of collective many-body state. On the one hand, this provides new efficient multi-bit schemes for quantum computing and, on the other hand, it gives access to non-classical states and interaction mechanisms in light-matter interfaces with applications in quantum optics and quantum communication.

Invited Talk A 15.2 Tue 11:00 V47.01

Cooperative non-linear optics using Rydberg atoms — •Charles Adams — Durham University, Durham, UK

The giant dipole associated with transitions between highly excited Rydberg states can be used to control the optical response of up to 1000 neighbouring atoms. This gives rise to a large cooperative optical non-linearity [1] that is effective at the single photon level providing the basis for fully deterministic all-optical quantum processing. In this talk we will discuss our recent progress in the area of Rydberg non-linear optics and present prospects for future developments.

[1] J. D. Pritchard et al. Phys. Rev. Lett. 105, 193603 (2010).

A 15.3 Tue 11:30 V47.01

Rydberg electromagnetically induced transparency in dense ultracold gases — •Christoph S. Hofmann, Georg Günter, Hanna Schempp, Henning Labuhn, Martin Robert-de-Saint-Vincent, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We report on our latest experimental results on Ryberg electromagnetically induced transparency performed in a regime which is governed by large Rydberg-induced nonlinearities. In these experiments the nonlinear optical response of a strongly interacting Rydberg gas is probed by means of a simple CCD camera. This work is a precursor experiment for realising direct optical images of Rydberg atoms [1]. The experiments are performed in our new apparatus which allows us to realise Bose-Einstein condensates (BECs) of ^{87}Rb for studies on Rydberg atoms excited from dense atomic gases. Starting with a high flux 2D-MOT, we efficiently load a MOT in order to pre-cool and efficiently transfer atoms into a crossed optical dipole trap. The latter acts as a reservoir that is superimposed with a dimple trap, in which we evaporatively cool the atoms to reach BEC. This simple and robust scheme allows us to perform experiments with short overall cycle times of only ~ 4.5 s.

[1] G. Günter et al., arXiv:1106.5443v1 (2011) to be published in PRL

A 15.4 Tue 11:45 V47.01

Electromagnetically Induced Transparency in Strongly Interacting Rydberg Gases — •Johannes Otterbach[1], David Petrosyan[2,3], Alexey V. Gorshkov[4], Thomas Pohl[5], Mikhail D. Lukin[1], and Michael Fleischhauer[2] — [1]Physics Department, Harvard University — [2]Fachbereich Physik, TU Kaiserslautern — [3]Institute of Electronic Structure and Laser, FORTH, Crete — [4]Institute for Quantum Information, California Institute of Technology — [5]Max Planck Institute for the Physics of Complex Systems, Dresden

The recent advance in coherently controlling and manipulating strong, long-range Rydberg interactions has triggered various studies of the Rydberg blockade effect for applications in quantum information processing and crystal formation. In this talk I show that Rydberg interactions can be used to alter the photon statistics of a weak probe field after propagating in a coherently prepared atomic Rydberg gas under conditions of Electromagnetically Induced Transparency (EIT). The Rydberg blockade mechanism leads to an effective two-level physics when two photons are separated less than the blockade radius resulting in a strong anti-correlation of two photons separated by an avoided volume. I argue that the formation of such hard-sphere photons is a key-ingredient in the explanation ofthe recent experiment of Pritchard et al. [Phys. Rev. Lett. 105, 193603 (2010)]. Finally the observation of such correlation in future experiments will be discussed.

A 15.5 Tue 12:00 V47.01

Dipolar Bose-Einstein condensate of Dark-state Polaritons — •Gor Nikoghosyan[1], Frank E. Zimmer[2], and Martin B. Plenio[1] — [1]Institut für Theoretische Physik, Albert-Einstein Allee 11, Universität Ulm, 89069 Ulm — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden

We put forward and discuss in detail a scheme to achieve BEC of stationary-light dark-state polaritons with dipolar interaction. We extend the works on Bose-Einstein condensation of photons and polaritonic quasiparticles, to the regime of dipolar quantum gases. To this end we introduce a diamond-like coupling scheme in a vapor of Rydberg atoms under the frozen gas approximation. To determine the system*s dynamics we employ normal modes and identify the dark-state polariton corresponding to one of the modes. We show that these polaritonic quasiparticles behave in adiabatic limit like Schrodinger particles with a purely dipolar inter-particle interaction. Moreover, we could show, by analyzing the Bogoliubov spectrum of a homogeneous dipolar BEC, that for a special choice of the dipolar interaction parameter the considered dipolar BEC is, in contrast to usual dipolar BEC, very stable.

A 15.6 Tue 12:15 V47.01

Rydberg four wave mixing in a thermal gas of Rb — •Andreas Kölle, Georg Epple, Thomas Baluktsian, Bernhard Huber, Harald Kübler, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Gerrmany

The Rydberg blockade effect is a promising candidate for use in quantum devices. In combination with a four wave mixing scheme a single photon source has been proposed. While ultracold gases seem to be the obvious choice, our vision is to use thermal atomic vapor in small glass cells which offers multiple advantages in terms of scalability and ease of use.

We present four wave mixing measurements including a Rydberg state in a thermal vapor cell and compare our results to a single atom model. Furthermore we demonstrate the tunability of the four wave mixing scheme by means of an electric field via the Stark effect on the Rydberg state.

A 16: Ultra-cold atoms, ions and BEC I

Time: Tuesday 14:00–16:00 Location: V7.02

Invited Talk A 16.1 Tue 14:00 V7.02

Macroscopic Quantum Tunneling of Solitons in Bose-Einstein Condensates — •Lincoln D. Carr[1,2] and Joseph A. Glick[2,3] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]Department of Physics, Colorado School of Mines, U.S.A — [3]Department of Physics and Astronomy, Michigan State University, U.S.A.

We study the quantum tunneling dynamics of many-body entangled solitons composed of ultracold bosonic gases in 1D optical lattices. A bright soliton, confined by a potential barrier, is allowed to tunnel out of confinement by reducing the barrier width and for varying strengths of attractive interactions. Simulation of the Bose Hubbard Hamiltonian is performed with time-evolving block decimation. We find the characteristic 1/e time for the escape of the soliton, substantially different from the mean field prediction, and address how many-body effects like quantum fluctuations, entanglement, and nonlocal correlations affect macroscopic quantum tunneling; number fluctuations and second order correlations are suggested as experimental signatures. We find that while the escape time scales exponentially in the interactions, the time at which both the von Neumann entanglement entropy and the slope of number fluctuations is maximized scale only linearly.

A 16.2 Tue 14:30 V7.02

Confinement-Induced collapse of a dipolar Bose-Einstein Condensate in an optical lattice — •Emanuel Henn[1], Juliette Billy[1], Stefan Müller[1], Holger Kadau[1], Thomas Maier[1], Mathias Schmitt[1], Mattia Jona-Lasinio[2], Luis Santos[2], Axel Griesmaier[1], and Tilman Pfau[1] — [1]5.Physikalisches Institut, Universitat Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institut fur Theoretische Physik, Leibniz Universitat Hannover, 30167 Hannover, Germany

We experimentally investigate the collapse of a dipolar Bose-Einstein Condensate (dBEC) in a 1D lattice. In contrast with the standard method of changing the contact interaction energy, the collapse is here induced by a sudden change in the confining potential. Only a dBEC offers this possibility since its stability threshold strongly depends on the lattice depth due to the anisotropic character of the dipolar interaction [1]. For shallow lattices, in the extreme case where the trapping potential is completely switched off, the dBEC collapses during the free expansion, which is also a unique feature of dipolar systems. For deep lattices, structured ground-states are expected to appear. However, strong atom losses and dephasing effects restrict the experimental parameter range. We present here our methods to overcome these limitations and discuss preliminary results.

[1] S. Müller et al., Phys. Rev. A 84, 053601 (2011)

A 16.3 Tue 14:45 V7.02

Quantum stochastic description of collisions in a canonical Bose gas — •Patrick Navez[1] and Achilleas Lazarides[2] — [1]Institut für Theoretische Physik, TU Dresden, 01062 Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

We derive a stochastic process that describes the kinetics of a one-dimensional Bose gas in a regime where three body collisions are important. In this situation the system becomes non integrable offering the possibility to investigate dissipative phenomena more simply compared to higher dimensional gases. Unlike the quantum Boltzmann equation describing the average momentum distribution, the stochastic approach allows a description of higher-order correlation functions in a canonical ensemble. As will be shown, this ensemble differs drastically from the grand canonical one. We illustrate the use of this method by determining the time evolution of the momentum mode particle number distribution and the static structure factor during the evaporative cooling process.

A 16.4 Tue 15:00 V7.02

Quasi-Particle Theory for Strongly Interacting Lattice Bosons — •Ulf Bissbort, Michael Buchhold, and Walter Hofstetter — Institut für Theoretische Physik, Goethe Universität Frankfurt a.M.

We develop a systematic quasi-particle theory for interacting bosons in optical lattices, which does not rely on a large condensate fraction and is valid for arbitrary interaction strengths. It is based upon the diagonalization of fluctuation operators on top of the bosonic Gutzwiller ground state and in the classical limit equivalent to the linearization of the time-dependent Gutzwiller equations of motion. The various collective modes, such as the sound and amplitude mode in the condensate, or the particle and hole mode in the Mott insulator emerge naturally from this unified formalism. It is valid beyond the realm of the latter, also being able to describe dynamics in the Mott insulator. For states in the vicinity of the respective Gutzwiller ground state, the system can be described as an ensemble of non-interacting quasi-particles, allowing for a direct treatment of time-dependent phenomena. Specifically, we calculate spectral functions and the dynamic structure factor for homogeneous systems in both the Mott insulator and condensate. The decay processes of the various quasi-particle modes induced by the higher order terms neglected in the quasi-particle

Hamiltonian are identified, and the lifetimes are calculated. Furthermore we apply our theory to study quantum quenches and subsequent relaxation processes.

A 16.5 Tue 15:15 V7.02

Breathing oscillations of a trapped impurity in a Bose gas — •Martin Bruderer[1], Tomi Johnson[2], and Dieter Jaksch[2] — [1]Universität Konstanz — [2]University of Oxford

Motivated by a recent experiment of Catani et al. [1] we study breathing oscillations in the width of a harmonically trapped impurity interacting with a separately trapped Bose gas. We provide an intuitive physical picture of such dynamics at zero temperature, using a time-dependent variational approach. In the Gross-Pitaevskii regime we obtain breathing oscillations whose amplitudes are suppressed by self-trapping due to interactions with the Bose gas. Introducing phonons in the Bose gas leads to the damping of breathing oscillations and non-Markovian dynamics of the width of the impurity. Our results reproduce the main features of the impurity dynamics observed by Catani et al. [1] despite experimental thermal effects, and are supported by simulations of the system in the Gross-Pitaevskii regime.

[1] J. Catani et al., Quantum dynamics of impurities in a 1D Bose gas, arXiv:1106.0828v1 preprint (2011)

A 16.6 Tue 15:30 V7.02

A novel route to BEC of calcium — •Purbasha Halder, Chih-Yun Yang, and Andreas Hemmerich — Institut für Laserphysik, Universität Hamburg

We present a novel scheme for obtaining a condensate of alkaline-earth-metal and rare earth elements, and demonstrate it successfully for ^{40}Ca atoms. This all-optical method avoids complications of narrow-line laser cooling and trapping schemes which form the basis of previous experimental approaches. By this method, we efficiently load a cold and dense sample of atoms into a dipole trap directly from a MOT operating on the metastable $^3P_2$ state. Loading is carried out by selectively depumping only those MOT atoms which are near the minimum of the dipole trap potential. This increases the phase space density by four orders of magnitude. Further cooling to quantum degeneracy is achieved by forced evaporation, yielding a condensate containing 6000 atoms.

A 16.7 Tue 15:45 V7.02

Ansatz for bosons in harmonic trap: from two to many — •Ioannis Brouzos and Peter Schmelcher — Zentrum für optischen Quantentechnolgien, Hamburg Germany

We develop an analytical many-body wave function to accurately describe the crossover of a one-dimensional bosonic system from weak to strong interactions in a harmonic trap. The explicit wave function, which is based on the exact two-body states, consists of symmetric multiple products of the corresponding parabolic cylinder functions, and respects the analytically known limits of zero and infinite repulsion for arbitrary number of particles. For intermediate interaction strengths we demonstrate, that the energies, as well as the reduced densities of first and second order, are in excellent agreement with large scale numerical calculations.

A 17: Precision spectroscopy of atoms and ions I

Time: Tuesday 14:00–16:00 Location: V55.01

Invited Talk A 17.1 Tue 14:00 V55.01

Single-photon interference experiments with single ions — •Gabriel Hétet[1], Lukas Slodicka[1], Nadia Rock[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Institute for Experimental Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck, Austria

We present experiments that study the interaction of single Barium ions with single photons and weak coherent fields in front of high-numerical aperture optical elements.

First, we show the experimental observation of the ion as the optical mirror of a Fabry-Perot cavity. This was achieved by tightly focussing a laser field onto the ion trapped in front of a far-distant dielectric mirror. We then demonstrate the very first steps towards entanglement of two far-distant ions using only single-photon detection events. Last, we will present our current efforts in the design of ion traps with even higher numerical aperture objectives and mirrors for efficient single photon collection and high entanglement rates.

A 17.2 Tue 14:30 V55.01

A Novel, Robust Quantum Detection Scheme for Ions — •Florian Gebert[1], Boerge Hemmerling[2], Yong Wan[1], and Piet O. Schmidt[1] — [1]QUEST Inst. for Exp. Quantum Metrology, PTB Braunschweig and Leibniz Univ. of Hannover — [2]Department of Physics, Harvard University, Cambridge, MA02138, USA

Protocols used in quantum information and precision spectroscopy rely on efficient detection of the internal quantum state of the system under investigation. The basic principle of state discrimination in ions relies on electron-shelving, where two different energy states (qubit) are distinguished by their state-dependent fluorescence via coupling to a third level. In its simplest form, the number of collected photons during a single detection cycle determines whether the ion is assigned to a so called bright (dark) state depending on this number being higher (lower) than a chosen threshold. Detection fidelities can be further improved if photon arrival times are taken into account. Despite their high fidelities this Bayesian inference or maximum likelihood detection methods are affected by fluctuations of the power of the detection laser. We demonstrate a novel detection technique which combines two detection outcome with an intermediate well-controlled state inversion [1]. Observation of anti-correlated detection events acts as a post-selective statistical filter, which effectively improves the detection fidelity. It is therefore extremely robust against fluctuations of detection parameters and particularly well-suited for systems in which only very few photons are detected and a method for efficient state inversion exists. [1] B. Hemmerling et al., arXiv:1109.4981v2

A 17.3 Tue 14:45 V55.01

Experimentelle Bestimmung des ersten Ionisationspotentials von Actinium — •Johannes Rossnagel[1], Sebastian Raeder[1,2], Amin Hakimi[1], Rafael Ferrer[3], Norbert Trautmann[4] und Klaus Wendt[1] — [1]Institut für Physik, Universität Mainz — [2]TRIUMF, Vancouver, Kanada — [3]Instituut voor Kern- en Stralingsfysica, K.U. Leuven, Belgien — [4]Institut für Kernchemie, Universität Mainz

Das erste Ionisationspotential (IP) von Actinium (^{227}Ac) konnte durch resonante Laserionisationsspektroskopie präzise bestimmt werden. Hierfür wurden in zweistufigen Anregungsschemata Rydbergzustände gerader Parität bevölkert und die Konvergenzen dreier unabhängiger Rydbergserien bestimmt, die gegen den Grundzustand sowie gegen den ersten und zweiten angeregten Zustand des einfach positiv geladenen Actinium-Ions konvergieren. Eine kombinierte Analyse dieser Serien mit zusätzlichen Korrekturen aufgrund interferierender Ionisationskanäle liefert einen Wert von V_{IP}(Ac) = 43394,45(20) cm^{-1} für das erste Ionisationspotential von Ac, entsprechend 5,380226(24) eV, in Übereinstimmung mit einer früheren, nicht reproduzierten Messung, wobei die Genauigkeit stark erhöht werden konnte.

A 17.4 Tue 15:00 V55.01

Resonanz-Ionisations-Spektroskopie an neutralem Aktinium — •Sebastian Raeder[1], Amin Hakimi[2], Thomas Fischbach[2], Jens Lassen[1], Johannes Rossnagel[2], Volker Sonnenschein[3], Andrea Teigelhöfer[1], Hideki Tomita[4], Norbert Trautmann[5] und Klaus Wendt[2] — [1]Trilis, Triumf, Vancouver, Canada — [2]Institut für Physik, Universität Mainz — [3]University of Jyväskylä — [4]University of Nagoya — [5]Institut für Kernchemie, Universität Mainz

Geplante laserspektroskopische Untersuchungen zur Isotopieverschiebung und Hyperfeinstrukturaufspaltung an der Isotopenkette des Aktiniums benötigen spektroskopische Informationen bzgl. einer effizienten resonanten Anregung und Ionisation von atomarem Aktinium. Als Vorbereitung wurde hierzu mittels Resonanzionisations-Spektroskopie das atomare Spektrum von Aktinium mit einem weit abstimmbaren gepulsten Ti:Saphir Lasersystem detailliert untersucht. Hierbei konnten zudem die verfügbaren Literaturangaben zu den atomaren Anregungslinien, die bisher auf einer einzigen Referenz beruhten, weitgehend bestätigt und vervollständigt werden. Die Identifikation bisher unbekannter hochliegender gebundener Zustände und autoionisierender Resonanzen ermöglichte die Etablierung eines effizienten resonanten Ionisationsschemas. Unter Verwendung eines über injection-locking schmalbandigen gepulsten Ti:Saphir Lasers wurden zudem erste spektroskopische Messungen zur Hyperfeinstruktur am neutralen Aktinium unternommen, wobei geeignete Übergänge für die vorgesehenen Untersuchungen an kurzlebigen Aktiniumisotopen identifiziert werden konnten.

A 17.5 Tue 15:15 V55.01

Multipass laser cavity for efficient transverse illumination of an elongated volume — •Jan Vogelsang and the CREMA collaboration — Max-Planck-Institute for Quantum Optics, Garching

The recent measurement of the Lamb shift (2S-2P energy difference) in muonic hydrogen has attracted a lot of interest. The laser spectroscopy measurement has utilized a novel multipass cavity design which we will present.

The muon beam is stopped in a 200mm long and 5mm high stop volume inside hydrogen gas. Since the muon beam can not pass any mirrors we had to illuminate the long stop volume from the transverse direction. The cavity is very robust against mechanical misalignment, so no active mirror stabilization is required. A similar cavity will be used in the upcoming laser spectroscopy experiment in muonic helium ions.

A 17.6 Tue 15:30 V55.01

Towards laser spectroscopy of trans-fermium elements — •Mustapha Laatiaoui[1,2], Hartmut Backe[3], Michael Block[2], Fritz-Peter Hessberger[2], Peter Kunz[4], Felix Lautenschläger[1], Werner Lauth[3], and Thomas Walther[1] — [1]Institut für Angewandte Physik, TU-Darmstadt, 64289 Darmstadt — [2]Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt — [3]Institut für Kernphysik, Universität Mainz, 55099 Mainz — [4]TRIUMF, Vancouver, Canada

The atomic structure of the heaviest elements allows to investigate relativistic effects and their description in modern theories. However, beyond the element fermium with a charge number Z=100, detailed atomic spectroscopy, even with the most sensitive laser methods, is hampered by their low production rates in nuclear fusion reactions. At present no experimental information on atomic levels is available for these elements. In our experiments [H. Backe et al., Eur. Phys. J. D **45** (2007) 99] behind the velocity filter SHIP at the GSI, we employ the radiation detected laser resonance ionization technique to search for the predicted $5f^{14}7s7p\ ^1P_1$ level in ^{254}No (Z=102). In a first 54 h experiment, the evaporation temperature of nobelium was determined and the atomic level search was started. In this talk, a brief status report on these activities will be given.

A 17.7 Tue 15:45 V55.01

Minimizing Time Dilation in Ion Traps for an Optical Clock — •Karsten Pyka[1], Norbert Herschbach[1], Kristijan Kuhlmann[1], Jonas Keller[1], David-Marcel Meyer[1], and Tanja E. Mehlstäubler[1,2] — [1]Quest-Institute, Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Department of Time & Frequency, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We present a new experimental setup to test scalable chip-based ion traps for the development of trap structures with reduced excess micromotion that allow precision spectroscopy on a large ensemble of ions. Based on our finite-element calculations [1] a novel trap is built employing high-precision laser machining and surface coating processes at PTB.

In a prototype made of Rogers4350B^{TM} we have succesfully trapped linear chains and 3D-Coulomb crystals of $^{172}Yb^+$ ions. We emphasize on the precision measurement of excess micromotion of a single $^{172}Yb^+$ ion using photon-correlation spectroscopy. We are able to resolve a micromotion amplitude of ≈ 1.1 nm corresponding to a fractional frequency shift of the atomic transition of less than 10^{-19}.

With this resolution we were able to characterize our prototype trap to have an axial rf electric field gradient that allows the trapping of linear Coulomb crystals of twelve ions, that experience a fractional frequency shift due to time-dilation of less than 10^{-18}.

[1] Herschbach et al., Appl. Phys. B, (2011), DOI: 10.1007/s00340-011-4790-y

A 18: Attosecond physics I

Time: Tuesday 14:00–16:00 Location: V47.03

Invited Talk A 18.1 Tue 14:00 V47.03

Ultrafast Quantum Photonics — •Alfred Leitenstorfer — Department of Physics and Center for Applied Photonics, University of Konstanz, Konstanz, Germany

This talk provides an overview of our efforts to investigate condensed-matter systems and light down to the molecular level of single electrons and photons, with direct access to the electric field amplitude and subcycle precision. First, ultrabroadband femtosecond fiber lasers are introduced as an enabling technology for ultrafast quantum photonics [1]. In the following, femtosecond experiments on single semiconductor quantum dots are featured [2]. Via broadband enhancement of light-matter coupling e.g. with plasmonic nanoantennas [3], we are aiming at a precise control of the photon number of ultrashort pulses. The third part discusses the field of multi-terahertz physics where new regimes for quantum optics [4] and a nonlinear access to low-energy excitations of complex matter [5] are currently arising.

[1] G. Krauss et al., Nature Photon. 4, 33 (2010)
[2] F. Sotier et al., Nature Phys. 5, 352 (2009)
[3] T. Hanke et al., Phys. Rev. Lett. 103, 257404 (2009)
[4] G. Günter et al., Nature 458, 178 (2009)
[5] T. Kampfrath et al., Nature Photon. 5, 31 (2011)

Invited Talk A 18.2 Tue 14:30 V47.03

Attosecond dynamics in laser-driver metal clusters — Johannes Passig[1], Sergey Zherebtsov[2], Robert Irsig[1], Slawomir Skruszewicz[1], Josef Tiggesbäumker[1], Matthias Kling[2], Karl-Heinz Meiwes-Broer[1], and •Thomas Fennel[1] — [1]University of Rostock, 18051 Rostock, Germany — [2]Max Planck Institute of Quantum Optics, 85748 Garching, Germany

Clusters in intense laser pulses are valuable systems to illuminate strong-field many-particle physics in the attosecond domain [1]. The understanding of key processes like collective excitations, ultrafast plasma creation, and electron rescattering in clusters may open up new routes for the analysis and control of nanosystems with light [2].

The extreme resonant field enhancement in clusters allows the acceleration of electrons to energies of a few hundred times the ponderpomotive potential in a single rescattering process [3]. In pump-probe experiments on silver cluster we found that the emission direction of electrons can be precisely controlled by the relative phase of a two-color laser field up to the keV energy range. A molecular dynamics analysis reveals that the asymmetric acceleration results from the attosecond timing of the induced polarization fields, demonstrating the opportunity of precise and highly efficient control of sub-cycle electron dynamics in resonant plasmonic many-particle systems.

[1] Th. Fennel et al., Rev. Mod. Phys. 82:1793 (2010)
[2] J. Köhn, Phys. Chem. Chem. Phys. 13:8747-8754 (2011)
[3] Th. Fennel et al., Phys. Rev. Lett. 98:143401 (2007)

A 18.3 Tue 15:00 V47.03

Two-dimensional spectroscopy methods to explore attosecond electron dynamics — Christian Ott, Philipp Raith, Andreas Kaldun, Kristina Meyer, Martin Laux, Yizhu Zhang, and •Thomas Pfeifer — Max-Planck Institut für Kernphysik, Heidelberg

Traditional two-dimensional (2D) spectroscopy methods are based on time-delayed mutually-coherent pulse sequences, allowing to map out correlations among different vibrational or electronic transition frequencies. This allows the measurement of population and (de-) coherence information of a system's density matrix and the coupling of quantum states, recently leading to the observation of coherent energy flow in macromolecular photosynthetic light-harvesting complexes, even at room temperature [1]. However, these powerful 2D-spectroscopy methods have thus far been limited to the femtosecond time scale.

Here, we present experimental results demonstrating novel concepts of 2D spectroscopy that are applicable to the attosecond strong-field domain and the exploration of one- and two-electron dynamics. The carrier-envelope phase (CEP) is used as a dynamical parameter, opening a second dimension to gain access to electron dynamics and to separately identify spectrally overlapping quantum paths within one and the same few-cycle strong-field laser pulse. We also used laser-dressed soft-x-ray transient-absorption spectroscopy to create experimental 2D spectrograms, from which we read the quantum-interference pathways of two-electron excited states and their dynamics embedded in an ionization continuum.

[1] Panitchayangkoon *et al.* PNAS **107**, 12766 (2010)

A 18.4 Tue 15:15 V47.03

Correlated motion of two electrons on a 1 fs time-scale — •Christian Ott, Andreas Kaldun, Philipp Raith, Kristina Meyer, Martin Laux, Yizhu Zhang, Steffen Hagstotz, Thomas Ding, Robert Heck, and Thomas Pfeifer — Max-Planck Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The concerted motion of two or more electrons is at the heart of almost any chemical reaction, as molecular bonding typically involves electron correlation dynamics. We experimentally observed and analyzed the time-resolved behavior of both electrons in helium, the prototype of the three-body Coulomb problem, via the technique of transient-absorption spectroscopy, combined with attosecond-pulsed soft-x-ray light produced via high harmonic generation using few-cycle (~ 7 fs) moderately intense (up to $5 \cdot 10^{12}$ W/cm^2) near-visible (VIS) laser pulses. Using broadband soft-x-ray light in the 60 to 70 eV energy range, we simultaneously excite up to 7 doubly-excited states of the $sp_{2,n+}$ ($^1P^o$) series. A temporally resolved coupling among the states with the VIS laser pulses at various field intensities (from the perturbative to the strong-coupling regime) was observed. In particular, we discuss VIS-intensity-dependent changes (up to complete inversion) of the Fano line shape which is characteristic of these intrinsically entangled two-electron states. A laser-induced coupling among various states allows the measurement of a two-electron quantum beating on a 1 fs timescale as theoretically predicted [1].

[1] L. Argenti and E. Lindroth, Phys. Rev. Lett. **105**, 053002 (2010).

A 18.5 Tue 15:30 V47.03

Attosecond control of electrons emitted from a nanoscale metal tip — •Michael Krüger, Markus Schenk, Michael Förster, Sebastian Thomas, Lothar Maisenbacher, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching bei München, Germany

By focusing low-power few-cycle Ti:sa pulses tightly onto sharp tungsten tips it is possible to reach a strong-field photoemission regime, a prerequisite for performing attosecond science. We have recently observed strong-field effects such as peak suppression and peak shifting [1] and rescattering [2] in this system. Here we use carrier-envelope phase (CEP) stabilized pulses and measure photoelectron spectra for varying CEP. We observe a CEP dependent current modulation that increases in amplitude to about 100% for high-energy electrons. Furthermore, we observe a clear change in the peak visibility of the high-energy plateau part of the spectrum when the phase is changed by π. The presence (absence) of spectral interference indicates that high-energy electrons are emitted within two time windows (one window) of sub-optical-cycle duration. Quantum mechanical theory models confirm this notion and show that photoelectrons from the metal tip can be steered with attosecond precision by changing the CEP, in analogy to atomic gases. We discuss results deepening the understanding of the processes involved.

[1] M. Schenk, M. Krüger, P. Hommelhoff, *PRL* **105**, 257601 (2010)
[2] see contribution of M. Schenk et al. at this conference
[3] M. Krüger, M. Schenk, P. Hommelhoff, *Nature* **475**, 79 (2011)

A 18.6 Tue 15:45 V47.03

Attosecond plasma wave dynamics in laser-driven cluster nanoplasmas — •Christian Peltz[1], Charles Varin[2], Thomas Brabec[2], and Thomas Fennel[1] — [1]Institute of Physics, University of Rostock, Germany — [2]Department of Physics and Centre for Photonics Research, University of Ottawa, Canada

Molecular dynamics (MD) and particle-in-cell (PIC) methods have been used with great success for modeling intense laser-plasma interaction, though both have certain important limitations. Electrostatic MD works well for small nanoplasmas, where the dipole approximation and the neglect of field propagation are justified. PIC codes average over the fine-grained atomic structure and thus neglect collisions and plasma microfields which is only justified at relativistic intensities or in weakly coupled plasmas and makes the treatment of large plasma volumes possible. We introduce a novel microscopic particle-in-cell (MicPIC) method that overcomes the above limitations with a P^3M-type force decomposition. In MicPIC, long-range electromagnetic interactions are described on a PIC level, on which particles are represented by wide Gaussian distributions on a relatively coarse numerical grid. When two particles come close, the PIC field is replaced by the analytic electrostatic field to resolve microscopic (Mic) interactions. As a first application, we study the resonant excitation of metal-like clusters (Mie plasmon and laser in resonance) where we found plasma waves in surprisingly small clusters at moderate laser intensities ($< 10^{14}$ W/cm^2). A detailed analysis of the wave dynamics and its impacct on absorption and ionization will be presented[submitted].

A 19: Atomic systems in external fields II

Time: Tuesday 14:00–15:15 Location: V57.05

A 19.1 Tue 14:00 V57.05

Spectra of harmonium in a magnetic field using the Herman-Kluk propagator — •Frank Grossmann[1] and Tobias Kramer[2] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden — [2]Institut für Thoeretische Physik, Universität Regensburg, 93053 Regensburg

For two interacting electrons in a harmonic quantum dot and a constant magnetic field, we show that time-dependent semiclassical calculations using the Herman-Kluk initial value representation of the propagator [1] lead to eigenvalues of the same accuracy as WKB calculations with Langer correction [2]. The latter are restricted to integrable systems, however, whereas the time-dependent initial value approach allows for applications to high-dimensional, possibly chaotic dynamics and can be extended to arbitrary shapes of the potential. The Langer correction is not needed due to the fact that we are using Cartesian coordinates [3].

[1] M. Herman and E. Kluk, Chem. Phys. **91**, 27 (1984)
[2] F. Grossmann and T. Kramer, J. Phys. A **44**, 445309 (2011)
[3] G. van de Sand and J.-M. Rost, Phys. Rev. A **59**, R1723 (1999)

This work was supported by the DFG through grants GR 1210/4-2 as well as KR 2889/2.

A 19.2 Tue 14:15 V57.05

Moving neutral atoms in neutron star magnetic fields — •Thorsten Kersting and Günter Wunner — 1. Institut für Theoretische Physik, Universtität Stuttgart

In the past years, significant improvements in numerical calculations of atoms in neutron star magnetic fields have lead to the possibility of producing a huge amount of atomic data, which can serve as a basis for modeling neutron star atmospheres. To calculate the quantity of interest, i.e. the opacity, from cross sections and dipole strengths, it is necessary to consider broadening effects due to influences of the hot plasma in the neutron star atmosphere. The largest broadening effect for atoms in neutron star magnetic fields is likely to be the influence of the motional stark effect induced by the magnetic field. We present a method for calculating energies and wave functions which not only works for hydrogen and hydrogen-like helium, as in previous work, but also for any neutral atom.

A 19.3 Tue 14:30 V57.05

Hartree-Fock calculations for the photoionisation of light to

medium-heavy atoms and ions in neutron star magnetic fields — •Peter Diemand, Thorsten Kersting, Damir Zajec, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

We derive the photoionisation cross section in dipole approximation for many-electron atoms and ions in neutron star magnetic field strengths in the range of 10^7 to 10^9 T. Both bound and continuum states are treated in adiabatic approximation in a self-consistent way. Bound states are calculated by solving the Hartree-Fock-Roothaan equations using finite element and B-spline techniques. We have taken into account mass and photon density in the neutron star's atmosphere as well as thermal occupation. The data are of importance for the quantitative interpretation of observed x-ray spectra that originate from the thermal emission of isolated neutron stars. They can serve as input for modeling neutron star atmospheres as regards chemical composition, magnetic field strength, temperature, and redshift. Our main focus in this talk lies on helium, since it is simple enough to calculate all possible transitions when limiting the quantum numbers, while still being sufficiently complicated to show all the basic structures and behaviour of heavier elements up to iron.

A 19.4 Tue 14:45 V57.05

Advanced Landau expansion of atoms in neutron star magnetic fields — •Christoph Schimeczek and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Chasing the origin of still unexplained absorption features in the spectra of neutron stars with intense magnetic fields of 10^8 T, we have developed efficient tools to describe atomic states under such conditions. By enhancing our Hartree-Fock method to a full 2D variation and introducing approximations for the electron interaction terms we can reduce the absolute error for the binding energies to below one per cent and increase the range of validity of our code towards the regime of intermediate magnetic field strengths. Furthermore, the increase in calculation time compared to simpler methods is kept very low, resulting in an extraordinary program efficiency.

A 19.5 Tue 15:00 V57.05

Correlation function quantum Monte Carlo calculations for ground and excited states of helium and lithium in neutron star magnetic fields — •Sebastian Boblest, Dirk Meyer, and Günter Wunner — Universität Stuttgart

We present results of the application of the correlation function quantum Monte Carlo method to the calculation of atomic data of helium and lithium in neutron star magnetic fields, using symmetry adapted basis sets computed with a Hartree-Fock-Roothaan method. These results include energy levels for ground and excited states at different magnetic field strengths with unprecedented accuracy. The atomic data obtained in these and future calculations for medium-heavy atoms are of relevance to the analysis of features discovered in the thermal emission spectra of isolated neutron stars.

A 20: SYRA 2: Ultracold Rydberg Atoms and Molecules 2

Time: Tuesday 14:00–16:00 Location: V47.01

Invited Talk A 20.1 Tue 14:00 V47.01

Ultralong-range Rydberg molecules — •Thomas Pohl — MPI for the Physics of Complex Systems, Dresden, Germany

Ultralong-range Rydberg molecules represent an extreme and peculiar example of chemical binding, where a ground state atom is bound inside the electronic wave function of a highly excited Rydberg atom. Owing to their large bond length of several thousand Bohr radii, these molecules - first produced in 2009 [1] - exhibit several unusual properties, some of which will be discussed in this talk.

Following a simplified discussion of the basic interaction mechanisms, I will describe more sophisticated calculations, which reveal, yet, another new binding mechanism based on internal quantum reflection [2]. Good agreement with experiments on ultracold Rubidium molecules, gives strong indication that the predicted molecular states indeed provide a manifestation of such elementary quantum phenomena. A close look at small-electric field effects uncovers the existence of a sizable molecular electric dipole moment [3], which comes as a surprise for homo-nuclear molecules.

Besides being of fundamental interest, such exotic molecules turn out to be also of relevance to other Rydberg-atom settings. In order to illustrate this point, I will consider their collective excitation dynamics in mesoscopic ultracold gases and discuss possible implications for ensemble-based quantum information/optics applications.

[1] V. Bendkowsky et al., Nature (London) **458**, 1005 (2009)
[2] V. Bendkowsky et al., Phys. Rev. Lett. **105**, 163201 (2010)
[3] W. Li et al., Science **334**, 1110 (2011)

Invited Talk A 20.2 Tue 14:30 V47.01

Quantum Information Processing with Rydberg Atoms — •Philippe Grangier — Institut d'Optique, RD128, 91127 Palaiseau, France

We will present an overview of the use of direct interactions between trapped cold Rydberg states for quantum information processing.

A first approach is to use dipole blockade between individually trapped atoms, used as quantum bits. This allows one to generate entangled pairs of of atomic qubits, and to perform quantum gates, as it has been demonstrated by several recent experiments that will be presented.

A second approach is to use atomic ensembles, and to excite Rydberg polaritons in order to generate "giant" optical non-linear effects, that may lead to quantum gates for photonic qubits. Perspectives in that direction will be also discussed.

A 20.3 Tue 15:00 V47.01

Electric field impact on ultra-long-range triatomic polar Rydberg molecules — •Michael Mayle[1], Seth T. Rittenhouse[2], Peter Schmelcher[3], and Hossein R. Sadeghpour[2] — [1]JILA, University of Colorado Boulder and NIST, USA — [2]ITAMP, Harvard-Smithsonian Center for Astrophysics, USA — [3]Zentrum für Optische Quantentechnologien, Universität Hamburg

We explore the impact of external electric fields on a recently predicted species of ultra-long-range molecules that emerge due to the interaction of a ground state polar molecule with a Rydberg atom. The external field mixes the Rydberg electronic states and therefore strongly alters the electric field seen by the polar diatomic molecule due to the Rydberg electron. As a consequence the adiabatic potential energy curves responsible for the binding can be tuned in such a way that an intersection with neighboring curves occurs. The latter leads to an admixture of s-wave character to the Rydberg wave function and should significantly facilitate the experimental preparation of this novel species.

A 20.4 Tue 15:15 V47.01

Supersymmetry in Rydberg-dressed lattice fermions — •Hendrik Weimer[1], Liza Huijse[1], Alexey Gorshkov[2], Guido Pupillo[3], Peter Zoller[4], Mikhail Lukin[1], and Eugene Demler[1] — [1]Physics Department, Harvard University, Cambridge, MA, USA — [2]IQI, Caltech, Pasadena, CA, USA — [3]University of Strasbourg, Strasbourg, France — [4]University of Innsbruck and IQOQI, Innsbruck, Austria

Supersymmetry is a powerful tool that allows the characterization of strongly correlated many-body systems, in particular in the case of supersymmetric extensions of the fermionic Hubbard model [1]. At the same time, these models can exhibit rich and exotic physics on their own, such as flat bands with a vanishing dispersion relation. We show that such lattice models can be realized with Rydberg-dressed fermions in optical lattices. Strong interactions within the ground state manifold of the atoms can be realized by admixing a weak contribution of a highly excited Rydberg state [2]. We discuss the unique possbilities of ultracold atoms for the detection of supersymmetry and the effects of tuning the system away from the supersymmetric point.

[1] P. Fendley, K. Schoutens, J. de Boer, PRL **90**, 120402 (2003).
[2] J. Honer, H. Weimer, T. Pfau, H. P. Büchler, PRL **105**, 160404 (2010).

A 20.5 Tue 15:30 V47.01

Aufbau eines Experiments zur Rydberganregung von $^{40}Ca^+$

Ionen — •Thomas Feldker, Julian Naber, Ferdinand Schmidt-Kaler, Daniel Kolbe, Matthias Stappel und Jochen Walz — Quantum, Institut für Physik, Johannes Gutenberg Universität, Mainz

In Paulfallen gefange, lasergekühlte Ionen gehören zu den vielversprechendsten Kandidaten für die Quanteninformationsverarbeitung, während hoch angeregte Rydbergzustände und die damit verbundene Dipol-Blockade zu den interessantesten Entwicklungen der letzten Jahre in der Atomphysik gehören. Wir vereinen diese Ansätze, indem wir $^{40}Ca^{+}$ Ionen in einer Paulfalle in Rydbergzustände anregen [1,2]. Ziel ist die Spektroskopie von Rydbergzuständen einzelner Ionen im dynamischen Potential der Paulfalle und die Erzeugung von Vielteilchen-Verschränkung in Ionenkristallen.

Wir fangen und kühlen $^{40}Ca^{+}$ in einer linearen Paulfalle. Die kalten Ionen sollen in den metastabilen $^{3}D_{5/2}$ Zustand angeregt werden, aus dem sie mit Laser-Licht bei 123 nm in einen Rydbergzustand angeregt werden können.

[1] F. Schmidt-Kaler, T. Feldker, D. Kolbe, J. Walz, M. Müller, P. Zoller, W. Li and I. Lesanovsky, New J. Phys., 2011 [2] M. Müller, Linmei Liang, Igor Lesanovsky and Peter Zoller, New J. Phys., 2008

A 20.6 Tue 15:45 V47.01

Strongly interacting single photons in an ultra-cold Rydberg gas — Stephan Jennewein, Huan Nguyen, Michael Schlagmüller, Christoph Tresp, and •Sebastian Hofferberth — 5. Phys. Institut, Universität Stuttgart

Strong photon-photon coupling can in principle be achieved inside extremely nonlinear media. The search for few-photon nonlinearities is a highly active field, including such diverse systems as quantum dots, NV centers in diamond, atomic ensembles, and single atoms in optical resonators. However, no robust and scalable realization of, for example, a single-photon switch has been achieved so far. Here, we present a new approach that aims to realize dramatically enhanced photon-photon interactions by mapping quantum correlations between strongly interacting atoms inside an ultra-cold gas onto single photons. We show that this technique can be used to implement building blocks for photonic quantum information processing, such as a deterministic single-photon source and a quantum phase gate.

A 21: Poster: Precision spectroscopy of atoms and ions

Time: Tuesday 16:30–19:00 Location: Poster.V

A 21.1 Tue 16:30 Poster.V

Einfach- und Doppelionisation von Heliumatomen in schnellen Stößen mit S^{14+}-Ionen — •Helena Gassert[1], Hong-Keun Kim[1], Jasmin Titze[1], Florian Trinter[1], Jörg Voigtsberger[1], Markus Waitz[1], Jasper Becht[1], Till Jahnke[1], Amine Cassimi[2] und Reinhard Dörner[1] — [1]Institut für Kernphysik Frankfurt, Goethe-Universität Frankfurt, Max-von-Laue-Str. 1, 60438 Frankfurt am Main — [2]CIMAP - GANIL, BP 5133, Bd H. Becquerel, 14070 Caen Cedex 5

Vor einigen Jahren durchgeführte Messungen zur Einfachionisation von Helium in schnellen Stößen mit C^{6+}[1] wiesen gravierende Unstimmigkeiten mit der Theorie auf. Die Impulsspektroskopie (COLTRIMS-Technologie) ist eine hervorragende Möglichkeit zur kinematisch vollständigen Untersuchung von Ionisationsprozessen. Diese wurde nun genutzt, um die Einfach- und Doppelionisation von Helium-Atomen in schnellen, nichtrelativistischen Stößen mit S^{14+}-Ionen (11 MeV/u) zu untersuchen und die Impulsvektoren aller geladenen Reaktionsprodukte zu rekonstruieren. Der koinzidente Nachweis erlaubt vor allem die Untersuchung von Korrelationseffekten.

[1] M.Schulz et al., Nature 422, 6927 (2003)

A 21.2 Tue 16:30 Poster.V

Spectroscopic reference for the measurement of the hyperfine transition frequency of highly charged bismuth ions — Sebastian Albrecht[1], •Heiko Jestädt[1], Sanah Altenburg[1], Tobias Murböck[1], Manuel Vogel[1,2], Gerhard Birkl[1], and the SPECTRAP collaboration[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt — [2]GSI, Planckstraße 1, 64291 Darmstadt

The investigation of the ground state hyperfine splitting of highly charged ions is one of the objectives of the experiments planned to be carried out by the SPECTRAP collaboration within the HITRAP facility at GSI. For $^{209}Bi^{82+}$ ions, transitions between hyperfine ground states can be exited using light at 243.9 nm. This light is produced in a laser system and two frequency-doubling stages resulting in 15 mW in the UV [1].

At twice the target wavelength ($\approx$ 488 nm) the light frequency is compared to previously calibrated resonances of molecular tellurium. A maximum deviation of 6 MHz at 244 nm relative to the tellurium spectrum was found. We report on the configuration of the laser system, on an improved determination of the tellurium resonances and on further improvements in the laser system for a reduction in the remaining uncertainty of the laser frequency.

[1] S. Albrecht, S. Altenburg, C. Siegel, N. Herschbach, G. Birkl, Appl. Phys. B, DOI: 10.1007/s00340-011-4732-8 (2011)

A 21.3 Tue 16:30 Poster.V

Radiation Detection Resonance Ionisation Spectroscopy on Nobelium in a buffer gas cell - state of actual development and progess in 2012 — •F. Lautenschläger[1], M. Laatiaoui[1,2], Th. Walther[1], M. Block[2], W. Lauth[3], H. Backe[3], and F.P. Hessberger[2] — [1]Laser und Quantenoptik, Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt — [2]Gesellschaft für Schwerionenforschung GmbH, 64291 Darmstadt — [3]Institut für Kernphysik der Universität Mainz, 55099 Mainz

A novel technique for exploration of the atomic structure of heavy elements has been developed. Based on the Radiation Detection Resonance Ionisation Spectroscopy, it is possible to investigate even isotopes with small half-liveslike nobelium, which can be produced with small rates of a few atoms per second at on-line facilities such as GSI/Darmstadt. After separation from the primary beam by the velocity filter SHIP, the fusion products enter a buffer gas cell, where they are stopped and collected on a tantalum filament. The next step is to re-evaporate the atoms and to ionize them with tunable lasers. Finally the ions will be identified by their characteristic α - decay. First online experiments were performed on Ytterbium and an efficiency of about 1% was obtained. For further improvements, a realistic simulation of the buffer gas cell has been performed. Some results of the simulation and off-line tests will be presented.

A 21.4 Tue 16:30 Poster.V

Prospects for quantum logic spectroscopy of molecular ions — •Yong Wan, Florian Gebert, and Piet O. Schmidt — QUEST Institute for Experimental Quantum Metrology, PTB, Braunschweig

The rapid development in laser cooling and coherent state manipulation over the past decades demonstrated exquisite control of the internal and external degrees of freedom of various species of atomic ions. The same technique can not be easily applied to molecular ions because of their rich internal level structure. On the other hand, ultra cold molecular ions lend themselves for a number of novel applications, ranging from cold chemistry to tests of fundamental theories.

To overcome the obstacle of laser cooling and to achieve a deterministic internal state preparation, we propose to employ the quantum logic technique [1] in which a laser-cooled atomic ion is simultaneously trapped with a single molecular ion. The cooling of the external degrees of freedom of the molecular ion is achieved via sympathetic cooling by the sideband-cooled atomic ion, while the preparation of its internal state will be achieved via a quantum-non-demolition measurement.

The investigated molecules MgH^{+}/CaH^{+} are relevant for the search of a possible temporal variation of the electron-to-proton mass $\mu = m_e/m_p$ [2]. The transition frequency of rovibrational overtone transitions in the molecule depend on μ and can be compared to another optical reference, such as the Al^{+} clock to obtain an improved upper limit for the time variation of μ.

[1] Schmidt et al., Science 309, 749 (2005)
[2] Kajita et al., J. Phys. B 42, 154022 (2009)

A 21.5 Tue 16:30 Poster.V

Spectroscopic studies of charge breeding processes in an elec-

tron beam ion trap — •Thomas Baumann, José Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik

A new generation of electron beam ion traps (EBITs) was developed at the Max-Planck-Institute für Kernphysik (MPIK) and recently introduced in facilities like TRIUMF (TITAN EBIT) and the Michigan State University (MSU EBIT) for charge breeding of rare radioactive isotope beams. Future, more powerful devices are under development. To achieve shorter breeding times, design efforts are aiming at the development of electron guns capable of delivering intensities of several amps. For this purpose a new high current EBIT has been built at MPIK.

The charge breeding process within this machine is studied spectroscopically using two grating spectrometers sensitive in the soft x-ray spectral region and a Silicon drift x-ray detector for photon energies above 1 keV. Soft x-ray spectra of highly charged Silicon ions are presented to show the charge state evolution in dependence of the electron beam energy. Furthermore, detailed spectra around the region of strong recombination resonances (KLL, KLM, KLN) in Si ions have been obtained and compared to structure calculations based on the Flexible Atomic Code (FAC). The data shows strong contribution arising from higher order multielectron resonant transitions.

A 21.6 Tue 16:30 Poster.V

Electromagnetic decay of nuclei by electron-positron pair conversion — •Nikolay Belov and Zoltan Harman — Max-Plank-Institute for Nuclear Physics, Heidelberg, Germany

The pair production process by γ-emission of nuclei has been investigated for a long time both theoretically and experimentally. But, in all theoretical works only the production of a free electron and positron was described. The case when an electron is "born" in the bound state of atom has been neglected as a relatively small effect.

We investigate this bound-free pair productions for different multipolarities of nuclear γ decay. We use a relativistic description of the electron and positron wave functions as it is necessary for heavy elements. It appeared that the contribution of this bound-free process for bare heavy ions at low γ-energies gives a contribution comparable to the free-free process.

These results for the bound-free pair production in bare or highly-stripped ions could be relevant in astrophysics, in the physics of heavy ion acceleration and in atomic spectroscopy.

A 21.7 Tue 16:30 Poster.V

Das SPECTRAP-Experiment zur Präzisionslaserspektroskopie an hochgeladenen Ionen — •Tobias Murböck[1], Zoran Andjelkovic[2,3], Radu Cazan[2], Shailen Bharadia[4], Richard Thompson[4], Manuel Vogel[1,3], Alexander Martin[1], Sebastian Albrecht[1], Wilfried Nörtershäuser[2] und Gerhard Birkl[1] — [1]TU Darmstadt — [2]Uni Mainz — [3]GSI Darmstadt — [4]Imperial College London

Mittels Präzisionslaserspektropie der verbotenen Hyperfeinstruktur-Übergänge von hochgeladenen, wasserstoff- und lithiumähnlichen Ionen kann ein stringenter Test der Quantenelektrodyanmik (QED) gebundener Zustände in starken elektrischen Feldern vollzogen werden. Diesem Zweck dient das SPECTRAP-Experiment, das derzeit als Teil der HITRAP-Kollaboration an der GSI in Darmstadt aufgebaut wird. Wir stellen den Status des Experimentes vor und präsentieren erste Ergebnisse zum Transport, zur Speicherung und Kühlung der Mg^+-Ionen sowie erste Testmessungen mit der *"rotating wall"*-Technik an Ca^+-Ionen. Durch den Aufbau entsprechender Lasersysteme wird die direkte Laserkühlung gespeicherter Mg^+-Ionen und die sympathetische Kühlung anderer Ionenspezies ermöglicht. Darüber hinaus wird ein Ausblick auf geplante Messungen an Pb^+, Ca^{14+} und Ar^{13+} auf dem Weg zur Vermessung der Aufspaltung der Hyperfeinstruktur von hochgeladenen Ionen gegeben.

A 21.8 Tue 16:30 Poster.V

High-precision calculation of the structure of highly charged Fe ions — •Natalia Oreshkina, Zoltan Harman, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

We present accurate theoretical values of the visible and x-ray transition energies in highly charged $^{56}_{26}Fe^{13+}$ to $^{56}_{26}Fe^{16+}$ ions. Relativistic electron correlation calculations are performed within the framework of the configuration interaction method with Dirac-Fock-Sturmian basis functions. For the $3p_{3/2} \rightarrow 3p_{1/2}$ green magnetic dipole transition in $^{56}_{26}Fe^{13+}$, we take into account QED effects by employing an effective screening potential. High-precision calculations of these systems may be important for astronomical research, and in investigations towards the time variation of the fine-structure constant.

A 21.9 Tue 16:30 Poster.V

Nuclear Shape Effect on the g Factor of Hydrogenlike Ions — •Jacek Zatorski, Natalia S. Oreshkina, Christoph H. Keitel, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The nuclear shape correction to the g factor of a bound electron in $1S$-state is calculated for a number of nuclei in the range of charge numbers from $Z = 6$ up to $Z = 92$. The leading relativistic deformation correction has been derived analytically and also its influence on one-loop quantum electrodynamic terms has been evaluated. We show the leading corrections to become significant for mid-Z ions and for very heavy elements to even reach the 10^{-6} level.

[1] J. Zatorski, Natalia S. Oreshkina, Christoph H. Keitel, and Zoltán Harman, 2011arXiv1110.3330Z.

A 21.10 Tue 16:30 Poster.V

A cryogenic Paul trap for highly charged ions and molecular ions — •Maria Schwarz[1], Oscar Versolato[1], Alexander Windberger[1], José R. Crespo López-Urrutia[1], Piet O. Schmidt[2], Michael Drewsen[3], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Gemany — [2]PTB, Braunschweig, Gemany — [3]University of Aarhus, Aarhus, Denmark

Electron beam ion traps are effective tools for spectroscopy of highly charged ions (HCIs). However, their deep trapping potential leads to high temperatures of the stored ions, and limits the final spectral resolution. A new linear cryogenic Paul trap experiment (CryPTEx) in-line with an EBIT will provide long storage times for HCIs due to the extremely low background pressure within a 4K enclosure. Since HCIs do not allow for direct laser cooling, as their optical transitions have low transition rates, one needs to apply sympathetic cooling. The trapped HCIs are coupled by Coulomb-interaction to a low-temperature bath of laser-cooled ions what ultimately should allow to resolve the natural linewidth of forbidden transitions. Our final goal is the application of quantum logic spectroscopy, where a singly charged ion species (Be^+) is responsible for the sympathetic cooling and state detection of the HCI. Crystals of Mg^+ ions and mixed crystals of Mg^+ and MgH^+ ions have been produced. Cooling of the MgH^+ ions allowed us to populate mainly the rovibrational ground state. The cryogenic trap allows to keep polar molecular ions in rotational and vibrational ground states by suppressing blackbody radiation. CryPTEx has been in Aarhus for such experiments in collaboration with the QUANTOP group.

A 21.11 Tue 16:30 Poster.V

Experimental Setup for Bound-Electron g-Factor Measurements by Double-Resonance Spectroscopy of a Fine Structure Transition — •Marco Wiesel[1,2], David von Lindenfels[1,2,4], Wolfgang Quint[1,2], Manuel Vogel[1,3], Alexander Martin[1,3], and Gerhard Birkl[3] — [1]GSI Darmstadt — [2]Universität Heidelberg — [3]TU Darmstadt — [4]MPIK Heidelberg

Magnetic moment measurements of electrons bound in highly charged ions provide access to QED effects in the extreme fields close to the ionic nucleus. Hence a cryogenic Penning trap setup is currently being built to determine the electronic g-factor of boron-like argon (Ar^{13+}) via double-resonance spectroscopy: A closed cycle between the fine structure levels $2^2P_{1/2}$ - $2^2P_{3/2}$ is driven by a laser whereas microwaves are tuned to get in resonance with the Zeeman-sublevel transition. With this frequency and the measurement of the cyclotron ion motion the g-factor can be determined with an expected accuracy of 10^{-9} or better. To this end, we employ an arrangement consisting of a creation trap and a spectroscopy trap. We present an overview of the experiment and give the details and status of the apparatus. In the future, the setup will be connected to the HITRAP beamline at GSI, so hyperfine structure transitions of hydrogen-like heavy ions can be studied and electronic and nuclear magnetic moments can be measured.

A 21.12 Tue 16:30 Poster.V

Discovery of new Praseodymium I energy levels with help of green laser light — •Shamim Khan, Imran Siddiqui, Syed Tanweer Iqbal, and Laurentius Windholz — Institute of Experimental Physics, Graz University of Technology, Petersgasse 16, A 8010 Graz, Austria

The hyperfine structure (hfs) of Praseodymium I spectral lines were experimentally investigated using LIF technique in a hollow cathode discharge lamp. We report here the investigation of 100 spectral lines which resulted in a discovery of 20 new energy levels of even and odd parity. The excitation source is a tunable ring-dye laser system, operated with Coumarin 102. The laser wavelength is tuned to a strong hyperfine component of the investigated spectral line, and fluorescence signals from excited levels are searched. The hfs of the investigated line is recorded by scanning the laser frequency across the investigated region. Magnetic hf interaction constant "A" and angular momentum "J" of the combining lower and upper levels involved in the formation of the line are evaluated. If one of the combining levels is not known (in most cases upper level), the determined angular momentum "J" and hyperfine constant "A" are used to identify one of the involved levels (in most cases the lower level) and the energy of the unknown level is determined by using center of gravity wave number of line and the energy of the identified level. The level found in this way must explain most of the observed fluorescence wavelengths and the hyperfine structure of the fluorescence lines appearing in FT spectrum [1].
[1] B. Gamper et al., J.Phys.B 44, 045003 (2011)

A 21.13 Tue 16:30 Poster.V

Hyperfine structure investigations of Pr-I lines in the region 4200-4450 Å — •Imran Siddiqui, Shamim Khan, Syed Tanweer Iqbal, and Laurentius Windhoz — Institute of Experimental Physics, Graz University of Technology, Petersgasse 16, A 8010 Graz, Austria

Praseodymium I spectral lines were investigated using laser induced fluorescence spectroscopy in a hollow cathode discharge lamp. The investigations led to the discovery of new Pr I energy levels of even and odd parity. A high resolution Fourier transform (FT) spectrum [1] was used to extract promising excitation wavelengths. In the FT spectrum the investigated line 4375.53 Å shows up as a narrow peak hfs with a weak SNR. Nevertheless, the line was excited and fluorescence signals were observed on 6 lines (4163 Å, 4816 Å, 5091 Å, 5164 Å, 5209 Å, 5233 Å). The hfs of the line was recorded by scanning the laser frequency and was fitted to obtain angular momentum J and hf constant A of the combining levels. We got $J_{up} = 5/2$, $A_{up} = 1028.30$ MHz, $J_{lo} = 7/2$ and $A_{lo} = 861.46$ MHz (the subscipts refer to upper and lower level). Assuming an unknown upper level, a known lower level was searched among the known levels having sufficient values of J and A.. The level 7617.440 cm^{-1}, even parity, $J_{lo} = 7/2$ and $A_{lo} = 868$ MHz fulfils these requirements. Using the center of gravity wave number of the line 4375.53 Å and the energy of the lower level, the unknown upper level was calculated to have 30465.424 cm^{-1}, odd parity, $J_{up} = 5/2$ and $A_{up} = 1033(6)$ MHz.
[1] B. Gamper et al., J.Phys.B 44, 045003 (2011)

A 21.14 Tue 16:30 Poster.V

The PRIOC experiment - precision studies on ion collisions using a magneto-optically trapped lithium target — Dominik Globig[1], •Johannes Goullon[1], Renate Hubele[1], Vitor L. B. de Jesus[2], Deepankar Misra[1], Aaron LaForge[1], Hannes Lindenblatt[1], Katharina Schneider[1], Michael Schulz[1], Martin Sell[1], Xincheng Wang[1], and Daniel Fischer[1] — [1]Max-Planck Institut für Kernphysik, Heidelberg — [2]Instituto Federal de Educação, Ciência e Tecnologia do Rio de Janeiro (IFRJ), Nilópolis, RJ, Brazil

In the PRIOC experiment three innovative experimental techniques are combined in order to study ion-atom collisions with unprecedented detail: A magneto-optical trap (MOT) for target preparation is implemented in a Reaction Microscope that enables momentum detection of all collision partners. This 'MOTRemi' setup is operated in an ion storage ring where intense and brilliant ion beams can be provided. Lithium is used as target which is particularly interesting for its simplicity with only one weakly bound outer shell electron. In test experiments on photoionization the performance of the MOTRemi has been tested and an excellent resolution for recoil ion as well as electron momenta has been achieved. Results of first experimental runs on single ionization in ion-atom collisions will be presented.

A 21.15 Tue 16:30 Poster.V

Quadrupole interactions in the hyperfine structure of the titanium atom — Jarosław Ruczkowski, Magdalena Elantkowska, and •Jerzy Dembczyński — Chair of Quantum Engineering and Metrology, Faculty of Technical Physics, Poznan University of Technology, Nieszawska 13B, 60-965 Poznan, Poland

Analysis of the hyperfine structure experimental data for the even configuration system in the titanium atom allow to divide the observed hyperfine splittings into contributions of ranks K=1,2 and 3 of the hyperfine structure operator.

The direct diagonalization of the hyperfine structure matrix yield the corrected values of the hyperfine structure constants A, B and C. The observed and calculated hyperfine structure intervals were in good agreement within the experimental accuracy.

Using the fine structure eigenvectors and the quadrupole interactions angular coefficients matrix, the radial parameters of the magnetic quadrupole interactions were determined.

This work was supported by The National Centre for Science under the project N N519 650740

A 21.16 Tue 16:30 Poster.V

Parametrization of the transition probabilities in Th II — •Przemysław Głowacki, Jerzy Dembczyński, Magdalena Elantkowska, and Jarosław Ruczkowski — Chair of Quantum Engineering and Metrology, Faculty of Technical Physics, Poznan University of Technology, Nieszawska 13B, 60-965 Poznan, Poland

In order to parametrize the transition probabilities, the matrix of angular coefficients of the possible transitions in multiconfiguration system were calculated.

Using the fine structure eigenvectors for both parities, the linear equations for the oscillator strengths were obtained.

The least square fit to experimental values for some transitions, allow to obtain the values of radial parameters and parametrize the transition probabilities.

This work was supported by The National Centre for Science under the project N N519 650740

A 21.17 Tue 16:30 Poster.V

A lattice-based magnesium frequency standard — •Dominika Fim, Hrishikesh Kelkar, Andre Pape, Temmo Wübbena, André Kulosa, Steffen Rühmann, Klaus Zipfel, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Optical lattice clocks outperform the best microwave clocks. A key for the improvement is the confinement in a lattice at the Lamb-Dicke limit to suppress the influence of the first order Doppler effect in frequency measurements. The application of this method requires the existence of a magic wavelength for the lattice, where the AC Stark shift of the two clock states compensate each other. Thanks to these methods today's state-of-the-art optical clocks are limited by Stark effect of the blackbody radiation (BBR). The element magnesium allows to implement an optical lattice clock and shows in addition a lower sensitivity in terms of uncertainty to BBR. We report on the status of the magnesium lattice clock at LUH.

A 21.18 Tue 16:30 Poster.V

Resonant K-shell hole excitation in highly charged iron ions — •Jan Rudolph[1,2], Sven Bernitt[1], René Steinbrügge[1], and José Crespo López-Urrutia[1] — [1]Max Planck Institut für Kernphysik, Heidelberg — [2]Institut für Atom- und Molekülphysik, Universität Gießen

K-shell transitions and especially Kα features are most prominent in active galactic nuclei X-ray spectra. To perform laboratory astrophysics experiments on these processes in iron ions, high fluxes of X-ray photons near 6700eV are required. We used the transportable Heidelberg electron beam ion trap (FLASH-EBIT) to carry out high resolution resonant X-ray scattering measurements on He- and Li-like iron ions at PETRA III, a new 4th generation synchrotron radiation source.

The undulator beam line P01 which is equipped with a double crystal monochromator provided beams of $10^{13}\gamma\ s^{-1}$ at 6700eV. With a photon beam resolution of 0.1 eV, the natural line width of electric dipole allowed X-ray transitions and their corresponding energies could be determined.

A 21.19 Tue 16:30 Poster.V

Dynamic properties of $^{172}Yb^{+}$ ion Coulomb crystals in Paul trap — •Kristijan Kuhlmann[1], Karsten Pyka[1], Jonas Keller[1], David-Marcel Meier[1], and Tanja E. Mehlstäubler[1,2] — [1]Quest-Institute, Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Department of Time & Frequency, Physikalisch-Technische Bundesanstalt, Braunschweig

Towards building an $^{172}Yb^{+}/^{115}In^{+}$ optical clock yielding a frequency standard with a relative inaccuracy $\Delta\nu/\nu \sim 10^{-18}$, we study the dynamic properties of $^{172}Yb^+$ ion Coulomb crystals in a linear Paul trap and the stability of linear ion chains close to the 'zigzag' phase transition. Furthermore, we present our new apparatus, the characterisation of our ion trap and results of micromotion measurements.

In order to obtain large secular frequencies, a helical resonator with a loaded Q=640 has been developed. In our experimental setup with a background pressure of $1\cdot10^{-10}$ mbar, single ion life times of up to 33h, linear chains of 50 ions and large 3D crystals have been realised. Also, using secular frequency measurements, decays in fluorescence of large laser cooled crystals were identified as $YbOH^+$ molecule formations.

A 21.20 Tue 16:30 Poster.V

Trapping of short lived Ra^+ ions — •H. Bekker, M. Nunes Portela, D. Seelen, O. Dermois, K. Jungmann, C.J.G. Onderwater, R.G.E. Timmermans, L. Willmann, and H.W. Wilschut — KVI, University of Groningen, NL

A Precision measurement of atomic parity violation in order to determine electroweak mixing angle at low energy scale is underway at the KVI, University of Groningen. The experiment exploits the large sensitivity of a single trapped Ra^+ ion. It requires the trapping of short lived radium ions in a Paul trap. Our first laser spectroscopy on an ensemble of trapped short-lived $^{209-214}Ra^+$ isotopes employed buffer gas cooled ions in a linear Paul trap. It provided hyperfine structure of the 6d $^2D_{3/2}$ states and isotope shift of the 6d $^2D_{3/2}$-7p $^2P_{1/2}$ transition [1,2]. In a next step the buffer gas cooled Ra ions are extracted from the trap and transported in an electrostatic transport system towards a small Paul trap in an UHV environment. Here the ion can be cooled and subsequently microwave transitions between hyperfine states in the 6d $^2D_{3/2}$ manifold can be driven in order to yield high precision results on the hyperfine constants. These results provide input for the ongoing precision atomic structure calculations.

[1] O. O. Versolato et al. Phys. Lett. A 375 (2011) 3130-3133.
[2] G. S. Giri et al. Phys. Rev. A 84 (2011) 020503(R).

A 21.21 Tue 16:30 Poster.V

maXs: Metallic Magnetic Calorimeters for High-Resolution X-ray Spectroscopy in Atomic Physics — •Christian Pies, Sönke Schäfer, Sebastian Kempf, Jan-Patrick Porst, Simon Uhl, Sebastian Heuser, Thomas Wolf, Loredana Gastaldo, Andreas Fleischmann, and Christian Enss — Kirchhoff Institut für Physik, INF 227, 69120 Heidelberg

Highly-charged ions are model systems for the investigation of quantum electrodynamical effects in strong electromagnetic fields.

We are developing x-ray detectors based on 1x8 arrays of Metallic Magnetic Calorimeters (MMCs) optimized for x-ray spectroscopy of highly-charged ions at GSI/FAIR and the EBIT facility at the MPI for Nuclear Physics in Heidelberg. One of the detector arrays (maXs-20) is designed to provide an energy resolution below 3 eV (FWHM) and sufficient stopping power for x-rays in the energy range up to 20 keV. The second device (maXs-200) is optimized for the detection of x-rays up to 200 keV and should yield an energy resolution below 30 eV (FWHM).

We present detector designs, outline the micro-fabrication process and discuss the results of characterization measurements with ^{55}Fe and ^{241}Am calibration sources including energy resolution, signal shape and cross-talk between adjacent detectors of both arrays.

A 21.22 Tue 16:30 Poster.V

Aufbau und Inbetriebnahme eines verbesserten Laser-Raman-Systems für das KATRIN-Experiment — •Sebastian Mirz — für die KATRIN-Kollaboration - Institut für exp. Kernphysik, Karlsruher Institut für Technologie, Karlsruhe, Deutschland

Das Karlsruhe Tritium Neutrino Experiment KATRIN untersucht das Energiespektrum des Tritium β-Zerfalls nahe des Endpunkts zur Bestimmung der Neutrinomasse mit einer Sensitivität von 200 meV/c^2 (90% C.L.). Dazu wird kontinuierlich Tritiumgas in die fensterlose gasförmige Tritiumquelle eingespeist, deren physikalischen Eigenschaften auf 10^{-3} stabilisiert werden müssen. Zu diesen gehört die Tritiumreiheit des eingespeisten Gases, die durch ein Laser-Raman-Systems mit einer statistischen Unsicherheit von besser 10^{-3} überwacht wird. Mit den bereits am Tritiumlabor Karlsruhe aufgebauten Systemen konnte diese Anforderung innerhalb von 250 s Messzeit erreicht werden.

Im Rahmen dieser Arbeit wurde ein verbessertes Laser-Raman-System aufgebaut und Testmessungen mit Tritium durchgeführt. Durch eine verbesserte Strahlführung wurde die Laserintensität im Messvolumen nahezu verdoppelt. Das Rauschen im Spektrum wurde durch eine optimierte Auslese des verwendeten Bildsensors reduziert. Durch diese Maßnahmen konnte die Präzision der Raman-Messung verbessert werden. Mit den Testmessungen konnte entsprechend gezeigt werden, dass die Messzeit, bei Wahrung einer stat. Unsicherheit von 10^{-3}, von 250 s auf 60 s reduziert werden kann.

In diesem Beitrag werden die Verbesserungen des Laser-Raman-Systems vorgestellt und die Ergebnisse der Testmessung präsentiert.

A 22: Poster: Interaction with strong or short laser pulses

Time: Tuesday 16:30–19:00 Location: Poster.V

A 22.1 Tue 16:30 Poster.V

A Penning trap experiment for advanced studies with ions in extreme laser fields — •Manuel Vogel[1,2], Wolfgang Quint[1,3], Gerhard Paulus[4,5], and Thomas Stöhlker[1,3,5] — [1]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt — [2]Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt — [3]Physikalisches Institut, Ruprecht Karls-Universität Heidelberg, 69120 Heidelberg — [4]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, 07743 Jena — [5]Helmholtz-Institut Jena, 07743 Jena

We present a Penning trap experiment for advanced studies with confined particles in extreme laser fields. Special interest lies in non-linear processes such as multiphoton ionization. Trap-specific manipulation techniques allow control over the stored particles' localization and spatial density. It is possible to select and prepare well-defined ion ensembles and to optimize the laser-particle interaction which is of special importance when laser foci are small. Non-destructive detection of reaction products with up to single-ion sensitivity supports advanced studies by maintaining the products for further studies at extended confinement times of minutes.

A 22.2 Tue 16:30 Poster.V

Strong field ionization to multiple electronic states in water — Joe P. Farrell[1], •Simon Petretti[2], Johann Förster[2], Brian K. McFarland[2], Limor S. Spector[2], Yulian V. Vanne[1], Piero Decleva[3], Philip H. Bucksbaum[2], Alejandro Saenz[1], and Markus Gühr[2] — [1]Stanford University, USA — [2]Humboldt-Universität zu Berlin, Germany — [3]Universitá di Trieste, Italy

In this combined experimental and theoretical work the high harmonic spectrum of water molecules has been investigated [1]. The experiment uses the ratio of H_2O and D_2O high harmonic yields to isolate the characteristic nuclear motion of the molecular ionic states without the necessity of prealignment. The nuclear motion initiated via ionization of the highest occupied molecular orbital (HOMO) is small and is expected to lead to similar harmonic yields for the two isotopes [2]. However, as is shown in this work, ionization of the second least bound orbital (HOMO-1) exhibits itself via a strong bending motion which creates a significant isotope effect. We elaborate on this interpretation by simulating strong field ionization and high harmonic generation from the water isotopes using the time-dependent Schrödinger equation [3]. We expect that this isotope marking scheme for probing excited ionic states in strong field processes can be generalized to other molecules.

[1] Farrell *et al.*, Phys. Rev. Lett., **107**, 083001 (2011).
[2] Falge *et al.*, Phys. Rev. A, **81**, 023412 (2010).
[3] Petretti *et al.*, Phys. Rev. Lett., **104**, 223001 (2010).

A 22.3 Tue 16:30 Poster.V

Electron spin dynamics in a laser field — •Oleg Skoromnik[1], Iliya Feranchuk[2], Christoph Keitel[1], and Karen Hatsagortsyan[1] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Physics Department, Belarusian State University, 4 Nezavisimosty avenue, 220030 Minsk, Belarus

In the present work the electron spin evolution in the presence of a quantized plane electromagnetic wave is considered. The initial problem for the Dirac equation was solved when the field is in the coherent state. The solution gives possibility to investigate the effect of the electron spin rotation which is originated from the quantum nature of the electromagnetic field.

A 22.4 Tue 16:30 Poster.V

Creation and Observation of Electronic Wave-Packet Motion in Atoms by Strong Field Ionization — •Lutz Fechner, Nicolas Camus, Thomas Pfeifer, Joachim Ullrich, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Heidelberg

Using a pump-probe scheme for sequential double ionization of atoms in strong few-cycle laser pulses we prepare a coherent superposition of electronically excited states in the singly charged ion with the first pulse that is probed by the time-delayed second pulse. The dynamics of the electronic wave-packet, which reflects the inner structure of the particular atom, has a strong influence on both the delay dependent total ionization yield and the momentum distribution of the electrons released in the second step. In comparison to a recent experiment [1], where recoil-ion momentum spectroscopy was used, we present first kinematically complete measurements on Ne and Ar using a Reaction Microscope that allows to measure the three-dimensional momenta of all particles (ions and electrons) in coincidence.

[1] A. Fleischer *et al.*, Phys. Rev. Lett. **107** (2011), 113003

A 22.5 Tue 16:30 Poster.V

Electron emission from H_2^+ in circularly polarized strong fields including nuclear motion or full electronic coordinate space — •Myroslav Zapukhlyak[1], Jost Henkel[1,2], and Manfred Lein[1] — [1]Institut für Theoretische Physik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Institut für Physikalische und Theoretische Chemie and Röntgen Research Center for Complex Material Systems, Am Hubland, 97074 Würzburg, Germany

Inspired by recent work on strong field ionization of H_2^+ [Odenweller *et al.*, PRL **107**, 143004 (2011)] we show new quantum mechanical calculations on this molecular system in circularly polarized laser pulses. We extend previous calculations by including nuclear motion on the one hand and full three-dimensional electronic motion on the other hand. By doing so, we explore the coupled nuclear-electronic dynamics to find the most contributing nuclear distance. Regarding the anisotropy of electron emission from the fixed-in-space molecular ion, we gain additional information from the lateral width of the electronic momentum distribution, which gives depletion-insensitive information about system and laser pulse.

A 22.6 Tue 16:30 Poster.V

Electron-energy bunching in laser-driven soft recollisions — •Alexander Kästner, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Dresden

We introduce soft recollisions in laser-matter interaction. They are characterized by a recollision of the electron aside the ion in contrast to the well-known head-on collisions responsible for high-harmonic generation or above-threshold ionization. We demonstrate that soft recollisions can cause a bunching of photo-electron energies through which a series of low-energy peaks emerges in the electron yield along the laser polarization axis [1]. This peak sequence is universal, it does not depend on the binding potential, and is found below an excess energy of one tenth of the ponderomotive energy. Furthermore we show that this series could be uncovered experimentally by use of few-cycle pulses with increasing pulse duration [2].

[1] A. Kästner, U. Saalmann and J.M. Rost, Phys. Rev. Lett. (in press).

[2] A. Kästner, U. Saalmann and J.M. Rost, J. Phys. B (in press).

A 22.7 Tue 16:30 Poster.V

The Physical Potential for the Tunneling Problem and Its Implementation — •Enderalp Yakaboylu, Michael Klaiber, Heiko Bauke, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik (MPIK) Saupfercheckweg 1 69117 Heidelberg, Germany

In this work, laser-driven tunnel-ionization of ionic systems in the relativistic regime is considered. After giving a phenomenological definition of tunneling, the form of the potential barrier is investigated. Therefore in a first step the gauge-dependency of the system is eliminated and conditions on the electromagnetic field that make the effective potential a physical one are found via a path dependent formalism. Then the validity of these conditions is discussed for typical laser parameters and the results of this theoretical analysis are applied to interpret numerical calculations of the problem.

A 22.8 Tue 16:30 Poster.V

Modeling atoms in laser fields using time-dependent density functional theory: Applicability of the frozen-core approximation — •Julius Rapp, Varun Kapoor, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

We check the validity of the frozen-core approximation (FCA) in time-dependent density functional theory (TDDFT) for an atom interacting with a laser field. For this purpose we investigate an exactly solvable 1D model for Li with the help of TDDFT considering different exchange-correlation (XC) functionals. Observables such as the ionisation rate, the energy absorption rate and the dipole expectation value are obtained with and without FCA.

Comparisons among the different TDDFT results on one hand and with the exact numerical solution of the time-dependent Schrödinger equation on the other hand show that the propagation of core electrons in time does significantly affect the observables of the valence electron. Additionally, we find a strong dependency of TDDFT observables on the XC functional used even though the values for the ionisation potentials are equal.

We conclude that pseudopotentials (which apply the FCA or even bolder approximations) must yield inaccurate results in TDDFT simulations of strong-field ionization even for an otherwise exact XC functional.

A 22.9 Tue 16:30 Poster.V

Energy Quantization in double-ionization of Helium — •Kevin Henrichs, Markus Schöffler, Till Jahnke, Hendrik Sann, Maksim Kunitzki, Martin Pitzer, Christoph Goihl, and Reinhard Dörner — Institut für Kernphysik, Frankfurt (Main), Germany

ATI("above-threshold-ionization")-peaks in single-ionization have been recorded several times. In double ionization they haven*t been observed so far, but should show up in the sum-energy of the two electrons. So far the explanation is the limited energy resolution. Therefore we use a laser with a wavelength of 400 nm instead of 800 nm to increase the energy spacing of the ATI-peaks from 1.5 to 3 eV. The laser is focused on a pre-cooled super sonic gas jet. Created electrons are projected onto position and time sensitive detector using a weak electric and for guidance also a magnetic field. Helium ions are projected onto a second detector and measured in coincidence with the electrons. With this information we calculate the three-dimensional momentum vectors of the participating particles and their energies.

A 22.10 Tue 16:30 Poster.V

TDDFT on a Curvilinear Grid — •Volker Mosert and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Ultrashort and intense laser pulses provide a magnificent tool for the investigation of electronic structure of atoms and molecules. For a theoretical understanding of the underlying physics one has to deal with the time dependent many particle Schrödinger equation. A method capable of this feat—at least in principle—is the time dependent density functional theory (TDDFT). In order to model strong field effects by TDDFT one needs an efficient numerical scheme to solve the time dependent Kohn-Sham equations.

By employing a spatially homogeneous representation of the Kohn-Sham Hamiltonian the storage and propagation of the Kohn-Sham orbitals rapidly becomes infeasible for increasing ionic charges and strong laser fields. Additionally ionization dynamics may not be correctly described by pseudo potentials. Hence it is desirable to provide a high spatial resolution in the vicinity of the ions and at the same time restrict the resolution where the orbitals can be expected to be smooth. This can be achieved by a suitable coordinate transformation as was shown for the case of ground state DFT more than ten years ago. In this contribution will be shown, that this technique can also ease the computational burden in the case of time dependent calculations.

A 22.11 Tue 16:30 Poster.V

Structure of XUV frequency combs generated by trains of few-cycle pulses — •Maria Tudorovskaya and Manfred Lein — Institut für Theoretische Physik and Centre for Quantum Engineering

and Space-Time Research (QUEST), Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

The spectrum of a high-repetition train of laser pulses consists of many equally spaced lines, known as an optical frequency comb and useful in high-precision spectroscopy. By exposing atoms to a strong pulse train, it is possible to produce an XUV frequency comb by means of high-harmonic generation. In these experiments, the driving laser field does not usually have zero offset frequency, leading to order-dependent harmonic offset frequencies. We study theoretically the generation of XUV frequency combs by trains of few-cycle pulses, which generate overlapping harmonics. The structure of such combs and in particular the spacing between the "teeth" is investigated.

A 22.12 Tue 16:30 Poster.V

XUV pulse induced fluorescence of a nano plasma from argon clusters — •Lena Nösel[1], Maria Müller[1], Marcus Adolph[1], Daniela Rupp[1], Tais Gorkhover[1], Maria Krikunova[1], Tim Oelze[1], Lasse Schrödter[2], Andreas Prystawik[2], Andreas Kickermann[2], Tim Laarmann[2], and Thomas Möller[1] — [1]TU Berlin, Institut für Optik und Atomare Physik, Deutschland — [2]Hasylab/DESY, Notkestr.85, 22607 Hamburg

The high peak intensities of up to $10^{15} * W/cm^2$ of the Free Electron Laser in Hamburg (FLASH) opened up a new field for the investigation of light-matter interaction especially with pulse durations of 10 fs to 100 fs in the soft x-ray regime at 90eV. Our experiment concentrates on argon clusters where a nano plasma is formed during the interaction with the soft x-ray pulses. Fluorescence spectroscopy is used to investigate recombination processes within this nano plasma. We follow the development of fluorescence spectral lines produced by the interaction of the argon clusters with the XUV- radiation. Results of our study show that with increasing intensity of ionizing radiation the photo lines corresponding to the higher charge states increase while the lines attributed to the lower ionic charge states drop down. Furthermore, at highest achieved intensity fluorescence lines with photon energy above the XUV excitation energy of 90eV could be detected. This is indicative for non-linear processes during excitation of the clusters.(cf. [1])

[1] U.Saalmann et al., J.Phys.B:At.Mol.Opt.Phys.39(2006)R39-R77.

A 22.13 Tue 16:30 Poster.V

Probing Fano resonances with ultrashort pulses — •Jing Zhao and Manfred Lein — Institut für Theoretische Physik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

Autoionizing states in the helium atom are investigated by numerical solution of the one-dimensional two-electron Schrödinger equation for irradiation of an XUV pulse and an infrared pulse with varying time delay. By analysing the photoelectron spectrum as a function of the time delay, it is shown that the line profile of the Fano resonance is modified by the laser-induced coupling between two doubly excited autoionizing resonances. The strong coupling leads to the population of higher autoionizing states, which cannot be reached by absorbing a single XUV photon from the ground state, and the excited atom can ionize from both states. An asymmetric Autler-Townes doublet due to the strong coupling is also observed in the photoelectron spectrum.

A 22.14 Tue 16:30 Poster.V

Doppelionisation von Helium mit ultrakurzen zirkular polarisierten Laserpulsen — •Markus Schöffler[1,2], Xinhua Xie[2], Stefan Roither[2], Danil Kartashov[2], Andrius Baltuska[2], and Markus Kitzler[2] — [1]Institut für Kernphysik, J. K. Goethe-Universität Frankfurt am Main, 60438 Frankfurt — [2]Institut für Photonik, TU Wien, 1040 Wien, Österreich

Doppelionsation von Atomen in starken Laserfeldern kann sequentiell oder nicht-sequentiell ablaufen. Bei den verwendeten zirkular polarisierten Laserpulen und Intensitäten bis 2e16 W/cm2 erfolgt die Doppelionisation ausschließlich sequentiell, da Rekollision ausgeschlossen ist. Ultrakurze Laserpulse (4 fs) wurden auf einen gekühlten Helium-Überschallgasstrahl fokussiert. Die geladenen Fragmente wurden mittels der Impulsspektroskopie (COLTRIMS) gemessen. Die Impulsverteilung der He2+ Ionen zeigt zwei Ringe, welche paralleler und antiparalleler Emission der Elektronen entspricht und variiert insgesamt sehr stark mit der Intensität, Pulslänge und der CE-Phase.

A 22.15 Tue 16:30 Poster.V

Quantum orbit analysis of molecular strong-field photoelectron spectra — •Norbert Weinkauf, Tian-Min Yan, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Laser-induced electron diffraction is a promising method for investigating molecular structure. The photoelectron momentum distributions contain a wealth of target information and sensitively depend on the laser parameters and the orientation of the molecule with respect to the laser polarization axis. We investigate photoelectron momentum spectra by solving the time-dependent Schrödinger equation for two-dimensional model molecules. We distinguish atom-like interference effects from the orientation-dependent molecular features. In order to identify Coulomb-effects we compare with the strong-field approximation (SFA) and the recently developed trajectory-based Coulomb-corrected SFA. The latter provides ultimate insight into the underlying quantum dynamics, as each spectral feature may be interpreted in terms of interfering quantum orbits.

A 22.16 Tue 16:30 Poster.V

Interference Effects in Electron-Positron Pair Creation by the Interaction of a Bichromatic Laser Field and a Nucleus — •Sven Augustin and Carsten Müller — Max-Planck-Institut für Kernphysik, Heidelberg

We investigate the creation of electron-positron pairs in the superposition of a nuclear Coulomb field and a two-colour laser field of high intensity. Herein our focus lies on quantum interference effects which may arise if the two laser frequencies are commensurate.

The interference manifests in the angular distributions of the created particles and the total pair production rates. In addition, the influence of the relative phase between the two laser modes is studied.

A 23: Poster: Electron scattering and recombination

Time: Tuesday 16:30–19:00 Location: Poster.V

A 23.1 Tue 16:30 Poster.V

Dielectronic recombination of highly charged iron measured by extracting ions from an EBIT — •René Steinbrügge, Sven Bernitt, Christian Beilmann, José R. Crespo López-Urrutia, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Dielectronic recombination (DR) is the resonant capture of an electron into a highly charged ion with the kinetic energy transferred to a bound electron, resulting in a doubly excited state. Due to large cross sections compared with non-resonant processes, it is highly important in hot plasmas. Electron beam ion traps (EBIT) are suitable tools for investigating this process. We present DR measurements of He-, Li- and Be-like iron carried out at the FLASH-EBIT. In addition to X-rays emitted during the relaxation of the excited state, DR was detected by the change in the charge state distribution. For this purpose the ions were extracted from the EBIT, charge separated by a Wien-type velocity filter and detected on a position sensitive detector. This allows to distinguish the contributions of different charge states. During the measurement new methods based on analysis of the extracted ions and space charge compensation were successful tested, promising further improvements in future experiments.

A 23.2 Tue 16:30 Poster.V

Multiple scattering in electron impact ionization of aligned H_2 molecules — Xueguang Ren, Thomas Pflüger, Arne Senftleben, •Alexander Dorn, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, 69117 Heidelberg

Ionization of molecular hydrogen (H_2) by 54 eV electron impact is investigated with an advanced reaction microscope. The alignment of the H_2 molecular axis during the collision is determined by the post-collision dissociation process of the H_2^+ ion. By triple-coincidence detection of the proton and both final state electrons the complete collision kinematics is determined. Therefore, fully differential cross sections for fixed in space molecular axis were measured. The ejected electron is observed to be emitted into two preferential directions: firstly, along the momentum transfered by the projectile and, secondly, along the molecular axis which involves another scattering process for the ejected electron. A first numerically demanding state-of-the-art theory shows satisfactory agreement with the experimental data.

A 23.3 Tue 16:30 Poster.V

Unexpected high strength of intershell trielectronic recombination — •C. Beilmann[1], P.H. Mokler[1], S. Bernitt[1], C.H. Keitel[1], J. Ullrich[1], J.R. Crespo López-Urrutia[1], and Z. Harman[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]ExtreMe Matter Institute (EMMI), Darmstadt, Germany

Intershell *KL-LLL* trielectronic recombination (TR) in highly charged ions, where a *K*-shell and a *L*-shell electron are simultaneously excited by the capture of a free one, was supposed to occure in neglectible strength due to the large excitation energy and a weak electron-electron interaction in inter-shell processes. In our experiments and accompanying *ab initio* MCDF calculations, we show that these higher order contributions to the total recombination yield grow to an unexpected strength in light and mid-heavy ions. The experimental results of TR measurements in Ar, Fe and Kr allow for the deduction of a scaling law for the TR strength in dependence of Z. In C-like ions with $Z \leq 20$, TR even dominates over the first order dielectronic process [1]. These surprising findings should be taken into account in the detailed modelling of astrophysical and fusion plasmas. This is important in view of the problem of missing opacities in calculations of the solar matter and can also help improving plasma diagnostics of laboratory plasmas. Furthermore, the strong sensitivity of the TR process to eletron-electron interaction gives new experimental access to the study of inner-atomic electron correlation effects.

[1] C. Beilmann et al., Phys. Rev. Lett. 107, 143201 (2011)

A 23.4 Tue 16:30 Poster.V

Nuclear Excitation by Electron Capture in Stellar Environments — •Stephan Helmrich, Katja Beckerle, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

In the resonant process of nuclear excitation by electron capture (NEEC), the recombination of a continuum electron leads to the excitation of the nucleus [1]. NEEC becomes increasingly efficient with rising electron density and degree of ionization of the atoms involved. These are the predominant conditions in the interior of stars and supernovae. In the context of isomer depletion, NEEC populating low-lying nuclear excited states under dense stellar plasma conditions has been investigated [2].

In the present work we consider for the first time NEEC built on highly excited states close to the neutron threshold prior to their decay. Neutron capture and successive gamma decay followed by beta decay of the thus formed neutron-rich daughter nucleus constitutes the basic reaction leading to the synthesis of heavy isotopes. We show that even low-energetic NEEC on the order of tens of keV following neutron capture may significantly change the net decay rates of the formed compound nucleus. Thus, neutron re-emission becomes predominant at the expense of gamma decay, significantly suppressing the production of the daughter isotope.

[1] A. Pálffy, W. Scheid and Z. Harman, Phys. Rev. A 73, 012715 (2006).
[2] G. Gosselin, P. Morel and P. Mohr, Phys. Rev. C 81, 055808 (2010).

A 23.5 Tue 16:30 Poster.V

Investigation into anomalies in electron scattering cross sections of H_2 and D_2 molecules — •Adrian Menssen[1], Florian Trinter[1], Markus Waitz[1], Markus Schöffler[1,3], Daniel Fischer[2], Horst Schmidt-Böcking[1], and Reinhard Dörner[1] — [1]Goethe Universität, Frankfurt, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Institut für Photonik, TU Wien, Gusshausstraße 27, Wien, Austria

For scattering of electrons or neutrons at a molecule at sufficiently high momentum transfers intramolecular dynamics and coherence effects are typically neglected: One only considers a binary scattering process between the incident electron and one constituent of the molecule. However recent experiments suggested an unexpected breakdown of this binary scattering approximation. Cooper et al. observed differences of up to 30 % in the total electron scattering cross-sections of H_2 and D_2: H_2 appeared to be "smaller "than expected.

We have been aiming to observe this same effect, however in a different experimental approach at momentum transfers between 2 and 4 a.u. Hydrogen-like O^{7+} and Magnesium Mg^{11+} were accelerated to energies between 30 and 90 MeV and then crossed with a supersonic gas-jet (50:50 mixture of H_2 and D_2) at 298 K. The projectile can be ionised by interaction of its electron with the target-molecule nucleus (n-e) or with one of the molecular electrons (e-e). Both processes (n-e and e-e) can be distinguished in momentum space.

A 23.6 Tue 16:30 Poster.V

Electron induced double and triple fragmentation of CH_4 — •Xueguang Ren, Thomas Pflueger, Shenyue Xu, Arne Senftleben, Alexander Dorn, and Joachim Ullrich — Max-Planck-Institut fuer Kernphysik , 69117 Heidelberg, Germany

Collisions of energetic electrons with molecules that induce chemical and physical reactions are of fundamental importance for a range of areas from plasma physics to radiation damage in living tissue. The study of dissociative ionization of molecules where the molecular ion is fragmenting can provide detailed insight into the molecular reaction dynamics. The fragmentation process of small polyatomic molecules has been extensively investigated for which one electron of the target molecule is ionized resulting in some dissociating states, see e.g. [1]. In this work, the fragmentation cross sections of doubly or triply charged methane induced by 130 eV electron impact has been measured using the reaction microscope, in which the momentum vectors of all charged particles emerging from the collision are measured in coincidence and detected in 4π solid angle. Therefore, the information of the kinetic energy of fragments is determined to get insight into its breakup mechanism. The sensitivity of the experimental method enable us to extend the study of the fragmentation pattern of CH_4^{2+} to include small breakup channels such as $H_3^+ + CH^+$. Furthermore, some breakup channels of the triply charged CH_4^{3+} have been detected as triple coincidence. [1] S. Xu, et al., Phys. Rev. A 83, 052702 (2011).

A 24: Poster: Interaction with VUV and X-ray light

Time: Wednesday 16:30–19:00 Location: Poster.V

A 24.1 Wed 16:30 Poster.V

Relativistic calculations of atomic transition, ionization and recombination properties — •Stephan Fritzsche — GSI Helmholtzzentrum für Schwerionenforschung & Frankfurt Institute for Advanced Studies, Germany; Department of Physics, University of Oulu, Finland

The Ratip program has been developed during the past years to calculate the electronic structure and properties of atoms and ions [1]. Today, this program provides a powerful platform in order to generate and evaluate atomic data for open-shell atoms, including level energies and energy shifts, transition probabilities, Auger parameters as well as a variety of excitation, ionization and recombination amplitudes and cross sections. Although the Ratip program focus on properties with just *one* electron within the continuum, recent emphasis was placed also on second-order processes as well as those properties for which different types of (many-electron) amplitudes need to be combined in order explain complex spectra at synchrotron and FEL light sources. Here, I present and discuss the (design of the) Ratip program, of which a major part now becomes public. Selected examples refer to the — direct and sequential — double ionization of various atoms [2,3].

[1] S. Fritzsche, submitted to Comput. Phys. Commun. (2011).
[2] P. Linusson et al., Phys. Rev. A **83** (2011) 023424.
[3] S. Fritzsche et al., J. Phys. B **44** (2011) 175602.

A 24.2 Wed 16:30 Poster.V

Two-photon absorption of few-electron heavy ions — Andrey Surzhykov[1,2], Paul Indelicato[3], Jose-Paulo Santos[4], Pedro Amaro[4], and •Stephan Fritzsche[2,5] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]GSI Helmholtzzentrum für Schw-

erionenforschung, Germany — [3]Laboratoire Kastler Brossel, Paris, France — [4]Departamento de Física, Universidade Nova de Lisboa, Portugal — [5]Department of Physics, University of Oulu, Finland

The two-photon absorption of few-electron ions has been studied theoretically in the framework of second-order perturbation theory and Dirac's relativistic equation. Expressions were derived especially for the excitation cross sections and rates, including the contribution of higher-order multipoles in the expansion of the electron-photon interaction. Though these expressions are independent of the particular shell structure of the ion, detailed computations have been carried out for the two-photon absorption of hydrogen-, helium-, and berylliumlike ions and are compared with the available theoretical and experimental data. In this contribution, we discuss the relativistic and nondipole effects upon the induced two-photon transitions as well as the potential for exploring parity-violating interactions in high-Z ions [1].

[1] A. Surzhykov et al., Phys. Rev. A **84** (2011) 022511.

A 24.3 Wed 16:30 Poster.V

Photon-ion spectrometer PIPE at the Variable Polarization XUV Beamline of PETRA III — •Stefan Schippers[1], Sándor Ricz[1,2], Ticia Buhr[1,3], Jonas Hellhund[1], Alfred Müller[1], Stephan Klumpp[4], Karolin Mertens[4], Michael Martins[4], Roman Flesch[5], Eckart Rühl[5], Julian Lower[6], Till Jahnke[6], Daniel Metz[6], Lothar Ph. H. Schmidt[6], Reinhard Dörner[6], Alexander Dorn[7], and Andreas Wolf[7] — [1]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen — [2]ATOMKI, Debrecen, Hungary — [3]PTB, Braunschweig — [4]Institut für Experimentalphysik, Universität Hamburg — [5]Institut für Chemie und Biochemie, Freie Universität Berlin — [6]Institut für Kernphysik, Johann-Wolfgang-Goethe Universitä Frankfurt — [7]Max-Planck-Institut für Kernphysik, Heidelberg

The Photon-Ion spectrometer at PETRA III (PIPE) is a newly built permanent end station at the Variable Polarization XUV Beamline (P04) of the third-generation synchrotron light source PETRA III in Hamburg. Mass/charge selected atomic, (bio)molecular and cluster ions with masses of up to 30000 u, and neutral species can be used as targets for the study of the interaction of gaseous matter with linearly and circularly polarized photons in the energy range 250–3000 eV. State-of-the-art photo-product detection techniques are employed, such as COLTRIMS, high-resolution electron spectroscopy, and fluorescence detection. Details will be presented on the poster.

A 24.4 Wed 16:30 Poster.V

Traptor - A Multipole Radiofrequency Trap for PIPE, the ion beam facility at PETRA III — Alexander Guda[1,2], •Ricarda Laasch[1], Stephan Klumpp[1], and Michael Martins[1] — [1]Universität Hamburg, Institut für Experimentalphysik, Hamburg — [2]Southern Federal University, Rostov-on-Don, Russia

The ion beam facility PIPE (Photo-Ion-Spectrometer at PETRA III) at the P04 beamline of the synchrotron storage ring PETRA III, DESY, Hamburg, is able to prepare mass selected ion beams up to particles with 30.000amu of weight with an mass resolution up to 500 for x-ray absorption studies.

Usually, the more complex and heavy the ion of choice becomes, the more diluted is the prepared ion beam, making it harder or impossible to detect an absorption or fragmentation signal. A possible solution is to catch the ions of the prepared beam in an ion trap over a distinct time to enhance the density of particles for the interaction increasing the signal-to-noise ration significantly [1].

We build an 16-pole segmented radio-frequency ion trap (Traptor) [2] for PIPE. We will show using simulations with SimIon that the presented concept of Traptor is capable of trapping the range of masses PIPE can prepare as well as eject produced fragments in the trap after excitation with synchrotron radiation efficiently with a gradient field applied at the different segments. First tests of the setup in the laboratory will be presented.

[1] D. Gerlich, Advances in Chemical Physics, 82:1-176 (1992)
[2] K. Hirsch et. al., J. Phys. B., 42(15), 154029 (2009)

A 24.5 Wed 16:30 Poster.V

Fragmentation dynamics of molecular ions containing inner-shell ionized sulphur — •Arne Senftleben[1], Kirsten Schnorr[1], Moritz Kurka[1], Georg Schmid[1], Benjamin Erk[2], Artem Rudenko[2], Tatiana Marchenko[3], Marc Simon[3], Claus-Dieter Schröter[1], Robert Moshammer[1], and Joachim Ullrich[1] — [1]Max-Planck-Institut f. Kernphysik, Heidelberg — [2]Max-Planck Advanced Study Group, Hamburg — [3]LCPMR, Paris

The sulphur-containing molecules OCS and SF_6 have been ionized by intense radiation of 200 eV photons from the free-electron laser in Hamburg (FLASH). The photon energy is sufficient to eject a sulphur 2p electron, leading to auto-ionization of one or more other electrons and consequently to dissociation of the molecule. Using a reaction microscope, we have measured photo-electrons in coincidence with the ionic fragments. This enables us to study interrelations between electron spectra and the fragmentation channel of the remaining ion. For OCS, molecular-frame photo-electron angular distributions can be shown, while in SF_6 traces of non-linear processes will be discussed.

A 24.6 Wed 16:30 Poster.V

Time-dependent theory of strong-field x-ray resonance fluorescence — •Stefano M. Cavaletto[1], Christian Buth[2], Zoltán Harman[1,3], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany — [2]Argonne National Laboratory, Argonne, Illinois 60439, USA — [3]ExtreMe Matter Institute EMMI, Planckstrasse 1, D-64291 Darmstadt, Germany

Resonance fluorescence is the emission of photons scattered off by atoms and molecules driven by a near-resonant external electric field; it is a cornerstone of x-ray spectroscopy and x-ray quantum optics. For intense x rays like those provided by existing and upcoming XFELs, the stimulated excitation and recombination at the Rabi frequency can compete with radiative and Auger decay. The signature of Rabi flopping in the electron spectrum of resonant Auger decay was studied for a two-level model of neon cations driven strongly by LCLS light tuned to the $1s\,2p^{-1} \to 1s^{-1}\,2p$ transition at 848 eV [1, 2]. Because of the advantages of photon detection over electron detection, we perform a time-dependent study of the spectrum of resonance fluorescence for neon cations, by considering two different scenarios, i.e. the chaotic pulses presently generated at LCLS and the coherent pulses which are going to become available in the near future via seeding techniques.

[1] N. Rohringer and R. Santra, Phys. Rev. A **77**, 053404 (2008).
[2] E. P. Kanter *et al.*, Phys. Rev. Lett. **107**, 233001 (2011).

A 24.7 Wed 16:30 Poster.V

Theory of field-assisted post-collision interaction in Auger decay of atoms — •Sebastian Bauch[1], Bernd Schütte[2,3], Ulrike Frühling[2], Markus Drescher[2], and Michael Bonitz[1] — [1]Christian-Albrechts-Universität Kiel — [2]Universität Hamburg — [3]Max-Born-Institut Berlin

Post-collision interaction (pci) is a three-body effect being present in photo-induced Auger decay if the Auger electron (AE) is significantly faster than the preceding photoelectron (PE). Under these conditions, the AE experiences a rapid change of the ion's potential upon overtaking of the PE due to altered screening. This is connected with an exchange of energy between both electrons, the net amount of which depends on the AE's release time.

Utilizing extensive simulations based on the time-dependent Schrödinger equation as well as classical molecular dynamics, we show that pci, in the presence of a laser field, imprints a non-linear negative chirp on the AE's energy. Our theoretical results are in good agreement with recent experiments based on the light-driven THz streak camera [1,2] for MNN decay in Krypton and NOO decay in Xenon. The physical mechanism is explained within an analytical model for the line shape of the Auger electron, incorporating the effect of field-assisted pci.

[1] U. Frühling et al., Nat. Photon. 3 523 (2009)
[2] B. Schütte et al., submitted to Phys. Rev. Lett. (2011)

A 24.8 Wed 16:30 Poster.V

Ordering of randomly orientated diffraction patterns with diffusion map — •Martin Winter, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Dresden

By means of manifold embedding techniques we recover the orientations of an ensemble of diffraction patterns from a randomly orientated molecule, which would be the outcome of experiments at X-ray free-electron lasers. Since the mapping of the orientation to the diffraction pattern is highly non-linear, we use an algorithm capable of dealing with non-linear data, like diffusion map [1].

Diffusion map can handle a certain degree of non-linearity. Problems arise especially when multiple parameters/angles get mixed up in the mapping/formation of the diffraction patterns [2]. This is illustrated with some simple examples which reveal the applicability of diffusion map for scattering problems.

[1] Ronald R. Coifman, Stéphane Lafon, Diffusion maps, Appl. Comp. Harm. Anal. 21 (2006) 5-30

[2] Amit Singer, Ronald R. Coifman, Non-linear independent component analysis with diffusion maps, Appl. Comp. Harm. Anal. 25 (2008) 226-239

A 24.9 Wed 16:30 Poster.V

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

Applying high gain harmonic generation process (HGHG) the new FERMI free electron laser in Trieste provides intense XUV pulses of high brilliance with tunable wavelength and excellent confinement in time.

The LDM endstation has been designed to combine the FERMI XUV radiation with molecular beam experiments. In several exchangeable beam sources, atomic, molecular and cluster beams are generated and can be doped by the pick-up technique in oven cells or in a laser ablation unit. Detailed information about the interaction with the FEL light is gathered by combined VMI, TOF and X-ray imaging detectors.

Design and characterization of two sources are presented: A versatile high temperature high pressure pulsed source is utilized for generation of atomic, molecular and cluster beams of various materials in a gas expansion or applying the seeded beams technique. A pulsed cryogenic source gives the opportunity to use helium droplets with their unique cold, superfluid properties.

A 24.10 Wed 16:30 Poster.V

Time-resolved photofragmentation of molecular iodine at FLASH — •Kirsten Schnorr[1], Arne Senftleben[1], Thomas Pfeifer[1], Artem Rudenko[2], Georg Schmid[1], Kristina Meyer[1], Moritz Kurka[1], Yuhai Jiang[1], Stefan Düsterer[3], Joachim Ullrich[1], Claus Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max-Planck Advanced Study Group, Hamburg — [3]DESY, Hamburg

A pump-probe experiment on the ultrafast photofragmentation of molecular iodine using an ultra-short XUV pulse at ≈ 14 nm delivered by the free-electron-laser facility FLASH and a femtosecond IR laser pulse at ≈ 800 nm was performed.

In order to trace the molecular dynamics as a function of the internuclear distance, the delay between XUV- and IR-pulse is varied. With a preceding IR-pulse the I_2 molecule is dissociated and further ionized via the absorption of multiple XUV photons. We observe charge states up to I_2^{15+} due to FEL-created 4d core holes followed by Auger cascades.

All reaction channels resulting in charged fragments can be followed by recoil ion momentum spectroscopy using a reaction microscope.

A 24.11 Wed 16:30 Poster.V

Autoionization of D2 molecules using ultra-short XUV pulses — •Andreas Fischer, Alexander Sperl, Michael Schönwald, Helga Rietz, Philipp Cörlin, Arne Senftleben, Thomas Pfeifer, Robert Moshammer, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg

Wave packet dynamics of molecules can be studied by combining an XUV pulse source and a Reaction Microscope. A Reaction Microscope allows for coincident measurements of ions and electrons. Further more it is capable of measuring the three dimensional momentum of each charged particle created in a reaction. We used this to study the autoionization of doubly-excited D2 molecules. The coupling with the dissociative photoionization channels leads to a symmetry breaking in the observed electron and ion angular distributions. Autoionizations occur on the same time scale as the molecular motion, therefore the nuclei can no longer be regarded stationary. In order to study these processes we probed the molecules with XUV pulse trains with photon energies of up to 32eV. We also modified the duration of the XUV pulse trains by changing the duration of the generating infrared pulses [1].

[1] J. Fernandez, F. Martin, New J Phys 11, 043020 (2009)

A 24.12 Wed 16:30 Poster.V

Gas-Based Photoemission Spectrometer for Online Shot-to-Shot Photon Beam Diagnostics at the European XFEL — •Jens Buck, Jan Grünert, Cigdem Ozkan, Bin Li, Wolfgang Freund, and Serguei Molodtsov — European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany

At free-electron laser facilities, non-invasive beam diagnostics on the basis of photoionization of rare gases has found broad applications in the past and is also under development at the future European X-ray Free Electron Laser (XFEL.EU) facility [1,2]. The Self-Amplified Spontaneous Emission (SASE) process utilized here is known to produce pulses with significant statistical variations of essential pulse properties such as energy, spectrum, temporal profile etc. Single-pulse resolved diagnostics data is therefore required as an essential reference for user experiments. The specifications of XFEL.EU, especially the high intra-bunch repetition rate of 4.5 MHz and the vast energy range between 280 eV and 25 keV pose particular challenges for the design of gas-based devices.

We report on our conceptual design [3] and our recent developments of a photoelectron time-of-flight spectrometer for spectroscopy of single SASE pulses and give a first assessment of the expected performance of the device as derived from detailed simulations in a realistic environment and first commissioning experiments with synchrotron radiation.

[1] M. Altarelli et. al.,*The European XFEL Technical Design Report* (2006). [2] J. Grünert, Proc. FEL09, Liverpool (2009). [3] J. Buck, *Conceptual Design Report: Photoemission Spectrometer*, in prep.

A 24.13 Wed 16:30 Poster.V

End-station for Low Density Matter Beamline at FERMI@Elettra Free Electron Laser — •Viktor Lyamayev, Raphael Katzy, Marcel Mudrich, and Frank Stienkemeier — Universität Freiburg, Physikalisches Institut, D-79104 Freiburg, Germany

FERMI@Elettra is a seeded type Free Electron Laser (FEL), which provides high brilliance femtosecond XUV-pulses in the 20-100 nm range with excellent temporal coherence and wavelength stability. Flexible tuning of both photon wavelength and polarization makes it unique tool for wide range of experiments.

The described setup will be installed as an end-station of the Low Density Matter beamline of FERMI@Elettra, which has been built for studying the interaction of FEL light with neutral molecular beams. It provides several types of sources for generating a wide range of atomic, molecular and cluster beams. Multiple pick-up cells as well as laser ablation can be used for beam doping. A unique detection unit combines time-of-flight, velocity map imaging and X-ray imaging techniques. This allows simultaneous detection of electrons and ions as well as recording of X-ray diffraction patterns.

A 24.14 Wed 16:30 Poster.V

Few-photon multiple ionization of N_2 by 52 eV photons at FLASH — •Moritz Kurka[1], Artem Rudenko[2], Yuhai Jiang[1], Kai-Uwe Kühnel[1], Lutz Foucar[2], Arne Senftleben[1], Kirsten Schnorr[1], Georg Schmid[1], Oliver Herrwerth[3], Matthias Kling[3], Stefan Düsterer[4], Rolf Treusch[4], Claus Dieter Schröter[1], Robert Moshammer[1], and Joachim Ullrich[1,2] — [1]Max-Planck Institut für Kernphysik, 69117 Heidelberg — [2]Max-Planck Advanced Study Group at CFEL, 22607 Hamburg — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching — [4]DESY, 22607 Hamburg

We report on the fragmentation of N_2 molecules induced by intense (10^{13}W/cm^2) XUV radiation ($\hbar\omega = 52$eV) from the Free-Electron Laser in Hamburg (FLASH). Using a dedicated reaction microscope we detect the resulting ions and electrons in coincidence. The combined information contained in the energy and angular distributions of the emerging particles enables us to disentangle the various fragmentation pathways occurring. We will compare our results with those of Jiang et al. which were performed also at FLASH at a photon energy of 44 eV [1].

[1] Y.H. Jiang et *al., Phys. Rev. Lett.* ***102****, 123002 (2009).*

A 24.15 Wed 16:30 Poster.V

Interference of states with different symmetries and differently localized electrons in N_2O — •Andre Knie, Benjamin Kambs, Philipp Reiss, and Arno Ehresmann — Insitut für Physik und CINSaT der Universität Kassel, Heinrich-Plett-Str. 40 34132 Kassel, Germany

Quantum mechanical interference effects were investigated in N_2O, by photon-induced fluorescence spectroscopy. Energetically overlapping resonances of states with different symmetries and differently localized 1s core electrons of the center and terminal N atoms may interfere under certain conditions, breaking the symmetries by observing the processes in distinct angles in respect to the electric field of the exciting photon. Angularly and spectrally resolved fragment fluorescence spectra taken after inner shell excitation of overlapping resonances of core electrons of the central and terminal nitrogen atom indicate interference. In a second step the polarization of the fluorescence was measured to fortify the first measurements.

Results of the measurements are shown, as well as first interpretations of these interferences.

A 25: Poster: Attosecond physics

Time: Wednesday 16:30–19:00 Location: Poster.V

A 25.1 Wed 16:30 Poster.V

CEP Spectral Interferometry measurements near the Cooper minimum in argon, using high-harmonic generation — •Matteo Ceci, Andreas Kaldun, Christian Ott, Philipp Raith, Kristina Meyer, Martin Laux, Yizhu Zhang, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

High-order harmonic generation (HHG) from laser-atom or laser-molecule interaction carries information about the structure and dynamics of the bound electronic wave function interfering with the returning wave packet. HHG spectra allow to gain insight into the electronic configuration of atoms and molecules that could lead to time resolved observations and time-domain control of atomic and molecular-scale electron dynamics. In the present work we measured HHG spectra in argon in the energy range of the Cooper Minimum (CM). While a microscopic single-atom response effect (structure of the bound-state wavefunction) is the origin of the CM, its spectral position observed with HHG has previously been measured to depend on macroscopic (phase-matching) parameters [1]. In our work, a few cycle CEP-stabilised laser with a central wavelength around 730 nm has been used to study the dependence of the CM on macroscopic parameters such as pressure variation and transient dynamics within the fewcycle field of the pulse. The experimental observations are discussed in the framework of our recently developed CEP spectral interferometry (CEPSI) approach [2]. [1] J. P. Farrell et al. Phys. Rev. A 83, 023420 (2011). [2] C. Ott et al., submitted (2011).

A 25.2 Wed 16:30 Poster.V

Quantitative measurement of phase matching in high harmonic generation — Sudipta Mondal[1], •Frederic L. Condin[1,2], Philipp L. Klaus[1,3], Kristen Gould[4], Benjamin Wilson[4], Erwin D. Poliakoff[4], and Carlos A. Trallero-Herrero[1] — [1]Department of Physics, Kansas State University, Manhattan, Kansas 66506, USA — [2]Eberhard Karls Universität Tübingen, D-72074 Tübingen, Germany — [3]Institut für Kernphysik, Goethe-Universität Frankfurt am Main, D-60438 Frankfurt am Main, Germany — [4]Department of Chemistry, Louisiana State University, Baton Rouge, Louisiana 70803, USA

Phase matching in high harmonic generation (HHG) is crucial for the quality and intensity of the generated harmonics and has important applications in modern attosecond science. We present a quantitative measurement of phase matching in HHG. In our experiments we simultaneously detect the generated harmonics and the produced ions as a function of laser focus position relative to a thin gas jet, intensity, and pressure for two pulse durations. The ion signal, the HHG yield, and the HHG yield divided by the squared ion signal serve as a measure of phase matching [cf. *PRL* **103,** 073902 (2009) for a justification of the latter]. We find that the conditions for ideal phase matching drastically change when we switch from Gaussian to Bessel mode. The results have implications for our ongoing research efforts to use HHG as a spectroscopic method. Using the recently developed quantitative rescattering theory of HHG [*PRA* **80,** 013401 (2009)], we want to extract photoionization cross sections from HHG spectra.

A 25.3 Wed 16:30 Poster.V

Design of an in-situ XUV spectrometer for attosecond experiments — •Michael Schönwald, Alexander Sperl, Andreas Fischer, Philipp Coerlin, Arne Senftleben, Thomas Pfeifer, Robert Moshammer, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

We present the design of a new extended ultraviolet (XUV) spectrometer for our attosecond beam line. We are producing attosecond pulses (AP) via high harmonic generation (HHG) in a small gas cell filled with rare gases in order to do pump-probe experiments in a reaction microscope (ReMi). Currently, a self-phase modulation hollow fiber filled with Neon in combination with a chirped mirror compressor is implemented in our setup to broaden the spectrum and shorten the infrared (IR) laser pulses from 30 fs to less than 10 fs for experiments with single AP. To measure the HHG spectra during ReMi type experiments and to be able to estimate the pulse durations of the AP, we build a spectrometer which uses the light transmitted through the interaction region of the ReMi. Immediately after entering the XUV spectrometer, the IR radiation is filtered out by thin Al or Zr foils. A spherical mirror is then used to focus the high harmonics through a transmission grating onto a MCP detector. Using a grazing-incidence reflection off a mirror with a 30 nm thin Au or B4C surface coating, we avoid bandwidth limitations and we are expecting a reflectivity of up to 75%. We will show first experimental results [hopefully] using the few-cycle driving laser pulses for HHG and discuss follow-on experiments enabled by the in-line combination of ReMi and XUV spectrometer.

A 25.4 Wed 16:30 Poster.V

Measurement of sub-1.5-cycle pulses from a single filament — •Martin Kretschmar[1], Daniel S. Steingrube[1], Emilia Schulz[1], Uwe Morgner[1], Milutin Kovacev[1], Dominik Hoff[2], Peter Hansinger[2], and Gerhard G. Paulus[2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, D-30167 Hannover, Germany; QUEST, Centre for Quantum Engineering and Space-Time Research, Hannover, Germany — [2]Friedrich-Schiller-Universität Jena , Institut für Optik und Quantenelektronik , Max-Wien-Platz 1, D-07743 Jena

Femtosecond laser filamentation is a prominent approach for few-cycle pulse generation. The precise characterization of the time-dependent electric field of such a pulse is challenging but necessary for the understanding of strong-field effects occuring during filamentary propagation. We present an experimental setup capable of measuring the pulse duration and CEO-phase contributions of pulses originating from a femtosecond filament. The experiment consists of a semi-infinite gas cell which truncates the filament at different positions and a Stereo-ATI-Phasemeter, enabling the measurement of the pulse duration of the resulting beam. We report on the dependence of the resulting pulses upon various experimental parameters resulting in the observation of pronounced pulse splitting signatures. We identify pulses with a sub-1.5-cycle temporal duration emerging from a single filament.

A 26: Poster: Atomic systems in external fields

Time: Wednesday 16:30–19:00 Location: Poster.V

A 26.1 Wed 16:30 Poster.V

Dynamics of laser-cooled Ca^+ ions in a Penning trap with a rotating wall — •Manuel Vogel[1], Shailen Bharadia[2], Richard Thompson[2], and Danny Segal[2] — [1]TU Darmstadt and GSI Darmstadt — [2]Imperial College London, UK

We have performed systematic measurements of the dynamics of laser-cooled $^{40}Ca^+$ ions confined in a Penning trap and driven by a rotating dipole field ("rotating wall"). The size and shape of the ion cloud has been monitored using a CCD camera to image the fluorescence light resulting from excitation by the cooling laser. We have systamatically varied the experimental conditions such as amplitude and frequency of the rotating wall drive as well as the trapping parameters. The rotating wall has been used for a more than 10-fold radial compression of the ion cloud thus increasing the ion density in the trap. We have also observed plasma mode excitations in agreement with theoretical expectations. This work will allow to define the optimum parameters for high compression of ions as needed for precision spectroscopy of forbidden transitions as in the SPECTRAP experiment at the HITRAP facility at GSI Darmstadt.

A 26.2 Wed 16:30 Poster.V

Parity Violation in Hydrogen — •Martin-Isbjörn Trappe, Thomas Gasenzer, and Otto Nachtmann — Institute for Theoretical Physics, University of Heidelberg

We discuss the propagation of hydrogen atoms in static electric and magnetic fields in a longitudinal atomic beam spin echo (lABSE) Interferometer. The atoms acquire geometric (Berry) phases that exhibit a manifestation of parity-(P-)violation effects arising from electroweak Z-boson exchange between electron and nucleus. We provide analytical as well as numerical calculations of the behaviour of the metastable n=2 states of hydrogen. We are able to systematically search for Berry phases with tailored properties. Besides maximizing P-violating geometric phases emerging for the respective states we also find the possibility to modify their decay rates, nearly at the order of a percent, solely through P-conserving geometric phases.

A 26.3 Wed 16:30 Poster.V

Dominant interaction Hamiltonians — •Carlos Zagoya[1], Martin Gerlach[1], Jan-Michael Rost[1], and Frank Grossmann[2] — [1]Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden — [2]Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden

We introduce the concept of dominant interaction Hamiltonians (DIH) in order to disentangle non-separable dynamics by splitting it into spatial regions where the dominant potential is taken as the only interaction. Firstly, by applying the DIH concept we obtain an integrable approximation to the dynamics of an electron exposed to a strong laser field and an atomic potential. The high harmonic generation spectrum obtained by using the semiclassical Herman-Kluk propagator (HK) [1] is in excellent agreement with the full quantum mechanical result [2]. Secondly, we apply the DIH scheme to the classical two electron dynamics of electron-ion scattering. We find that the energy sharing deflection function and energy sharing cross-section obtained by the DIH approximation show the essential features present in the full dynamics [3].

[1] M. F. Herman and E. Kluk, Chem. Phys. **91**, 27 (1984)
[2] G. van de Sand and J.-M. Rost, Phys. Rev. Lett. **83**, 524 (1999)
[3] M. Gerlach et al., preprint, arXiv:1110.1545

This work was partly supported by the DFG through grant GR 1210/4-2 (FG).

A 26.4 Wed 16:30 Poster.V

Fingerprints of exceptional points in the survival probability of resonances in atomic spectra — •Holger Cartarius[1,2], Günter Wunner[1], Jörg Main[1], and Nimrod Moiseyev[3] — [1]1. Institut für Theoretische Physik, Universität Stuttgart — [2]Chemical Physics Department, Weizmann Institute of Science, Rehovot, Israel — [3]Department of Physics and Minerva Center for Nonlinear Physics of Complex Systems, Technion, Haifa, Israel

Exceptional points, i.e. branch point singularities in non-Hermitian physical systems, where two complex eigenvalues degenerate and the corresponding eigenstates coalesce, have shown to exhibit prominent effects not observable in their absence. They appear in quantum resonance spectra and have been found for decaying unbound states of the hydrogen atom in crossed electric and magnetic fields [1].

For the decay of two resonances exactly at the exceptional point parameters a unique time signature is expected. We show that indeed the survival probability $S(t) = |\langle\psi(0)|\psi(t)\rangle|^2$ decays exactly as $|1 - at|^2 e^{-\Gamma_{EP} t/\hbar}$ where Γ_{EP} is associated with the decay rate at the exceptional point and a is a complex constant depending solely on the initial wave packet that populates exclusively the two almost degenerate states of the non-Hermitian Hamiltonian [2]. This may open the possibility for a first experimental detection of exceptional points in a quantum system.

[1] H. Cartarius, J. Main, G. Wunner, Phys. Rev. Lett. 99, 173003 (2007)
[2] H. Cartarius, N. Moiseyev, Phys. Rev. A 84, 013419 (2011)

A 26.5 Wed 16:30 Poster.V

Treatment of spatially inhomogeneous, finite systems with the Generalized Kadanoff–Baym Ansatz — •Sebastian Hermanns, Karsten Balzer, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, CAU Kiel, Leibnizstraße 15, 24098 Kiel

For the description of many–particle systems the Green's function method has become widely used in the last decades. In this formalism the Kadanoff–Baym equation is solved using an appropriate self–energy. Additionaly the Generalized Kadanoff–Baym ansatz[1] (GKBA) is introduced to reconstruct the double–time single–particle Green's function from its time–diagonal value: $G(t_1, t_2) = F_{\text{GKBA}}[G(t_1 = t_2)]$. This approximation is well tested for large, homogeneous systems.

In this contribution, we apply the proposed scheme to *finite* model systems with *strong spatial inhomogeneities*: a Hubbard model, a 4–electron quantum dot[2] and a one–dimensional helium model. By comparing with results obtained from exact diagonalization, solutions of the time–dependent Schrödinger equation[3], Hartree–Fock– and full double–time Green's function calculations[4], we test the validity of the approximation used.

[1] P. Lipavsky, V. Spicka, and B.Velicky, Phys. Rev. B **34**, 6933–6942 (1986), [2] for comparison see poster by K. Balzer, [3] K. Balzer, S. Bauch, and M. Bonitz, Phys. Rev. A **81**, 022510 (2010), [4] K. Balzer, S. Bauch, and M. Bonitz, Phys. Rev. A **82**, 033427 (2010)

A 26.6 Wed 16:30 Poster.V

Double excitations from the solution of the Kadanoff–Baym equations — •Karsten Balzer and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, CAU Kiel, Leibnizstraße 15, 24098 Kiel

In a quantum many–body system, the population of states of double excitation character (doubly excited states) is a clear indicator for correlations importantly contributing to the nonequilibrium dynamics.

In this contribution, we analyze such correlation-induced transitions, being absent in a mean–field Hartree–Fock (HF) treatment, on the basis of the nonequilibrium Green function solving the Kadanoff–Baym equations by direct time–propagation [1]. As test system, we consider a four–electron quantum dot at zero temperature in the regime of moderate–to–strong coupling (see also poster by S. Hermanns [3]). The approximate (HF and second-order Born) absorption spectra are compared to exact diagonalization results where singly, doubly and other multiply excited states are identified by means of the approximate excitation level [2].

[1] K. Balzer, S. Bauch and M. Bonitz, Phys. Rev. A 81, 022510 (2010); ibid. 82, 033427 (2010). [2] J.F. Stanton and R.J. Bartlett, J. Chem. Phys. 98, 7029 (1993). [3] This contribution focuses on the generalized Kadanoff–Baym ansatz.

A 26.7 Wed 16:30 Poster.V

Two-photon transitions of high-Z few electron ions in strong laser fields — •Thorsten Jahrsetz[1,2] and Andrey Surzhykov[1,2] — [1]Physikalisches Institut University of Heidelberg — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt, German

During the last decades, two-photon transitions in highly charged heavy ions have attracted much attention as a promising tool for studying atomic parity-violation (PV) effects [1]. For example, the $1s_{1/2}2s_{1/2} : J = 0 \rightarrow 1s_{1/2}2p_{1/2} : J = 0$ transition of helium-like uranium, when induced by polarized light, should proceed via the PV electric-dipole 2E1 channel and provide an accurate probe of parity non-conservation. Theoretical predictions for this transition clearly indicate the need for high-intensity lasers in order to make the parity-violating transitions visible [2]. However, such intense laser fields also may lead to sizable Stark shift and mixing of different ionic levels even in the high-Z regime. In this contribution, therefore, we apply the Green's function approach and relativistic Dirac theory in order to investigate the influence of Stark effects on the total as well as differential two-photon rates. Special emphasis in our analysis is placed on the (laser-dressed) $2p_{1/2} \rightarrow 1s_{1/2}$ and $1s_{1/2}2p_{1/2} : J = 0 \rightarrow 1s^2_{1/2} : J = 0$ transitions in hydrogen-and helium-like heavy ions.

[1]A Schäfer et al. PRA 40,12(1989)
[2] A. Surzhykov et al., Phys. Rev. A 84, 022511 (2011)

This work was supported by the Helmholtz Gemeinschaft (Nachwuchsgruppe VH-NG-421).

A 26.8 Wed 16:30 Poster.V

Numerical simulations of the pump-probe ionization of

Lithium — •David Hochstuhl and Michael Bonitz — Universität Kiel

In this contribution we study the IR-XUV pump-probe ionization of Lithium. The basic scenario is [1]: (i) the XUV photon ionizes an 1s electron. (ii) the 2s electron becomes excited through a shake-up process. (iii) depending on the frequency and intensity of the IR field, the 2s electron is excited above the threshold and gets ionized by the IR field. In existing models, this process is described using certain approximations to the XUV ionization step (like the strong field approximation), as well as to the subsequent inner-electronic processes (like a sudden switching to the ion). To overcome these limitations, we directly solve the time-dependent Schrödinger equation in a restricted, problem-adapted subspace of the three-particle Hilbert space.

[1] A.K. Kazansky, N.M. Kabachnik, J. Phys. B 41 135601

A 26.9 Wed 16:30 Poster.V

Quantum Breathing Mode of Interacting Particles in a Harmonic Trap — •Jan Willem Abraham, David Hochstuhl, Karsten Balzer, and Michael Bonitz — Institut für theoretische Physik und Astrophysik, CAU Kiel

Time-dependent properties of interacting, harmonically confined quantum systems are of growing interest in many areas, including correlated electrons in metal clusters or quantum dots and ultracold Bose and Fermi gases in traps or optical lattices. Among these properties the behaviour of the breathing mode (BM)—the [uniform] radial expansion and contraction of the system—attracts special interest as it is easily excited experimentally, and turns out to give information of the system's dimensionality, spin statistics, as well as the form and strength of the pair interaction potential. Extending our previous work, we deepen the understanding of the BM during the transition from the ideal quantum to the strongly coupled classical regime, where the breathing frequency depends on the pair interaction strength. We present time-dependent Hartree-Fock simulations for 2 to 20 fermions with Coulomb interaction which yield the dependency of the quantum BM on the particle number.

A 26.10 Wed 16:30 Poster.V

Phase-controlled electron acceleration from metal clusters in few-cycle laser pulses — •Lennart Seiffert, Jörg Köhn, and Thomas Fennel — Universität Rostock, 18051 Rostock, Germany

It is well-known that the ionization of atoms and molecules in intense few-cycle laser pulses can be precisely controlled (with sub-fs resolution) by the carrier-envelope-phase [1]. Recently it has been shown that such pulses also allow to unravel and control ionization processes in more complex many particle systems, such as silica nanoparticles [2]. Here we investigate the phase controlled electron acceleration from laser driven metal clusters, where the resonant excitation of Mie-plasmons leads to extreme field enhancement. Angular- and energy resolved electron spectra are calculated for resonant jellium-like clusters using a semiclassical Vlasov approach [3]. We observe a strong phase dependence of the electron spectra, with pronounced left-right asymmetry in the energy distribution of electrons emitted parallel to the laser polarization axis. A detailed analysis of the electron trajectories allows the identification of the leading acceleration mechanisms and supports the dominant role of surface plasmon assited rescattering in clusters (SPARC) [3]. A systematic analysis of the phase effects as function of the laser pulse duration is presented.

[1] G. G. Paulus et al., Phys. Rev. Lett. 91, 253004 (2003)
[2] S. Zherebtsov et al., Nature Phys. 7, 656 (2011)
[3] Th. Fennel et al., Phys. Rev. Lett. 98, 143401 (2007)

A 26.11 Wed 16:30 Poster.V

Temporal dynamics of Coulomb correlations in atomic strong-field processes — •Maximilian Hollstein, Benjamin Baxevanis, and Daniela Pfannkuche — 1. Institut für Theoretische Physik, Universität Hamburg, Hamburg,Germany

The temporal dynamics of Coulomb correlations in atomic strong-field processes are investigated theoretically on a model system.

In order to study atomic strong-field processes various methods have been developed to solve the time-dependent Schrödinger equation as for instance the single-active-electron approach or the time-dependent configuration-interaction singles method. In contrast to these approaches which do not take into account the complete Coulomb correlations we are using a numerically exact method to study the ionization process on a model system. We are focusing on the temporal dynamics of the Coulomb correlations by considering the time evolution of pair correlation functions. By comparing the exact results with Hartree-Fock based methods we are investigating the importance of Coulomb correlations atomic strong-field processes.

A 26.12 Wed 16:30 Poster.V

Analysis of Freeman resonances in strong field ionization — •Thomas Keil and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

The interaction of atoms with a strong laser field leads to nonperturbative AC Stark shifts of atomic energy levels. Especially in the multiphoton regime these shifts affect the ionization rate. By varying the laser intensity bound states can be shifted into and out of multiphoton resonances. In the case of Rydberg states the corresponding phenomena are called Freeman resonances. These resonances are treated numerically by solving the time-dependent Schrödinger equation as well as analytically by applying perturbation theory and the strong field approximation. Floquet-results from Potvliege and Shakeshaft are reproduced numerically using trapezoidal laser pulses. Possible explanations for the ionization behavior are presented in terms of atomic levels involved in the process. The resulting line shape in the ionization rate vs intensity is discussed.

A 26.13 Wed 16:30 Poster.V

Breathing modes in harmonically confined quantum systems — •David Hochstuhl[1], Jan-Willem Abraham[1], Chris McDonald[2], Thomas Brabec[2], and Michael Bonitz[1] — [1]Christian-Albrechts-Universität Kiel — [2]University of Ottawa

The Breathing Mode (BM), collective oscillations induced by monopole excitations, constitutes a versatile tool for the characterization of many-particle systems as, e.g., Bose-Einstein condensates, nuclear matter or quantum dots. It has been thoroughly investigated in classical Coulomb systems [1], where it shows a universal, particle-number independent frequency of $\omega = \sqrt{3}$ (in units of the harmonic trap frequency). For BMs in quantum systems, due to the non-locality of the wavefunctions, a different picture arises: the classical frequency is recovered only in the Wigner-cristallization regime. On the other hand, in the ideal quantum limit of weakly interacting systems, the BM frequency approaches $\omega = 2$. These two extrema are well known and can be conveniently handled by perturbation theory.

Our focus here is on the intermediate region. Therefore, we solve the Schrödinger equation for systems consisting up to 12 particles, trapped in a two-dimensional parabolic potential, and determine their BM frequencies with respect to the particle interaction strength. For the solution, we apply the Multiconfigurational time-depedent Hartree-Fock method as well as a restricted active-space variant of the Configuration Interaction method.

[1] C. Henning, et al., Phys. Rev. Lett. 101 045002 (2008) [2] S. Bauch, et al., Phys. Rev. B 80 054515 (2009)

A 26.14 Wed 16:30 Poster.V

Monte-Carlo Simulation of Atomic and Molecular Fragmentation Processes in Reaction Microscopes. — •Philipp Cörlin, Arne Senftleben, Alexander Sperl, Michael Schönwald, Andreas Fischer, Robert Moshammer, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Deutschland

By reconstructing the trajectories of electrons and (molecular) ions in an electric and a magnetic field, reaction microscopes are used to measure the three dimensional momenta of the ionization products. In combination with ultra short laser pulses this allows one to image ultra-fast molecular dynamics.

In this work laser-induced ionization of atoms and Coulomb explosion of small molecules are simulated in order to determine appropriate operating parameters for reaction microscopes. This is done by analyzing simulated time-of-flight spectra as well as hit positions on the detectors for different sets of parameters.

Furthermore, characteristic time-of-flight spectra of Coulomb exploding polyatomic molecules are created in order to simplify the interpretation of experimental data.

A 26.15 Wed 16:30 Poster.V

New Compact Magnetically Shielded ^{3}He MEOP Polarizing Facility — •Christian Mrozik, Werner Heil, Sergei Karpuk, and Ernst Otten — Institut für Physik, Johannes Gutenberg-Universität Mainz

Applications of hyperpolarized ^{3}He exist in fundamental research as well as in medical studies. Since a decade ^{3}He is polarized in a central facility, located at the University of Mainz and shipped to the users. The gas is polarized via metastability exchange optical pumping (MEOP) at a pressure of approximately 1 mbar inside a magnetic field of 1 mT. The process requires a magnetic field with a relative gradient of $\Delta B/B < 3.8 \cdot 10^{-4}\,\mathrm{cm}^{-1}$. To construct a compact facility for local gas-polarization it is imperative to create a sufficiently homogeneous magnetic field all over a solenoid's volume in order to be able to use its complete volume for the MEOP assembly. Our concept of a spacious homogenization of a solenoid's magnetic field consists of enclosing it into a shielding of soft magnetic material, providing a high magnetic permeability [1]. In addition to the homogenization of the magnetic field a new concept for the optics, used for the optical pumping has been developed, to fit into the new compact facility. The design of the compact apparatus aims to reach a flux of hyperpolarized ^{3}He at $P > 65\%$ of several standard liters per hour. First experimental results, gained from the new compact polarizing apparatus, will be presented.

[1] C. Mrozik *et al.* Journal of Physics: Conference Series **294** (2011)

A 26.16 Wed 16:30 Poster.V

Nonequilibrium Green's functions approach to the pair distribution function of quantum many-body systems — •Kay Kobusch, Karsten Balzer, Lasse Rosenthal, Alexei Filinov, and Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Universität Kiel, D-24098 Germany

The pair distribution function (PDF) is a key quantity for analyzing correlation effects of quantum systems both in and far from equilibrium. We derive an expression for the PDF in terms of single particle Green's functions - the solutions of the Keldysh-Kadanoff-Baym equations in the two-time plane. The result includes initial correlations and generalizes previous density matrix expressions from single-time quantum kinetic theory. As an illustration we present numerical results for the PDF of electrons and holes in a strongly correlated electron-hole bilayer. These are calculated in different many-body approximations and then compared with Path integral Monte Carlo results.

A 27: Poster: Photoionization

Time: Wednesday 16:30–19:00 Location: Poster.V

A 27.1 Wed 16:30 Poster.V

Frequenzstabilisierung eines Systems dreier Diodenlaser zur Laserresonanzionisation an Uranisotopen — •Thomas Fischbach[1], Amin Hakimi[1], Sebastian Raeder[2], Norbert Trautmann[3] und Klaus Wendt[1] — [1]Institut für Physik, Johannes Gutenberg Universität, Mainz — [2]TRIUMF, Vancouver, Canada — [3]Institut für Kernchemie, Johannes Gutenberg Universität, Mainz

Die hochauflösende Resonanzionisations-Massenspektrometrie (HR-RIMS) bietet durch Kombination von mehrstufig resonanter Laserionisation mit schmalbandigen kontinuierlichen Lasern sowie der Quadrupolmassenspektrometrie die Möglichkeit, extremste Isotopenverhältnisse zu erschließen. Die Ionisation erfolgt hierbei isotopenselektiv mittels transversaler Überlagerung der Strahlung dreier Diodenlaser mit einem kollimierten Atomstrahl; diese stellt hohe Ansprüche an die Frequenzstabilität der Laser im Bereich von < 1 MHz. Zur Frequenzstabilisierung mit kontrollierter Verstimmung über die Isotopieverschiebung wurde ein kommerzielles System von festen Quadraturinterferometern mit einer Fringe-Offset-Technik bestehend aus einem Scanning Fabry-Perot-Interferometer und einem Referenzlaser kombiniert. Neben der Kurz- und Langzeitstabilität im Bereich weniger MHz Sollfrequenzabweichung über mehrere Stunden hinweg bietet das System die Möglichkeit für eine schnelle, automatisierte Abstimmung zwischen den Anregungsschritten verschiedener Uran-Isotope, sowie für weiterführende spektroskopische Messungen. Der Aufbau des Systems, Stabilitätsmessungen und der Status aktueller spektroskopischer Untersuchungen an Uran-238 werden vorgestellt.

A 27.2 Wed 16:30 Poster.V

Laser-Assisted Photonuclear Effect in Halo-Nuclei — •Anis Dadi and Carsten Müller — Max-Planck-Institut für Kernphysik Saupfercheckweg 1, D-69117 Heidelberg

The emission of a proton from a halo nucleus by absorption of a high-energy photon in the presence of a strong optical laser beam is studied. It is shown that the assisting laser field modifies the properties of the photonuclear effect in a characteristic way. We investigate the energy distribution of the photoproton in terms of the number of absorbed laser photons, as well as the angular proton distribution as a function of the polar emission angle. The dependencies on the photon energy, the laser polarization, and the field geometry are discussed as well.

A 27.3 Wed 16:30 Poster.V

Quasi free mechanism in single photon double ionization of Helium — •Markus Schöffler[1,2], Till Jahnke[1], Markus Waitz[1], Florian Trinter[1], Ute Lenz[1], Christian Stuck[1,2], Mathew Jones[3], Ali Belkacem[2], Lew Cocke[4], Allen Landers[3], Horst Schmidt-Böcking[1], Thorsten Weber[2], and Reinhard Dörner[1] — [1]Institut für Kernphysik, J. K. Goethe-Universität Frankfurt am Main, 60438 Frankfurt — [2]Lawrence Berkeley National Lab, Berkeley, CA, 94720, USA — [3]Auburn University, Auburn, AL, 36849, USA — [4]Kansas State University, Manhattan, KS, 66506, USA

Double ionization of Helium by a single photon is widely believed to proceed through two mechanisms: knock-off (TS1) or shake-off, with the last one dominating at high photon energies. A new mechanism, termed "Quasi Free Mechanism" (QFM) was predicted 35 years ago by Amusia and coworkers, but escaped experimental observation till today. Here we provide the first proof of this mechanism using 800 eV photons from the Advanced Light Source. Fragments (electrons and ions) were measured in coincidence using momentum spectroscopy (COLTRIMS). He2+ ions with zero momentum were found - the fingerprint for the QFM.

A 27.4 Wed 16:30 Poster.V

Photoelectron-Auger electron coincidence experiments: the next generation — Tiberiu Arion[1], Cosmin Lupulescu[2], Ruslan Ovsyannikov[3], Marko Förstel[4], Gunnar Öhrwall[5], Andreas Lindblad[5], Svante Svensson[6], Alex M. Bradshaw[4,7], Ralph Püttner[8], Wolfgang Eberhardt[1,2], and •Uwe Hergenhahn[4] — [1]CFEL, 22607 Hamburg — [2]TU Berlin, 10623 Berlin — [3]Helmholtz-Zentrum Berlin, 12489 Berlin — [4]Max-Planck-Institut für Plasmaphysik, 85748 Garching — [5]MAX-Lab, SE-22100 Lund, Sweden — [6]Uppsala University, SE-75120 Uppsala, Sweden — [7]Fritz-Haber-Institut, 14195 Berlin — [8]FU Berlin, 14195 Berlin

Inner shell photoionization of atoms and molecules almost always leads to sequential photo double ionization. The primary photoelectron is followed within a few fs by an Auger electron. Detecting these electrons in coincidence can greatly enhance the amount of information that can be spectroscopically retrieved. We present our latest set-up which primarily aims at coincidence electron spectroscopy with very high energy resolution. Our approach is based on a combination of a conventional hemispherical electron analyser with a novel time-of-flight electron spectrometer (ArTOF). Due to its use of an angle resolving electron lens, the ArTOF is superior over conventional, linear time-of-flight spectrometers in both collection angle and energy resolution. With this, we are able to achieve energy resolutions comparable to the vibrational energies of simple molecules in a coincidence experiment, while maintaining acceptable solid angles at the same time. Results of recent experiments on O_2 and $C_2H_2F_2$ will be presented.

A 27.5 Wed 16:30 Poster.V

Long-lived states and decay of Helium in the one and two dimensional configuration — •Klaus Zimmermann[1], Vera Neimanns[1], Felix Jörder[1], Alberto Rodriguez[1], Pierre Lugan[2], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg — [2]École Polytechnique Fédérale de Lausanne, Lausanne, Schweiz

Helium is a prototypical model for complex decaying systems. While being the simplest system beyond Hydrogen it exhibits intriguing features due to the electron electron interaction that leads to multiple decay channels. We present studies on the driven and undriven one dimensional Zee configuration that provide insight into its (auto-)fragmentation with resolution of distinct channels. Furthermore we show the planar configuration with non-vanishing angular momentum, focusing on surprisingly stable states. This gives rise to a comparative study of the corresponding classical Helium model.

A 27.6 Wed 16:30 Poster.V

Dynamic chirality in the weakly-bound Ar tetramer studied by Coulomb explosion imaging — •Maksim Kunitski, Markus Schöffler, Jian Wu, Martin Pitzer, Till Jahnke, Lothar Ph. H. Schmidt, and Reinhard Dörner — Institut für Kernphysik, Goethe-Universität Frankfurt am Main, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany

Chirality related phenomena such as parity violation, circular dichroism, homochirality [1,2] have attracted much attention in the recent time. Besides "normal" or "static" chirality one distinguishes also instantaneous or "dynamic" chirality, which, for instance, can be induced by zero point vibrations in systems that are in average achiral and symmetric [3].

In this contribution we are going to present our recent results on the investigation of dynamic chirality in the weakly-bound Ar tetramer. Namely, we successfully applied Coulomb explosion imaging by means of the COLd Target Recoil Ion Momentum Spectroscopy (COLTRIMS) [4] for determination of two instantaneous enantiomeric structures of Ar tetramer. Experiments with left- and right-handed circularly polarized femtosecond laser fields reveal no circular dichroism in quadruple ionization of these two enantiomeric forms.

[1] M. Quack, Faraday Discuss. 150, p. 533 (2011)
[2] L. D. Barron, Space Sci. Rev. 135, p.187 (2008)
[3] T. Kitamura et al., J. Chem. Phys. 115, p.5 (2001)
[4] R. Dörner et al., Phys. Rep. 330, p. 95 (2000)

A 27.7 Wed 16:30 Poster.V

The photoabsorption spectrum of O_2 below the O 1s threshold reanalysed — •Ralph Püttner[1], Catalin Miron[2], Kiyoshi Ueda[3], and Uwe Becker[4] — [1]Freie Universität Berlin, Berlin, Germany — [2]Synchrotron SOLEIL, Gif-sur-Yvette Cedex, France — [3]Institut for Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai, Japan — [4]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

The photoabsorption spectrum of O_2 below the O 1s ionization threshold is known to be complex mainly because of two reason. First, O_2 in the ground state has a open-shell structure and second the antibonding O $1s_g^{-1}3\sigma_u^*$ resonance is – contrary to most of the other molecules – below the ionization threshold and interacts strongly with the Rydberg states. The resulting complexity initiated in the last three decades numerous experimental and theoretical investigations, which led to a general understanding of the photoabsorption spectra. However, some details are still not fully explained.

In this work we present an extended fit analysis of angular resolved total ion yield spectra, which allowed us to observe novel information. First, we observed Fano lineshapes for the lowest Rydberg state, which is due to an interaction with O $1s_g^{-1}3\sigma_u^*$ excitation via the nuclear degree of freedom. Second, two previously unknown and unexpected Rydberg series were identified; these series are probably due to a transition in the coupling scheme of the spins from triplet states of the neutral molecule to doublet and quartet states of the ion.

A 28: Poster: Interaction of matter with ions

Time: Wednesday 16:30–19:00 Location: Poster.V

A 28.1 Wed 16:30 Poster.V

Optimierung der Strahlinjektion in den Frankfurter Niederenergie-Speicherring — •Annika M. Jung, Kurt E. Stiebing, Reinhard Dörner, Lothar Ph. H. Schmidt, Dirk Tiedemann, Marco Völp, Steffen Enz und Thomas Kruppi — Institut für Kernphysik der Goethe Universität Frankfurt, Max von Laue Straße 1, 60438 Frankfurt a.M.

Bei dem Frankfurter Niederenergie-Speicherring (Frankfurt Low Energy Storage Ring - FLSR [1]) handelt es sich um einen elektrostatischen Speicherring des Instituts für Kernphysik der Universität Frankfurt a.M., der Ionen und Moleküle beliebiger Masse bis zu einer Energie von 50 keV speichern kann. Das Projekt befasst sich mit der Optimierung der Injektion in den FLSR und schließt auch die Konstruktion eines 50 kV Terminals für Ionenquellen zur Versorgung des Rings mit Ionen/Molekülen ein. In diesem Beitrag werden erste Ergebnisse vorgestellt. [1] K.E. Stiebing et al. Nucl. Instr. And Meth. A 614 (2010) 10-16

A 28.2 Wed 16:30 Poster.V

Projectile coherence effects in ion-impact induced single ionization of He — •Xincheng Wang[1,2], Micheal Schulz[2], Aaron LaForge[1], Katharina Schneider[1], Aditya Kelkar[1], Joachim Ullrich[1], Robert Moshammer[1], and Daniel Fischer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany — [2]Institut für Kernphysik, Universität Frankfurt, Max-von-Laue Strasse 1, D-60438 Frankfurt, Germany

In recent ion-molecule collision experiments the influence of the spatial coherence of the projectile ions on the differential cross sections has been discovered. Even though this effect seems - due to wave-particle duality - rather evident, it has not been considered before: In essentially all theoretical models the projectile ions either have been regarded as plane waves or as classical particles. We investigate the influence of the projectile coherence length in single ionization of helium and have measured the fully differential cross sections in 3MeV proton collisions at the Test Storage Ring (TSR). Here the projectile beam was cooled down using the electron cooling, thus decreasing the beam emittance and thereby increasing the transverse coherence length. The results are in a much better agreement with the theoretical prediction than earlier 100MeV/u C^{6+} data with smaller coherence length and the same perturbation. These observations suggest, that the earlier observed discrepancies between experiment and theory that have been a puzzle for many years, can be explained considering the coherence properties of the ion beam.

A 28.3 Wed 16:30 Poster.V

State-selective study of electron capture by coincident recoil-ion and x-ray measurement — •Zhangyong Song, Xincheng Wang, Aditya Kelkar, Daniel Fischer, Robert Moshammer, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

Electron capture in collisions between slow highly charge ions (HCI) and neutral atoms will be studied at the Heidelberg EBIT using a Reaction Microscope. In such collisions predominantly highly excited states in the projectile ions are populated that, for one-electron transitions, decay radiatively. In our experiments, the momentum of the recoil ions will be measured containing the information on the Q-values (i.e. inelasticity) of the collisions. The direct measurement of the x-rays emitted from the projectile subsequently will additionally enable to obtain information on the decay channels. Thus, a more complete picture of charge transfer and relaxation processes in HCI-atom collisions can be gained.

A 28.4 Wed 16:30 Poster.V

Observation of the $2p_{3/2}$-$2s_{1/2}$ Radiative Transition in Li-like Uranium using the Resonant Coherent Excitation in Si-crystal. — •Alena Ananyeva[1,2], Toshiyuki Azuma[3,5], Harald Bräuning[2], Angela Bräuning-Demian[2], Denis Dauvergne[4], Christina Dimopoulou[2], Yasuyuki Kanai[5], Carl Kleffner[2], Yuji Nakano[3,5], Yuri Pivovarov[6], Marcus Steck[2], Shintaro Suda[3], and Yasunori Yamazaki[5,7] — [1]Goethe Universität Frankfurt am Main, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [3]Tokyo Metropolitan University, Japan — [4]IPNL - Institut de Physique Nucléaire de'Lyon, France — [5]RIKEN, Tokyo, Japan — [6]National ResearchTomsk Polytechnic University, Russia — [7]University of Tokyo, Japan

Taking advantage of the cooled, relativistic ion beams delivered by the Experimental Storage Ring (ESR) at GSI, Darmstadt the energy of the $1s^22p_{3/2}$- $1s^22s_{1/2}$ transition in Li-like U ions was measured by using the resonant excitation of ions in a Si-crystal in channelling conditions. The excitation of the projectile traversing a solid target with an ordered structure is induced with great probability by the periodic potential defined by the atoms of the crystal lattice when the oscillation frequency of the crystal field fits the energy difference between two levels of the ion. The resonant character of the process enables the determination of transition energy with high precision. The present scheme is quite universal being applicable for various ions and for a wide range of transition energies in the field of atomic as well as nuclear physics.

A 28.5 Wed 16:30 Poster.V

Dynamics of transfer ionization in 1MeV/u O^{7+} on He collisions — •Katharina Schneider[1,2], Michael Schulz[3], Aditya Kelkar[1,4], Xincheng Wang[1,2], Manfred Grieser[1], Robert Moshammer[1], Joachim Ullrich[1], and Daniel Fischer[1] — [1]MPI für Kernphysik, Heidelberg, Germany — [2]EMMI at GSI, Darmstadt, Germany — [3]Missouri University of Science and Technology, Rolla, USA — [4]Universität Innsbruck, Austria

In ion-atom collisions, the capture of one target electron with simultaneous emission of a second target electron may occur. This process is called Transfer Ionization and has gained much interest in recent years. Here the correlation between the target electrons plays an important role, as it is involved in several mechanisms that result in this two-electron transition. Two of them are in the literature referred to as Thomas transfer ionization and ee-process which both have a distinct signature in the final momentum space. At large perturbations η (projectile charge to velocity ratio), an independent process dominates, where capture and ionization can be considered as two separate interactions with the projectile. We studied Transfer Ionization in O^{7+} + He collisions obtaining kinematically complete information with a Reaction Microscope implemented at the Test Storage Ring TSR at the MPI-K. The differential cross sections are compared to single ionization and severe differences were observed. Here we present the data as well as a comparison to several theoretical models.

A 28.6 Wed 16:30 Poster.V

An asymptotically corrected two-centre potential for the description of He^+- He collisions — •Gerald Schenk[1], Tom Kirchner[1], and Hans-Jürgen Lüdde[2] — [1]Department of Physics and Astronomy, York University, Toronto, Ontario, M3J 1P3, Canada — [2]Institut für Theoretische Physik, Goethe Universität Frankfurt, Germany

The Basis Generator Method (BGM) was developed to calculate ionization and electron transfer probabilities in ion-atom collisions [1]. In its two-centre (TC) implementation electrons from both collision centres can be propagated in a single potential, based on the Independent Particle Model. However, this leads to a complication. Looking at the asymptotic behaviour of the potential towards large internuclear distances it becomes apparent, that a combination of (screened) atomic potentials can not be asymptotically correct for both centres simultaneously. Either a potential correct for the target or for the projectile electron can be chosen.

An approach to avoid this is to use a potential that locally shows the correct asymptotic behaviour for both collision centres by combining both cases through a minimum function. First results obtained from TC-BGM calculations with such a potential will be presented for He^+-He collisions at intermediate impact energies.

[1] M Zapukhlyak *et al* 2005 *J. Phys. B:* **38** 2353

A 28.7 Wed 16:30 Poster.V

Interference in Dissociative Ionization of H_2^+ - Helium Collisions — •Shaofeng Zhang[1,2], Daniel Fischer[1], Robert Moshammer[1], Alexander Voitkiv[1], Michael Schulz[1], Bennaceur Najjari[1], Joachim Ullrich[1], and Xinwen Ma[2] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institute of Modern Physics, CAS, Nanchang Road 509, Lanzhou, China

The wave properties of moving particles have gained increasing attention in collision physics in the last decades. One fundamental manifestation arises from the scattering of two atomic centers of diatomic molecules (the so-called Young-type interference). So far, two different kinds of Young-type interference in ion collisions have been reported: One is due to the electron emission from the two molecular centers, where the interference results in a significant modification of the electron energy and angular distributions. In the second branch of interference studies, electron capture involving a molecular projectile or target has been investigated where a strong dependence on the molecular orientation was observed.

In the present study we report on interference in ionization of atoms colliding with molecules. At the Max-Planck-Institut für Kernphysik in Heidelberg, we investigated the dissociative ionization channel in He-H_2^+ collisions. Interference effects in the momentum transfer patterns as well as in the individual momenta of electrons and He^+ -ions are investigated. The experimental results are reproduced by a model based on the first Born approximation.

A 29: Ultra-cold atoms, ions and BEC II

Time: Thursday 10:30–12:30 Location: V47.02

A 29.1 Thu 10:30 V47.02

Pomeranchuk effect and spin-gradient cooling of Bose-Bose mixtures in an optical lattice — •Yongqiang Li, Reza Bakhtiari, Liang He, and Walter Hofstetter — Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt/Main, Germany

We theoretically investigate finite-temperature thermodynamics and demagnetization cooling of two-component Bose-Bose mixtures in a cubic optical lattice, by using bosonic dynamical mean field theory (BDMFT). We calculate the finite-temperature phase diagram, and remarkably find that the system can be *heated* from the superfluid into the Mott insulator at low temperature, analogous to the Pomeranchuk effect in ^{3}He. This provides a promising many-body cooling technique. We examine the entropy distribution in the trapped system and discuss its dependence on temperature and an applied magnetic field gradient. Our numerical simulations quantitatively validate the spin-gradient demagnetization cooling scheme proposed in recent experiments.

A 29.2 Thu 10:45 V47.02

Raman cooling in a 1D lattice with additional radial confinement — •Andreas Steffen, Noomen Belmechri, Sebastian Hild, Andrea Alberti, Wolfgang Alt, and Dieter Meschede — Institut für angewandte Physik, Wegelerstr. 8, Bonn

Quantum information technology requires the interaction of qubits to realize devices like quantum cellular automata or phenomena like molecular bound states in quantum walks. For atoms in optical lattices, it is implemented most conveniently by controlled cold collisions, which requires the preparation of the atoms in the vibrational 3D ground state to achieve a well-defined interaction phase. We present current results on cooling single atoms in a 1D optical lattice with enhanced radial confinement. Two optically phase-locked Raman lasers have been built to couple different motional states. To meet the Lamb-Dicke criterion to cool the motion in the radial directions of our 1D lattice geometry, we overlap a repulsive hollow-core beam created by a phase mask. This increases the radial trap frequency by a factor of ten, allowing resolved Raman sideband cooling.

A 29.3 Thu 11:00 V47.02

Quantum phases of Bose-Bose mixtures in a triangular lattice — •Liang He[1], Yongqiang Li[1], Sebastian D. Huber[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe Universität Frankfurt (Main), Germany — [2]Department of Condensed Matter Physics, The Weizmann Institute of Science, Rehovot 76100, Israel

Geometric frustration arises when magnetic interactions between different spins on a lattice are incompatible with the underlying crystal geometry. Motivated by recent experimental progress in making non-bipartite optical lattices [1], we investigate the zero-temperature quantum phases of a Bose-Bose mixture in a triangular lattice, using bosonic dynamical mean field theory (BDMFT) [2]. We map out the ground state phase diagram of the system which contains spin-ordered phases, weak charge density wave, superfluid, and supersolid phases. The effects of geometric frustration on the spin-ordered phases and phase transitions between different spin-ordered phases are also discussed.

[1] C. Becker et al., New J. Phys. **12**, 065025 (2010); W. S. Bakr et al., Science **329**, 547 (2010); Gyu-Boong Jo et al., arXiv:1109.1591.

[2] K. Byczuk et al., Phys. Rev. B 77, 235106 (2008); A. Hubener

et al., Phys. Rev. B **80**, 245109 (2009); W. J. Hu et al., Phys. Rev. B **80**, 245110 (2009); Y. Li et al., Phys. Rev. B **84**, 144411 (2011).

A 29.4 Thu 11:15 V47.02

Investigation of $\mathcal{PT}$ symmetry in a model of a Bose-Einstein condensate — •Holger Cartarius and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

The observation of $\mathcal{PT}$ symmetry in a coupled optical wave guide system that involves a complex refractive index has been demonstrated impressively in the recent experiment by Rüter et al. [1]. This is, however, only an optical analogue of a quantum system, and it would be highly desirable to observe the manifestation of $\mathcal{PT}$ symmetry and its resulting properties also in a real, experimentally accessible, *quantum* system. Following a suggestion by Klaiman et al. [2], we investigate a $\mathcal{PT}$ symmetric arrangement of a Bose-Einstein condensate in a double δ well potential, where in one well cold atoms are injected while in the other particles are extracted from the condensate.

[1] C. E. Rüter, K. G. Makris, R. El-Ganainy, D. N. Christodoulides, M. Segev, and D. Kip, Nature Physics 6, 192 (2010)
[2] S. Klaiman, U. Günther, and N. Moiseyev, Phys. Rev. Lett. 101, 080402 (2008)

A 29.5 Thu 11:30 V47.02

Light-cone-like spreading of correlations in a quantum many-body system — Marc Cheneau[1], Peter Barmettler[2], Dario Poletti[2], Manuel Endres[1], •Peter Schauss[1], Takeshi Fukuhara[1], Christian Gross[1], Immanuel Bloch[1,3], Corinna Kollath[2,4], and Stefan Kuhr[1,5] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Département de physique théorique, Université de Genève, 1211 Geneva, Switzerland — [3]Ludwig-Maximilians-Universität, 80799 München — [4]Centre de physique théorique, École Polytechnique, CNRS, 91128 Palaiseau, France — [5]University of Strathclyde, SUPA, Glasgow G4 0NG, UK

How fast can correlations spread in a quantum many-body system? Based on the seminal work by Lieb and Robinson, it has recently been shown that several interacting many-body systems exhibit an effective light cone that bounds the propagation speed of correlations. The existence of such a "speed of light" has profound implications for condensed matter physics and quantum information, but has never been observed experimentally. In this talk I will report on the time-resolved detection of propagating correlations in an interacting quantum many-body system. By quenching a one-dimensional quantum gas in an optical lattice, we have revealed how quasiparticle pairs transport correlations with a finite velocity across the system, resulting in an effective light cone for the quantum dynamics. These results open important perspectives for understanding relaxation of closed quantum systems far from equilibrium as well as for engineering efficient quantum channels necessary for fast quantum computations.

A 29.6 Thu 11:45 V47.02

Progress and Outlook on Optically Trapped Ions — •Thomas Huber[1,2], Martin Enderlein[1,2], Christian Schneider[1,2], Michael Zugenmaier[2], Magnus Albert[1,2], and Tobias Schätz[1,2] — [1]Max-Planck-Institut für Quantenoptik — [2]Albert-Ludwigs-Universität Freiburg

In 2010 we trapped a Mg^+ ion in an optical dipole trap for the first time [1]. Compared to conventional ion traps optically trapped ions are promising in several ways: For example to study ultra-cold atom-ion collisions not suffering from micromotion-induced heating [2] and as potentially scalable systems with long-range interaction for quantum simulations.

The aim of quantum simulation is to study the complex dynamics of a quantum system by simulating it with an easier controllable one. One of the bottlenecks that still have to be passed is the scalability of the controllable systems. Next to ions in surface RF traps, ions or ions and simultaneously atoms trapped in optical lattices seem to be promising candidates. In this talk we will report on our results on confining a single ion in an one dimensional optical lattice.

Furthermore we will report on our proposals on optically trapping Ba^+ ions. Due to the transition wavelength in the visible regime this element offers several advantages. Recently it had been shown in a hybrid (RF + optical) trap, that Ba^+ is a good candidate to be sympathetically cooled by a cloud of ultracold Rb Atoms.

[1]Schneider et al., Nat. Photonics 4(2010)
[2]Cormick et al., New J. Phys. 13 (2011)

A 29.7 Thu 12:00 V47.02

Variational treatment of Faraday and resonant waves in Bose-Einstein condensates — •Alexandru Nicolin — Horia Hulubei National Institute for Physics and Nuclear Engineering, 30 Reactorului, Magurele 077125, Romania

The dynamics of Faraday and resonant waves in trapped Bose-Einstein condensates is analyzed by variational means. These waves can be excited by modulating periodically either the strength of the magnetic trap or the atomic scattering length. To study their dynamics, we develop a variational model that describes consistently both the bulk part of an inhomogeneous cigar-shaped condensate and small-amplitude, small-wavelength surface waves. The main ansatz used in the variational treatment is tailored around a set of Gaussian envelopes and we show extensions for the high-density regime using a q-Gaussian function. Finally, we show explicitly that for drives of small amplitude, the two methods of obtaining surface waves are equivalent, and we discuss the existing experimental results.

A 29.8 Thu 12:15 V47.02

Ballistic expansion of interacting fermions in one-dimensional optical lattices — •Stephan Langer[1], Martin J. A. Schuetz[2], Ian P. McCulloch[3], Ulrich Schollwöck[1], and Fabian Heidrich-Meisner[1] — [1]LMU München — [2]MPQ Garching — [3]U Queensland, Brisbane, Australia

In most quantum quenches, no net particle currents arise. Access to studying transport properties can be gained by letting a two-component Fermi gas that is originally confined by the presence of a trapping potential expand into an empty optical lattice. In recent experiments, this situation was addressed in 2D and 3D optical lattices [1]. We focus on the 1D case in which an exact numerical simulation of the time-evolution is possible by means of the DMRG method. Concretely, we study the expansion in the 1D Hubbard model with repulsive interactions, driven by quenching the trapping potential to zero, and we concentrate on the most direct experimental observable, namely density profiles [2]. In the strict 1D case, we identify conditions for which the expansion is ballistic, characterized by an increase of the cloud's radius that is linear in time. This behavior is found whenever initial densities are smaller or equal to one, both for the expansion from box and harmonic traps. We make quantitative predictions for the expansion velocity as a function of onsite repulsion and initial density that can be probed in experiments.

[1] Schneider et al., arXiv:1005.3545
[2] Langer et al., arXiv:1109.4364

A 30: Precision spectroscopy of atoms and ions II

Time: Thursday 10:30–12:30 Location: V47.03

Invited Talk A 30.1 Thu 10:30 V47.03

X-ray laser spectroscopy at the free-electron laser LCLS — •José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

X-ray laser spectroscopy (XRLS) has been demonstrated by using an electron beam ion trap (EBIT) at the recently commissioned free-electron laser Linac Coherent Light Source (LCLS) at SLAC. Many of the limitations in accuracy and selectivity which had hitherto hampered spectroscopic investigations of highly charged ions (HCIs) are overcome by the introduction of XRLS. The present results on $Fe^{15+,16+}$ strongly challenge state-of-the-art calculations widely used for astrophysical plasma diagnostics.

The novel method has also been applied to high-energy synchrotron radiation sources (BESSY II, PETRA III) for studies of the photoionization and excitation of HCIs in charge states as high as Fe^{24+} and at photon energies in the 6 keV range.

Future improvements of these X-ray sources, e. g. through radiation seeding, will help to develop this field further. New possibilities appear for the study and diagnostics of astrophysical and terrestrial plasmas as well as for X-ray metrology. Moreover, the new data stringently benchmark and guide the development of relativistic atomic structure theory.

Invited Talk A 30.2 Thu 11:00 V47.03

Test of fundamental physics with highly charged ions — •Z. Harman[1], C. Beilmann[1], J. R. Crespo López-Urrutia[1], S. Sturm[1,2], V. Yerokhin[1,3], J. Zatorski[1], K. Blaum[1], J. Ullrich[1], and C. H. Keitel[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]University of Mainz, Germany — [3]St. Petersburg State Polytechnical University, Russia

In highly charged ions (HCI), the strong nuclear Coulomb force renders the electron dynamics relativistic, and effects of strong-field quantum electrodynamics (QED) are increasingly relevant at higher and higher charges. A recent study has shown that surprising electron correlation effects appear already at low charge states, e.g. in C-like Ar: it was found that a recombination process with the participation of three electrons may result in a cross section higher than that of the usual dielectronic recombination [1]. Furthermore, we propose an alternative way of determining spectral properties of HCI by employing an x-ray free electron laser and an optical laser. Bound-state QED effects can be scrutinized to high precision in Penning trap experiments: a recent measurement yielded a value for the g factor of H-like Si with a $5 \cdot 10^{-10}$ fractional uncertainty, allowing to test certain higher-order QED corrections for the first time [2]. As theoretically suggested, similar experiments may even deliver more accurate or so far unknown nuclear shape parameters [3] and magnetic moments, relevant to NMR spectroscopy [4]. – [1] C. Beilmann *et al.*, PRL **107**, 143201 (2011); [2] S. Sturm *et al.*, PRL **107**, 023002 (2011); [3] J. Zatorski *et al.*, arxiv:1110:3330; [4] V. I. Yerokhin *et al.*, PRL **107**, 043004 (2011).

A 30.3 Thu 11:30 V47.03

Accurate spectroscopic references near 488 nm — •Sebastian Albrecht[1], Heiko Jestädt[1], Sanah Altenburg[1], Tobias Murböck[1], Manuel Vogel[1], Gerhard Birkl[1], and the SPECTRAP collaboration[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt — [2]GSI, Planckstraße 1, 64291 Darmstadt

Several current experimental ventures such as the study of the hyperfine transition of highly charged $^{209}Bi^{82+}$ ions or the excitation of Rydberg states in atomic rubidium strongly profit from a spectroscopic reference at wavelengths of 480 to 490 nm. Molecular tellurium provides a map of recorded spectra in this wavelength region [1].

We operate a frequency-quadrupled laser system for the generation of light at a wavelength of 244 nm for $^{209}Bi^{82+}$ spectroscopy [2]. The blue light available after the first frequency-doubling stage allows us to record tellurium spectra with improved accuracy. Previous measurements of the 1S-2S transition of muonium, deuterium and hydrogen as well as coinciding reference lines of an Ar^{+} laser have lead to calibrated tellurium resonances. Using these sub-Megahertz precise lines we can generate a continuous spectrum of tellurium with a span of 1.4 THz around 488 nm. This easily can be expanded to other wavelength regions in the blue for extended frequency calibration.

[1] J. Cariou and P. Luc, Atlas du spectre d'absorption de la molecule de tellure (Laboratoire Aime-Cotton, Paris, 1980)

[2] S. Albrecht, S. Altenburg, C. Siegel, N. Herschbach, G. Birkl, Appl. Phys. B, DOI: 10.1007/s00340-011-4732-8 (2011)

A 30.4 Thu 11:45 V47.03

Laserspektroskopie an relativistischen 209-Bi82+ und 209-Bi80+ Ionen am Speicherring ESR der GSI — •Christopher Geppert[1,2], Matthias Lochmann[1], Rodolfo M. Sanchez[1,2], Michael Hammen[1], Nadja Frömmgen[1], Elisa Will[1], Benjamin Botermann[1], Zoran Andjelkovic[1], Raphael Jöhren[3], Jonas Mader[3], Volker Hannen[3], Christian Weinheimer[3], Danyal Winters[2,4], Thomas Kühl[2], Yuri Litvinov[2], Thomas Stöhlker[2,4], Andreas Dax[5], Michael Bussmann[6], Weiqiang Wen[7], Richard Thompson[8] und Wilfried Nörtershäuser[1,2] — [1]Institut für Kernchemie, Universität Mainz — [2]GSI Helmholtzzentrum, Darmstadt — [3]Institut für Kernphysik, Universität Münster — [4]Physikalisches Institut, Universität Heidelberg — [5]Department of Physics, University Tokyo — [6]Helmholtz-Zentrum Dresden-Rossendorf — [7]IMP Lanzhou — [8]Imperial College, London

Die genaue Bestimmung der Hyperfeinstrukturaufspaltung (HFS) von hochgeladenen Ionen erlaubt im Abgleich mit theoretischen Berechnungen einen Test der QED. Die Messung an schweren und hochgeladenen Ionen erlaubt einen Test der QED in starken Feldern.

Im Rahmen der LIBELLE (E083)-Kollaboration am Helmholtzzentrum für Schwerionenforschung (GSI) wurden hierzu wasserstoff- und lithium-ähnliches Bismut bei Geschwindigkeiten von β=0.7 im Speicherring ESR gespeichert und mittels Laserspektroskopie untersucht. Nach 12-jähriger Suche wurde nun erstmals der verbotene HFS-Übergang im lithium-ähnlichen Bismut gefunden.

A 30.5 Thu 12:00 V47.03

Test of many-electron QED effects in the presence of magnetic fields — •Andrey Volotka[1], Dmitry Glazov[2], Oleg Andreev[2], Vladimir Shabaev[2], Ilya Tupitsyn[2], and Günter Plunien[1] — [1]Institut für Theoretische Physik, TU Dresden — [2]St. Petersburg State University, Russia

Recent progress in rigorous QED calculations of the hyperfine splitting and g factor of highly charged Li-like ions will be reported. A special attention will be paid to the evaluation of the two-photon exchange corrections in the presence of a magnetic field. Together with the screening radiative corrections they represent the most difficult many-electron QED diagrams, which have been so far rigorously evaluated. As a result, the accuracy for the specific difference between the hyperfine splitting values of H- and Li-like ions as well as for the g factor of Li-like ions has been significantly increased, thus providing the theoretical prerequisite for a test of many-electron QED effects at strong electromagnetic fields.

A 30.6 Thu 12:15 V47.03

Production of Be^{+} crystals in a cryogenic Paul trap for the sympathetic cooling of highly charged ions — •Alexander Windberger[1], Maria Schwarz[1], Oscar O. Versolato[1], José R. Crespo López-Urrutia[1], Alexander D. Gingell[2], Anders K. Hansen[2], Magnus A. Sørensen[2], Michael Drewsen[2], Piet O. Schmidt[3], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]University of Aarhus, Denmark — [3]Physikalisch-Technische Bundesanstalt, Braunschweig und Leibniz Universität, Hannover, Germany

Due to the deep core potential of highly charged ions (HCIs), optically active electrons involved in forbidden transitions are strongly bound. This type of electronic configuration offers various possibilities for high precision spectroscopy with applications to metrology and fundamental quantum dynamics. An efficient way of producing and trapping HCIs is the electron beam ion trap (EBIT). However, ion temperatures in the order of MK limit spectral resolution. With a new cryogenic Paul trap (CryPTEx) HCIs can be stored and laser cooled in a 4 K environment in which the rate of collisions with residual gas is strongly reduced. HCIs in CryPTEx will be sympathetically cooled with Be^{+} ions. To address the 313 nm cooling transition, a cw laser system has been developed. It comprises sum frequency and second harmonic generation stages of 1050 nm and 1550 nm fiber lasers. An output power at 313 nm of up to 750 mW can be reached. Furthermore, a source is under development for providing sufficient amounts of Be^{+} ions without disturbing the excellent cryogenic conditions inside the trap.

A 31: Interaction with strong or short laser pulses IV

Time: Thursday 10:30–12:30 Location: V57.05

Invited Talk A 31.1 Thu 10:30 V57.05

Coulomb potential effect on the tunneling electron from molecules — •Jian Wu and Reinhard Dörner — Institut für Kernphysik, Goethe Universität, Max-von-Laue-Strasse 1, D-60438 Frankfurt, Germany

What is the influence of the remaining ionic core on an electron wave emitted from an atom or molecule and on the ionization process itself? This question is general across all ionization phenomena. We study the electron recapture and Coulomb asymmetry in the strong field ionization of diatomic molecules. By measuring the kinetic energy release and angular distribution of the multiply ionized argon dimers, we can trace the recapture of up to two electrons by the highly charged compound at the end of the laser pulse. The trapping of the electron leads to population of a Rydberg orbital of the charged dimer. Subsequently the system dissociates. Upon its dissociation, the Rydberg electron prefers to localize at the atomic ion with the higher charge state. We further study the Coulomb asymmetric effect in the strong field ionization of molecules. We measure the angular distribution of an electron emitted from exploding doubly charged molecular nitrogen. The emission from the down-field core leads to a slight rotation with respect to the internuclear axis in the direction expected by the Coulomb effect of the remaining ion; while for emission from the up-field core this direction is inversed. Our semi-classical simulations suggest that this unexpected rotation is caused by an initial longitudinal momentum of the electron freed by over the barrier ionization above the inner barrier in the molecule.

A 31.2 Thu 11:00 V57.05

Charge selective ion energy distributions generated in the Coulomb explosion of Ag clusters — •Christian Schaal, Robert Irsig, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Institut für Physik, Universität Rostock, Universitätsplatz 3, D-18051 Rostock, Germany

There are only a few number of attempts to simultaneously analyze energetic ions from clusters exposed to strong laser fields for their specific charge state and energy. Therefore the contribution of a single charge state to the whole energy distribution is not studied in detail so far. The main problem is the low transmission of ions, since small appertures have to be used. We use the method of Magnetic Deflection TOF to obtain charge state selective energy spectra. Instead of recording ion spectra at certain energies, a position and time sensitive detector is used, which allows to record the impact of all transmitted ions at all energies in each shot. This results in a strong decrease in the exposure time, making this method feasible to also study low density cluster targets. The influence of the pulse parameters on the energy distributions are discussed.

A 31.3 Thu 11:15 V57.05

Time-resolved Dynamics after fs-excitation of Magnesium embedded in Helium Nanodroplets — •Sebastian Göde, Robert Irsig, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Institut für Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock, D

Magnesium atoms embedded in droplets show an interesting spectroscopic pattern when excited with ns laser pulses. An absorption feature near the atomic $3\ ^1P_1^0 \leftarrow 3\ ^1S_0$ transition is obtained, irrespective on the doping level. This observation is consistent with the assumption of a metastable foam like structure, where the helium prevents a relaxation into the structural ground state [1].

In the present study we conducted off-resonance fs pump-probe experiments to analyze the real time dynamics. By varying the pulse energy and ratio of the subpulses, different excitation regimes have been investigated. At low intensities 10^{12}W/cm^2, the cluster ion signals show a notable dependence on the order when unbalanced pulses are used. A weaker prepulse favors the appearance of cluster ions, while fragments are enhanced when stronger prepulses are used. When increasing the laser intensity a clear pump-probe signature evolves. Possible ionisation scenarios for compact clusters and a foam like constitution are discussed.

[1] A. Przystawik, S. Göde et. al., PRA **78**, 021202 (2008)

A 31.4 Thu 11:30 V57.05

Time-resolved nanoplasma dynamics in single xenon clusters driven by intense XUV and NIR pulses — •L. Flückiger[1], M. Adolph[1], T. Gorkhover[1], D. Rupp[1], M. Sauppe[1], S. Schorb[2], S. Düsterer[3], M. Harmand[3], H. Redlin[3], R. Treusch[3], C. Bostedt[2], M. Krikunova[1], and T. Möller[1] — [1]Technische Universität, Berlin — [2]LCLS, SLAC National Accelerator Laboratory — [3]Deutsches Elektronen-Synchrotron, Hamburg

We performed first two-colour pump-probe experiments on individual free xenon clusters at FLASH. New insight into the timescales of ionization dynamics, thermalization and fragmentation was achieved by simultaneous measurements of scattering patterns and ion time-of-flight spectra. Both, intense NIR and XUV pulses can highly ionize clusters and create a nanoplasma. However, only the radiation field of a NIR pulse couples strongly to the quasi-free electrons within the cluster. Therefore, the dynamics depend on the relative timing of the pulses.

With NIR as pump and FEL as probe pulse we follow the cluster fragmentation in real time by taking snapshots of the disintegrating sample while ion spectra provide information about the degree of cluster ionization. By reversing the temporal order of the beams, resonance conditions are reached - where the laser frequency corresponds to the plasma frequency - resulting in an enhanced energy absorption. A clear time and cluster size dependent signature was revealed by the charge state distribution and the flourescence yield detected.

A 31.5 Thu 11:45 V57.05

Angular-Resolved Electron Spectroscopy on Metal Clusters Exposed to Intense Laser Fields — •Johannes Passig, Dzimitri Komar, Robert Irsig, Thomas Fennel, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Cluster & Nanostrukturen, Institut für Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock, Germany, www.physik.uni-rostock.de/cluster

Collective electron motion induces strong polarization fields in metal clusters exposed to intense IR-pulses. By resonant excitation of the cluster plasmon mode via an optimized pump-probe sequence, strong energy capture from the laser field and subsequent emission of highly charged and energetic species. We present first full angular-resolved electron spectra from silver nanoparticles exceeding 1keV (100 Up) at moderate laser intensities of 10^{14} W/cm^2. The emission shows a pronounced alignment along the laser polarization axis. Comparison of the experimental data with molecular dynamical simulations gives evidence, that the efficient acceleration proceeds via surface plasmon assisted rescattering, a mechanism unique for small particles [Fennel et al., Phys. Rev. Lett. 98, 143401 (2007)].

A 31.6 Thu 12:00 V57.05

Parametric studies of high-order harmonic generation in liquid water droplets — •H. G. Kurz[1,2], D. S. Steingrube[1,2], D. Ristau[2,3], M. Lein[4], U. Morgner[1,2,3], and M. Kovačev[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, D-30167 Hannover — [2]QUEST - Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, D-30167 Hannover — [3]Laser Zentrum Hannover e.V., Hollerithallee 8, D-30419 Hannover — [4]Leibniz Universität Hannover, Institut für theoretische Physik, Appelstrasse 2, D-30167 Hannover

We report on high-order harmonic generation (HHG) in micrometer-sized liquid water droplets under vacuum condition. A chirped pulse amplification laser system delivers 100 fs-pulses with energies up to 5 mJ for HHG in an ensemble of emitters. The coherent sum of all emitters within the droplet forms the harmonic signal. Therefore, macroscopic effects have to be taken into account. To maximize the harmonic yield, the phases of all these emitters have to be matched. The influence of phase-matching aspects onto HHG are demonstrated by different parameters. Additionally, a pump-probe setup allows for the observation of the spatiotemporal evolution of the target. When the droplet is hit by the pump pulse it starts evaporating, while the probe pulse creates the harmonic radiation. Thus, different pump-probe time delays give access to different states of the target during HHG. Results of phase-matching experiments and the spatiotemporal evolution of the target will be presented.

A 31.7 Thu 12:15 V57.05

Dopant-induced ignition and expansion dynamics of He nanodroplets in intense few-cycle NIR pulses — •Siva Rama Krishnan[1], Lutz Fechner[1], Manuel Kremer[1], Vandana Sharma[1], Bettina Fischer[1], Nicolas Camus[1], Thomas Pfeifer[1], Jagannath Jha[2], Krishnamurthi Manchikanti[2], Claus-Dieter Schröter[1], Robert Moshammer[1], Joachim Ullrich[1], Frank Stienkemeier[3], and Marcel Mudrich[3] — [1]Max Planck Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Tata Institute of Fundamental Research, 1 Homi Bhabha Road, Mumbai 400005, India — [3]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany

We report our investigations on dopant-induced ignition (DII) of He nanodroplets by intense few-cycle (10 fs) near-infrared (NIR) pulses. DII is triggered by less than 10 dopant Xe atoms residing at the center of the nanodroplet. This results in the complete ionization of a nanodroplet containing about 10000 He atoms, which is otherwise transparent to these pulses. Our studies demonstrate a very efficient energy transfer from intense NIR laser fields to the droplet nanoplasma on a sub-10 fs timescale for the first time. Further, the consequences of DII on the ionic expansion dynamics of these doped nanodroplets occurring on ps timescales is also examined. Thus, we present a complete picture of the intense NIR ionization dynamics of doped He nanodroplets from sub-10fs to a few picoseconds.

A 32: SYPC 1: From Atoms to Photonic Circuits 1

Time: Thursday 10:30–12:30 Location: V47.01

Invited Talk A 32.1 Thu 10:30 V47.01
Quantum Communication: real-world applications and academic research — •Nicolas Gisin — GAP, University of geneva

Quantum communication is the art of transferring a quantum state from one place, Alice, to another, Zeus. The simplest technique consists in merely sending a system carrying the quantum state, typically a photon, directly from Alice to Zeus. This is basically the way commercial quantum key distribution apparatuses work today, though direct communication is definitively limited to a few hundreds of km due to losses in optical fibers. But there are more sophisticated ways to realize quantum communication, each more fascinating than the other. First, one could exploit 2-photon entanglement and their EPR-like correlations. Next, one could perform quantum teleportation, a mind-boggling 3-photon process. All these have been demonstrated in and outside labs. But the real grand challenge for quantum communication is much more ambitious and fascinating: teleport a quantum state along a chain of sections: from A to B, then from B to C and so on until Y to Z. Moreover, in order to outperform direct communication, the process should be efficient. This requires that the A-B and B-C and * Y-Z entanglements necessary for quantum teleportation, must all be ready before one starts the teleportation processes. This, in turn, implies that the entanglement must be in-between quantum memories located at each node A, B, C, etc, able to hold the quantum state for ms.

Invited Talk A 32.2 Thu 11:00 V47.01
Trapping and Interfacing Cold Neutral Atoms Using Optical Nanofibers — •Arno Rauschenbeutel — Vienna Center for Quantum Science and Technology, TU Wien–Atominstitut, Stadionallee 2, 1020 Wien, Austria

We have recently demonstrated a new experimental platform for trapping and optically interfacing laser-cooled cesium atoms [1]. The scheme uses a two-color evanescent field surrounding an optical nanofiber to localize the atoms in a one-dimensional optical lattice 200 nm above the nanofiber surface. At the same time, the atoms are efficiently interrogated with light which is sent through the nanofiber. Remarkably, an ensemble of 2000 trapped atoms yields an optical depth of up to 30, equivalent to 1.5 % absorbance per atom. Moreover, when dispersively interfacing the atoms, we observe ~ 1 mrad phase shift per atom at a detuning of six times the natural linewidth [2].

Our technique provides unprecedented ease of access for the coherent optical manipulation of trapped neutral atoms and opens the route towards the direct integration of atomic ensembles into fiber networks, an important prerequisite for large scale quantum communication. Moreover, our nanofiber trap is ideally suited to the realization of hybrid quantum systems combining atoms with solid state quantum devices.

Financial support by the ESF (EURYI Award), the FWF (Vienna Doctoral Program CoQuS), and the Volkswagen Foundation (Lichtenberg Professorship) is gratefully acknowledged.

[1] E. Vetsch *et al.*, Phys. Rev. Lett. **104**, 203603 (2010).
[2] S. T. Dawkins *et al.*, Phys. Rev. Lett. **107**, 243601 (2011).

A 32.3 Thu 11:30 V47.01
Quantum networking with time-bin encoded qubits, qutrits and qquads using single photons from an atom-cavity system — Peter B. R. Nisbet-Jones, Jerome Dilley, Oliver Barter, •Annemarie Holleczek, and Axel Kuhn — Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU

We report on the production of time-bin encoded qubits, qutrits and qquads which are one fundamental building block in quantum information processing, networking and cryptography. They are produced by full coherent control of the single-photon generation in a strongly coupled atom-cavity system. This allows for the preparation of single photons in an n-time-bin superposition state with arbitrarily defined amplitudes and phases. The qubits', qutrits' and qquads' properties are determined and demonstrated with the help of a small linear optics quantum network [1].

[1] P. B. R. Nisbet-Jones, et al., "Quantum networking with time-bin encoded qubits, qutrits and qquads using single photons from an atom-cavity system," *in preparation* (2011).

A 32.4 Thu 11:45 V47.01
Highly efficient, fibre-integrated single photon to single mode coupling - based on defect centres in nanodiamonds — •Tim Schröder[1], Masazumi Fujiwara[2], Tetsuya Noda[2], Hong-Quan Zhao[2], Oliver Benson[1], and Shigeki Takeuchi[2] — [1]Nano-Optics, Humboldt University — [2]RIES, Hokkaido University, Japan

Recently, the most direct approach to fabricate a reliable single photon source, by mounting a single quantum emitter on an optical fibre, was demonstrated*. A nanodiamond containing a single nitrogen vacancy (NV) centre was placed on the fibre facet. Such a system easily integrates into fibre optic networks for quantum cryptography and is promising for quantum metrology applications.

Here, we present a tapered fibre based single photon system that has an even wider application range. Single nanodiamonds containing NV centres are deposited on such a tapered fibre of 273 nm in diameter. The tapered fibres were fabricated from standard single mode fibres. For the deposition on the taper, a dip-coating technique was developed, that enables controlled deposition of nanodiamonds and other nanoparticles. For a single NV centre, 689 kcts/s of single photons are coupled into a single mode. The system was cooled to cryogenic temperatures and can be coupled evanescently to other nanophotonic structures, such as microresonators. It is suitable for integrated quantum transmission experiments, two-photon interference, quantum-random-number generation. As a nanoprobe it can be used for well localized, ultra-sensitive sensing applications such as nanomagnetometry.

* Schroeder et al. Nano Letters 11, 198, 2011

A 32.5 Thu 12:00 V47.01
Towards optical quantum logic: Source, interface and memory — Jerome Dilley, Peter B. R. Nisbet-Jones, •Annemarie Holleczek, Oliver Barter, and Axel Kuhn — Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU

We present a highly efficient, deterministic source of indistinguishable photons which is based on a vacuum stimulated Raman process (V-STIRAP) in a strongly coupled atom-cavity system [1]. This device operates intermittently for periods of up to $100\mu s$, with a single-photon repetition rate of 1 MHz, and an efficiency of greater than 65% [2]. The single photons are not only produced on demand but also with total control of their shape and intrinsic phase. In addition, we present a scheme how a single photon can be reabsorbed by the emitting atom as this is the key to a single-photon quantum memory [3].

[1] A. Kuhn and D. Ljunggren, Contem. Phys. **51**, 298 (2010).
[2] P. B. R. Nisbet-Jones, et al., New J. Phys. **13**, 103036 (2011).
[3] J. Dilley, et al., arXiv 1105.1699 (2011).

A 32.6 Thu 12:15 V47.01
Asymmetric-coupled vertical quantum dots: Towards a light controlled quantum gate — •Elisabeth Koroknay[1], Christian Kessler[1], Matthias Reischle[1], Ulrich Rengstl[1], Moritz Bommer[1], Robert Rossbach[1], Heinz Schweizer[2], Michael Jetter[1], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart, Germany — [2]4. Physikalisches Institut, Pfaffenwaldring 57, 70569, Stuttgart, Germany

In this talk we show the route towards the realization of a laterally and vertically positioned triple dot structure consisting of a tunnel-coupled vertical asymmetric double quantum dot structure (ADQD) and a single dot (larger than the ADQD). The triple dot structure serves as a quantum gate with the ADQD as source dot and the large dot as target dot. The coupling between source and target is achieved by light induced dipole fields originating from the ADQD which influence via the Stark effect the target dot transition.

The quantum dot (QD) structures are grown by metal-organic vapor-phase epitaxy (MOVPE) on GaAs substrates. The ADQD consists of two vertically stacked differently sized InP QDs embedded in GaInP, grown lattice matched to GaAs. Time integrated and time-resolved photoluminescence (PL) measurements have been performed on ADQDs to investigate the coupling behavior. For the target QD the InGaAs material system was chosen to clearly differ in emission energy of the InP ADQD. Next to our growth efforts we present structural and optical analysis of the current status.

A 33: SYRA 3: Ultracold Rydberg Atoms and Molecules 3

Time: Thursday 10:30–13:00 Location: V7.03

A 33.1 Thu 10:30 V7.03

Interaction enhanced imaging of individual Rydberg atoms in dense gases — •Martin Robert-de-Saint-Vincent, Georg Günter, Christoph S. Hofmann, Hanna Schempp, Henning Labuhn, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

Neutral atoms in Rydberg states are highly-polarisable particles, which can experience quantum effects and interactions over macroscopic distances. Many-body systems of Rydberg atoms offer a unique opportunity to create and investigate strong correlations in ultra-cold atomic gases [1]. Until recently, Rydberg ensembles have mostly been studied via field-ionization and subsequent ion detection, typically providing ensemble properties. Here, we present an all-optical method to image individual Rydberg atoms embedded within dense gases of ground state atoms [2]. The scheme exploits interaction-induced shifts on highly polarizable excited states of probe atoms, which can be spatially resolved via an electromagnetically induced transparency resonance. Using a realistic model, we show that individual Rydberg atoms can be imaged with enhanced sensitivity and high resolution despite photon shot noise and atomic density fluctuations. This scheme could be extended to other impurities such as ions, and is ideally suited to studies of spatially-correlated many-body systems.

[1] Pohl et al., PRL 104, 043002 (2010)
[2] G. Günter et al., arXiv:1106.5443v1 (2011), to be published in PRL

A 33.2 Thu 10:45 V7.03

Rydberg Atom Spectroscopy in Electric Fields — •Atreju Tauschinsky, Richard Newell, Vanessa Leung, Ben van Linden van den Heuvell, and Robert Spreeuw — Institute of Physics, University of Amsterdam, Amsterdam, Netherlands

We study rubidium Rydberg states in static and oscillating electric fields using Electromagnetically Induced Transparency (EIT) in the 5s-5p-nℓ system for $n \geq 28$ and $\ell = 0 \dots 2$. We present high-precision Doppler free measurements of DC Stark shifts in a room temperature vapour cell which are in excellent agreement with theoretical calculations. These measurements clearly show that the assumption of quadratically shifting energy levels where the shift is determined by the polarizability of the state is valid only for very small fields, less than 5% of the Inglis-Teller Limit.

We furthermore investigate the behaviour of Rydberg states in superposed AC and DC electric fields and observe populated sidebands of very high order. We present a model, based on generalized Bessel functions for the sideband population induced by oscillating fields in arbitrarily stark-shifting levels and compare the results of this model to our measurements.

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

C. S. E. van Ditzhuizen *et al.* Observation of Stückelberg oscillations in dipole-dipole interactions. Phys. Rev. A **80**, 063407 (2009)

A 33.3 Thu 11:00 V7.03

Coherent spectroscopy involving Rydberg states in electrically contacted microcells — •Renate Daschner, Ralf Ritter, Daniel Barredo, Harald Kübler, Robert Löw, and Tilman Pfau — Universität Stuttgart

Micron sized glass cells filled with atomic vapor are promising candidates for quantum devices based on the Rydberg blockade. Due to the strong interaction between two Rydberg atoms, only one Rydberg excitation is possible within a certain volume characterized by the blockade radius (typically few microns). This effect also provides a nonlinearity that is an essential tool for proposals to entangle mesoscopic ensembles and to realize single photon sources. Measurements show, that coherent Rydberg excitation in thermal vapor and micron-sized cells is possible [1].

The large DC Stark shift of Rydberg atoms provides a possibility to induce transmission or absorption in the medium. To address individual cells one needs electrical contact of the cells. This can be done by coating the inside of glass cells for example with a metal. We show first measurements in coated electrically contacted cells where we can shift the signal by more than one linewidth with a DC electric field.

[1] Kübler, H., Shaffer, J. P., Baluktsian, T., Löw, R. & Pfau, T. Coherent excitation of Rydberg atoms in micrometre-sized atomic vapour cells, Nature Photon. 4, 112-116 (2010)

A 33.4 Thu 11:15 V7.03

Measurement of the Rydberg ionization current in thermal vapor cells — •Daniel Barredo, Renate Daschner, Harald Kübler, Ralf Ritter, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

Rydberg atoms confined in atomic vapor cells are promising candidates for the realization of single photon sources and quantum optical devices [1].To date, most information about the behavior of the Rydberg ensembles in thermal vapors has been extracted by absorptive measurements, e.g. EIT. However, to access directly quantities, like the population of the excited states, new methods are needed. In this task, the detection of the Rydberg ionization current provides a complementary and direct insight in the atomic processes.

We show measurements of the Rydberg-ion current in thermal vapor cells equipped with field plates.

[1] Kübler, H., Shaffer, J.P., Baluktsian, T., Löw, R. and Pfau, T. Coherent excitation of Rydberg atoms in micrometre-sized atomic vapour cells, *Nature Photon.* **4**, 112-116 (2010).

A 33.5 Thu 11:30 V7.03

Scaling laws and correlations in finite Rydberg gases — •Martin Gärttner[1,2], Thomas Gasenzer[2], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, D-69120 Heidelberg

We study the coherent dynamics of a finite laser-driven cloud of ultracold Rydberg atoms by calculating the time evolution from the full many body Hamiltonian. Using the frozen gas approximation and treating the atoms as effective two level systems, we are mainly interested in the spatially resolved properties of the gas in its thermalized state. Even for resonant coupling to the Rydberg state, the pair correlation function shows a pronounced structure. It turns out that a simple estimation of the blockade radius predicts the position of the first maximum of the $g^{(2)}$-function quite well. However, we show that algebraic scaling laws as predicted in [1] are modified by finite size effects which serves as a test of the validity of the super atom picture. At positive detuning crystalline structures are observed even without using chirped laser pulses [2], which can be explained by resonant excitation processes and finite size effects.

[1] H. Weimer *et al.*, Phys. Rev. Lett. 101, 250601 (2008)
[2] T. Pohl *et al.*, Phys. Rev. Lett. 104, 043002 (2010)

A 33.6 Thu 11:45 V7.03

Coherence on Förster resonances between Rydberg atoms — •Alexander Krupp, Johannes Nipper, Jonathan Balewski, Robert Löw, and Tilman Pfau — 5.Physikalisches Institut, Universität Stuttgart

Förster resonances are non-radiative dipole-dipole interactions between oscillating dipoles. Especially in biochemistry these resonances play a crucial role and describe the energy transfer process between two chromophores, parts of molecules which are responsible for their colors. In our work these resonances occur between a pair of Rydberg atoms, creating strong interactions between the atoms.

We report on studies of Förster resonances between Rydberg atoms in an ultra-cold atomic cloud of ^{87}Rb. By applying a small electric field we tune dipole coupled pair states into resonance, giving rise to Förster resonances. Via a Ramsey-type atom interferometer we can resolve several resonances at distinct electric field strengths. We study the coherence of the system at and close to the resonances and we observe a change in phase and visibility of the Ramsey fringes on resonance. The individual resonances are expected to exhibit different angular dependencies, opening the possibility to tune not only the interaction strength but also the angular dependence of the pair state potentials by an external electric field. In summary, we now have a tool to coherently tune interactions between Rydberg atoms. In further studies Rydberg atoms could be used as a model system to simulate energy transfer processes in bio-molecules.

A 33.7 Thu 12:00 V7.03

Collective and quasiparticle excitations in 2D dipolar gases — •Alexey Filinov und Michael Bonitz — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität, Leibnizstr. 15, D-24098 Kiel, Germany

The Berezinskii-Kosterlitz-Thouless transition in dipolar atomic, molecular and indirect exciton systems has been recently studied by path integral Monte Carlo simulations [1,2]. Here, we complement these analyses by the spectral densities of the longitudinal collective and single particle (SP) excitations by computing the dynamic structure factor, $S(q,\omega)$, and the SP spectral function, $A(q,\omega)$, across the superfluid to normal fluid transition. The SP spectrum has been worked out by evaluation of the one-particle Matsubara Green's function together with a stochastic optimization method for the reconstruction of $A(q,\omega)$ from imaginary times. We discuss the coupling of both spectra in the *superfluid phase*. We observe sharp resonances due to the quasi-condensate. The excitations in the normal phase are shifted to higher energies and significantly damped beyond the acoustic branch. Our results generalize previous zero-temperature analyses based on variational many-body wavefunctions [2,3]. The underlying physics of excitations and the role of the condensate is not easily extracted from such calculations. Moreover, at finite temperatures the use of the variational approach becomes problematic as the excitation damping becomes significant.

[1] A. Filinov et al., PRL 105, 070401(2010); [2] J. Böning et al., PRB 84, 075130(2011); [3] F. Mazzanti et al., PRL 102, 110405(2009); [4] D. Hufnagl et al., PRL 107, 065303(2011)

A 33.8 Thu 12:15 V7.03

Crystallization of Rydberg excitations in continuously driven atomic ensembles — •David Petrosyan[1,2] and Michael Fleischhauer[1] — [1]Fachbereich Physik, Technische Universitaet Kaiserslautern, D-67663 Kaiserslautern — [2]Institute of Electronic Structure and Laser, FORTH, GR-71110 Heraklion, Crete, Greece

We study resonant optical excitations of dense atomic ensembles to the strongly interacting Rydberg states. We show that in the steady state of strong continuous driving the correlations of Rydberg excitation probabilities exhibit damped spatial oscillations reminiscent of the density waves of a finite temperature Luttinger-liquid with Luttinger parameter K << 1/2. For very strong driving, the period of the spatial oscillations saturates to a value corresponding to one collective Rydberg excitation (superatom) per blockade distance. After sudden switching off of the coupling lasers, the Rydberg quasi-crystal can survive for tens or hundreds of microseconds, it can be detected in situ by spatially-resolved Rydberg state ionization or adiabatically converted into a train of single-photon pulses.

A 33.9 Thu 12:30 V7.03

Nonlocal Nonlinear Optics in cold Rydberg Gases — •Sevilay Sevinçli[1,2], Nils Henkel[1], Cenap Ates[1], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden,Germany — [2]Department of Physics and Astronomy, Aarhus University, 8000 Aarhus C, Denmark

Electromagnetically induced transparency (EIT) provides remarkable possibilities for nonlinear optics by enabling ultraslow group velocities and storage of light. The combination of EIT and interacting Rydberg gases has recently attracted considerable theoretical and experimental interest, as it holds promise for realizing extremely large nonlinearities by exploiting the exaggerated interactions between Rydberg atoms.

We present an analytical theory of the nonlinear response of cold Rydberg gases. This yields simple expressions for the third order susceptibilities which are in excellent agreement with recent measurements. It is further found that the nonlinear susceptibility is not only drastically enhanced but also highly nonlocal in nature, corresponding to long-range photon-photon interactions. Considering the propagation of light in such a Rydberg-EIT medium, this gives rise to a wealth of nonlinear wave phenomena, including soliton formation or modulation instabilities of strongly interacting light fields.

A 33.10 Thu 12:45 V7.03

Collective interactions in Rydberg-dressed Bose-Einstein condensates — •Nils Henkel and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden

We investigate a Bose-Einstein condensate where atoms are dressed to high Rydberg states with strong van der Waals interactions. Solving exactly the internal many-body state dynamics, we show that this leads to effective ground state interactions with genuine many-body character. In the limit of large laser detunings, two-body interactions dominate [1,2] while many-body interactions become relevant in the strong-driving limit, i.e. in the limit of large laser intensities or weak detunings. We study the effects of these higher order interactions and show that nonlocal phenomena found for binary interactions are still also observable in the presence of strong collective, i.e. genuine many-body, interactions.

[1] N. Henkel, R. Nath and T. Pohl, Phys. Rev. Lett. **104** 195302
[2] F. Maucher et al., Phys. Rev. Lett. **106** 170401

A 34: Kalte Atome: Manipulation und Detektion

Time: Thursday 14:00–16:00 Location: V7.03

A 34.1 Thu 14:00 V7.03

Fibre-optical tweezers to preparate and interface single atoms — •Dominik Maxein, Sébastien Garcia, Leander Hohmann, Jakob Reichel, and Romain Long — Laboratoire Kastler Brossel UPMC ENS CNRS, 24 rue Lhomond, 75231 Paris Cedex 05

Preparing and manipulating single quantum objects is crucial to explore their interactions and to use them as components in quantum information processing. Atoms can be trapped in a focussed red-detuned laser beam forming an optical dipole trap or "tweezers". Sufficiently small tweezers exhibit the regime of collisional blockade, in which at most one atom stays trapped, making this an advantageous system to prepare single atomic qubits. However, the size and complexity of existing single-atom tweezers experiments impedes their highly desirable combination with other elements such as optical cavities.

Our approach is to simplify and miniaturize single-atom tweezers, turning them into a robust and versatile tool in quantum optics. This is achieved by using a single-mode fibre fixed to a small aspheric lens. This simple system serves the dual purpose of providing strongly focussed trapping light and collecting atomic fluorescence with high numerical aperture. A first implementation has been realized, and the obtained fluorescence signals clearly indicate the trapping of single atoms. We will study the properties of the system and furthermore characterize it as a single-photon source, expecting narrowband emission and good indistinguishability of successive photons. Finally, opportunities for continuing integration of fibre-optical single-atom tweezers and their combination with other experiments will be discussed.

A 34.2 Thu 14:15 V7.03

Quantum computation with ultracold atoms in driven optical lattices — •Philipp-Immanuel Schneider and Alejandro Saenz — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstrasse 15, 12489 Berlin, Germany

In the last years tremendous progress has been made in controlling and observing ultracold atoms in optical lattices. One of the latest developments has been the optical detection of atoms with single site resolution in lattices of increasingly smaller periodicity [1,2]. Along with these detection schemes comes the possibility to control the lattice potential with single-site resolution.

We propose a scheme that makes use of these approved technologies to perform quantum computation in optical lattices. The qubits are encoded in the spacial wavefunction of atoms in the Mott insulator phase such that spin decoherence does not influence the computation. Quantum operations are steered by shaking the lattice while the qubits are addressed by locally changing the lattice potential. Numerical calculations show possible fidelities above 99% with gate times on the order of a few milliseconds [3].

[1] W. S. Bakr et al. Nature **462**, 74 (2009).
[2] J. F. Sherson et al. Nature **467**, 68 (2010).
[3] P.-I. Schneider, A. Saenz preprint arXiv:1103.4950

A 34.3 Thu 14:30 V7.03

Temperature measurement of ultracold atoms using electromagnetically induced transparency — •Frank Blatt[1], Benjamin Wittrock[1], Thorsten Peters[1], Leonid Yatsenko[2], and Thomas Halfmann[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 6, 64289 Darmstadt — [2]Institute of Physics, National Academy of Sciences of Ukraine, Prospect Nauki 46, Kiev-39, 03650, Ukraine

Determination of temperatures in ultracold atomic clouds is a crucial requirement for many experiments in quantum optics. Temperature determination is typically realized by time-of-flight (TOF) measurements. The latter is easy to implement and precise - but also slow and destructive to the atomic cloud.

In this talk we present experimental results on temperature measurements in an ultracold atomic cloud by electromagnetically induced transparency (EIT). We compare the data to numerical simulations, as well as temperature measurements by TOF. As an important feature in EIT with two counter propagating beams, the absorption of the probe beam depends on the Doppler broadening, i.e. the temperature of the medium. This enables determination of temperatures from rather simple EIT spectra. The technique is robust, fast and does not destroy or perturb the atomic cloud.

A 34.4 Thu 14:45 V7.03

Quantum Memory Assisted Probing of Dynamical Spin Correlations — Oriol Romero-Isart[1], •Matteo Rizzi[1], Christine Muschik[1,4], Eugene Polzik[2], Maciej Lewenstein[3,4], and Anna Sanpera[3,5] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Niels Bohr Institute, QUANTOP, Copenhagen University, Denmark — [3]ICREA-Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain — [4]ICFO-Institut de Ciències Fotòniques, Castelldefels, Spain — [5]Departament de Física. Universitat Autònoma de Barcelona, Bellaterra, Spain

We propose a method to probe time dependent correlations of non trivial observables in many-body ultracold lattice gases. The scheme uses a quantum non-demolition matter-light interface, first, to map the observable of interest on the many body system into the light and, then, to store coherently such information into an external system acting as a quantum memory. Correlations of the observable at two (or more) instances of time are retrieved with a single final measurement that includes the readout of the quantum memory. Such method brings at reach the study of dynamics of many-body systems in and out of equilibrium by means of quantum memories in the field of quantum simulators.

A 34.5 Thu 15:00 V7.03

Classicality from the continuous measurement of a BEC in a double-well potential — •Moritz Hiller[1,2], Thomas Konrad[3,4], Magnus Rehn[3], Francesco Petruccione[3], and Andreas Buchleitner[2] — [1]Institute for Theoretical Physics, Vienna University of Technology, Austria — [2]Fakultät für Physik, Albert-Ludwigs-Universität Freiburg, Germany — [3]Centre for Quantum Technologies, University of KwaZulu-Natal, Durban, South Africa — [4]National Institute of Theoretical Physics, South Africa

We study continuous (unsharp) measurements of a Bose-Einstein condensate (BEC) in a double-well potential. We find, that the interplay between measurement and inter-atomic interactions can drastically reduce the complexity of the quantum many-body wave function – to the extent, that the latter resembles a coherent, i.e., a classical state despite the presence of interactions. We demonstrate that in this regime, the dynamics of the system (including the influence of the measurement) can be monitored faithfully after a certain time. That is, the time-evolving state can be inferred from the measurement signal without destroying the BEC.

A 34.6 Thu 15:15 V7.03

Efficient quantum state tomography of atoms in optical lattices — •Matthias Ohliger[1,2], Christian Gogolin[1], Vincent Nesme[1], and Jens Eisert[1] — [1]Dahlem center for complex quantum systems, Berlin, Germany — [2]Universität Potsdam, Potsdam, Germany

Due to the high level of experimental control, ultra-cold atoms in optical lattices are almost perfectly suited as a model for various many-body systems. We propose a method for efficient quantum state tomography in such settings, relying only on experimentally feasible techniques like super-lattices, laser-speckles, and time-of-flight measurements. We consider the most general situation of an arbitrary quantum states and discuss the simplifications which occur when the state is of low rank or well approximated by a matrix-product state. Furthermore, we introduce a protocol to certify the success of the tomography procedure based on the measured data.

A 34.7 Thu 15:30 V7.03

Trapping and guiding atoms on a mesoscopic chip structure — •Jan Mahnke[1], Stefan Jöllenbeck[1], Ilka Geisel[1], Jan Arlt[2], Wolfgang Ertmer[1], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]Department of Physics and Astronomy, Aarhus University, Denmark

We investigate guiding and trapping of rubidium atoms on a mesoscopic chip structure with millimeter scale wires. This structure is used to create a quadrupole field for a magneto-optical trap, a magnetic guide and a flexible magnetic trapping potential. In our experiments this allows us to transport cold atoms into a region that provides better vacuum conditions and very effective stray light protection. It is therefore particularly well suited to simultaneously trap and collect atoms. We show that our control of the local magnetic fields and the effective light shielding enable us to load another MOT without significantly reducing the lifetime of previously trapped atoms. This enables reloading the magnetic guide and may lead towards a continuous loading scheme [1].

[1] Continuous loading of a non-dissipative atom trap C. F. Roos et al 2003 Europhys. Lett. 61 187

A 34.8 Thu 15:45 V7.03

Formation of helical ion chains — •Ramil Nigmatullin[1,2], Adolfo del Campo[3], Gabriele de Chiara[4,5], Giovanna Morigi[6], Martin Plenio[1,2], and Alex Retzker[1] — [1]Ulm University, Ulm, Germany — [2]Imperial College London, London, UK — [3]Los Alamos National Laboratory, Los Alamos, USA — [4]Universitat Autonoma de Barcelona, Barcelona, Spain — [5]Queen's University Belfast, Belfast, UK — [6]University of Saarlandes, Saarbruecken

We study the formation of helices in the structural phase transition of linear Wigner crystals to zigzag Wigner crystals. Wigner crystals are confined radially by a harmonic potential and with periodic boundary conditions in the axial direction, which in principle can be realized experimentally using ring ion traps. Molecular dynamics simulations are used to show that the dependence of the average winding number of the helix is consistent with the prediction of the Kibble-Zurek mechanism.

A 35: Ultra-cold atoms, ions and BEC III

Time: Thursday 14:00–16:00 Location: V47.02

A 35.1 Thu 14:00 V47.02

A transportable setup for investigation of multiple charge transfer — •Simone Götz[1], Bastian Höltkemeier[1], Matthias Weidemüller[1], and Brett DePaola[2] — [1]Philosophenweg 12, 69126 Heidelberg — [2]Kansas State University, Kansas, USA

We report on a transportable compact setup combining a dark SPOT (spontaneous optical trap) for Rubidium atoms with a recoil ion momentum spectrometer [1]. The target is loaded with high flux from a

2 dimensional magneto-optical trap, achieving densities of up to 10^{11} atoms/cm^{-3}. The spectrometer is characterized measuring the ion recoil energy in photoionization of the trapped atoms [2,3].

In collaboration with the GSI in Darmstadt this setup will be used to investigate correlation effects in multiple charge transfer between the rubidium atoms and highly charged ions. An outlook will be given.

[1] J. Ullrich *et al.*, J Phys. B **30**, 2971 (1997)
[2] S. Wolf *et al.*, PRA **56**, R4385 (1997)
[3] S. Wolf *et al.*, PRA **62**, 043408 (2000)

A 35.2 Thu 14:15 V47.02

Quantum magnetism of mass-imbalanced fermionic mixtures — •Andrii Sotnikov[1], Daniel Cocks[1], Michiel Snoek[2], and Walter Hofstetter[1] — [1]Goethe University, Frankfurt am Main, Germany — [2]Universiteit van Amsterdam, The Netherlands

We study magnetic phases of two-component mixtures of repulsive fermions in optical lattices in the presence of mass imbalance. The analysis is based on dynamical mean-field theory (DMFT) and its real-space generalization at finite temperature. The dependencies of the transition temperature to the ordered state on the interaction strength and the imbalance parameter are studied both in two and three spatial dimensions. For a harmonic trap, we compare our results obtained by real-space DMFT to results from a local-density approximation.

Our approach allows us to calculate the entropy at different parameters of the system and discuss the cases in which mass-imbalanced mixtures can have additional advantages for reaching quantum magnetism. We point out that at half-filling with a finite value of hopping imbalance the system has additional signatures (e.g., charge-density wave) of Neel (magnetic) ordering. We also consider additional population imbalance and study transitions between different magnetic phases in this case.

A 35.3 Thu 14:30 V47.02

Quantum Simulation of Frustrated Quantum Ising models with cold ion crystals — •Alejandro Bermudez[1], Javier Almeida[1], Ferdinand Schmidt-Kaler[2], Alex Retzker[1], and Martin Plenio[1] — [1]Institut fur Theoretische Physik, Albert-Einstein Allee 11, Universita *t Ulm, 89069 Ulm, Germany — [2]Institut fur Physik, Staudingerweg 7, Johannes Gutenberg-Universita *t Mainz, 55099 Mainz, Germany

In this talk, I will describe how to exploit the geometry of cold-ion crystals to build a quantum simulator capable of exploring the interplay between magnetic frustration and long-ranged interactions. By modifying the anisotropy of the trapping frequencies, a number of ladder compounds can be synthetized, which give access to different frustrated quantum Ising models. I will pay special attention to the so-called zigzag ladder, which yields a neat realization of a paradigm of quantum frustration: the J1-J2 quantum Ising model [1]. I will discuss how the ordered phases are modified by the presence of the dipolar range of interactions typical of trapped-ion setups.

[1] A. Bermudez, J. Almeida, F. Schmidt-Kaler, A. Retzker, and M. B. Plenio, Phys. Rev. Lett. 107, 207209 (2011).

A 35.4 Thu 14:45 V47.02

Electronically excited cold ion crystals — •Weibin Li and Igor Lesanovsky — School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, UK

The laser excitation of an ion crystal to high lying and long-lived electronic states is a genuine many-body process even if in fact only a single ion is excited. This is a direct manifestation of the strong coupling between internal and external dynamics and becomes most apparent in the vicinity of a structural phase transition. Here we show that utilizing highly excited states offers a new approach to the coherent manipulation of ion crystals. This opens up a new route towards the creation of non-classical motional states in a Paul trap and permits the study of quantum phenomena that rely on a strong coupling between electronic and vibrational dynamics.

A 35.5 Thu 15:00 V47.02

A bosonic Josephson junction controlled by a single trapped ion — •Rene Gerritsma[1], Antonio Negretti[2], Hauke Doerk[3], Zbigniew Idziaszek[4], Tomasso Calarco[2], and Ferdinand Schmidt-Kaler[1] — [1]Quantum, Institut für Physik, Johannes Gutenberg Universität, Mainz — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm — [3]Max-Planck-Institut für Plasmaphysik, Garching — [4]Faculty of Physics, University of Warsaw, Poland

We theoretically investigate the properties of a double-well bosonic Josephson junction coupled to a single trapped ion. We find that the coupling between the wells can be controlled by the internal state of the ion, which can be used for studying mesoscopic entanglement between the two systems and to measure their interaction with high precision. As a particular example we consider a small ^{87}Rb Bose-Einstein condensate controlled by a single ^{171}Yb^{+} ion. We calculate interwell coupling rates reaching 100 Hz, while the state dependence amounts to 10s of Hz for plausible values of the currently unknown s-wave scattering length between the atom and the ion. The system could be realized in an experiment by combining trapped ions with optical dipole traps for cold atoms or in a combined atom-ion micro trap, where both approaches are within reach using current technology.

A 35.6 Thu 15:15 V47.02

Sympathetic cooling of ions to ultralow energies — •Artjom Krükow, Andreas Brunner, Arne Härter, Stefan Schmid, Wolfgang Schnitzler, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Albert-Einstein Allee 45, 89081 Ulm, Germany

We investigate the interaction of a laser-cooled trapped ion (^{138}Ba^{+} or ^{87}Rb^{+}) with an ultracold cloud of optically confined ^{87}Rb atoms. The ion is held in a linear Paul trap and is immersed in the center of the cold atomic cloud. The atom-ion interaction gives rise to a long range attractive $\frac{1}{r^4}$ polarization potential. Charge transfer processes and elastic scattering were observed at millikelvin collision energies [1,2]. The collision energy scale is given by the effect of stray electric fields on ions in a dynamic Paul trap, namely causing ion micromotion [3]. Using field compensation techniques, we achieve sympathetic cooling of the ion to Ba^{+} sub-Doppler temperatures ($<$300 μK) and examine the influence of ion micromotion energy over a wide range. By decreasing the ion temperatures even further we are aiming at novel experiments, such as the creation of mesoscopic atom-ion bound states [4] or the production of ultracold, charged molecules in a well-defined quantum state.

[1] S. Schmid et al, Phys. Rev. Lett. **105**, 133202 (2010)
[2] C. Zipkes et al, Phys. Rev. Lett. **105**, 133201 (2010)
[3] D. Berkeland et al, J. Appl. Phys. **83**, 10 (1998)
[4] R. Côté et al., Phys. Rev. Lett. **89**, 093001 (2002)

A 35.7 Thu 15:30 V47.02

Scattering of ultracold atoms by a single nanowire — •Martin Fink[1], Johannes Eiglsperger[2], Javier Madroñero[1], and Harald Friedrich[1] — [1]Technische Universität München — [2]Universität Regensburg

In view of the intense attention currently given to hybrid quantum systems containing atoms at low temperatures and nanostructures, we study the dynamics of a fundamental quasi two-dimensional system consisting of an ultracold atom and a conducting nanowire of infinite length. A thorough understanding of this system is a first step towards the understanding of more complex setups involving, e.g., nanogratings that are used in diffraction experiments with atoms or large molecules. The seemingly simple atom-wire system is highly nontrivial as the interaction potential does not have a simple analytical structure, and scattering theory in two dimensions differs significantly from the well-studied three-dimensional case. Based on the full Casimir-Polder potential, we formulate an approximation that enables the numerical determination of this potential to any desired accuracy. Various scattering properties, e.g. scattering length, elastic and absorption cross section, are calculated and their characteristic behavior is discussed. We draw our attention to possible experimental realizations.

A 35.8 Thu 15:45 V47.02

Precise radio-frequency spectroscopy of weakly bound Li-6 molecules with trap-sideband resolution — •Andre Wenz[1,2], Gerhard Zuern[1,2], Friedhelm Serwane[1,2], Thomas Lompe[1,2] und Selim Jochim[1,2] — [1]Physikalisches Institut, Universität Heidelberg — [2]Max-Planck-Institut für Kernphysik, Heidelberg

A precise knowledge of the ultracold scattering parameters is vital for most measurements performed with ultracold gases. The position of the Feshbach resonance for example is the main source of uncertainty for the determination of the Bertsch parameter. This parameter, which is universal for every strongly interacting fermionic system, rescales the energy of a resonantly interacting Fermi gas onto a non-interacting one. Its experimental determination strongly relies on the exact position of the Feshbach resonance.

We report on a measurement of the binding energy of a weakly bound molecular state in fermionic Li-6 with an improved accuracy utilizing radio-frequency spectroscopy with resolved trap-sideband resolution. The average error is reduced by more than a factor of 15 compared to previous measurements [Bartenstein et al., PRL 94,103201 (2005)]. This allows to determine the position of the Feshbach Resonance with significantly improved accuracy.

A 36: Precision spectroscopy of atoms and ions III

Time: Thursday 14:00–16:00 Location: V47.03

A 36.1 Thu 14:00 V47.03

Towards Precision Spectroscopy of Cold Highly Charged Ions — •Oscar O. Versolato[1], Maria Schwarz[1], Alexander Windberger[1], José R. Crespo López-Urrutia[1], Alexander D. Gingell[2], Anders K. Hansen[2], Magnus A. Sørensen[2], Michael Drewsen[2], Piet O. Schmidt[3], and Joachim Ullrich[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]University of Aarhus, Aarhus, Denmark — [3]Physikalisch-Technische Bundesanstalt Braunschweig and Leibniz Universität Hannover

Forbidden optical transitions in highly charged ions (HCIs) are excellent candidates for high stability frequency standards due to their low susceptibility to external fields. Certain lines in HCIs can be used to probe the the hypothesized time evolution of fundamental constants due to a enhanced sensitivity to variations of the fine structure constant. However, such high accuracy experiments require HCIs at rest in space, i. e. they need to be trapped and cooled. A broad range of HCIs can be sympthetically cooled using a Be^+ ion cloud trapped in a Paul trap if the ratio of charge over mass is similar to that of the co-trapped Be^+ ions. A laser system at 313 nm wavelength for laser cooling of Be^+ ions has been constructed towards this end. Our 4 K cryogenic linear Paul trap CryPTEx has been commissioned successfully, trapping rovibrationally cold molecular ions (MgH^+) in collaboration with the QUANTOP group in Aarhus. A proof-of-principle experiment on the $^2P_{3/2}$-$^2P_{1/2}$ (M1) transition at 441 nm in boron-like Ar^{13+} is currently being set up, using CryPTEx in combination with the electron beam ion traps (EBITs) at MPIK Heidelberg to produce HCIs.

A 36.2 Thu 14:15 V47.03

Status of the HITRAP cooler Penning trap. — •Svetlana Fedotova[1], Elizabeth Boulton[1], Klaas Brantjes[1], Frank Herfurth[1], Nikita Kotovskiy[1], Claude Krantz[2], Denis Neidherr[1], Wolfgang Quint[1], and Jochen Steinmann[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [2]Heidelberg University

The HITRAP cooler Penning trap will be used for cooling and storing of bunches of up to 10^5 ions as heavy as U^{92+}. Using both electron cooling and resistive cooling will allow cooling down ions from temperature of 6keV/u to a value below 1meV. Bunches of 10^{10} electrons can be injected into the trap from an electron source installed downstream. The electrostatic potentials of the trap electrodes will be arranged to form a nested trap in order to allow capture both, ions and electrons, simultaneously inside the trap. The sequence of the different processes: electron injection, ion capture in flight, electron cooling, resistive cooling and controlled ejection requires a sophisticated control system. Recent injection tests with ions and electrons showed the necessity of electrical and magnetic field alignment. A test ion source together with a system of apertures and imaging detectors will be used to align the fields.

A 36.3 Thu 14:30 V47.03

Bound-electron *g*-factor measurement by double-resonance spectroscopy of a fine-structure transition — •David von Lindenfels[1,2,3], Marco Wiesel[1,2], Wolfgang Quint[1,2], Manuel Vogel[1,4], Alexander Martin[1,4], and Gerhard Birkl[4] — [1]GSI Darmstadt — [2]Universität Heidelberg — [3]MPIK Heidelberg — [4]TU Darmstadt

The precise determination of bound-electron *g*-factors in highly-charged ions (e.g. boron-like argon Ar^{13+} and calcium Ca^{15+}) provides a stringent test of bound-state QED in extreme fields and contributes to the determination of fundamental constants. We have prepared a cryogenic Penning trap that features interaction of ions with electromagnetic fields in the static (DC), radio frequency, microwave, and visible regime. We will excite the fine-structure transition $2^2P_{1/2}$ – $2^2P_{3/2}$ with laser radiation and probe microwave transitions between Zeeman sub-levels (in a laser-microwave double-resonance technique). The ion cyclotron resonance measures the static magnetic field. From this the electronic *g*-factor g_J can be determined on a parts-per-billion level of accuracy. The experiment is currently being set up for measurements with medium heavy ions, which we produce inside the trap vacuum chamber. In the future, the trap will be connected to the HITRAP beamline at GSI, and the method will be applied to hyperfine-structure transitions of hydrogen-like heavy ions in order to measure electronic and nuclear magnetic moments. In this contribution, we present the physics background, the measurement principle, and the current status of the experiment.

A 36.4 Thu 14:45 V47.03

Electric Dipole Moments in heavy atomic systems — •Bodhaditya Santra, Umakanth Dammalapati, Klaus Jungmann, and Lorenz Willmann — KVI, University of Groningen, NL

Permanent electric dipole moments (EDMs) violate both discrete symmetries parity (P) and time-reversal (T). Any observation of an EDM at the present stage of sensitivity would imply CP-violation beyond the Standard Model. EDMs in compound systems like nuclei, atoms or molecules can experience enhancements which scale as Z^3. Atomic radium will be discussed in comparison to other systems. The particularly sensitivity of radium arises from its nuclear and atomic structure. As a result radium offers the largest known atomic enhancement factors to nuclear and electron EDMs. The enhancement factors are depending on atomic state and are particularly large for metastable D-states. An experimental exploitation requires sources of suitable isotopes, the preparation of laser cooled and trapped samples and a sensitive detection method. These issues will be discussed and with the particular view on the atomic physics aspects of the sample preparation.

A 36.5 Thu 15:00 V47.03

Erste direkte Bestimmung der Larmorfrequenz eines einzelnen gespeicherten Protons — •Holger Kracke[1,2], Klaus Blaum[3,4], Clemens Leiteritz[2], Andreas Mooser[1,2], Wolfgang Quint[5], Cricia Rodegheri[2,3], Stefan Ulmer[2,4,5] und Jochen Walz[1,2] — [1]Helmholtz Institut Mainz, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [3]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [4]Ruprecht-Karls-Universität, 69047 Heidelberg — [5]GSI Darmstadt, 64291 Darmstadt

Die Bestimmung des *g*-Faktors eines einzelnen Protons resultiert aus der Messung seiner freien Zyklotronfrequenz und Larmorfrequenz in einem Doppel-Penning-Fallen-System. Die freie Zyklotronfrequenz wird aus den drei unabhängigen Eigenbewegungen in der sogenannten Präzisionsfalle bestimmt. In der sogenannten Analysefalle wird durch Einführung einer magnetischen Inhomogenität das Spin-Moment an die Bewegung entlang der Fallenachse gekoppelt. Die axiale Bewegungsfrequenz wird somit abhängig vom Spin-Zustand des Protons. Der Sprung, der einem Spin-Flip entspricht, beträgt allerdings nur $\delta\nu_z = 200\,\text{mHz}$ bei einer Axialfrequenz von $\nu_z = 680\,\text{kHz}$, was hohe Anforderungen an die Stabilität des Systems und die Präparation des Protons stellt. Im Vortrag wird vorgestellt, wie zum ersten Mal die Larmorresonanzkurve eines einzelnen Protons gemessen wurde.

A 36.6 Thu 15:15 V47.03

Erste gespeicherte und lasergekühlte Ionen in der SPECTRAP-Penningfalle — •Zoran Andjelkovic[1,2], Radu Cazan[1], Manuel Vogel[3], Raphael Jöhren[4], Jonas Mader[4], Volker Hannen[4], Christian Weinheimer[4] und Wilfried Nörtershäuser[1] — [1]Universität Mainz — [2]GSI Darmstadt — [3]Technische Üniversität Darmstadt — [4]Üniversität Münster

Am SPECTRAP-Experiment an der GSI Darmstadt wurden erstmals Mg Ionen aus einer externen Quelle in die zylindrische Penningfalle transportiert, gespeichert und mit Hilfe eines frequenzvervierfachten Faserlasersystems gekühlt. Die Ionen wurden nichtdestruktiv mit Hilfe des Fluoreszenzsignals aber auch elektronisch über den an die Elektroden angeschlossenen Resonanzschwingkreis detektiert. Mit dem direkten optischen Zugang zur Fallenmitte und dem elektronischem

Ionennachweis bietet das Experiment einzigartige Möglichkeiten zur Untersuchung der Dynamik der Ionen und der verschiedenen Kühlverfahren. An SPECTRAP soll sowohl das Widerstandskühlen als auch sympathetisches Kühlen mit Mg Ionen eingesetzt werden. Die ersten Experimentergebnisse von SPECTRAP werden präsentiert und sind ein wichtiger Schritt auf dem Weg zur Laserspektroskopie von schweren, hochgeladenen Ionen an HITRAP. Weiterhin wird ein Ausblick auf die sich anschließenden Experimente an SPECTRAP gegeben.

A 36.7 Thu 15:30 V47.03

Status des Experiments zur Bestimmung des *g*-Faktor des Protons — •Andreas Mooser[1,2], Klaus Blaum[3,4], Holger Kracke[1,2], Clemens Leiteritz[2], Wolfgang Quint[5], Cricia Rodegheri[2,3], Stefan Ulmer[2,4,5] und Jochen Walz[1,2] — [1]Helmholtz Institut Mainz, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [3]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [4]Ruprecht-Karls-Universität, 69047 Heidelberg — [5]GSI Darmstadt, 64291 Darmstadt

Ziel des Experiments ist die erste direkte Messung des g-Faktors eines einzelnen Protons in einer Penningfalle mit einer Präzision von 10^{-9}. Der g-Faktor kann hierbei aus der Zyklotronfrequenz und der Larmorfrequenz bestimmt werden. Die Messung der Larmorfrequenz erfolgt über den kontinuierlichen Stern-Gerlach Effekt, einer Kopplung des Eigendrehimpulses an die Bewegung des Ions im imhomogenen Magnetfeld einer sogenannten magnetischen Flasche. Die Zyklotronfrequenz wird über die drei Eigenfrequenzen des Ions in der Falle bestimmt. Um die angestrebte Präzision erreichen zu können, werden zum einen höchste Anforderungen an die Stabilität der Speicherpotentiale gestellt. Zum anderen werden hochsensitive Nachweise benötigt, welche mit hohen Signal-zu-Rausch Verhältnissen genaue und schnelle Messzyklen erlauben. Hierzu wurden neuartige toroidale Detektoren entwickelt sowie ein flüssig He-Kryostat aufgebaut. Im Vortrag werden erste Resultate zu diesen Entwicklungen präsentiert.

A 36.8 Thu 15:45 V47.03

Präzisionsoptimierung eines Penningfallen-Experiments zur Bestimmung des *g*-Faktors von gebundenen Elektronen in mittelschweren Ionen — •Florian Köhler[1], Klaus Blaum[2], Wolfgang Quint[1], Birgit Schabinger[3], Sven Sturm[2,3], Anke Wagner[2] und Günter Werth[3] — [1]GSI, 64291 Darmstadt, Deutschland — [2]MPI für Kernphysik, 69117 Heidelberg, Deutschland — [3]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Deutschland

Zur Überprüfung der Quantenelektrodynamik in sehr starken elektrischen Feldern eignen sich Hochpräzisionsmessungen des gyromagnetischen Faktors (g-Faktor) eines atomar gebundenen Elektrons (BS-QED). Aktuell wurde mit dem verwendeten Penningfallen-Aufbau der g-Faktor von wasserstoffähnlichem Silizium $^{28}Si^{13+}$ aus dem Verhältnis zwischen der freien Zyklotron- und der Lamor-Frequenz mit einer relativen Genauigkeit von $5 \cdot 10^{-10}$ gemessen [1].

Eine neu entwickelte Phasenmethode (Pulse 'N' Amplify, PNA) [2], mit der die modifizierte Zyklotronfrequenz bei Energien am Kühlungslimit noch genauer messbar ist, erfordert weitere Minimierungen von Störeinflüssen. Verbesserungen der Druckkompensation der Helium- und Stickstoff-Reservoire und die Magnetfeldstabilität werden vorgestellt. Insbesonders wird der Einfluss einer optimierten supraleitenden Abschirmspule auf die zu messende modifizierte Zyklotronfrequenz präsentiert.

[1] S. Sturm *et al.*, Phys. Rev. Lett. **107**, 023002 (2011)
[2] S. Sturm *et al.*, Phys. Rev. Lett. **107**, 143003 (2011)

A 37: Atomic clusters

Time: Thursday 14:00–16:00 Location: V57.05

Invited Talk A 37.1 Thu 14:00 V57.05

X-ray magnetic circular dichroism spectroscopy of size-selected free cluster ions: spin coupling, orbital angular momentum quenching, and magnetic dopants — •Tobias Lau — Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Albert-Einstein-Straße 15, 12489 Berlin

X-ray magnetic circular dichroism (XMCD) spectroscopy is a local and element specific probe to study spin and orbit contributions to the total magnetic moment. With a 5 T and 15 K linear ion trap setup we have sucessfully applied XMCD of size selected cluster ions to study fundamental magnetic properties of transition metals in the molecular limit. Recent results include the observation of ferromagnetic spin coupling in small clusters of archetypical bulk antiferromagnets, as well as antiferromagnetic spin coupling in iron, the most typical 3d bulk ferromagnet. We could also show that the orbital angular momentum is largely quenched already for the smallest iron clusters. Furthermore, magnetization curves recorded at fixed ion trap temperature can be used to determine the cluster ion temperature. As an outlook, first results of XMCD spectroscopy of single impurity atoms in size selected clusters ions will be presented.

Invited Talk A 37.2 Thu 14:30 V57.05

Autoionization of clusters: Energy transfer vs. electron transfer — •Uwe Hergenhahn — Max-Planck-Institut für Plasmaphysik, EURATOM Association, 85748 Garching

In this talk I will give a progress report about our experimental work on autoionization of clusters. The discovery of autoionizing decays into charge separated two-hole sites in clusters (Interatomic/Intermolecular Coulombic Decay, ICD) has been followed by experiments, in which such decays are mediated by charge transfer between sites (Electron Transfer Mediated Decay, ETMD). For ICD, which proceeds by energy transfer, evidence for the occurence of this process as a second step in a cascade after normal Auger decay of water clusters will be presented. For ETMD, the interpretation of outer valence and electron,electron coincidence spectra allows to get a comprehensive picture of this autoionization channel in ArXe clusters of varying size.

A 37.3 Thu 15:00 V57.05

First-order corrections and structural information in semiclassical Gaussian approximations to the Boltzmann operator for clusters of atoms — •Holger Cartarius[1] and Eli Pollak[2] — [1]1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany — [2]Chemical Physics Department, Weizmann Institute of Science, 76100 Rehovot, Israel

Gaussian approximations to the Boltzmann operator have proven themselves in recent years as useful tools for the study of the thermodynamic properties of rare gas clusters. They are, however, not necessarily correct at very low temperatures. We introduce a numerically cheap frozen Gaussian approximation to the imaginary time propagator with a width matrix especially suited for the dynamics of clusters [1] and investigate its first-order correction to diagnose the quality of the approximation [2]. The strength of the correction to the Gaussian partition function monitored as a function of the temperature indicates that the results of the Gaussian propagator become questionable below a certain temperature, however, thermodynamic henomena such as structural transformations occur in a temperature range for which the Gaussian approximation is predicted to be accurate.

To study transformations or dissociation effects of rare gas clusters for increasing temperature information about the structure is essential. We show how structural information can be extracted from the Gaussian imaginary time propagator.

[1] H. Cartarius, E. Pollak, J. Chem. Phys. 134, 044107 (2011)
[2] H. Cartarius, E. Pollak, Chem. Phys., in press (2011)

A 37.4 Thu 15:15 V57.05

Core-level photoelectron spectroscopy on free mass-selected Gold clusters at the free-electron laser FLASH — •Patrice Oelssner[1], Jens Bahn[1], Michael Köther[1], Christian Braun[2], Volkmar Senz[1], Steffen Palutke[3], Michael Martins[3], Gerd Ganteför[2], Bernd von Issendorff[4], Josef Tiggesbäumker[1], and Karl-Heinz Meiwes-Broer[1] — [1]IfPh, Uni-Rostock — [2]FB Physik, Uni-Konstanz — [3]IfExp. Physik, Uni Hamburg — [4]Fak. f. Physik, Uni Freiburg

A promising method to investigate the electronic structure of clusters is core-level photoelectron spectroscopy as used extensively in surface science [Phys. Rev. Lett. 102, 138303 (2009)]. The VUV free electron laser FLASH at DESY delivers intense light with a wavelength down to 4.8 nm (258 eV) to allow such studies. With a hemispherical analyzer equipped with a Delay-Line-Detector we studied core-level-binding energies. Results on mass-selected gold clusters anions from 45 to 150 atoms show a size-dependent 4f core-level shift as predicted by the metal sphere model [Phys. Rev. B 50,5744 (1994)]. By measuring the gold 4f binding energies of anions and cations as a function of cluster-size one can calculate, e.g. the chemical potential.

A 37.5 Thu 15:30 V57.05

Core level photoelectron spectroscopy on free mass-selected lead clusters at FLASH — •Jens Bahn[1], Patrice Oelssner[1], Michael Köther[1], Christian Braun[3], Volkmar Senz[2], Steffen Palutke[4], Bernd von Issendorff[5], Gerd Ganteför[3], Michael Martins[4], Josef Tiggesbäumker[1], and Karl-Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock — [2]Institut für Biomedizinische Technik, Universität Rostock — [3]Fachbereich Physik, Universität Konstanz — [4]Institut für Experimentalphysik, Universität Hamburg — [5]Fakultät für Physik, Universität Freiburg

The electronic structure forms the basis for understanding the physical and chemical properties of clusters. A promising method to study this issue is core-level photoelectron spectroscopy using the VUV free electron laser FLASH at DESY providing wavelengths down to 4.8 nm. Results on lead clusters feature size-dependent 5d and 4f core-level shifts and reveal a remarkable change of final state screening conditions due to a metal to nonmetal transition at cluster sizes about 20 atoms [Phys. Rev. Lett. 102, 138303 (2009)]. In recent experiments a hemispherical electron spectrometer has been utilized. It became possible to allocate electron signals to each micro pulse of FLASH with a time-resolved delay-line-detector. A sequence of cluster sizes can be probed by this approach. By study of 4f core-level of lead clusters the change of the gaussian line shape to a Doniach-Sunjic profile has been observed as function of size. The evolution of the line profiles can be understood as scattering processes in finite systems.

A 37.6 Thu 15:45 V57.05

Spin Coupling and Orbital Momentum Quenching in Small Iron and Cobalt Clusters — •Andreas Langenberg[1,2], Konstantin Hirsch[1,2], Vicente Zamudio-Bayer[1,2], Markus Niemeyer[1,2], Arkadiusz Lawicki[2], Marlene Vogel[2], Kazuhiro Egashira[3], Thomas Möller[2], Akira Terasaki[3], Bernd von Issendorff[4], and Tobias Lau[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert Einstein Str. 15, 12489 Berlin — [2]Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin — [3]Cluster Research Laboratory, Toyota Technological Institute, Ichikawa 272-0001, Japan — [4]Universität Freiburg, Fakultät für Physik, 79104 Freiburg, Germany

X-ray magnetic circular dichroism (XMCD) spectroscopy was performed on free and size selected iron and cobalt clusters in a linear penning trap giving direct access to spin and orbital resolved magnetic moments (m_s, m_l). For iron clusters a quenching of the orbital magnetic moments for already very small clustersizes and an antiferromagnetic coupling of Fe_{13}^+ [1] can be observed. Moreover the measured total magnetic moments of the clusters $(m_j = m_l + m_s)$ are in good agreement with results from Stern-Gerlach experiments [2,3]. High resolution XMCD spectra as well as magnetization curves of cobalt and iron clusters will be discussed in detail.

[1] P. Bobadova-Parvanova, K. A. Jackson et.al., Phys. Rev. B 66, 195402 (2002)

[2] X. Xu, S. Yin et.al., Phys. Rev. Lett. 95, 237209 (2005)

[3] M. Knickelbein, Chem. Phys. Lett. 353, 221-225 (2002)

A 38: SYPC 2: From Atoms to Photonic Circuits 2

Time: Thursday 14:00–16:00 Location: V47.01

Invited Talk A 38.1 Thu 14:00 V47.01

Coherent population trapping in quantum dot molecules — Katharina Weiss, Jeroen Elzerman, and •Atac Imamoglu — ETH, Zurich, Switzerland

Low-frequency atomic transitions that are insensitive to magnetic fields play a fundamental role in precision measurements and metrology. In contrast, most solid-state quantum systems are subject to either strong electric or magnetic field fluctuations that severely limit their T2*coherence time. In this talk, we will describe experiments where we demonstrate that by adjusting the applied bias voltage and the magnetic field, spin singlet and triplet ground states of an optically active quantum dot molecule can be rendered insensitive to both electric and magnetic field fluctuations. By using coherent population trapping on transitions to a common optically excited state, we show that the singlet-triplet T2* time can exceed 100 nanoseconds. The rich optical spectrum of this quantum system exhibiting recycling transitions for spin measurements and indirect excitons for spin-state dependent long-range dipole-dipole interactions, potentially allow for applications in quantum information processing.

Invited Talk A 38.2 Thu 14:30 V47.01

Nanophotonic Interconnection Networks for Performance-Energy Optimized Computing — •Keren Bergman — Department of Electrical Engineering, Columbia University, New York, NY

As chip multiprocessors (CMPs) scale to increasing numbers of cores and greater on-chip computational power, the gap between the available off-chip bandwidth and that which is required to appropriately feed the processors continues to widen under current memory access architectures. For many high-performance computing applications, the bandwidth available for both on- and off-chip communications can play a vital role in efficient execution due to the use of data-parallel or data-centric algorithms. Electronic interconnected systems are increasingly bound by their communications infrastructure and the associated power dissipation of high-bandwidth data movement. Recent advances in chip-scale silicon photonic technologies have created the potential for developing optical interconnection networks that can offer highly energy efficient communications and significantly improve computing performance-per-Watt. This talk will examine the design and performance of photonic networks-on-chip architectures that support both on-chip communication and off-chip memory access in an energy efficient manner.

A 38.3 Thu 15:00 V47.01

Controlled coupling of single solid-state quantum emitters to optical antennas — •Markus Pfeiffer[1,2], Klas Lindfors[1,2], Paola Atkinson[3], Armando Rastelli[3], Oliver Schmidt[3], Harald Giessen[2], and Markus Lippitz[1,2] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]University of Stuttgart, Stuttgart, Germany — [3]IFW Dresden, Dresden, Germany

Plasmonic structures combined with stable solid-state quantum emitters are a promising approach to integrated photonic circuits and quantum optics applications. One of the main challenges in realizing such structures is the controlled positioning of single plasmonic structures next to a single emitter. To address this challenge, we have developed an electron-beam lithography based technique that enables fabrication of nanostructures aligned with respect to single self-assembled semiconductor quantum dots with nanometer precision.

We have applied our fabrication method to couple excitons in single quantum dots with plasmons in rod-shaped optical antennas. The plasmon-exciton coupling is manifested as a significant change in the polarization state of the photoluminescence. We investigate the strength of the coupling as a function of the position of the quantum dot with respect to the antenna. We observe large variations in the polarization properties of the luminescence as the quantum dot is placed at different positions in the vicinity of an antenna.

A 38.4 Thu 15:15 V47.01

Telecom wavelength semiconductor-superconductor based quantum emitters — •Claus Hermannstädter[1,2], Hirotaka Sasakura[1], Nahid A. Jahan[1], Jae-Hoon Huh[1], and Ikuo Suemune[1] — [1]Hokkaido University, Sapporo, Japan — [2]JSPS

Practical integrated single and entangled photon-pair sources in the telecommunication band are attracting plenteous attention for on-chip and fiber-based technologies. We use semiconductor quantum dot (QD) and light emitting diode (LED) structures grown on InP substrates as quantum emitters in the spectral range between 1.3 and 1.6 μm.

We present one approach to realize a source of single photons and polarization entangled photon-pairs by isolating a small number of QDs inside InGaAlAs nano-mesas of around 150 nm diameter. For enhanced photon extraction, the nano-mesas are embedded in metal and the InP substrate is removed [Jpn. J. Appl. Phys. 50, 06GG02 (2011); New. J. Phys., submitted (2011)]. Another approach for the realization of entangled photon-pairs is the concept of Cooper-pair (Josephson) LEDs [PRL 103, 187001 (2009); PRL 107, 157403 (2011)]. InGaAs LEDs are processed with superconducting Niobium electrodes for the injection of electron Cooper-pairs. The presence of these Cooper-pairs at the p-n-junction leads to their radiative recombination with two normal holes and thus the simultaneous generation of entangled photon-pairs. Both demonstrated approaches have the potential to be combined to "Cooper-pair QD-LEDs" and allow for integration on semiconductor chips as parts of larger devices. Moreover, the target wavelength of 1.55 μm for application in silica fiber networks is successfully covered.

A 38.5 Thu 15:30 V47.01

Si-based light emitters in integrated photonic circuits for smart biosensor applications — •Susette Germer — Institute of Ion-Beam Physics and Materials Research (FWI), Helmholtz-Centre Dresden-Rossendorf (HZDR), Dresden, Germany

In this report we present our recent developments for utilizing the Si-based light emitter consisting of a MOS structure for the detection of organic pollutants. In the latest approach the light emitters are intended to serve as light sources in smart biosensors. Now we discuss our concept of an integrated light emitter and a receiver in a dielectric waveguide structure below the bioactive layer for the detection of harmful substances, like synthetic estrogens or plasticizer in drinking water. Optical properties of waveguides, e.g. the transmission, are very sensitive to changes of the effective refraction index, which might be induced by the immobilization of biomolecules on the waveguide surface or in cavity structures, e.g. photonic crystals. The guiding of the light depends on the geometry and material composition of the waveguide. First waveguides were fabricated through plasma enhanced chemical vapor deposition (PECVD) and optical photolithography with following etching steps. Afterwards the layer thicknesses were analyzed by ellipsometry and the surface roughness via scanning electron microscopy (SEM). However, the investigation of the different waveguides will be allowed through finite element method (FEM) simulations (COMSOL) and experimentally through a setup for the optical transmission measurement. In summary, this lab-on-a-chip system provides fast light transmission and achieves further portability and miniaturization.

A 38.6 Thu 15:45 V47.01

Arrayed waveguide grating based interrogator for fiber Bragg grating sensors: measurement and simulation — •Jan Koch[1,2], Martin Angelmahr[1], and Wolfgang Schade[1,2] — [1]Fraunhofer Heinrich Hertz Institute, Am Stollen 19B, 38640 Goslar, Germany — [2]Clausthal University of Technology, Am Stollen 19B, 38640 Goslar, Germany

Fiber Bragg grating (FBG) strain sensors offer great potential. Compared to strain gauges they are small and lightweight, can easily be multiplexed, and are immune to electromagnetic disturbance. In addition the new femtosecond laser processed FBG sensors are very robust and easy to handle. However, the main disadvantage of those fiber-optical measurement systems lies within the applied FBG interrogator, which usually consists of expensive and fragile components.

In this work a FBG interrogator based on an arrayed waveguide grating (AWG) chip, known as cost efficient and very stable multi-/demultiplexer module in the telecommunication industry, is presented. In order to achieve high wavelength resolution, the interpretation of the response signal of the FBG strain sensors has to be done very carefully. Hence, the required evaluation algorithm is examined in detail. The corresponding calibration parameters are determined by calibration measurements and by simulations. The system simulation provides additional information for the error estimation of the measurand.

A 39: Poster: Atomic clusters

Time: Thursday 16:30–19:00 Location: Poster.V

A 39.1 Thu 16:30 Poster.V

Electron emission from C_{60} in strong FEL pulses — •Abraham Camacho, Ulf Saalman, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Electron-energy spectra of C_{60} molecules induced by strong FEL radiation over a wide range of (currently experimentally available) photon energies and intensities is studied theoretically. Our microscopic model includes inner-shell photo-ionization and Auger decays and, most importantly, the dynamics due to Coulomb interaction of the released electrons. On the ground of this model, particular attention is given to two clearly identifiable limiting cases. On the one hand, for long and weak pulses, electron emission takes place sequentially leading to small interactions between outgoing electrons. On the other hand, for short and intense pulses, all the photo-electrons are emitted simultaneously and thus interaction between them is enforced. By switching on and off this interaction, we observe that the electron spectra are qualitatively different. Furthermore, a simple analytical model is proposed, which is found to be in good agreement with the microscopic model.

A 39.2 Thu 16:30 Poster.V

Asymmetric ion emission from Xe-clusters in intense near-few-cycle-pulses — •Alexander Breier, Christian Peltz, and Thomas Fennel — Universität Rostock, 18051 Rostock, Germany

Atomic clusters in intense laser fields are an area of high interest for very different scientific areas, ranging from plasma physics to applied laser-matter research. Phenomena like high energy absorption, rapid cluster explosion, the emission of highly charged and energetic ions and fast electrons as well as the emission of energetic photons from the vacuum ultraviolet up to the xray range have been observed [1]. Most of the available data has been measured using relativly short pulses with durations $\tau > 50$fs. The availability of even shorter pulses down to the few-cycle-regime makes it possible to explore new response regimes or even control the cluster dynamics. For example, enhanced ion emission in the laser polarization direction has been observed in the long pulse regime (many cycles)[2], whereas enhanced emission perpendicular to the polarization direction was found for near few-cycle excitation [3]. In this contribution we present a systematic molecular dynamics analysis of the ion emission from medium sized Xe-clusters in infrared laser pulses as function of laser intensity and pulse duration. Our analyses shows an energy-dependent anisotropy of the ion emission.

[1] Th.Fennel et al., Rev. Mod. Phys. 82:1793 (2010)
[2] V. Kumarappan et al, Phys. Rev. Lett. 87:85005 (2001)
[3] E. Skopalová et al., Phys. Rev. Lett. 104:203401 (2010)

A 39.3 Thu 16:30 Poster.V

Observation of single and multiple ionization by electron impact ionization of small noble gas clusters — Thomas Pflüger, Arne Senftleben, Xueguang Ren, •Alexander Dorn, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, 69117 Heidelberg

A kinematically complete experiment for 100 eV electron-impact ionization of small argon and neon clusters was realized. For argon the triple coincidence detection of both outgoing electrons and the residual ion allows the discrimination between single ionization of atoms, dimers and non-mass-selected small clusters as well as between pure ionization and ionization with additional excitation within the same cluster. Comparison of fully differential ionization cross sections for clusters with those of atoms reveals clear signatures of multiple-scattering reactions. For ionization with excitation, an almost isotropic electron emission pattern is observed.

Ionization of dimers and trimers with subsequent Coulomb explosion resulting in two charged fragments shows interisting collisional ionization mechanisms as the interatomic Coulombic decay (ICD) and sequential ionization of two cluster atoms by the projectile.

A 39.4 Thu 16:30 Poster.V

XUV-fluorescence spectroscopy on rare gas clusters irradiated by intense XUV radiation — •T Oelze[1], M Adolph[1], L Flückiger[1], T Gorkhover[1], M Krikunova[1], M Müller[1], L Nösel[1], Y Ovcharenko[1], R Richter[1], D Rupp[1], M Sauppe[1], S Schorb[1,3], D Wolter[1], A Przystawik[2], L Schrödter[2], C Bostedt[1,3], T Laarmann[2], and T Möller[1] — [1]TUB — [2]FLASH@DESY — [3]LCLS@SLAC

Free-electron lasers like FLASH combine short wavelengths with a high number of photons in ultrashort coherent pulses, extending the possibilities to study the interaction between intense light and matter. Rare gas clusters as size scalable gas phase objects are used in our studies. By analyzing different ionization products such as charged particles as well as scattered and fluorescence light we strive to achieve a complete picture of ionization and disintegration dynamics and of the corresponding time scales. In a recent experiment at FLASH the fluorescence spectra of rare gas clusters excited with 90 eV photons exhibited a large number of lines between 10 nm and 70 nm. In order to understand their origin, we plan to analyze the fluorescence of the clusters in an altered setup where clusters are excited by high kinetic energy electrons from an electron gun. By tuning the energy, selected charge states can be addressed. The transitions can be used to assign the lines measured at FLASH to the different charge states and to gain further insight into the charge distribution of the nanoplasma. The setups will be discussed and first results will be shown.

A 39.5 Thu 16:30 Poster.V

Experimente an der Greifswalder EBIT — •Birgit Schabinger[1], Christoph Biedermann[2], Stephan Gierke[1], Gerrit Marx[1], Rainer Radtke[1,2] und Lutz Schweikhard[1] — [1]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald — [2]Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

Mit einer Elektronenstrahl-Ionenfalle (EBIT, electron beam ion trap) können hochgeladene Ionen bis zu H-artigem Uran [1] erzeugt und erforscht werden [2]. Dazu wird durch ein Magnetfeld von einigen Tesla, welches durch supraleitende Helmholtzspulen erzeugt wird, eine Kompression eines Elektronenstrahls herbeigeführt. So werden Stromdichten von einigen tausend A/cm^2 erreicht. Der Einschluss der Ionen erfolgt in axialer Richtung durch ein Speicherpotential, erzeugt durch drei segmentierte Driftröhren, und radial durch das attraktive Potential des Elektronenstrahls. Durch Elektronenstoßionisation werden Atome und niedrig geladene Ionen schrittweise höher geladen.
Es wird über die Wiederinbetriebnahme der vormals Berliner EBIT [3] berichtet, die in Zukunft u.a. hochgeladene Ionen für die Wechselwirkung mit atomaren Clustern zur Verfügung stellen soll.

[1]R. E. Marrs *et.* al, Phys. Rev. Lett. 72 (1994) 4082
[2]F. Currell *et.* al, IEEE Trans. Plasma Sci., 33 (2005) 1763
[3]C. Biedermann *et.* al, Phys. Scr. T. 73 (1997) 360

A 39.6 Thu 16:30 Poster.V

Collective electron dynamics in xenon clusters, studied with XUV-IR pump-probe experiments at FLASH — •M Sauppe[1], M Adolph[1], L Flückiger[1], T Gorkhover[1], D Rupp[1], S Schorb[2], S Düsterer[3], M Harmand[3], R Treusch[3], C Bostedt[2], M Krikunova[1], and T Möller[1] — [1]IOAP, TUB — [2]LCLS, SLAC — [3]HASYLAB, DESY

Femtosecond short and intense light pulses are able to transform matter into a highly excited non-equilibrium state. Clusters, exposed to short and intense XUV pulses reveal complex electron and nuclear dynamics. By using XUV radiation from FLASH synchronized to IR pulses in pump-probe configuration it is possible to gain information about the expansion and desintegration dynamics of the clusters. In our setup the XUV pump pulse creates a nano plasma of quasi-free electrons and the cluster expansion process is iniciated. The time delayed IR pulse probes the dynamics of the quasi-free electrons.
The clusters were produced by supersonic expansion of xenon gas into vacuum. We recorded ions and scattered XUV photons of single clusters simultaneously. The scattering pattern allows us to sort for cluster size. In the produced nano plasma the density of the generated quasi-free electrons decreases with the cluster expansion. At some point the plasma frequency gets in resonance with the frequency of the IR pulse. This results in optimum condition for energy absorption of cluster for which reason the degree of cluster ionization and fluorescence yield on the scattering pattern increases substantially. We discuss the relationship between cluster size and delay time.

A 39.7 Thu 16:30 Poster.V

Photoelectron spectroscopy of large water clusters — •Kiran Majer und Bernd von Issendorff — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

The excess electron of a singly charged water droplet or cluster has been the subject of many experiments and research groups in the past decades. Although progress has been made recently in determine the vertical electron binding energy of water beams and water clusters, the development of the binding energy from the different isomers found for small water cluster, to the bulk solvated electron is still unknown.

We present results of a photoelectron spectroscopy study of large water clusters, which aims at closing the gap in the size distribution of present measurements.

A 39.8 Thu 16:30 Poster.V

Charging energies of medium-sized potassium clusters — •Jacob Chapman, Sebastian Illner, Holger Beh, Kiran Majer, Lei Ma, and Bernd von Issendorff — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

We present measurements of the charging energies of medium-sized potassium clusters in the size range between 55 and 310 potassium atoms. A general size dependent trend of the charging energy can be drawn and correlated with a simple spherical droplet model. The results will be compared with charging energy measurements of sodium clusters.

The charging energy of a cluster can be determined by photoelectron spectroscopy (PES) with varying laser intensities. In oder to obtain the underlying data, PES of potassium clusters were recorded for a wide size range and at cluster temperatures of about 10K and 80K respectively.

A 40: Poster: Ultra-cold atoms, ions and BEC

Time: Thursday 16:30–19:00 Location: Poster.V

A 40.1 Thu 16:30 Poster.V

Direct synthesis of light polarization for state-dependent transport of atoms — •Anna Hambitzer and Sebastian Hild — Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

We report on a new approach for state-dependent transport in a spin-dependent optical lattice. It is based on a direct synthesis of light polarization by employing RF sources integrated with acousto-optic modulators for phase control.

Circulary polarized states are synthesized by superimposing two linearly polarized beams with controlled phase shift.

An interferometrically stable phase difference between the two beams is guaranteed by locking it actively with a heterodyne technique.

Compared to conventional methods [citation to Bloch & Mandel PRL03 and arXiv:1102.3356] this avoids the need of an electro-optic modulator, where rotations on the Poincare sphere are limited by the applicable voltage and restrictions on manufacturing and crystal quality exist. Overcoming these limitations we expect to reach higher polarization purity and large shift distances in the new design.

A 40.2 Thu 16:30 Poster.V

Beyond the Hubbard model: best effective single dressed band description of interacting atoms in optical lattices — •Ulf Bissbort, Frank Deuretzbacher, and Walter Hofstetter — Institut für Theoretische Physik, Goethe Universität Frankfurt a.M.

We construct the effective lowest-band Bose-Hubbard model incorporating interaction-induced on-site correlations. The model is based on ladder operators for local correlated states, which deviate from the usual Wannier creation and annihilation operators, allowing for a systematic construction of the most appropriate single-band low-energy description in form of the extended Bose-Hubbard model. A formulation of this model in terms of ladder operators not only naturally contains the previously found effective multi-body interactions, but also contains multi-body induced single particle tunneling, pair tunneling and nearest-neighbor interaction processes of higher orders. An alternative description of the same model can be formulated in terms of occupation-dependent Bose-Hubbard parameters. These multi-particle effects can be enhanced using Feshbach resonances, leading to corrections which are well within experimental reach and of significance to the phase diagram of ultracold bosonic atoms in an optical lattice. We analyze the energy reduction mechanism of interacting atoms on a local lattice site and show that this cannot be explained only by a spatial broadening of Wannier orbitals on a single particle level, which neglects correlations.

A 40.3 Thu 16:30 Poster.V

Dynamical molecules in interacting quantum walks — Andre Ahlbrecht[1], Volkher B. Scholz[1], Albert H. Werner[1], Reinhard F. Werner[1], •Andrea Alberti[2], and Dieter Meschede[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover Appelstr. 2, 30167 Hannover, Germany — [2]Institut für Angewandte Physik der Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany

We report on the theoretical prediction of dynamically stable molecular states in a system of two atoms which interact through discrete quantum walks [1]. This novel dynamical binding mechanism is explained in terms of an interference effect which leads to an exponential localization of the relative position of the two atoms. The interference is brought about by the coherent collisional phase accumulated in the on-site interactions. The evolution of the molecular states is studied both in the unperturbed case, showing ballistic spreading of molecule wave packets, and in the case of an applied external force, displaying Bloch oscillations at twice the frequency of single particles.

A proposal to experimentally implement this molecular dynamical binding will be also discussed under the realistic conditions of an existing experiment [2]. Taking advantage of the anomalously large triplet scattering length of Cs atoms (a_T=2400 a_0) we expect sufficiently strong interactions to allow the observation of coherent evolution of molecules in the range of 20–50 quantum walk steps.

[1]: A. Ahlbrecht *et al.*, arXiv:1105.1051v1 (2011)
[2]: M. Karski *et al.*, Science 325, 174 (2009)

A 40.4 Thu 16:30 Poster.V

Atomic collisions with high angular momenta interactions in axially symmetric geometries — •Panagiotis Giannakeas[1], Vladimir Melezhik[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — [2]Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russian Federation

We observe and analyze d-wave resonant scattering of bosons in tightly confining harmonic waveguides. It is shown that the d-wave resonance emerges in the quasi-1D regime as an imprint of a 3D d-wave shape resonance. A scaling relation for the position of the d-wave resonance is provided. By changing the trap frequency, ultracold scattering can be continuously tuned from s-wave to d-wave resonant behavior. Additionally, we observed similar effect for fermionic collisions, where an f-wave shape resonance from the free space interferes with a p-wave confinement-induced resonance. The effect can be utilized for the realization of ultracold atomic gases interacting via higher partial waves and opens a novel possibility for studying strongly correlated atomic systems.

A 40.5 Thu 16:30 Poster.V

Cold, Magnetically-Trapped Br Atoms — William Doherty, •Jessica Lam, Christopher Rennick, and Tim Softley — Department of Physical and Theoretical Chemistry, Univeristy of Oxford, Chemistry Research Laboratory, Mansfield Road, Oxford, United Kingdom

Photodissociation of molecular bromine near threshold produces a pair of bromine atoms that recoil along the polarization axis of the laser. At an appropriate wavelength, the velocity vector of one of the atoms can be aligned to exactly oppose the molecular beam velocity; this atom will then be stopped in the lab frame. The stopped atoms are probed by delayed multiphoton ionization. We have constructed a 300 mK deep magnetic trap with the field minimum at the intersection of the molecular beam with the photodissociation laser. The trap is filled from the photofragment velocity distribution, and the Br density accumulates with successive molecular beam pulses. We have developed a molecular dynamics model of the bromine atoms in the magnetic trapping field, including collisions with the molecular beam backing gas and vacuum chamber background pressure. This shows that, while a fraction of the atoms are lost through collisions with xenon, sufficient numbers are re-loaded on each shot to accumulate a steady-state density after a few seconds.

A 40.6 Thu 16:30 Poster.V

Dark-bright ring solitons in Bose-Einstein condensates — •Jan Stockhofe[1], Panayotis G. Kevrekidis[2], Dimitri J. Frantzeskakis[3], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Deutschland — [2]Department of Mathematics and Statistics, University of Massachusetts, USA — [3]Department of Physics, University of Athens, Greece

We study dark-bright (DB) ring solitons in two-component Bose-Einstein condensates. In the limit of large densities of the dark component, we describe the soliton dynamics by means of an equation of motion for the ring radius. The presence of the bright, "filling" species is demonstrated to have a stabilizing effect on the ring dark soliton. Near the linear limit, we discuss the symmetry-breaking bifurcations of DB soliton stripes and vortex-bright soliton clusters from the DB ring and relate the stabilizing effect of filling to changes in the bifurcation diagram. Finally, we show that the stabilization by means of a second component is not limited to the radially symmetric structures, but can also be observed in a cross-like DB soliton configuration.

A 40.7 Thu 16:30 Poster.V

Hybrid quantum systems of Ultracold Atoms and Superconductors — •Helge Hattermann, Florian Jessen, Simon Bernon, Daniel Cano, Daniel Bothner, Martin Knufinke, Matthias Kemmler, Reinhold Kleiner, Dieter Koelle, and Jozsef Fortagh — Physikalisches Institut, Eberhard-Karls-Universität Tübingen, CQ Center for Collective Quantum Phenomena and their Applications, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

Hybridizing quantum systems such as ultracold atoms and superconductors is of very first interest for quantum information processing. In this poster, we will report on the experimental realization and recent progress of our superconducting atom chip experiment. We will, in particular, discuss two physical effects that were shown to affect our magnetic trap properties and that are the Johnson noise and the Meissner effect.

Combining in a single experiment solid state and cold atom physics is also a technical challenge. To succeed, we developed the fabrication and interfacing of integrated niobium thin film superconducting chips to make them compatible to both ultra-high vacuum and cryogenic environment. The microtrap formed by this superconducting chip allowed us to reach a gas in the quantum degeneracy regime showing the feasibility of such hybrid systems. We also report on the recent progress obtained to couple cold atomic sample to superconducting microstructures at liquid helium temperature.

A 40.8 Thu 16:30 Poster.V

Degenerate mixtures of ultracold ^{40}K-^{6}Li Fermions in low dimensions — •Franz Sievers, Norman Kretzschmar, Diogo Fernandes, Frederic Chevy, and Christophe Salomon — Laboratoire Kastler Brossel, Paris

We present the design of our new apparatus for creating cold mixtures of ^{6}Li and ^{40}K Fermions with which we intend to study condensed matter physics phenomena. Our experimental setup will allow us to simulate several Hamiltonians describing interacting many-body Fermionic systems in one, two and three dimensions. We report on the initial performances of our subsystems including a 2D MOT source of Potassium atoms, a Zeeman slowed Lithium beam, a dual species magnetooptical trap and a magnetic transport from the MOT- to the science chamber. We are now working on the evaporative cooling of the mixture in an optically plugged quadrupole trap. In the science chamber with large optical access periodic potentials will be realized using optical lattices and a high resolution imaging system will be installed.

A 40.9 Thu 16:30 Poster.V

Numerical solutions for Bose-Einstein condensates in $\mathcal{PT}$ symmetric double well potentials — •Daniel Haag, Dennis Dast, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

$\mathcal{PT}$ symmetry has been studied mainly within the context of mathematical physics. Recently it could be experimentally observed in an optical analogue by Rüter et. al.[1]. However it is desirable to observe $\mathcal{PT}$ symmetry in real quantum mechanical systems. For this purpose we investigate Bose-Einstein condensates in $\mathcal{PT}$ symmetric double well potentials. The $\mathcal{PT}$ symmetry is achieved by inducing particles to one well and extracting them from the other. We solve the nonlinear Gross-Pitaevskii equation numerically and examine the behaviour near the $\mathcal{PT}$ symmetry breaking.

[1] C. E. Rüter, K. G. Makris, R. El-Ganainy, D. N. Christodoulides, M. Segev, and D. Kip, Nature Physics 6, 198 (2010)

A 40.10 Thu 16:30 Poster.V

Variational methods for Bose-Einstein condensates in $\mathcal{PT}$ symmetric double well potentials — •Dennis Dast, Daniel Haag, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

$\mathcal{PT}$ symmetric Hamiltonians can have entirely real spectra [1]. Recently this has been widely studied in optical microwave guide systems with a complex refractive index [2]. However, it would be highly interesting to investigate real quantum systems that are experimentally accessible. Such a system is a Bose-Einstein condensate in a double well potential, where particles are removed in one well and injected into the other well. We examine this system by variational methods. The time-dependent variational principle is used to search stationary solutions of the nonlinear Gross-Pitaevskii equation. In addition this ansatz offers the possibility of investigating the dynamics of the system.

[1] C. M. Bender, and S. Boettcher, Phys. Rev. Lett. 80, 5243 (1998)
[2] C. E. Rüter, K. G. Makris, R. El-Ganainy, D. N. Christodoulides, M. Segev, and D. Kip, Nature Physics 6, 198 (2010)

A 40.11 Thu 16:30 Poster.V

GG-TOP a multidisciplinary atom interferometry project — •Alexander Niggebaum, Tristan Valenzuela, Vincent Boyer, and Kai Bongs — Midlands Ultracold Atom Research Centre, School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom

We present the GG-TOP project, an holistic research program in the field of atom interferometry gravity gradiometry. GG-TOP is a joint effort by physicists, civil engineers and archaeologists to develop an applications driven full tensor gravity sensor based on cutting-edge atom interferometry. The project aims to develop two sensors. On the one hand, we will build a roughed gravity gradiometer capable of field deployment for applications in Civil Engineering and Archaeology. Its sensitivity should allow the detection small underground voids or other high density-contrast features located at depths in the range of 1 to 10 meters. On the other hand we will develop a laboratory sensor where we will seek the ultimate sensitivity using the latest technologies (eg. large momentum transfer, expansion suppression of cold atom clouds, ...).

A 40.12 Thu 16:30 Poster.V

Emergence of exotic condensates from a melting bosonic Mott insulator in a 2D optical lattice — •Ulrike Bornheimer, Julia Wernsdorfer, and Walter Hofstetter — Goethe Universität Frankfurt am Main, Institut für theoretische Physik, Max-von-Laue Str. 1, 60438 Frankfurt am Main, Germany

We investigate the expansion dynamics of a bosonic quantum gas initially prepared in the Mott insulating ground state of an optical lattice. Once released from harmonic confinement, the interacting many-body system is observed to develop coherence while simultaneously populating states with finite quasi-momentum. We demonstrate that for strong and intermediate interactions the emerging condensate fraction depends on the number of particles in the MI phase rather than on the particular interaction or tunneling strength. During expansion, the condensate is observed to develop a spiked structure breaking the initial spherical symmetry of the density distribution. The expanding spikes exhibit the maximal lattice velocity, independent of other system parameters. These dynamical properties of the system are obtained by means of Gutzwiller mean-field theory and confirmed analytically.

A 40.13 Thu 16:30 Poster.V

Millikelvin System for Hybrid Quantum Devices — •Florian Jessen, Martin Knufinke, Petra Vergien, Helge Hattermann, Simon Bernon, Tobias Gaber, Matthias Kemmler, Dieter Kölle, Reinhold Kleiner, and József Fortágh — Center for Collective Quantum Phenomena and their Applications, Eberhard Karls Universität Tübingen

Hybrid quantum systems based on ultracold atoms and superconductors have been proposed to be used in quantum information processing. In these systems the logical operations will be carried out by the solid state devices, while the cold atomic ensemble can be used as a long lived memory for quantum information.

We report on the construction of a Millikelvin system which meets the requirements of long coherence and strong coupling of superconducting devices and ultracold atomic samples. The atoms are loaded into the MOT via a Zeeman slower and transported close to the superconductiong devices by means of a magnetic conveyor belt within the Millikelvin environment.

A 40.14 Thu 16:30 Poster.V

Inelastic Confinement-Induced Resonances in Low-Dimensional Quantum Systems — •Simon Sala, Philipp-Immanuel Schneider, and Alejandro Saenz — Institut für Physik, Humboldt-Universität zu Berlin, Newtonstrasse 15, 12489 Berlin

Ultracold atomic systems of reduced dimensionality show intriguing phenomena like fermionization of bosons in the Tonks-Girardeau gas or confinement-induced resonances (CIRs) which allow for a manipulation of the interaction strength by varying the trap geometry. Here, a theoretical model is presented describing inelastic confinement-induced resonances which appear in addition to the regular (elastic) ones and were observed in the recent loss experiment of Haller et al. in terms of particle losses [1]. These resonances originate from possible molecule formation due to the coupling of center-of-mass and relative motion. The model is verified by ab initio calculations and predicts the resonance positions in 1D as well as in 2D confinement in agreement with the experiment. This resolves the contradiction of the experimental observations to previous theoretical predictions.

[1] E. Haller et al., *Phys. Rev. Lett.* **104**, 153203 (2010).

A 40.15 Thu 16:30 Poster.V

Few-fermion systems in multiple well potentials — •Vincent Klinkhamer[1,2], Friedhelm Serwane[1,2], Thomas Lompe[1,2], Gerhard Zürn[1,2], Andre Wenz[1,2], and Selim Jochim[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisches Institut, Heidelberg

With our current experimental setup it is possible to reliably prepare systems with up to 10 fermionic ^{6}Li atoms in a single optical microtrap. The inter-particle coupling can be tuned to study interacting few-particle systems inside the potential. We will extend the current setup in order to create a small array of such microtraps which will allow us to explore systems in periodic potentials. We present our progress creating this setup. The multiple wells will be created using a high resolution objective with a NA of 0.6 which is optimized for two wavelengths, 1064nm and 671nm. The high numerical aperture ensures a high detection efficiency of the fluorescence signal at 671nm. Starting point of our experiments will be a ground state system in one microtrap. It will be split adiabatically into a multiple well potential using a 2-D acousto-optical deflector. With this setup one can examine the tunneling behavior of the particles leading to magnetic ordering in an ultracold Fermi gas.

A 40.16 Thu 16:30 Poster.V

Semiclassical Dynamics of Ultracold Bosons in Multiple Wells — •Lena Simon and Walter T. Strunz — Institut für theoretische Physik, TU Dresden, Dresden

We aim to shed light on the transition from a nonequilibrium to an equilibrium state of an interacting bosonic manybody system. We investigate the dynamics of an ensemble of Bosons in a multiple well potential, which has been initially set up in a nonequilibrium state. The Bosons display interesting dynamics, gouverned by the interplay of tunneling and the interaction amongst the particles. The dynamics are investigated by solving the full Schroedinger equation for a Bose-Hubbard-model, by introducing the WKB-approximation and finally by means of the so called (semiclassical) Herman-Kluk propagator. The results are also compared to the often applied mean-field approximation.

A 40.17 Thu 16:30 Poster.V

Interaction of ultracold rubidium atoms with trapped OH$^-$-ions — •Bastian Höltkemeier[1], Simone Götz[1], Matthias Weidemüller[1], Thorsten Best[2], Roland Wester[2], and Johannes Deiglmayr[3] — [1]Physikalisches Institut, Philosophenweg 12, 69120 Heidelberg — [2]Institut f. Ionenphysik und Angewandte Physik, Technikerstraße 25/3, 6020 Innsbruck — [3]Laboratory of Physical Chemistry, ETH Hönggerberg, Wolfgang-Pauli-Strasse 10, 8093 Zürich

Based on previous experiments on ion-atom reactions, we present a new setup to investigate the interaction of ultracold rubidium atoms in a Dark-SPOT and mass-selected OH^--water clusters. The ions are trapped in an octupole RF-trap consisting of thin wires instead of metal rods to give maximum optical access.
In first experiments, this setup will be used to investigate cooling of the ions due to collisions with the neutral Rb-atoms. For efficient cooling a dense cloud of atoms preferably in the ground state, to minimize ion-losses due to collisions with excited atoms, is needed. In a recent experiment we succeeded in creating a cloud of 4×10^8 atoms at a peak density of up to 3×10^{11}atoms/cm^3 which can be loaded in less than two seconds from a 2D-MOT. In this Dark-SPOT we estimated that about 95% of the atoms are in the ground state, perfectly fulfilling our requirements for efficient cooling of ions. This setup will now be adapted for our future OH^- experiments.

A 40.18 Thu 16:30 Poster.V

Thermodynamic properties of 2D dipolar gases — •Alexey Filinov und Michael Bonitz — Institute for Theoretical Physics and Astrophysics, Christian-Albrechts-Universität, Kiel, Germany

We perform the path integral Monte Carlo simulations to study the finite temperature properties of interacting dipolar Bose gas in two-dimensional geometry in the grand canonical ensemble. We investigate the equation of state, the temperature dependence of the superfluid fraction, the quasi-condensate n_0, the momentum distribution and the isothermal compressibility κ for temperatures above and below the Berezinskii-Kosterlitz-Thouless crossover to the superfluid phase. The increase in the occupation of the zero-momentum state n_0 leads to suppression of the density fluctuations and a non-monotonic behavior of the compressibility κ in the presuperfluid regime. We also analyse dependence of the phonon-maxon-roton excitation branch and the dynamic structure factor on the chemical potential (or density) and temperature. The spectrum of longitudinal collective modes is reconstructed from the imaginary time density-density correlation function.

A 40.19 Thu 16:30 Poster.V

Anisotropic pair-superfluidity of trapped two-component Bose gases — •Yongqiang Li, Liang He, and Walter Hofstetter — Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt/Main, Germany

We theoretically simulate the pair-superfluid phase of homogeneous and trapped two-component ultracold gases in an optical lattice with attractive inter-species interactions, by means of Bosonic Dynamical Mean Field Theory. We obtain the phase diagram for filling $n = 1$ at zero and finite temperature for asymmetric parameters in a three dimensional optical lattice, and confirm the stability of pair superfluidity in a wide range of parameters. We calculate the critical temperature of the pair-superfluid phase. In the presence of an external trap, we discuss the effects of inhomogeneity and imbalance between the two species on the pair-superfluid phase.

A 40.20 Thu 16:30 Poster.V

Interference of a Rydberg-dressed Bose-Einstein condensate released from an optical lattice — •Lama Hamadeh, Weibin Li, and Igor Lesanovsky — School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, UK

We study the interference of bosonic atoms in a superfluid state released from an optical lattice. The electronic ground state of each atom is weakly coupled to a highly excited Rydberg state by a far-off-resonant laser. This admixture of the Rydberg state induces effective short-range and long-range interactions between ground state atoms. We study the influence of the far-off-resonant laser driving on the interference pattern produced when the atoms are released from the optical lattice. For a fixed dressing time, the interference pattern depends strongly on the relative strength of the short-range and long-range interactions. Our study reveals that the corresponding visibility differs significantly for different momentum components of the expanded atomic cloud. As a result, the momentum dependent visibility can be used to distinguish the relative strength of the long-range and the short-range interactions.

A 40.21 Thu 16:30 Poster.V

Towards probing of fermionic quantum many body systems on the single atom level — •Martin Boll[1], Ahmed Omran[1], Thomas Gantner[1], Timon Hilker[1], Michael Lohse[1], Seth Coleman[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str.1, 85748 Garching — [2]Ludwig-Maximilians-Universität München, Fakultät für Physik, Schellingstraße 4, 80799 München

Ultracold atoms in optical lattices have proven to be a powerful tool for investigating quantum many body systems. Recent experiments have demonstrated the power of single-site resolved detection in optical lattices for the study of strongly correlated bosonic many body systems. In our new experiment we plan to apply similar techniques to fermionic systems. We will use mixtures of Li-6 and Li-7 atoms to achieve a degenerate bosonic or fermionic many body system trapped in a 3D optical lattice. With a high resolution imaging system, we will be able to resolve single sites in a 2D plane of the lattice and image single atoms. Superimposing an additional small-scale pinning lattice onto the larger-scale physics lattice in order to freeze out the distribution of atoms during imaging, we separate the detector from the physical system under study. This will allow for the investigation of different lattice geometries with in-situ detection of the atoms and precise measurement of the momentum distribution. As a first application we plan to study the quantum phases of the Fermi-Hubbard Hamiltonian locally, and investigate the underlying phenomena associated with condensed matter systems, e.g. quantum magnetism.

A 40.22 Thu 16:30 Poster.V

Spin dynamics and Rydberg excitations on the single-atom level — •Peter Schauss[1], Takeshi Fukuhara Fukuhara[1], Marc Cheneau[1], Manuel Endres[1], Christian Gross[1], Stefan Kuhr[1,2], and Immanuel Bloch[1,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]University of Strathclyde, SUPA, Glasgow G4 0NG, UK — [3]Ludwig-Maximilians-Universität, 80799 München

Recently, we demonstrated single atom imaging of a quantum gas in an optical lattice [1] and site selective spin manipulation [2]. Here we report on the most recent results obtained using this apparatus: the spreading of a single spin impurity in a fully polarised Mott insulator and the excitation of Rydberg atoms in a quantum gas. In the first project, we make use of a Spatial Light Modulator to flip the spin of a single atom in a fully polarised 1D Mott insulating state. We subsequently record the spreading dynamics of this impurity and distinguish between different regimes depending on the lattice depth. The goal of the second project is to add long-range interactions to our system via Rydberg dressing. The high spatial resolution of our imaging system should allow us, for example, to reveal the strong correlations induced by the long-range interaction.

[1] J. Sherson et al., Nature 467, 68 (2010)
[2] C. Weitenberg et al., Nature 471, 319 (2011)

A 40.23 Thu 16:30 Poster.V

Evaporation limited loading of an atomic trap — Markus Falkenau, •Valentin V Volchkov, Jahn Rührig, Hannes Gorniaczyk, Mesut Ceylan, Tilman Pfau, and Axel Griesmaier — 5.Physikalische Institut, Universität Stuttgart, Pfaffenwaldring 57, Stuttgart, 70569

Recently, we have experimentally demonstrated a continuous loading mechanism for an optical dipole trap from a guided atomic beam [1]. The observed evolution of the number of atoms and temperature in the trap are consequences of the unusual trap geometry. On this poster, we present a model based on a set of rate equations to describe the loading dynamics of such a mechanism. We consider the collision statistics in the non-uniform trap potential that leads to twodimensional evaporation. The comparison between the resulting computations and experimental data allows to identify the dominant loss process and suggests ways to enhance the achievable steady-state atom number and phase-space density.

[1] M. Falkenau, V. V. Volchkov, J. Rührig, A. Griesmaier and T. Pfau, Phys. Rev. Lett. 106, 163002 (2011).

A 40.24 Thu 16:30 Poster.V

Stability and Collapse of a ^{52}Cr BEC in a 1D optical lattice — •Juliette Billy[1], Emanuel Henn[1], Stefan Müller[1], Holger Kadau[1], Thomas Maier[1], Matthias Schmitt[1], Mattia Jona-Lasinio[2], Luis Santos[2], Axel Griesmaier[1], and Tilman Pfau[1] — [1]Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, D-30167 Hannover, Germany

We have recently measured the stability diagram of a ^{52}Cr dipolar BEC in a 1D optical lattice, showing its strong dependence on the lattice depth [1]. This result opens up the way to investigate the collapse of this system in various regimes. The regime of deep lattice is of particular interest, as for the quasi-2D geometry of the lattice sites, roton features are expected to emerge and be enhanced. We discuss recent results on both lines of investigation, as well as future experiments on dipolar BECs in tailored multi-well potentials.

[1] S. Müller *et al.*, Phys. Rev. A **84**, 053601 (2011)

A 40.25 Thu 16:30 Poster.V

Towards stable groundstate NaK molecules — •Zhenkai Lu, Nikolaus Buchheim, Ingo Laut, Tobias Schneider, Christoph Gohle, and Immanuel Bloch — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching

Ultracold quantum gases in optical lattices are bench mark systems for strongly interacting manybody physics [1]. Conventional alkali atomic systems at ultra low temperatures exhibit interaction potentials that have essentially zero range. Therefore the associated Hamiltonians are limited to on site interaction. If long range interaction can be achieved, many intriguing effects and new quantum phases will be accessible. This includes real space long range (crystalline) order for bulk systems, supersolids or fractional mott insulators in optical lattices, to mention a few.

Promising candidates for ultra cold particles with long range (anisotropic) interaction include Rydberg atoms as well as photoassociated ground state polar diatomic molecules.

We are setting up an experiment to create ultracold NaK molecules. In this system instability, due to inelastic two body collisions known from pioneering experiments [2] does not exist and chances are good to reach far into the interesting parameter space.

[1] Bloch, I., Dalibard, J., & Zwerger, W. Many-body physics with ultracold gases. Reviews Of Modern Physics, 80, 885*964 (2008).

[2] Ni, K.-K., Ospelkaus, S., et al. A high phase-space-density gas of polar molecules. Science, 322, 231-5 (2008).

A 40.26 Thu 16:30 Poster.V

Matter wave guiding through a photonic bandgap fiber — •Hannes Duncker, Lars Wacker, Patrick Windpassinger, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

In this contribution, we present a project where we intend to study light-matter interaction in an extremely one-dimensional geometry by loading ultracold atoms into a hollow core photonic bandgap (HCPBG) fiber. As a first step, we have been able to demonstrate guiding of cold, slow atoms through an 88 mm long piece of fiber [1]. The guiding potential is created by a far-off resonance dipole trap which propagates in the hollow core of the HCPBG fiber. By imaging the guided atoms' fluorescence signal, we are able to analyze the dynamics of the atoms inside the fiber in detail. The tight confinement of both atoms and light fields inside the fiber leads to an increased interaction probability which will allow us to study atom mediated photon-photon interaction in the future.

[1] S. Vorrath et al, NJP 12, 123015 (2010)

A 40.27 Thu 16:30 Poster.V

Non-linear and metastable dynamics of a Bose-Einstein condensate — •Holger Hauptmann[1], Sigmund Heller[1], Patrick Navez[1], Holger Kantz[2], and Walter Strunz[1] — [1]Technische Universität Dresden — [2]Max-Planck-Institut für Physik komplexer Systeme, Dresden

We examine the non-linear dynamics associated to the lowest breathing mode of a self-interacting repulsive Bose-Einstein condensate at zero temperature with the Gross-Pitaevskii equation in a three-dimensional harmonic trap under external time-periodic stretching and squeezing. This perturbation leads to collective excitations of this many-body system und we observe a resonance-like behavior. To understand this phenomenon qualitatively, we derive an approximative system of equations, which resembles equations of motion for a classical particle in an electromagnetic field and external potential. This analogy allows us to identify the resonance as emerging from a saddle point.

Furthermore we investigate the metastability of the relative motion between a Bose-Einstein condensate und its thermal cloud at finite temperature in a harmonic trap. Stirring the system at low frequencies leads to a rotation of the thermal cloud with a resting condensate. We are looking for the critical angular velocity between condensate and thermal cloud for which the system becomes unstable.

A 40.28 Thu 16:30 Poster.V

Cooling and trapping erbium atoms — •Patrizia Weiss, Florian Jessen, Claus Zimmermann, and József Fortágh — Physikalisches Institut der Universität Tübingen, Center for Collective Quantum Phenomena and their Applications

Erbium is a rare-earth element with a complex energy level structure, and a range of possible laser cooling transitions, including very strong and narrow transition lines. Erbium has a large magnetic moment of $7\mu_B$. This property makes it interesting for studying magnetic interactions between cold atoms and superconducting nanostructures.

We present our experimental progress towards cooling and trapping erbium and the current status of the setup, that is compatible with cooling nanostructures to cryogenic temperatures.

A 40.29 Thu 16:30 Poster.V

A new lattice setup for a three-component Fermi gas — •Johanna Bohn[1,2], Thomas Lompe[1,2], Martin Ries[1,2], Friedhelm Serwane[1,2], Juliana Stachurska[1,2], Andre Wenz[1,2], Gerhard Zürn[1,2], and Selim Jochim[1,2] — [1]Physikalisches Institut, Universität Heidelberg — [2]Max-Planck-Institut für Kernphysik, Heidelberg

Strongly interacting degenerate three-component Fermi gases promise to show interesting many-body physics. However, preparing such systems has so far been inhibited by large three-body loss rates which scale with the scattering length to the fourth power. On this poster we present progress towards the preparation of a three-component Fermi gas of Li-6 atoms in a two-dimensional optical lattice potential. This should allow to stabilize the three-component system by making use of the quantum-Zeno effect which suppresses three-body loss as described in [1]. We have cooled a gas of two-component ^{6}Li atoms to quantum degeneracy in an optical dipole trap and transferred atoms into the third state using a radio frequency signal. The next step is loading them into a two-dimensional light sheet onto which the two-dimensional lattice will be projected to produce a stable strongly interacting three-component Fermi gas.

[1] A. Kantian et al. PRL 103, 240401 (2009)

A 40.30 Thu 16:30 Poster.V

Interaction quenches in a one-dimensional Bose gas — •Fedja Oručević[1], Anton Piccardo-Selg[1], Gal Aviv[1], Susanne Pielawa[2], Thomas Fernholz[1], and Peter Krüger[1] — [1]Midlands Ultracold Atom Research Centre, School of Physics and Astronomy, University of Nottingham, UK — [2]The Weizmann Institute of Science, Rehovot, Israel

Atom chips allow for almost arbitrary trapping geometries for atomic ensembles and are ideally suited for the investigation of low-dimensional ultracold quantum gases at the low temperatures.

We use such an atom chip to trap and prepare a one-dimensional quasi-condensed Bose gas. Its first order correlation function (g_1) decays algebraically slowly with distance, rather than exponentially like a non-degenerate thermal gas would. The exponent of this decay depends on the Luttinger parameter, i.e. the interaction strength in the system. The aim of our experiment is to address the question of what happens when the interaction strength in the gas is changed abruptly in a quench and how quickly the system adapts to the new Luttinger parameter. It is predicted that after some prethermalization time the gas will display correlations that would be expected for a more strongly interacting equilibrium gas. One can further ask whether or not or on which time scale full thermalization occurs. Answers to these questions can be obtained from determining phase correlations from interference patterns that form when one or two similar systems are released from the trap(s) after a varied time following the quench. The current progress of the experimental setup will be presented.

A 40.31 Thu 16:30 Poster.V

Collisions of ultracold Rb_2 triplet molecules — •Markus Deiss, Björn Drews, Manuel Thoma, Benjamin Deissler, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Albert-Einstein-Allee 45, 89081 Ulm, Germany

In recent years it has become possible to prepare ultracold and dense molecular samples in the rovibrational ground state which opens the door for novel experiments [1,2,3]. Here, we report on our current status concerning collisions between ultracold Rb_2 triplet molecules. Starting with a BEC of ^{87}Rb atoms, we use a magnetic Feshbach resonance at 1007.4G to produce a pure sample of molecules which are held in a 3D optical lattice and transferred to the rovibrational ground state by STIRAP. One question of interest is how quickly these triplet molecules relax into a singlet state.

[1] F. Lang et. al., Phys. Rev. Lett. **101**, 133005 (2008)

[2] J. G. Danzl et. al., Nature Physics **6**, 265 (2010)
[3] K.-K. Ni et. al., Science **322**, 231 (2008)

A 40.32 Thu 16:30 Poster.V

Phase control of optical lattice by the interferometer — •Amir Mohamamdi and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Albert-Einstein-Allee 45, 89081 Ulm, Germany

Optical lattices are used as a fundamental tool for investigating the physics of ultracold atoms [1]. Particularly interesting are superlattices, which are generated by the superposition of two lattices with different wavelengths. In a superlattice of period two, the relative height of the potential wells can be varied by controlling the relative phase of the two lattices. In this way, particles can be moved between lattice wells in a controlled way, making it possible to realize quantum information schemes or measure particle correlations [2]. We present a new scheme to stabilize the phase of a 1D optical lattice using an interferometric scheme. A Michelson interferometer is used to measure the relative phase of two counterpropagating laser beams. Using two AOMs, this phase can then be stabilized. We discuss our experimental results and compare with existing schemes.

References: [1] I. Bloch, nature physics, 1, 23, 2005.– [2] O. Romero-Isart and J. José Phys. Rev. A, 76, 052304 (2007).

A 40.33 Thu 16:30 Poster.V

Conduction of ultracold Fermions through a mesoscopic channel — •Sebastian Krinner, Jakob Meineke, Jean-Philippe Brantut, David Stadler, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland

We present a conduction measurement of ultracold Fermions flowing through a quasi two-dimensional channel which is connected to two macroscopic atom reservoirs. A controlled imbalance of the atom number in the two reservoirs induces a current from one side to the other. We observe this current as a function of time and see a characteristic decay of the atom number imbalance to its equilibrium position. In addition we measure in-situ the density distribution in the channel for two different situations: a purely ballistic channel and a channel containing disorder. Eventhough the macroscopic atom current is the same, we observe a very different local behaviour of the atomic density in the channel and at the contacts.

A 40.34 Thu 16:30 Poster.V

Narrow-line magneto-optical trap for erbium: A simple approach for a complex atom — •Albert Frisch[1], Kiyotaka Aikawa[1], Michael Mark[1], Simon Baier[1], Rudolf Grimm[1,2], and Francesca Ferlaino[1] — [1]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

We report on the experimental realization of a robust and efficient magneto-optical trap (MOT) for erbium atoms, based on a weak cooling transition at 583 nm. The atomic beam is captured into the narrow-line MOT from a Zeeman slower operating on the strong optical transition at 401 nm. We observe up to $N = 3 \times 10^8$ atoms at a temperature of $T = 15$ μK. This simple scheme provides better starting conditions for loading the dipole trap compared to approaches based on the strong cooling transition or on the combination of a strong and an ultra-narrow transition.

We demonstrate direct loading of the dipole trap from the narrow-line MOT without any additonal cooling stages. Finally we investigate collisional properties of ultracold dipolar erbium atoms.

Our cooling and trapping scheme simplifies the route towards quantum degneracy and thus we speculate it can be successfully applied to other atoms in the lanthanide series.

A 41: Poster: Ultra-cold plasmas and Rydberg systems

Time: Thursday 16:30–19:00 Location: Poster.V

A 41.1 Thu 16:30 Poster.V

A Ramsey interferometer to study Förster induced Rydberg interactions — •Jonathan Balewski, Johannes Nipper, Alexander Krupp, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

Interacting Rydberg systems show promising prospects in different fields ranging from quantum computing to the simulation of quantum systems. An important ingredient hereof is a strong controllable interaction as it is provided by Stark tuned Förster resonances. Such resonances occur in Rydberg systems by the coupling of degenerate dipole transitions between different atomic states. This leads to an energy transfer between the atoms and to a strong interaction with distinct angular dependence. The sign and strength of this interaction can be controlled by changing the pair state energy levels by applying external electric fields.

We use an interferometric technique based on an optical Ramsey sequence to study such resonances in the $44d_{5/2}$ Rydberg state of ultracold ^{87}Rb atoms. With this phase sensitive method we show that we can switch and tune the interatomic interaction. Extending the scheme using different electric pulse sequences we can additionally probe the coherent coupling of the involved pair states. The coherent nature of the Förster induced interaction is crucial for many of its applications.

Furthermore the system presented here could in principle be used to model Förster induced energy transfer processes which play an important role in biophysics.

A 41.2 Thu 16:30 Poster.V

A new setup for experiments with ultracold Rydberg atoms — •Johannes Deiglmayr, Heiner Sassmannshausen, and Frederic Merkt — LPC, ETH Zuerich, Switzerland

The study of dense samples of ultracold atoms in high Rydberg states has yielded many spectacular results in recent years, such as the observation of exotic dimers with bond-lengths exceeding 1 μm or the realization of quantum gates based on neutral atoms [1].

Here we present a new setup for high resolution spectroscopy of atomic Rydberg states. Laser-cooled cesium atoms are excited from the $6S_{1/2}$ state to Rydberg states by a UV photon from a pulsed laser. A phase-locked narrowband source of continuous millimeter waves (linewidth <10 kHz) is then used to determine Rydberg-Rydberg transition energies with highest accuracy. First measurements characterizing the performance of our setup are shown.

We also envision the combination of this setup with a chip-based Rydberg decelerator recently developed in our group [2]. Prospects for energy-controlled collisions between Rydberg and ground state atoms are discussed and a new scheme for a single-atom on demand source is presented.

[1] Bendkowsky *et al.*, Nature 458 (2009); Isenhower *et al.*, PRL 104 (2010); Wilk *et al.*, ibid [2] SD Hogan *et al.*, accepted for publication in PRL

A 41.3 Thu 16:30 Poster.V

Second-generation apparatus for Ryberg-atoms in an ultracold gas — •Huan Nguyen, Michael Schlagmüller, Stephan Jennewein, Christoph Tresp, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Phys. Institut, Universität Stuttgart

The giant size and large polarizibility of Rydberg-atoms, resulting in strong long-range Rydberg-Rydberg interactions, make them ideal for studying many-body cooperative effects. In particular, the investigation of dense, ultracold Rydberg-gases in a magnetic trap has opened the door to novel effects such as Rydberg-molecules. Here, we present a new experimental apparatus for the creation and dynamic study of Rydberg-atoms in dense, ultra-cold atomic ensembles. Specific design goals of this new setup are single ion-detection capability, sub-micron optical resolution, and high flexibility in creating both magnetic and optical trapping potentials. We discuss how these different aspects are combined in a single, compact experimental realization.

A 41.4 Thu 16:30 Poster.V

Phase diagram of Rydberg atoms with repulsive van der Waals interaction — •Yaroslav Lutsyshyn and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Atoms excited to orbitals with high principal quantum number, also known as Rydberg atoms, present rich opportunities for studying strongly correlated quantum many-body effects. Interactions between atoms shift their levels, thus preventing neighboring atoms from being excited simultaneously, an effect called Rydberg blockade. Because of the blockade, excited atoms are spatially correlated and often spaced out to distances where the interaction has the van der Waals C_6/r^6 form. To understand possible ordering and phase transitions in such situations, we consider a phase diagram of particles with a repulsive van der Waals interaction. The system is studied with quantum and classical Monte Carlo methods, and the harmonic theory. With a proper selection of units, the entire phase diagram may be expressed in terms of just the reduced number density and temperature. This allows to compare phase conditions for considerably different interaction constants. Most present experiments are deeply in the “classical” regime of such a phase diagram, where the solidification would happen at temperature $T = 0.22\rho^2 C_6$ (C_6 being the interaction constant, and ρ the number density). At zero temperature, the transition occurs at density $\rho = 3.9(\hbar^2/mC_6)^{3/4}$. The preferred solid phase is fcc. The findings are reported in arXiv:1106.2997 (2011).

A 41.5 Thu 16:30 Poster.V

An electron microscope for the detection and manipulation of Rydberg atoms — •Thomas Niederprüm, Tobias Massimo Weber, Torsten Manthey, Philipp Langer, Vera Guarrera, Giovanni Barontini, and Herwig Ott — TU Kaiserslautern, Germany

In order to control the interactions between ultracold atoms the usage of the strong dipole-dipole coupling between highly excited Rydberg states is very promising. Especially the dressing of Rydberg states can give rise to exotic quantum phases and other phenomena predicted by the Bose-Hubbard-Model. In this poster, we will present a new apparatus for the production, the manipulation and the detection of ultracold Rydberg atoms. A scanning electron microscope inside the vacuum chamber will allow for single Rydberg atom detection with a high spatial resolution.

A 41.6 Thu 16:30 Poster.V

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

Relaxation processes in plasmas are well described within the framework of the Landau-Spitzer theory as long as the plasma is in a weakly coupled state, for which the Debye screening length is larger than the mean interparticle distance. However, these two length scales become comparable as the plasma approaches the strongly coupled regime, leading to a divergence of the Landau-Spitzer rate. Ultracold plasmas, created at the onset of strong correlations, grant experimental access to the parameter regime beyond the validity of the Landau-Spitzer theory.

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

A 41.7 Thu 16:30 Poster.V

Strong plasma correlations via Rydberg dipole blockade — •Georg Bannasch and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

One major challenge in ultracold plasmas research is the realization of strong coupling conditions. Since ultracold plasmas are typically created by photoionization of spatially uncorrelated ultracold atoms, the subsequent plasma relaxation leads to heating and, thus, limits the strength of achievable correlations.

Here we propose a double-pulse ionization scheme, consisting of an excitation laser pulse and an additional microwave field. Exploiting the dipole blockade between highly excited Rydberg atoms, this "pump-probe" type sequence produces strongly correlated ions by reducing disorder-induced heating of the system. On the other hand, the resulting plasma coupling strength allows to easily probe the degree of correlation in the Rydberg blocked atomic system. We thoroughly study the involved steps to discuss the feasibility of our approach and show universal scaling behavior of the achievable plasma coupling strength.

A 41.8 Thu 16:30 Poster.V

Investigation of Rydberg atom interactions by observing electromagnetically induced transparency spectra — •Markus Mack, Florian Karlewski, Helge Hattermann, Peter Federsel, Simone Höckh, Florian Jessen, Daniel Cano, and József Fortágh — Physikalisches Institut, Eberhard-Karls-Universität Tübingen

Rydberg atoms stand out due to their high polarizability which makes them highly sensitive to electric fields and increases many-body interactions.

We determined the binding energy of the 87Rb isotope by extrapolating our recent results for excitation energies of optically accessible Rydberg states.

The combination of measurements of the stark shifts of these Rydberg levels close to a metallic surface and calculated Stark maps provides information concerning the dipole field of any atoms which are adsorbed to the surface.

All Rydberg states and their energy shifts were detected by observing electromagnetically induced transparency.

A 41.9 Thu 16:30 Poster.V

Effects of correlated disorder on optical properties of molecular aggregates — •Sebastian Möbius[1], Sebastiaan M. Vlaming[2], Victor A. Malyshev[2], Jasper Knoester[2], and Alexander Eisfeld[1,3] — [1]Max Planck Intitute for physics of complex systems, Dresden, Germany — [2]Centre for Theoretical Physics and Zernike Institute for Advanced Materials, University of Groningen, Netherlands — [3]Department for Chemistry and Chemical Biology, Harvard University, USA

The dynamical and optical properties of excitons in quantum aggregates are strongly influenced by static disorder, due to inhomogeneities in the environment. This disorder leads to variation of the site energies of the individual monomers, which in turn results in localization of the exciton wavefunctions. In most theoretical studies, an uncorrelated Gaussian static disorder of the site energies has been used, which results in a strong exchange narrowing of the optical absorption upon increasing the interaction between the monomers. Recent results have shown that for certain types of non-Gaussian (Levy-stable) distributions the opposite effect, broadening of the spectrum, can occur. For these type of distributions, only uncorrelated disorder has been studied so far. Using an atomistic model, we show how different types of system-environment interaction lead to various Levy-stable distributions. Within the model, correlations between molecular transition energies can be naturally taken into account. Furthermore, we propose a method to numerically generate correlated Levy-stable distributions.

A 41.10 Thu 16:30 Poster.V

Interplay of conical intersections and entanglement transport in two-dimensional flexible Rydberg aggregates — •Karsten Leonhardt, Sebastian Wüster, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, Germany

Dipole-dipole transfer of electronic excitations on aggregates of atoms or molecules is important in many areas of physics, such as photosynthetic light-harvesting [1] or trapped assemblies of Rydberg atoms. The dipole-dipole interactions can also induce motion of the atoms in the chain [2]. In such a flexible aggregate, ring geometries exhibit conical intersections (CIs) [3] while one-dimensional linear geometries possess entanglement transporting modes [4, 5]. Here we combine both features and study two-dimensional, parallel-chain arrangements of Rydberg atoms. We locate CIs and highlight dynamical scenarios where directed transport is affected by the CIs.

[1] R. van Grondelle and V. I. Novoderezhkin, Phys. Chem. Chem. Phys. **8**, 793 (2006).

[2] C. Ates, A. Eisfeld, and J. M. Rost, New J. Phys. **10**, 045030 (2008).

[3] S. Wüster, A. Eisfeld, and J. M. Rost, Phys. Rev. Lett. **106**, 153002 (2011).

[4] S. Wüster, C. Ates, A. Eisfeld, and J. M. Rost, Phys. Rev. Lett. **105**, 053004 (2010).

[5] S. Möbius, S. Wüster, C. Ates, A. Eisfeld, and J. M. Rost, J. Phys. B: At. Mol. Opt. Phys. **44**, 184011 (2011).

A 41.11 Thu 16:30 Poster.V

Molecular-interaction effects on the dipole blockade in cold

Rydberg ensembles — •Weibin Li[1], Thomas Pohl[2], and Jan-Michael Rost[2] — [1]School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, UK — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

In high density ultracold gases, the interaction between ground state and Rydberg atoms can lead to the formation of ultralong-range molecules upon direct off-resonant photoassociation [1,2,3]. Here, we study resonant excitation in dipole blocked mesoscopic ensembles, in which all but a single excitation is inhibited by the strong Rydberg-Rydberg interaction. We show that the molecular interactions can have considerable effects on the resulting collective Rabi oscillations and investigate corresponding limitations for proposed implementations of quantum information schemes.

[1] V. Bendkowsky et al., Nature 458, 1005 (2009)
[2] V. Bendkowsky et al., Phys. Rev. Lett. 105, 163201 (2010)
[3] W. Li et al., Science 334, 1110 (2011)

A 42: Ultra-cold atoms, ions and BEC IV

Time: Friday 10:30–12:30 Location: V57.03

Invited Talk A 42.1 Fri 10:30 V57.03

Quantum reflection and matter-wave optics with helium atoms and molecules — •Wieland Schöllkopf — Fritz-Haber-Institut, Berlin

Quantum reflection allows atoms or molecules to be reflected from a solid without colliding with the actual surface. For sufficiently small incident kinetic energy the particle can scatter back at the attractive Casimir-van der Waals potential way in front of the surface. This effect is incompatible with classical physics, but readily explained by quantum mechanics. We have observed non-destructive scattering of He_2 (binding energy 10^{-7} eV) from a solid reflection grating. Helium dimers are quantum reflected tens of nm above the surface where the surface-induced forces are too weak to dissociate the fragile bond [1].

In another experiment we applied quantum reflection from a grating to observe *emerging beam resonances* in an atom-optical diffraction experiment for the first time [2]. This effect, also known as *Rayleigh-Wood anomalies*, had first been observed in 1902 by R.W. Wood in white-light grating diffraction. Rayleigh found that the anomalies occur when the wavelength and grating period are such that one of the diffraction beams just emerges from the grating surface, causing abrupt intensity variations in the other diffraction beams. Later, the effect was also observed with electrons diffracted from crystal surfaces. Our observation completes the analogy between photon optics and matter-wave optics and might provide a sensitive probe of atom-surface interactions.

[1] B.S. Zhao, G. Meijer, and W. Schöllkopf, Science **331**, 892 (2011).
[2] B.S. Zhao, G. Meijer, and W. Schöllkopf, PRL **104**, 240404 (2010).

A 42.2 Fri 11:00 V57.03

Interactions of Cold Atoms with Graphene and Carbon Nanotubes — Benjamin Jetter[1], Johannes Märkle[1], Philipp Schneeweiss[1], Michael Gierling[1], Robin Scott[2], Andrew Martin[3], Bartek Kaczmarek[4], Andreas Günther[1], József Fortágh[1], Mark Fromhold[4], and •Thomas Judd[1] — [1]University of Tübingen, Tübingen, Germany — [2]University of Trento, Trento, Italy — [3]University of Melbourne, Melbourne, Australia — [4]University of Nottingham, Nottingham, UK

A unique perspective on carbon nanostructures may be gained by combining such devices with cold atom clouds since these constitute the slowest and softest possible probe. Here, we investigate elastic and inelastic scattering of cold atoms on graphene and carbon nanotubes. We show that atomic quantum reflection probabilities from a graphene monolayer can be over 90% and that such experiments can distinguish between theoretical descriptions of graphene. We show that atoms that do not reflect noticeably increase the electrical resistance of graphene, opening the door to a new form of hybrid electronics and real-time monitoring of cold atoms. We also analyse recent data for cold atom scattering on a single carbon nanotube. Quantum reflection is shown to be negligible for thermal clouds, allowing one to extract van der Waals coefficients using classical theories. However, if a BEC is used, the scattering becomes highly non-trivial and effects such as inter-atomic interactions and quantum pressure become important. The van der Waals forces due to the nanotube are shown to be exceptionally small; this suggests a single nanotube can be an effective photon trap.

A 42.3 Fri 11:15 V57.03

Superconducting Atom Chips for Ultracold Atoms — •Simon Bernon, Helge Hattermann, Florian Jessen, Daniel Cano, Daniel Bothner, Martin Knufinke, Matthias Kemmler, Reinhold Kleiner, Dieter Koelle, and Jozsef Fortagh — Physikalisches Institut, Eberhard-Karls-Universität Tübingen, CQ Center for Collective Quantum Phenomena and their Applications, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

Hybrid quantum systems, which combine ultra-cold atoms with solid-state devices, have attracted considerable attention in the last years. Promising applications have been proposed in the areas of precision sensing and quantum information processing for which the long coherence time of atomic ensembles completes very well the fast logical operations performed by solid-state devices.

We report on experiments on ultracold atoms in a superconducting microtrap based on Niobium microstructures at 4.2K. Our data show that we achieved a full control of the magnetic fields of the trap, even in the vicinity of the superconductor where the trap positions and frequencies are modified by the Meissner effect. We also proved that electromagnetic noise near the superconductor is below the Johnson noise limit of normal conductor. This suggests long coherence time of atomic spin states even in the close proximity of superconductors. As a further step, we implemented a superconducting atom chip made of Niobium thin film wires on a Sapphire substrate. There, we achieved Bose-Einstein condensation showing the compatibility and interfacing of cold atoms and integrated superconducting chip.

A 42.4 Fri 11:30 V57.03

Light-assisted ion-neutral reactive processes in the cold regime: radiative molecule formation vs. charge exchange — Felix H. J. Hall[1], Mireille Aymar[2], Nadia Bouloufa[2], •Olivier Dulieu[2], and Stefan Willistch[1] — [1]Department of Chemistry, University of Basel, Klingelbergstrasse 80, 4056 Basel, Switzerland — [2]Laboratoire Aimé Cotton, CNRS, Université Paris-Sud, Orsay, France

We present a combined experimental and theoretical study of cold reactive collisions between lasercooled Ca^+ ions and Rb atoms in an ion-atom hybrid trap. We observe rich chemical dynamics which are interpreted in terms of non-adiabatic and radiative charge exchange as well as radiative molecule formation using high-level electronic structure calculations. We study the role of light-assisted processes and show that the efficiency of the dominant chemical pathways is considerably enhanced in excited reaction channels. Our results illustrate the importance of radiative and non-radiative processes for the cold chemistry occurring in ion-atom hybrid traps.

A 42.5 Fri 11:45 V57.03

Laser cooling of dense gases by collisional redistribution of radiation — •Anne Sass[1], Ulrich Vogl[2], and Martin Weitz[1] — [1]Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn — [2]Joint Quantum Institute, University of Maryland in College Park, USA

We study laser cooling of atomic gases by collisional redistribution of fluorescence, a technique applicable to ultradense atomic ensembles of alkali atoms and a few hundred bar of buffer gas pressure. The cooled gas has a density of more than ten orders of magnitude above the typical values in Doppler cooling experiments of dilute atomic gases.

In frequent collisions with noble gas atoms in the dense gas system, the energy levels of the alkali atoms are shifted, and absorption of far red detuned incident radiation becomes feasible. The subsequent spontaneous decay occurs close to the unperturbed resonance frequency, leading to a redistribution of the fluorescence. The emitted photons have a higher energy than the incident ones, and the dense atomic ensemble is cooled. We here describe recent experiments on the redistribution laser cooling of atomic gases carried out using an industrial high power diode laser, with which cooling of a rubidium argon gas mixture from an initial temperature of 390°C down to room temperature is observed. With radiation from a Ti:sapphire laser, cooling to -120°C has been measured.

For the future, we expect that redistribution laser cooling might also be applied to molecular gas samples, where cooling can start directly from room temperature.

A 42.6 Fri 12:00 V57.03

Dynamical arrest of ultracold lattice fermions. — •Bernd Schmidt[1], M. Reza Bakhtiari[1], Irakli Titvinidze[1,2], Ulrich Schneider[3], Michiel Snoek[4], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität Frankfurt, Frankfurt/Main, Germany — [2]Institut für Theoretische Physik, Universität Hamburg, Hamburg, Germany — [3]Ludwig-Maximilians-Universität, München, Germany — [4]Institute for Theoretical Physics, Universiteit van Amsterdam, Amsterdam, The Netherlands

When a parameter of a system is changed non-adiabatically, it might happen that under certain conditions the system freezes in a metastable state and will not be able to reach equilibrium again. This kind of phenomenon is often called dynamical arrest and is a well known effect in other fields of physics, for example, the gelation of colloidal systems in soft-matter physics. We investigate a very similar effect in a cloud of fermionic atoms during the ramp-up of an optical lattice. We use Dynamical Mean Field Theory to calculate the equilibrium radius of the cloud and compare it to experimental results. This comparison reveals that the system gets indeed trapped into a meta-stable state. Although the theoretical equilibrium behaviour of the system shows an anomalous expansion of the cloud as in the experiment, the experimental size of the cloud is significantly affected by dynamical arrest. Using a combination of numerical simulations and experimental data we are able to determine the critical lattice depth of dynamical arrest. Our results are of major relevance for the interpretation of past and future experiments with attractive fermions in optical lattices.

A 42.7 Fri 12:15 V57.03

Efimov trimers and universal N-body states — •Alessandro Zenesini[1], B. Huang[1,2], M. Berninger[1], S. Besler[1], H.-C Naegerl[1], F. Ferlaino[1], and R. Grimm[1,2] — [1]Institut fuer Experimentalphysik, Universitaet Innsbruck, 6020 Innsbruck, Austria — [2]Institut fuer Quantenoptik und Quanteninformation, OEsterreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

An atomic system becomes "universal" when the scattering length is tuned to large values and the low-energy physics is independent on the details of interaction potential. Efimov trimers and tetramers are two of the most striking examples of universal systems observed in experiment on ultracold atoms [1]. Open questions are whether universality is preserved when different Feshbach resonances are employed for interaction tuning or when another body is added to the system. Our latest results show not only that universality survives across Feshbach resonances but also that hints of a five-body bound state can be observed, in agreement with theoretical predictions of universal N-body states [2].

[1] "Forty years of Efimov physics: How a bizarre prediction turned into a hot topic" F. Ferlaino and R. Grimm, Physics 3, 9 (2010) [2] "General Theoretical Description of N-Body Recombination" N. P. Mehta et al, PRL 103, 153201 (2009)

A 43: Precision spectroscopy of atoms and ions IV

Time: Friday 10:30–12:15 Location: V47.03

A 43.1 Fri 10:30 V47.03

Lifetime and population of muonic hydrogen and deuterium in the metastable 2S state. — Marc Diepold and •the CREMA collaboration — Max-Planck-Institute for Quantum Optics, Garching

Recently, the CREMA collaboration succeeded to measure the Lamb shift (2S-2P energy difference) in muonic hydrogen doing laser spectroscopy.

In the present study we analyze the data sets taken with muonic hydrogen and muonic deuterium, and investigate the deexcitation of the metastable 2S state of muonic hydrogen and deuterium. We have observed a long-lived and a short-lived component, and determined the populations and lifetimes. Interesting differences between muonic hydrogen and muonic deuterium are revealed.

The results serve as an important observable for cascade calculations in exotic atoms. In addition, precise knowledge of populations and lifetimes of the 2S state will enable improvements for the next generation muonic hydrogen 2S-2P spectroscopy experiment.

A 43.2 Fri 10:45 V47.03

Atomic Parity Violation in a single Ra ion — •M. Nunes Portela, H. Beker, G. Giri, K. Jungmann, C.J.G. Onderwater, S. Schlesser, R.G.E. Timmermans, O.O. Versolato, L. Willmann, and H.W. Wilschut — KVI, University of Groningen, NL

Precision measurements of atomic parity violation is the only path to determine the electroweak mixing angle in the Standard Model of particle physics at low energy scale. A single trapped Ra+ ion is the most promising candidate for such an experiment. The system combines the advantages of large parity violation amplitudes due to the faster than Z^3 scaling, the possibility to perform accurate atomic structure calculation on this one valence electron system and the ability to precision frequency measurements on trapped ion. Our first laser spectroscopy on an ensemble of trapped short-lived $^{209-214}Ra^+$ isotopes in a linear Paul trap provided hyperfine structure of the 6d $^2D_{3/2}$ states and isotope shift of the 6d $^2D_{3/2}$ - 7p $^2P_{1/2}$ transition [1,2]. These results provide input for the ongoing precision atomic structure calculations. The next step of the experiments towards laser cooling of a single trapped radium ion. The experimental setup is being commissioned with Ba ions.

[1] O.O. Versolato et al. Phys. Lett. A 375 (2011) 3130-3133.
[2] G.S. Giri et al. Phys. Rev. A 84 (2011) 020503(R).

A 43.3 Fri 11:00 V47.03

***g*-faktor Messungen am gebunden Elektron in wasserstoff- und lithiumähnlichem Silizium ^{28}Si$^{13+,11+}$** — •Anke Wagner[1], Sven Sturm[1,2], Florian Köhler[3], Wolfgang Quint[3], Birgit Schabinger[1,2], Günter Werth[2] und Klaus Blaum[1] — [1]MPI für Kernphysik, 69117 Heidelberg, Deutschland — [2]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Deutschland — [3]GSI, 64291 Darmstadt, Deutschland

Hochpräzisionsmessungen des gyromagnetischen Faktors (g-Faktors) des Elektrons gebunden an hochgeladenen mittelschweren Ionen bieten die Möglichkeit Rechnungen zur Quantenelektrodynamik gebundener Systeme (BS-QED) unter extremen Bedinungen sehr genau zu testen. Zu diesem Zweck wurde der g-Faktor des Elektrons gebunden in wasserstoffähnlichem Silizium $^{28}Si^{13+}$ mit einer relativen Unsicherheit von nur $5 \cdot 10^{-10}$ gemessen und stellt derzeit den zwingendste Test der BS-QED in starken Feldern dar [1]. Die g-Faktor Messung an einem lithiumähnlichem System des gleichen Elements $^{28}Si^{11+}$ ermöglicht im Vergleich mit dem wasserstoffähnlichem System einen Test der Elektronen-Elektronen Wechselwirkung. Aus diesem Grund soll als nächster Schritt der g-Faktor des Elektrons gebunden in $^{28}Si^{11+}$ gemessen werden. Um den g-Faktor zu bestimmen, werden die Larmorfrequenz und die freie Zyklotronfrequenz eines einzelnen Ions in einer Penningfalle gemessen. Die Messmethode sowie die Ergebnisse werden präsentiert.

[1] Sturm et al., Phys. Rev. Lett. **107**, 023002 (2011)

A 43.4 Fri 11:15 V47.03

X-ray laser spectroscopy with trapped highly charged ions at the free-electron laser LCLS — •Sven Bernitt — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The emission lines of highly charged iron ions are prominent in the spectra of many astrophysical objects. However, some features, such as the relative intensities of two prominent bright Fe XVII lines around 15Å, are not well reproduced by todays most sophisticated spectral models. This limits the reliability of information that can be extracted from spectra. For this reasons, precise laboratory wavelength and intensity measurements with highly charged ions in the X-ray range are urgently needed. Laser spectroscopy is a remarkably succesful experimental method, but the X-ray regime was not accessible due to the lack of appropriate lasers. In recent years, a new kind of ultrabrilliant light sources, free electron lasers, have become available. Results of a first experiment overlapping x-ray laser pulses with highly charged ions in an electron beam ion trap and directly addressing photonic excitations will be presented. The experiment introduced the techniques of laser spectroscopy into the x-ray spectral range, opening new possibilities, not only for astrophysics, but also for benchmarking general atomic theory.

A 43.5 Fri 11:30 V47.03

Ein transversales Elektrontarget zur Untersuchung von Elektron-Ion-Wechselwirkungen — •Sabrina Geyer[1,2] und Oliver Kester[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [2]Institut für Angewandte Physik, Goethe-Universität Frankfurt

Ein neuartiges Konzept für Untersuchungen von Elektron-Ion-Wechselwirkungen an Speicherringen ist ein transversales Elektrontarget. Dort bietet es vielfältige Anwendungsmöglichkeiten, beispielsweise in der Spektroskopie von emittierten Elektronen und Photonen unter großen Raumwinkeln, sowie der genauen Messung von absoluten Wirkungsquerschnitten. Im Vergleich zu einem Gastarget führt ein Elektrontarget zu einer wesentlich besseren Energieauflösung, lediglich begrenzt durch die thermische Energieverteilung der Elektronen. Das Target-Design basiert auf einem Schichtstrahl, der im Vergleich zu einer runden Geometrie nicht nur eine längere Wechselwirkungszone generiert, sondern vor allem auch hohe Strahlströme bei niedrigeren Potentialdepressionen ermöglicht. Zur Fokussierung des Strahls werden rein elektrostatische Felder gewählt. Die Strahlenergie in der Wechselwirkungszone beträgt zwischen einigen 10eV und einigen keV. Das Elektrontarget wird für den Einsatz des FAIR-Projekts (Facility for Antiproton and Ion Research) an der GSI gebaut und in nächster Zeit am elektrostatischen Speicherring FLSR (Frankfurt Low Energy Storage Ring) der Universität Frankfurt getestet. Eine Übersicht über den Fortschritt des Elektrontargets wird präsentiert.

A 43.6 Fri 11:45 V47.03

Einsatz von Grafikkarten zur Simulation von Ionenwolken in Penningfallen — •Jochen Steinmann[1,2], Juergen Gross[2], Guenter Zwicknagel[3], Frank Herfurth[1] und Svetlana Fedotova[1] — [1]1GSI Helmholtzzentrum für Schwerionenforschung — [2]Hochschule Darmstadt — [3]Universität Erlangen-Nürnberg

An der HITRAP-Anlage (Highly Charged Ion Trap) der Gesellschaft für Schwerionenforschung (GSI) sollen Präzisionsexperimente mit hochgeladenen Ionen, bis hin zu nacktem Uran (U92+), durchgeführt werden. Teil der HITRAP-Anlage ist eine kryogene Penningfalle, in der bis zu 10^5 Ionen gespeichert werden können, die durch Elektronen- und anschließender Widerstandskühlung bis auf 4 K abgekühlt werden. Der Abkühlprozess führt im Potentialminimum der Falle zu einem Anstieg der Ionendichte, sodass Coulombwechselwirkung zunehmend das Verhalten des Vielteilchensystems bestimmt und somit die Bewegungsgleichungen der Ionen nicht mehr als entkoppeltes System betrachtet werden können. Der Rechenaufwand zur Lösung solcher Differentialgleichungssysteme skaliert quadratisch mit der Teilchenzahl, selbst für Hochleistungsrechner ergeben sich daher schnell Simulationszeiten auf einer Zeitskala von Jahren. Aufgrund des hohen Parallelisierungsgrades des Vielteilchensystems ist eine drastische Senkung der Simulationszeit durch den Einsatz von Grafikkarten möglich. Es konnte bereits die Abkühlung von bis zu 10000 Teilchen simuliert werden, unter Verwendung handelsüblicher Grafikkarten.

A 43.7 Fri 12:00 V47.03

Van der Waals interaction with a complex surface — Elad Eizner[1], Baruch Horovitz[1], and •Carsten Henkel[2] — [1]Ben Gurion University of the Negev, Beer Sheva, Israel — [2]Universität Potsdam, Germany

When an atom or molecule approaches a surface, it is subject to a (typically) attractive interaction due to fluctuations in its electric and magnetic dipole moments (London 1930, Casimir and Polder 1948, Lifshitz 1955). We discuss the impact of mobile charges localized at and below the surface on this well-known van der Waals potential. This is relevant, for example, in miniaturized traps (atom chips) and in the scattering of atomic beams. The charges at the surface participate in the screening of the fields due to the molecular dipole. As a result, new regimes and power laws emerge when the surface distance gets comparable to the electronic screening length. We analyze different materials (metals and semiconductors) and suggest that the interaction can be used as a probe of charge transport at the surface. The temperature-dependence of the van der Waals potential is compared to the macroscopic Casimir force between two conducting plates.

A 44: Attosecond physics II

Time: Friday 10:30–12:30 Location: V57.05

Invited Talk A 44.1 Fri 10:30 V57.05

Attosecond control and tracing of collective electron dynamics in nanoparticles — •Matthias Kling — Max-Planck Institut für Quantenoptik, Garching, Germany

Collective electron motion can unfold on attosecond time scales in nanoplasmonic systems, as defined by the inverse spectral bandwidth of the plasmonic resonant region. Similarly, in dielectrics or semiconductors, the laser-driven collective motion of electrons can occur on this characteristic time scale. One of the most promising routes to the realization of electronics operating at Petahertz frequencies arises from applying waveform controlled fields to nanoscale systems, where the nanolocalized near-fields enable for ultimate temporal and spatial control of the relevant electron transport processes. We demonstrate the emission and directional control of highly energetic electrons from isolated nanoparticles in few-cycle laser fields with well defined light waveform. Comparison of the obtained electron momentum distributions to results from quasi-classical simulations indicates that the electron acceleration mechanism is based on rescattering in the enhanced near-field of the nanoparticles. Attosecond nanoplasmonic streaking as one of the potential methods to map the near-fields of isolated nanoparticles in the presence of a strong external driving field will be introduced and discussed.

A 44.2 Fri 11:00 V57.05

Trajectory interferences in a semi-infinite gas cell — •Stephan M. Teichmann[1], Dane R. Austin[1], Matteo Clerici[2], Antonio Lotti[3,4], Daniele Faccio[5], Paolo Di Trapani[3], Arnaud Couairon[4], and Jens Biegert[1,6] — [1]ICFO-Institut de Ciencies Fotoniques, Castelldefels (Barcelona), Spain — [2]INRS-EMT, Université du Québec, Varennes, Canada — [3]Università dell'Insurbia,Como, Italy — [4]École Polytechnique, Centre National de la Recherche Scientifique, Palaiseau, France — [5]Heriot-Watt University, Edinburgh, Scotland — [6]ICREA-Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

Interferences between different quantum paths in the high harmonic generation (HHG) process offer insight into the interplay between the microscopic and macroscopic responses. Structures in spectrally resolved far-field spectra can be related to quantum path interference (QPI) effects. Here, we study QPI in the very loose focusing regime for the first time in high harmonic radiation generated in a semi-infinite gas cell. We assign the observed structures to interference of trajectories across the transverse plane of the generating field. A simple model based on the stationary phase approximation (SPA) within the strong field approximation (SFA) is used to describe the underlying effects.

A 44.3 Fri 11:15 V57.05

Tracking temporal dynamics along a femtosecond filament — •M. Kretschmar[1], D.S. Steingrube[1], E. Schulz[1], M. Kovacev[1], U. Morgner[1], M.B. Gaarde[2], and A. Couairon[3] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, D-30167 Hannover, Germany; QUEST, Centre for Quantum Engineering and Space-Time Research, Hannover, Germany — [2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803-4001, USA; PULSE Institute, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA — [3]Centre de Physique Theorique, Ecole Polytechnique, CNRS, F-91128, Palaiseau, France

Filamentation of femtosecond laser pulses serves as a versatile and fascinating tool for ultrafast phenomena such as few-cycle-pulse and high-order harmonic generation, which are essential steps for the production of attosecond laser pulses. We present a cell design capable of tracking dynamics inside a filament along its propagation direction, enabling detailed studies of the complex temporal and spatial evolution of the fundamental pulse. The localized analysis is done by truncation of the filament with a pressure gradient at variable positions. We report on the temporal pulse dynamics inside the filament observed by measuring the fundamental spectrum [1] and the pulse duration as well as high-order harmonic radiation originating directly from the filament [2].

[1] E Schulz et al., Opt. Express 19, 19495-19507 (2011)
[2] D S Steingrube et al., New J. Phys. 13 043022 (2011)

A 44.4 Fri 11:30 V57.05

Theory of attosecond transient absorption spectroscopy for overlapping pump and probe pulses — •Stefan Pabst[1,2], Arina Sytcheva[1], Adrian Wirth[3], Eleftherios Goulielmakis[3], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany

Attosecond transient absorption spectroscopy has been successfully applied to the measurement of the ion density matrix of strong-field ionized Krypton. In a recent experiment [A. Wirth et al., Science 334, 195 (2011)] it was shown that it is possible to probe the ionization dynamics of Krypton during an ionizing strong-field pulse that lasted approx. 2 fs. The theory of transient absorption has recently been developed [R. Santra et al., PRA 83, 033405 (2011)] for non-overlapping pump and probe pulses. In the case of overlapping pulses, the question remained whether one probes directly the instantaneous hole population or rather some effective population. Here, we present a theory of attosecond transient absorption spectroscopy for overlapping pump and probe pulses. Within the time-dependent configuration-interaction singles (TDCIS) approach, we describe the pump step (strong-field ionization) as well as the probe step (resonant electron excitation) on equal footing. Furthermore, we include propagation effects and detector resolution in our analysis. Our results support the concept that the transient absorption signal can be directly related to the instantaneous hole population even during the ionizing pump pulse.

A 44.5 Fri 11:45 V57.05

Real-time probing of field ionization induced by sub-cycle light transients — •Antoine Moulet[1], Adrian Wirth[1], Mohammed Tharwat Hassan[1], Ivanka Grguraš[1], Justin Gagnon[1], Tran Trung Luu[1], Stefan Pabst[3,4], Robin Santra[3,4], Zeyad Ahmed Alahmed[2], Abdallah Mohammed Azzeer[2], Vladislav Yakovlev[1,5], Volodymyr Pervak[5], Ferenc Krausz[1,5], and Eleftherios Goulielmakis[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]King Saud University, Riyadh, Kingdom of Saudi Arabia — [3]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [4]Department of Physics, University of Hamburg, Germany — [5]Department für Physik, Ludwig-Maximilians-Universität, Garching, Germany

We present the application of field-synthesized sub-cycle pulses (1) to the strong field ionization of atoms and the triggering of valence electron coherent motion in the generated ions. We use attosecond XUV transient absorption spectroscopy (2) to probe the dynamics.

Because with such pulses strong field ionization of krypton atoms can be confined to a single light crest, it creates a valence electron wavepacket with an unprecedented degree of coherence. Dynamic spectral distortions shed light on the instantaneous polarization of the electronic system by a varying electric field, often referred to as AC-Stark shift.

(1) A. Wirth *et al., Science* **334**, 195 (2011)
(2) E. Goulielmakis *et al., Nature* **466**, 739 (2010)

A 44.6 Fri 12:00 V57.05

Enhanced High-Order Harmonic Generation using dual gas targets — •Christoph M. Heyl, Fernando Brizuela, Piotr Rudawski, Cord Arnold, and Anne L'Huillier — Department of Physics, Lund University, P. O. Box 118, SE-22100 Lund, Sweden

High-order harmonic generation (HHG) in gases is nowadays well established and used for a variety of applications, in particular for the generation of attosecond pulses which give access to ultrafast phenomena in various fields of physics. This highly nonlinear light conversion process suffers, however, from a relatively low conversion efficiency. Several techniques have been implemented in order to enhance the efficiency, based on either improving phase matching or enhancing the single atom response. In this work, we investigate the possibilities of using a dual gas target in order to enhance the single atom response in the second target by driving the HHG process with an intense laser field and a superimposed harmonic field, generated in the first target. We demonstrate a significant enhancement of the harmonic signal (up to an order of magnitude), if an argon cell is placed in front of our low pressure neon cell. A similar effect has been observed earlier [1,2] involving an interpretation focusing on the role of the high-order harmonic field for controlling the ionization process in the second target. Our experimental results indicate that the enhancement happens due to low order harmonics which are efficiently generated in the first target.

[1] K. Ishikawa *et al.*, Phys. Rev. Lett. **91**, 043002 (2003)
[2] A. Heinrich *et al.*, J. Phys. B. **39**, S275 (2006)

A 44.7 Fri 12:15 V57.05

Fractional High-order Harmonic Combs and Energy Tuning by Split-spectrum Field Synthesis — •Philipp Raith, Christian Ott, Christopher Anderson, Andreas Kaldun, Kristina Meyer, Martin Laux, Yizhu Zhang, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

High-order harmonic generation in argon is experimentally controlled by splitting up a single broadband continuous spectrum into two components and applying a relative time delay. We observe a pronounced energy tuning of the individual harmonics and present an intuitive, quantitative model for explanation: the tuning results from a change of the instantaneous laser frequency at the interference-induced intensity maxima of the driving shaped pulse. Furthermore, we measured combs of fractional (noninteger) high-order harmonics generated by the controlled interference of two attosecond pulse trains with adjustable relative intensity. The noninteger harmonic combs can be fully modulated and are obtained when the driving laser field is shaped such that it forms two intensity maxima with controllable relative intensities. Simulations based on the strong field approximation show excellent agreement with the measurements, thus demonstrating the microscopic (single-atom response) nature of the control mechanism. In total, the attosecond-precision broadband split-spectrum field synthesis provides comprehensive control of high-harmonic generation and a versatile basis for coherent control of electron dynamics in atoms and molecules with tailored attosecond pulses in the extreme ultraviolet region.

A 45: Kalte Atome

Time: Friday 10:30–12:30 Location: V7.02

Group Report A 45.1 Fri 10:30 V7.02

Linear-zigzag transition in a quantum potential — •Cecilia Cormick and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66041, Saarbrücken, Deutschland

We study the dynamics of a chain of ultracold ions in a pumped standing-wave optical resonator, in the regime in which a dipolar transition of the ions couples with a cavity mode. In this scenario the ions' motion is determined by the trapping potential, the Coulomb repulsion, and the quantum potential of the cavity field. In particular, we focus on the case when the chain is close to the linear-zigzag structural transition. We first consider the limit in which the cavity field represents a negligible perturbation to the motion of the ions, and study how to obtain information about the structure and dynamics of the ion chain by measuring the intensity and spectrum of the light at the cavity output. We then analyze the behaviour when the back-action of the cavity field on the ions' dynamics relevantly affects the state of the crystal and show that hysteresis may appear where in free space one expects a continuous transition.

A 45.2 Fri 11:00 V7.02

Production of Antihydrogen via Double Charge Ex-

change — •Andreas Müllers[1], Daniel Fitzakerley[2], Robert McConnell[3], Jochen Walz[1], Eric Hessels[2], and Gerald Gabrielse[3] — [1]Johannes Gutenberg-Universität und Helmholtz Institut Mainz — [2]York University, Toronto, Kanada — [3]Harvard University, Cambridge (MA), USA

For the ATRAP collaboration

Spectroscopy of the $1S-2S$ transition of trapped antihydrogen and comparison with the equivalent line in hydrogen will provide an accurate test of CPT symmetry. However, the established method of producing antihydrogen creates them with an average temperature much higher than the typical trap-depth of a neutral atom trap. So far, only very few antihydrogen-atoms could be confined at a time.

Therefore the ATRAP collaboration developed a different method that has the potential of producing much larger numbers of cold antihydrogen atoms, the double charge exchange: Positrons and antiprotons are stored and cooled in the same Penning trap. Laser-excited cesium atoms collide with the positrons, forming Rydberg-Positronium, a bound state of an electron and a positron. The Positronium atoms are no longer confined by the electric potentials of the Penning trap and some will drift into the neighbouring cloud of antiprotons where, in a second charge exchange collision, they form antihydrogen.

ATRAP demonstrated this method in 2004. With a newly developed Penning trap and a custom laser system we now achieved a large increase in particle numbers and efficiency.

A 45.3 Fri 11:15 V7.02

Confinement induced resonance for a driven ultracold atom gas — •Maryam Roghani and Michael Thorwart — I. Institut für Theoretische Physik, Universität Hamburg, Germany

We solve the two-particle s-wave scattering for ultracold atom gases confined in quasi-one-dimensional trapping potential which is periodically driven. The interaction between the atoms is represented in term of the Fermi pseudopotential. For an isotropic harmonic oscillator the decoupling of center of mass and relative degrees of freedom is feasible. We use the Floquet approach to show that new resonance channels open due to the harmonic modulation. Applying the Bethe-Peierls boundary condition, we obtain the general scattering solution. The binding energies and the one dimensional scattering length for this driven system are studied.

A 45.4 Fri 11:30 V7.02

Continuous Coupling of Ultracold Atoms to Ionic Plasma via Rydberg Excitation — •Torsten Manthey, Tobias Massimo Weber, Thomas Niederprüm, Philipp Langer, Vera Guarrera, Giovanni Barontini, and Herwig Ott — Research Center Optimas, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We characterize the two-photon excitation of an ultracold gas of Rubidium atoms to Rydberg states analysing the induced atomic losses from an optical dipole trap. Extending the duration of the Rydberg excitation to several ms, the ground state atoms are continuously coupled to the formed positively charged plasma. In this regime we measure the n-dependence of the blockade effect and we characterise the interaction of the excited states and the ground state with the plasma.

A 45.5 Fri 11:45 V7.02

Accelerated split-operator method for GPU simulations of 3D atomic dynamics — •Lee J. O' Riordan[1,3], Neil Crowley[1], Tadhg Morgan[1], Thomas Fernholz[2], Peter Krüger[2], and Thomas Busch[1,3] — [1]Department of Physics, University College Cork, Ireland — [2]School of Physics & Astronomy, University of Nottingham, UK — [3]Quantum Systems Unit, OIST, Okinawa, Japan

Precise control over the external degrees of freedom of cold atomic systems for applications in quantum technologies often requires a fully three dimensional description. For numerical simulations this usually means large grids leading to long processing times, making highly scalable parallel approaches essential for obtaining results within useful timescales. We present a study into two sets of codes developed for the purpose of simulating the adiabatic dynamics of a single atom on a multi-waveguide atom chip. The first is a CPU approach utilising MPI and FFTW, and the second is a modern GPU-based approach. We find that the GPU approach offers a potential reduction in calculation time of up to an order of magnitude, making detailed simulations of even large structures realistic. The example we are investigating aims to show Coherent Tunneling Adiabatic Passage (CTAP) in a system of waveguides on an atom chip. Due to the absence of Rabi oscillations in this process, very large transfer fidelities can be achieved. All results we present closely mirror experimentally realistic systems and we present strategies we have developed to combat currently existing problems with other experimental approaches in order to fulfil the conditions to observe CTAP.

A 45.6 Fri 12:00 V7.02

Ultracold atoms in a disordered quantum potential — •Hessam Habibian[1,2], Simone Paganelli[1], and Giovanna Morigi[1,2] — [1]Universitat Autónoma de Barcelona, Spain — [2]Universität des Saarlandes, Germany

Self-organization of matter has been reported in experiments confining atomic gases in high-Q cavities [1]. When the atoms scatter laser photons into the cavity mode, they can form periodic patterns that maximize elastic scattering into the cavity [2]. It was predicted that the quantum ground state of these patterns can exhibit the properties of a Mott-Insulator state [3]. Here, we consider the case in which the atoms are confined along the cavity axis by classical fields and scatter laser photons into a cavity mode but, contrarily with previous works, we assume that the lattice periodicity and the phase of the scattered field are *incommensurate*. The model thus exhibits disorder whose features depend on the atomic density and on the pump laser intensity. We identify the regimes where the ground state is either incompressible or compressible. In the latter case we study when the atomic phase is a Bose glass and when it is a superfluid.

[1] A. Black, et al., Phys. Rev. Lett. 91, 203001 (2003); K. Baumann, et al., Nature 464, 1301 (2010).

[2] P. Domokos, H. Ritsch, Phys. Rev. Lett. 89, 253003 (2002).

[3] S. Fernandez-Vidal, et al., Phys. Rev. A 81, 043407 (2010).

A 45.7 Fri 12:15 V7.02

A self-optimizing experimental apparatus — •Ilka Geisel[1], Stefan Jöllenbeck[1], Jan Mahnke[1], Kai Cordes[2], Wolfgang Ertmer[1], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Informationsverabeitung, Leibniz Universität Hannover

Even though most parameters in a typical cold atom experimental setup are controlled by one computer program, optimization is still usually done by hand. One has to find the correlations between unknown parameters in the experiment in order to reach the optimum. Systematically scanning the whole parameter space will quickly become impossible as one goes to higher dimensions.

The logical step is to use an automated optimization procedure. The demands on such a program include finding the global optimum and being robust against experimental noise while reaching a sensible solution within a small number of experimental cycles. We present a genetic algorithm based on Differential Evolution, which quickly finds the optimum even with strong experimental noise. Relying only on basic mathematics it requires little computing power and is easy to implement.

Using the algorithm we improved our magneto-optical trap in a nine dimensional partly correlated parameter space by over 20%. A simulation allows for studying the behavior of the algorithm under different noise levels and parameters and thus reaching the optimal configuration for optimizing a wide range of experimental tasks.

A 46: Cluster

Time: Friday 10:30–12:00 Location: V38.02

A 46.1 Fri 10:30 V38.02

Isomer-Selective IR/IR Double Resonance Spectroscopy: Isolating the Spectral Signatures of $H^+ \cdot (H_2O)_6^+$ Isomers — •Nadja Heine[1], Giel Berden[2], Gerard Meijer[1], and Knut Asmis[1] — [1]Fritz-Haber-Institut, 14195 Berlin, Germany — [2]FOM Institute, 3439 Nieuwegein, The Netherlands

Understanding how protons are hydrated remains an important and challenging research area. The anomalously high proton mobility of water can be explained by a periodic isomerization between the Eigen and Zundel binding motifs, H_3O^+(aq)and $H_5O_2^+$(aq), respectively, even though the detailed mechanism is considerably more complex. These rapidly interconverting structures from the condensed phase can be stabilized, isolated and studied in the gas phase in the form of protonated water clusters. The smallest protonated water clusters that exhibits structural isomers related to the Eigen and Zundel motifs experimentally is the protonated water hexamer $H^+{\cdot}(H_2O)_6^+$.

Here, we present first results on infrared/infrared (IR/IR) double resonance experiments on $H^+{\cdot}(H_2O)_6^+$. Protonated water clusters are formed by electrospray ionization, mass-selected, cooled to cryogenic temperatures, and messenger-tagged (H_2) in a buffer gas filled ion trap. Isomer-selective IR/IR photodissociation spectra are measured from 300-4000 cm^{-1} by combining population-labeling double resonance spectroscopy with the widely tunable IR radiation of the free electron laser FELIX. The results demonstrate that two isomers, an Eigen and a Zundel-type isomer, are indeed present and that their IR spectra can be measured individually over the complete spectral range.

A 46.2 Fri 10:45 V38.02

Structural Variability in Transition Metal Oxide Clusters: Gas Phase Vibrational Spectroscopy of $V_3O_{6-8}^+$ — •Claudia Brieger[1], Torsten Wende[1], Jens Döbler[2], Andrzej Niedziela[2], Joachim Sauer[2], Gerard Meijer[1], and Knut R. Asmis[1] — [1]Fritz-Haber Institut der MPG, Berlin — [2]Humboldt Universität Berlin

Vanadium oxides exhibit a high structural variability and redox activity which comes to play into heterogeneous catalysis. Interestingly, the structure of the active sites in vanadium oxide catalysts is often not well known. Infrared photodissociation (IRPD) spectroscopy can be used to obtain structural information on isolated clusters in the gas phase. Here, we study the structures of tri-nuclear vanadium oxide cations. IRPD spectra of $V_3O_6^+He_{1-4}$, $V_3O_7^+Ar_{0-1}$, and $V_3O_8^+Ar_{0-2}$ from 350 to 1200 cm^{-1} are presented. $V_3O_7^+$ and $V_3O_8^+$ have a cage-like structure whereas a chain isomer is found to be most stable for $V_3O_6^+$. The binding of the rare gas atoms to $V_3O_{6-8}^+$ clusters is found to be strong, up to 58 kJ/mol for Ar, and markedly isomer-dependent, resulting in two interesting effects. First, for $V_3O_7^+Ar_1$ and $V_3O_8^+Ar_1$ an energetic reordering of the isomers compared to the bare ion is observed, making the ring-motif the most stable one. Second, different isomers bind different number of rare gas atoms. We demonstrate, how both effects can be exploited to isolate and assign the contributions from multiple isomers to the IR spectrum. The present results exemplify the sensitivity of the structure of vanadium oxide clusters on small perturbations in their environment.

A 46.3 Fri 11:00 V38.02

Activation of oxygen on small cationic platinum clusters in the gas phase — •Christian Kerpal[1], Dan Harding[1], Alexander Hermes[2], Suzanne Hamilton[2], Robert Moffatt[2], Stuart Mackenzie[2], Gerard Meijer[1], and André Fielicke[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin — [2]Department of Chemistry, University of Oxford, South Parks Road, Oxford, OX1 3QZ, UK

Small clusters of platinum represent model systems for potentially important industrial catalysts, e.g. for the activation of C-H bonds and for fuel cells. The long term goal of such cluster model studies is to understand the chemistry occurring at specific low coordinated metal sites in heterogeneous catalysis. However, the properties of metal clusters often differ dramatically with particle size. As most of the physical and chemical properties of clusters are directly related to their geometries, the determination of the precise structure is essential. The combination of infrared multiple photon dissociation (IR-MPD) spectroscopy and density functional theory (DFT) calculations provides a means to get detailed knowledge of the structures of both bare metal clusters and the adsorption geometries of small ligands on the clusters. Here we present IR-MPD spectra of $Pt_nO_{2m}{}^+$ clusters for $n \leq 6; m = 1, 2$ and a comparison to DFT calculations, allowing structural determination for the cluster-ligand complexes. These structures give direct information on the activation of the oxygen, showing different types of molecular and dissociated binding and in some cases a mixture of both, depending on cluster size and oxygen coverage.

A 46.4 Fri 11:15 V38.02

Electronic structure and binding energies of structurally modified diamondoid complexes studied with photoemission spectroscopy — •Tobias Zimmermann[1], Robert Richter[1], David Wolter[1], Torbjörn Rander[1], Peter Schreiner[2], and Thomas Möller[1] — [1]Technische Universität Berlin, Institut für Optik und Atomare Physik — [2]Justus-Liebig-Universität Gießen, Institut für Organische Chemie

While the smallest diamondoids, in particular Adamantane, have been known for some decades as perfectly shape- and mass-selectable carbon clusters, their significant scientific interest has risen only in the last few years. This is due to the fact that now also the larger ones have become more widely available due to new extraction and synthesis possibilities. Adamantane, with only ten carbon atoms, can be seen as the smallest unit of the macroscopic diamond crystal structure. The electronic structure of such nanoparticles can be analyzed with the help of photoemission spectroscopy (PES). In recent experiments we investigated the electronic structure of structurally modified lower diamondoids and lower diamondoid complexes. In particular we focus on lower diamondoid complexes containing sp^2-impurities. These systems are of interest due to the fact that sp^2-impurities in bulk diamond are known to enhance luminescence. Recently, it has also been reported that this type of structures possesses some of the longest C-C bonds known, the peculiarities of which may be studied by using PES.

A 46.5 Fri 11:30 V38.02

Experimental and theoretical Raman analysis of functionalized diamondoids — •Reinhard Meinke[1], Robert Richter[1], Thomas Möller[1], Boryslav Tkachenko[2], Peter R. Schreiner[2], Christian Thomsen[1], and Janina Maultzsch[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Institut für Organische Chemie, Justus-Liebig-Universität Giessen, Germany

Diamondoids functionalized with thiol, alcohol and amine groups [1] are investigated by means of Raman spectroscopy. Here we present so-called fingerprint regions in the Raman spectra which can be used for determination of functionalization in diamondoids. Several effects due to functionalization are observed: frequency shift of Raman modes, activation of Raman-inactive modes, and splitting of degenerate modes. We show how to determine the site and the type of the functional group with the help of the fingerprint regions. The Raman modes have been characterized and assigned by supporting DFT computations using Gaussian 09, using the B3LYP functional and the basis set 6-311G(d).

[1] Hartmut Schwertfeger, Andrey A. Fokin, and Peter R. Schreiner, Angew. Chem. Int. Ed. 2008, 47, 1022/1036. DOI: 10.1002/anie.200701684

A 46.6 Fri 11:45 V38.02

Molecular fragmentation and charge redistribution in XeF_2 after *K*-shell photoionization — Robert W. Dunford[1], Stephen H. Southworth[1], Dipanwita Ray[1], Elliot P. Kanter[1], Bertold Kraessig[1], Linda Young[1], Dohn A. Arms[1], Eric M. Dufresne[1], Donald A. Walko[1], •Oriol Vendrell[2], Sang-Kil Son[2], and Robin Santra[2,3] — [1]Argonne National Laboratory, Lemont, IL 60439, USA — [2]Center for Free-Electron Laser Science, DESY, 22607 Hamburg, Germany — [3]Department of Physics, University of Hamburg, 20355 Hamburg, Germany

The photoionization of an inner-shell electron in a heavy atom by synchrotron radiation sets off a cascade of x-ray and Auger transitions as the atom relaxes and reaches its final charge state. If the heavy atom is embedded in a molecule, the decay is accompanied by charge redistribution and molecular fragmentation processes.

In this work, we investigate the effect of Xe *K*-shell hole in XeF_2 and compare it to the isolated atomic case, Xe. The average total charge produced for Xe is +8, whereas it is +9 for XeF_2. Such similarity suggests a model in which the cascade proceeds at the atomic level followed by charge redistribution and Coulomb explosion. Simulations of the decay cascade of Xe, however, indicate that the cascade lasts for about 100 fs, in which case nuclear motion may play a role. Moreover, energetic considerations based on an independent ion model suggest that it is unlikely that the total charge in XeF_2 is initially produced entirely on Xe. Therefore, a more complex mechanism involving molecular effects is probably at play.

A 47: SYPC 3: From Atoms to Photonic Circuits 3

Time: Friday 10:30–12:30 Location: V47.02

A 47.1 Fri 10:30 V47.02

Towards quantum dot - photon entanglement swapping — •Tim Kroh, Otto Dietz, Andreas W Schell, and Oliver Benson — AG Nano Optics, Institut für Physik, HU Berlin

The distance of fiber based quantum communication can be increased arbitrarily with the help of quantum repeaters. In realizations of quantum repeater architectures involving semiconductor quantum dots (QDs) entanglement swapping between two dissimilar entangled states, i.e. an entangled QD-photon state on one hand and a photon pair on the other hand is a crucial operation. A first experiment involving a quantum dot and a photon pair was demonstrated recently [1].

The next important step is to demonstrate two-photon interference between a single photon from a quantum dot and a photon from an entangled photon pair. To achieve indistinguishability at least one of the photon sources has to be tunable. We present first experiments in this direction where we investigate different semiconductor QDs which are tunable with respect to photon pair sources.

[1] Solomon et al., Phys. Rev. Lett. 107, 157402

A 47.2 Fri 10:45 V47.02

Heralded Quantum Entanglement between two Crystals — •Christoph Clausen, Imam Usmani, Félix Bussières, Nicolas Sangouard, Mikael Afzelius, and Nicolas Gisin — GAP-Optique, Université de Genève, Switzerland

A crucial requirement for quantum networks is the ability to entangle quantum nodes. With the help of a quantum repeater, for example, quantum information can be transmitted at a rate that scales polynomially with distance, whereas the exponential loss in direct transmission of single photons through optical fibers inhibits quantum communication over distances larger than a few hundred kilometers. This is only possible if two remote quantum memories can be entangled in a heralded fashion.

We present the creation of heralded entanglement between two ensembles of rare-earth ions doped into separate crystals. A heralded single photon is sent through a 50/50 beamsplitter with one crystal at each output acting as quantum memories. The absorption of the photon by one of the crystals leads to a single collective excitation delocalized between the two crystals. The entanglement between the crystals is revealed by mapping it back to optical modes and performing a series of measurements that provide a lower bound on the concurrence of the retrieved light state. Our results are a step on the way towards quantum networks based on solid-state resources.

A 47.3 Fri 11:00 V47.02

An All-Integrated PDC Source for Heralded Single Photons in Ti:LiNbO$_3$ Waveguides — •Stephan Krapick, Benjamin Brecht, Viktor Quiring, Harald Herrmann, Wolfgang Sohler, and Christine Silberhorn — IQO, Uni Paderborn

Many applications in quantum information networking rely on heralded single photons. We present a waveguide-based source for the efficient generation of heralded single photons in Ti-diffused Lithium Niobate. Pumping with pulsed light at 532 nm, photon pairs at around 810nm and 1550nm are created in a type-I PDC process and split up into signal and idler beams using an integrated WDM coupler on the very same chip. We will optimize our source and aim to achieve heralded efficiencies of up to 93% in coincidence measurements, which are theoretically limited by the waveguide-fiber-coupling.

A 47.4 Fri 11:15 V47.02

The inhomogeneous broadening of the zero phonon line of single nitrogen-vacancy centers in nano-diamonds — •Nikola Sadzak, Janik Wolters, and Oliver Benson — Humboldt Universität zu Berlin, Nano-optics, Newtonstraße 15, D-12489 Berlin, Germany

Color centers in diamond have proven to be a promising resource for quantum technology applications. In particular, the negatively charged nitrogen-vacancy defect (NV) center in bulk diamond is attractive as a source of indistinguishable single photons, as it provides a narrow zero phonon line (ZPL) at the optical $^3A \rightarrow ^3E$ transition at 638 nm. However, for integrated solid state devices, nano-diamonds with single NV centers are preferable as they can be manipulated and integrated in different photonic structures [1, 2]. Here, a major problem is the inhomogeneous broadening of the ZPL due to spectral diffusion. Performing interferometric and photon-correlation measurements we determine the time-scale of the spectral diffusion and gain further knowledge about the underlying processes.

[1] J. Wolters et al., *Enhancement of the zero phonon line emission from a single nitrogen vacancy center in a nanodiamond via coupling to a photonic crystal cavity*, Appl. Phys. Lett. **97**, 141108 (2010)

[2] A. Schell et al., *A scanning probe-based pick-and-place procedure for assembly of integrated quantum optical hybrid devices*, Rev. Sci. Instrum. **82**, 073709 (2011)

A 47.5 Fri 11:30 V47.02

Ultrafast all-optical switching by single photons — •Thomas Volz, Andreas Reinhard, and Atac Imamoglu — Institute of Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

While two-color spectroscopy of the Jaynes-Cummings ladder has been performed in the microwave domain, it has so far not been demonstrated for cavity QED experiments in the optical domain. Here, we report on frequency- and time-resolved two-color spectroscopy of a strongly coupled quantum dot-cavity system which consists of a single self-assembled InGaAs quantum dot positioned at the field maximum of a photonic crystal L3 cavity. The coupled system is highly non-linear as witnessed by strong photon blockade on both fundamental polariton transitions [1]. Two (near-)resonant laser pulses with variable relative time delay are used to probe the non-linear system dynamics. With the center frequency of the first laser pulse fixed to one of the fundamental polariton transitions, we record the non-linear system response as a function of the center frequency of the second laser pulse. We obtain a clear signature due to the corresponding transition from the first to the second Jaynes-Cummings manifold. By varying the time delay between the laser pulses, we demonstrate all-optical switching by single photons on picosecond timescales [2]. Besides the single-photon switching, the present device can also be used as a single-photon pulse correlator.

[1] A. Reinhard et al., accepted for publication in Nature Photonics, arXiv:1108.3053.

[2] T. Volz et al., submitted for publication, arXiv:1111.2915.

A 47.6 Fri 11:45 V47.02

Influence of the excitation pulse width on the purity of single-photon emission from light emitting diodes — •Fabian Hargart[1], Christian Kessler[1], Matthias Reischle[1], Wolfgang-Michael Schulz[1], Marcus Eichfelder[1], Robert Rossbach[1], Michael Jetter[1], Paul Gartner[2], Matthias Florian[2], Christopher Gies[2], Frank Jahnke[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Institut für Theoretische Physik, Universität Bremen, Postfach 330 440, 28334 Bremen

For many applications in quantum information single-photons on demand are desirable. Electrically driven semiconductor quantum dots (QDs) are a promising solution due to their tailorable emission energy and the integration in well-known semiconductor devices.

Pulsed lasers afford an almost instantaneous excitation of the QDs compared to their decay time. In contrast, electrical pulse generators feature pulsewidths only down to several 10 ps. Therefore we determine the influence of the excitation pulses on the purity of single-photon emission from InP/GaInP quantum dots. For rising widths we observe an increasing $g^{(2)}(0)$ - value, which we relate to an increasing probability of further excitations during one single cycle. Using autocorrelation measurements with high temporal resolution we can distinguish the background contribution from re-excitation processes on the non-vanishing $g^{(2)}(0)$-value. Theoretical investigations are in a good agreement with the experimental results.

A 47.7 Fri 12:00 V47.02

Quantum Simulations with a two-dimensional Quantum Walk — •Andreas Schreiber[1,2], Aurél Gábris[3], Peter P. Rohde[1,4], Kaisa Laiho[1], Martin Štefaňák[3], Václav Potoček[3], Craig Hamilton[3], Igor Jex[3], and Christine Silberhorn[1,2] — [1]IQO Group, MPI for the Science of Light,91058 Erlangen, Germany. — [2]Integrated Quantum Optics, Applied Physics, University of Pader-

born, 33098 Paderborn, Germany — [3]Department of Physics, FNSPE, Czech Technical University in Prague, Praha, Czech Republic. — [4]Centre for Engineered Quantum Systems, Department of Physics and Astronomy, Macquarie University, Sydney NSW 2113, Australia

The concept of quantum walks has become a promising candidate for quantum computation and simulations of quantum transfer. Although theoretical models already exploit the power of higher-dimensional quantum walks all experimental implementations so far were limited to a spread in a single dimension.

Here we present the first implementation of a quantum walk in a scalable and flexible two-dimensional system. We demonstrate a highly coherent evolution of photons in an optical fiber network, allowing for a spread over up to 169 positions after 12 steps. Having full control over the quantum coin enables us to simulate entanglement in bipartite systems with conditioned interactions including non-linearities or two-particle scattering.

A 47.8 Fri 12:15 V47.02

Quantum key distribution using a single-photon emitting diode in the red spectral range — •Christian Kessler[1], Fabian Hargart[1], Markus Rau[2], Martin Fuerst[2], Wolfgang-Michael Schulz[1], Marcus Eichfelder[1], Robert Rossbach[1], Sebastian Nauerth[2], Michael Jetter[1], Harald Weinfurter[2,3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, 70569 Stuttgart — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching

In 1984 Bennett and Brassard presented a scheme for secure quantum key distribution (QKD), the so-called BB84 protocol. Several QKD-experiments have been arranged with strongly attenuated lasers. But due to multi-photon emission additional shrinking of the key compared to systems using single-photon sources (SPS) is necessary. Therefore, using a SPS afford higher key rates at the same total count rate.

In this report we present free-space quantum key distribution experiments using an electrically driven SPS, based on InP quantum dots. A polarizer in combination with an electro-optical modulator prepare the polarization state. After a free-space channel of about 50 cm the beam is detected and analyzed by a single-photon polarization analyzer setup. The influence of several excitation parameters, e.g. the peak-to-peak voltage, the DC voltage and the pulse width on the $g^{(2)}(0)$-value and the transfer rate are investigated. Sifted key rates up to 81.6 kBits/s at a quantum bit error-rate of 4.2 % and a $g^{(2)}(0)$-value of 0.48 were achieved.

A 48: SYQM 1: Quantum limited measurement applications 1

Time: Friday 10:30–12:45 Location: V47.01

Invited Talk A 48.1 Fri 10:30 V47.01

Overview of some recent "atomic-physics" experiments with nitrogen-vacancy centers in diamond — •Dmitry Budker — University of California, Berkeley, USA 94720-7300

I will report on several recent measurements conducted by our group and our collaborators on NV-center ensembles, including a systematic study of spin-relaxation processes, pump-probe spectroscopy of singlet states, the "light-narrowing" effect, and optical polarization of large ensembles of nuclear spins. Up-to-date bibliography related to this work can be found at http://budker.berkeley.edu/PubList

Invited Talk A 48.2 Fri 11:00 V47.01

Quantum Limits and Quantum Enhancement in Magnetometry — Federica Beduini, Naeimeh Behbood, Yannick de Icaza, Brice Dubost, Marco Koschorreck, Mario Napolitano, Ana Predojevic, Robert Sewell, Florian Wolfgramm, and •Morgan Mitchell — ICFO-Institut de Ciencies Fotoniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain

Quantum Metrology uses entanglement and other quantum resources to improve the sensitivity of interferometric measurements. Strongly-interacting light-matter systems, or "quantum interfaces," offer several routes to improved sensitivity, including quantum non-demolition measurements, squeezing-enhanced optical readout of atomic sensors, and interaction-based measurements. I will describe recent experimental work that applies these quantum techniques in optical magnetometry, including sensitivity enhancements using optical entanglement, generation of squeezed states in magnetically-sensitive atomic ensembles, and interaction-based spin measurements that scale better than the so-called "Heisenberg limit" of sensitivity.

A 48.3 Fri 11:30 V47.01

Differential Magnetometry using Singlets — •Iñigo Urizar-Lanz[1], Philipp Hyllus[1], Iñigo Egusquiza[1], and Géza Tóth[1,2,3] — [1]Department of Theoretical Physics, The University of the Basque Country, P.O. Box 644, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest, Hungary

The gradient of a magnetic field can be measured using a single cloud of non-interacting spins, prepared initially in a state with vanishing angular momentum. The magnetic field gradient can be estimated from a measurement of the square of the angular momentum operator $\hat{J}_x$. The measurement uncertainty can then be estimated by the error propagation formula if $\langle \hat{J}_x^2 \rangle$ and $\langle \hat{J}_x^4 \rangle$ are known as a function of the gradient. We show how these quantities can be computed for the ideal state. Finally, we discuss how the results can be applied to a state close to a singlet which can be realistically prepared experimentally with a cloud of cold atoms.

A 48.4 Fri 11:45 V47.01

Ultimate quantum bounds on mass measurements with a nano-mechanical resonator — •Daniel Braun — Université de Toulouse, UPS, Laboratoire de Physique Théorique (IRSAMC), F-31062 Toulouse, France — CNRS, LPT (IRSAMC), F-31062 Toulouse, France

I establish the ultimate lower bound on the mass that can be measured with a nano-mechanical resonator in a given quantum state based on the fundamental quantum Cramér–Rao bound, and identify the quantum states of the oscillator which will allow the largest sensitivity for a given maximum energy. I show that with existing carbon nanotube resonators it should be possible in principle to measure a thousandth of the mass of an electron, and future improvements might allow to reach a regime where one can measure the relativistic change of mass due to absorption of a single photon, or the creation of a chemical bond.

[1] D. Braun, Eur.Phys.Lett. **94**, 68007 (2011)

A 48.5 Fri 12:00 V47.01

Entanglement-Enhanced Interferometer on an Atom Chip — •Caspar Ockeloen, Roman Schmied, Max F. Riedel, and Philipp Treutlein — Departement Physik, Universität Basel, Switzerland

We experimentally realize a Ramsey interferometer operating beyond the standard quantum limit (SQL), using two internal spin states of a two-component Bose-Einstein condensate. We first produce spin-squeezed states by controlled collisional interactions between the atoms using a state-dependent microwave near-field potential. We observe spin noise reduction by up to 4.5 dB below the SQL with a spin coherence of > 98%, corresponding to a depth of entanglement of at least 40 particles.

Using such spin-squeezed states as interferometer input states, we demonstrate performance beyond the SQL. Our interferometer outperforms an ideal classical interferometer with the same number of particles (≈ 1300) for interrogation times up to 5 ms.

These experiments are performed on a micro-fabricated atom chip providing small and well-localized trapped atomic ensembles. This makes our technique promising for high-precision measurements with micrometer spatial resolution, e.g. probing near-field magnetic or microwave fields close to the chip surface.

A 48.6 Fri 12:15 V47.01

Heisenberg-limited metrology without entanglement — •Daniel Braun[1,2] and John Martin[3] — [1]Université de Toulouse, UPS, Laboratoire de Physique Théorique (IRSAMC), F-31062 Toulouse, France — [2]CNRS, LPT (IRSAMC), F-31062 Toulouse, France — [3]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, 4000 Liège, Belgium

It is common experimental practice to improve the signal-to-noise ratio by averaging many measurements of identically prepared systems. If the systems are independent, the overall sensitivity of the measurement, defined as the smallest resolvable change of the quantity under consideration, improves as $1/\sqrt{N}$. Quantum enhanced measurements promise the possibility to improve this scaling behavior. Indeed, if the N systems are initially entangled, one may achieve in principle a $1/N$ scaling of the sensitivity, known as the "Heisenberg limit". Unfortunately, decoherence has so far limited the implementation of such "quantum enhanced protocols" to small values of N. Here we show that a setup in which N quantum systems interact with a $N+1$st system allows one to achieve Heisenberg limited sensitivity, without using or ever creating any entanglement. Local decoherence changes only the prefactor but not the scaling with N. We present a general theoretical framework for this new kind of measurement scheme, and propose a possible application in high precision measurements of the length of an optical cavity.

[1] Braun, D. & Martin, J., Nature Comm. **2**, 223, 2011.
[2] Braun, D. & Martin, J., arXiv:1005.4443.

A 48.7 Fri 12:30 V47.01

Quantum logic readout and cooling of a single dark electron spin — Fazhan Shi[1,3], Boris Naydenov[2], Fedor Jelezko[2], Jiangfeng Du[3], •Friedemann Reinhard[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart und Forschungszentrum SCoPE — [2]Universität Ulm — [3]University of Science and Technology of China, Hefei/China

The electron spin of the NV center in diamond can be polarized and read out optically. These incidental features have spawned rapidly progressing efforts to use this center for quantum information processing and magnetic sensing. However, the NV center is only one of numerous electron spin defects in diamond, most of which do not feature these attractive properties and are hence refered to as dark spins.

In my talk I present techniques to implement optical initialization and readout on these dark spins by quantum logic control. We have successfully mapped the state of a dark spin to a nearby NV center where it can be read out optically. Using this technique, we have performed pulsed electron spin resonance experiments on a single dark spin. Moreover, we were able to cool a dark spin by swapping its state with a nearby polarized NV.

These two results allow to extend the NV center's two key properties - optical spin polarisation and readout - to any electron spin in its vicinity.

A 49: Ultra-cold plasmas and Rydberg systems

Time: Friday 14:00–15:30 Location: V57.03

A 49.1 Fri 14:00 V57.03

Dynamical phases and intermittency of a dissipative Rydberg lattice gas — •Cenap Ates, Beatriz Olmos, Juan P. Garrahan, and Igor Lesanovsky — School of Physics and Astronomy, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Taking into account the radiative decay of Rydberg states, we use a Rydberg lattice gas to implement a dissipative quantum Ising model. For a certain range of values of the spin-spin coupling, transverse magnetic field and dissipation rate, we identify a first order dynamical phase transition between active and inactive *dynamical phases*. We demonstrate that dynamical phase-coexistence becomes manifest in an intermittent behavior of bath quanta emission. Moreover, we illuminate the connection between the dynamical order parameter that quantifies activity, and the longitudinal magnetization that conventionally serves as static order parameter. We investigate the dynamical phases of the system using the concept of "thermodynamics of quantum jump trajectories" on a mean field level. The physical picture thus obtained is fully supported by Quantum Jump Monte Carlo simulations.

A 49.2 Fri 14:15 V57.03

Realization of Newton's cradle with interaction-blockaded atom clouds — Sebastian Möbius[1], •Michael Genkin[1], Sebastian Wüster[1], Alexander Eisfeld[1,2], and Jan Michael Rost[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [2]Harvard University, Cambridge, MA 02138, USA

The remarkable properties of Rydberg atoms, such as long lifetimes, large polarizability and strong long-range interactions, make them a promising medium for quantum transport. As recently proposed [1], beyond classical (energy, momentum) also purely quantum mechanical (coherence, entanglement) properties can be adiabatically transported along a flexible chain of Rydberg atoms, reminiscent of Newton's cradle. However, an experimental realization of such a single atom chain is quite challenging. Here, we extend the scheme to a chain of Rydberg-blockaded atom clouds and study their dynamics induced by resonant dipole-dipole interactions. We first consider frozen nuclei, where dephasing due to static disorder is observed. Subsequently, we include atomic motion in the framework of a quantum-classical hybrid method. It is found that in such a setup only one atom from each trap would effectively participate in the transfer dynamics, and the bulk clouds remain stationary. We conclude that blockaded atom clouds facilitate an experimental realization of the Newton's cradle type of entanglement transport, since they overcome the need for single atoms.

[1] S. Wüster, C. Ates, A. Eisfeld and J.M. Rost, Phys. Rev. Lett. 105, 053004 (2010)

A 49.3 Fri 14:30 V57.03

Amplifying single impurities immersed in a gas of ultracold atoms — •Beatriz Olmos[1], Weibin Li[1], Sebastian Hofferberth[2], and Igor Lesanovsky[1] — [1]Midlands Ultracold Atom Research Centre (MUARC), School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [2]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany

We present a method for amplifying a single or scattered impurities immersed in a background gas of ultracold atoms so that they can be optically imaged and spatially resolved. Our approach relies on a Raman transfer between two stable atomic hyperfine states that is conditioned on the presence of an impurity atom. The amplification is based on the strong interaction among atoms excited to Rydberg states. We perform a detailed analytical study of the performance of the proposed scheme with particular emphasis on the influence of inevitable many-body effects.

A 49.4 Fri 14:45 V57.03

Many body physics using alkaline-earth atoms — •Rick Mukherjee[1], James Millen[2], Rejish Nath[3], Matthew Jones[2], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dreden, Germany — [2]Durham University, United Kingdom — [3]Institute for theoretical physics, University of Innsbruck

We show that alkali earth metals offer a promising possibility of trapping ions as well as atoms in ground and highly excited Rydberg states in a common lattice potential [1]. Considering optical core-dressing, we identify experimentally accessible magic wavelengths to achieve this simultaneous trapping for the case of Strontium. We discuss various loss mechanisms and show that the additional lattice potential does not induce additional lifetime limitations even for rather large trapping frequencies. By exploiting the Rydberg interactions, applications for studying many-body dynamics such as generating many-body entanglement are also discussed.

[1] R Mukherjee, J Millen, R Nath, M Jones, T Pohl J. Phys. B 44, 184010 (2011)

A 49.5 Fri 15:00 V57.03

Three-Photon Rydberg Excitation in a Thermal Vapour — •Christopher Carr, Kevin Weatherill, and Charles Adams — Department of Physics, Durham University, Durham, DH1 3LE, England

We perform three-photon excitation to highly excited Rydberg states in a thermal Caesium vapour. The three-photon excitation scheme provides a coherent and non-destructive probe of the Rydberg state using inexpensive diode lasers at convenient wavelengths.

We have demonstrated the compensation of Doppler broadening by velocity-dependent light shifts in three-photon Rydberg electromagnetically induced transparency (EIT). Additionally, we study the strong atom-atom interactions which occur at high atomic densities by confining the atomic sample in a thin cell. These interactions lead to asymmetric frequency-shifted lineshapes in the absorption spectrum.

References:
[1] S. Reynaud, *et al.*, Phys. Rev. Lett **42** 756 (1979)
[2] R P Abel, *et al.*, Phys. Rev. A **84** 023408 (2011)
[3] C Carr, *et al.*, Polarization spectroscopy of an excited state transition, accepted for publication in Optics Letters (2011)

A 49.6 Fri 15:15 V57.03

A fat Schrödinger's cat of Rydberg dressed atomic clouds — Sebastian Möbius, Michael Genkin, Alexander Eisfeld, •Sebastian Wüster, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, Germany

We propose Schrödinger's cat-states of hundreds of atoms, in a spatial superposition of locations micrometers apart, which would come closer to the original than even the impressive recent experimental progress, e.g. [1].

In Rydberg dressed ultra-cold gases, ground state atoms inherit properties of the admixed Rydberg state, such as long-range hyperfine state-dependent interactions [2-4]. We present an idea, how a pair of atomic clouds can evolve into a spatial Schrödinger's cat state under the influence of these interactions. The two clouds, containing about 50-100 atoms each, are then in a coherent superposition of two discrete locations, separated by micrometers. The same interactions responsible for this spatial state, can also be exploited to create the initially required entanglement in hyperfine space.

[1] S. Gerlich et al., Nature Comm. 2, 263 (2011).
[2] L. Santos, G. V. Shlyapnikov, P. Zoller, and M. Lewenstein, Phys. Rev. Lett. 85, 1791 (2000).
[3] M. Müller, L. Liang, I. Lesanovsky, and P. Zoller, New J. Phys. 10, 093009 (2008).
[4] S. Wüster, C. Ates, A. Eisfeld, and J. Rost, New J. Phys. 13, 073044 (2011).

A 50: Interaction of matter with ions

Time: Friday 14:00–15:30 Location: V57.05

A 50.1 Fri 14:00 V57.05

Starke Rueckwaerts-Fokussierung von in Transfer-Ionisation Emittierten Elektronen — •Michael Schulz[1,2], Xingcheng Wang[3], Magnus Gundmundsson[4], Katharina Schneider[3,5], Aditya Kelkar[3,5], Alexander Voitkiv[3], Bennaceur Najjari[3], Markus Schoeffler[2], Lothar Schmidt[2], Reinhard Doerner[2], Joachim Ullrich[3], Robert Moshammer[3] und Daniel Fischer[3] — [1]Missouri University of Science & Technology — [2]Institut f. Kernphysik Universitaet Frankfurt — [3]Max-Planck-Institut f. Kernphysik Heidelberg — [4]Atomic Physics Institute, Stockholm University — [5]Extreme Matter Institute EMMI GSI Darmstadt

Kinematisch vollständige Experimente zu Stössen zwischen Ionen und Helium Atomen wurden durch geführt. Dabei wurden umgeladene Projektile in Koinzidenz mit den Impuls-analysierten Elektronen und doppelt geladenen Rückstossionen gemessen. Es wurden 3-dimensionale Winkelverteilungen der Elektronen extrahiert, die in Transfer-Ionisations Prozessen (TI) emittiert wurden. Wir beobachten eine starke Fokussierung des Elektronenflusses in Rückwärtsrichtung [1]. Dieses Verhalten ist in starkem Kontrast zu Einfachionisation und lässt sich somit auch nicht durch einen TI - Mechanismus erklären, bei dem der Einfang und die Ionisation unabhängig sind. Dagegen sind die Daten konsistent mit einem korrelierten Prozess, der erst kürzlich vorrausgesagt wurde [2] und der mit den hier präsentierten Resultaten erstmals experimentell bestätigt ist.

[1] M. Schulz et al., accepted in Phys. Rev. Lett. (2011) [2] A. Voitkiv, Phys. Rev. Lett. 101, 223201 (2008)

A 50.2 Fri 14:15 V57.05

Laser Cooling and Optical Diagnostics for Relativistic Ion Beams — Michael Bussmann[1], Uwe Stuhr[1], Matthias Siebold[1], Ulrich Schramm[1,2], Danyal Winters[3], Thomas Kühl[3], Christophor Kozhuharov[3], Christina Dimopoulou[3], Fritz Nolden[3], Markus Steck[3], •Christopher Geppert[3,4], Rodolfo Marcelo Sanchez Alarcon[3,4], Wilfried Nörstershäuser[3,4], Thomas Stöhlker[3,5], Tobias Beck[6], Thomas Walther[6], Sascha Tichelmann[6], Gerhard Birkl[6], Weiqiang Wen[7], and Xinwen Ma[7] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]TU Dresden — [3]GSI Helmholtzzentrum für Schwerionenforschung — [4]Universität Mainz — [5]Universität Heidelberg — [6]TU Darmstadt — [7]IMPCAS Lanzhou

Cooling of ion beams is essential for precision experiments at future storage rings. Laser cooling is one of the most promising techniques to reach high phase space densities at relativistic ion energies for all ion species which provide suitable atomic cooling transitions.

Establishing laser cooling as a standard technique at future storage rings requires laser sources that can address ion beams with large initial velocity spreads.

Without optical diagnostics however, the dynamics of ions at very low temperatures cannot be resolved, as conventional beam diagnostics reach their resolution limits.

We discuss concepts and techniques that pave the way for making laser cooling a reliable tool at future storage rings, some of which can already be tested at the ESR at GSI.

A 50.3 Fri 14:30 V57.05

Inner and outer shell single ionization of laser-cooled lithium by ion impact — •Aaron LaForge[1], Renate Hubele[1], Xincheng Wang[1], Johannes Goullon[1], Michael Schulz[2,3], and Daniel Fischer[1] — [1]Max Planck Institut fuer Kernphysik, Heidelberg, DE — [2]Misouri University of Science & Technology, Rolla, USA — [3]Institut fuer Kernphysik, Goethe Universitaet, Frankfurt, DE

We have performed a kinematically complete experiment of single ionization of optically trapped and cooled lithium by 1.5 MeV/amu O^{8+}. In comparison to prior work, the overall experimental resolution was drastically improved. As a result, it is possible to resolve ionization from the different energey shells (n=1 & n=2). Furthermore, from the higher order differential data, one can see clear difference between the emitted electron energy, momentum transfer, and other quantities depending on the initial state. Double and fully differential cross sections will be presented. This represents the first direct and simultaneous comparison between such data for inner and outer shell ionization.

A 50.4 Fri 14:45 V57.05

Combined Radiation Effects of Protons and Electrons in Silicon Bipolar Junction Transistor — Chaoming Liu, •Xingji Li, Erming Rui, and Hongbin Geng — Harbin Institute of Technology, Harbin, China

This investigation compares individual radiation effects of 110keV electrons and 170keV protons with combined ones, including simultaneous and sequential radiation effects, caused by 110keV electrons together with 170keV protons, on the forward current gain of bipolar junction transistor. The experimental procedure for the simultaneous irradiation is that the 170keV protons and 110keV electrons irradiation are performed in the same time, while the procedure for the sequential irradiation is the protons and electrons irradiation are performed on same alternate exposure time. The combined exposures will produce both the ionization in the oxide layer (due to the 110keV electrons) and the displacement effect in Si bulk (due to the 170keV protons), resulting in the synergistic radiation effects on bipolar junction transistor. It is instructive to characterize the combined radiation damage caused by electrons and protons with lower energies based on analyzing the damage effects both in the oxide layer and the Si bulk. From the experimental data, the interaction between ionizing damage and displacement damage of bipolar junction transistor is discussed.

A 50.5 Fri 15:00 V57.05

Dense monoenergetic proton beams from chirped laser-plasma interaction — •Benjamin J. Galow[1], Yousef I. Salamin[1,2], Tatyana V. Liseykina[3], Zoltán Harman[1,4], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69029 Heidelberg, Germany — [2]Department of Physics, American University of Sharjah, POB 26666, Sharjah, United

Arab Emirates — [3]Institut für Physik, Universität Rostock, 18051 Rostock, Germany — [4]ExtreMe Matter Institute EMMI, Planckstrasse 1, 64291 Darmstadt, Germany

Interaction of a frequency-chirped laser pulse with single protons and a hydrogen gas target is studied analytically and by means of particle-in-cell simulations, respectively. Feasibility of generating ultra-intense (10^7 particles per bunch) and phase-space collimated beams of protons (energy spread of about 1%) is demonstrated. Phase synchronization of the protons and the laser field, guaranteed by the appropriate chirping of the laser pulse, allows the particles to gain sufficient kinetic energy (around 250 MeV) required for such applications as hadron cancer therapy, from state-of-the-art laser systems of intensities of the order of 10^{21} W/cm^2 [1].

[1] B. J. Galow, Y. I. Salamin, T. V. Liseykina, Z. Harman, and C. H. Keitel, Phys. Rev. Lett. **107**, 185002 (2011)

A 50.6 Fri 15:15 V57.05

Electron transfer and ionization in collisions of highly charged ions with Na(3s) and Na*(3p) — •Ina Blank[1], Sebastian Otranto[2], Ronald E. Olson[3], and Ronnie Hoekstra[1] — [1]KVI Atomic and Molecular Physics, University of Groningen, The Netherlands — [2]Departamento de Fisica, Universidad Nacional del Sur, Bahia Blanca, Argentina — [3]Physics Department, Missouri University of Science and Technology, Rolla, USA

We present an experimental and theoretical study of single electron transfer and ionization in collisions of highly charged ions (N^{5+}, O^{6+} and Ne^{8+}) with ground state Na(3s) and excited state Na*(3p). The investigated collision energy ranges from 1 to 10 keV/amu which includes the classical orbital velocity of the target's valence electron.

In order to test theory on the most basic level multiply differential cross sections are required. Experimental differential cross sections are obtained by combining recoil-ion momentum spectroscopy with a magneto-optically cooled Na atom target. The results are compared with three-body classical-trajectory Monte Carlo calculations which also provide impact parameter dependences of the processes under study. Differential cross for highly excited projectile final states feature an oscillatory structure for each presented collision system, which is also predicted by the theory.

A 51: Materiewellenoptik

Time: Friday 14:00–16:00 Location: V53.01

A 51.1 Fri 14:00 V53.01

QUANTUS I - Matter wave interferometry in the bremen drop tower — •Hauke Müntinga[1], Sven Herrmann[1], Claus Lämmerzahl[1], and the QUANTUS TEAM[1,2,3,4,5,6,7,8,9] — [1]ZARM - Universität Bremen — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham — [8]FBH, Berlin — [9]DLR Institut für Raumfahrtsysteme, Bremen

In 2007 the first Bose-Einstein condensate in microgravity was realized by the QUANTUS collaboration in the ZARM drop tower in Bremen.

In nearly 350 drops from a height of 110 m, our setup has proven the feasibility of operating delicate quantum optical experiments in demanding environments and allowed us to study the physics of ultracold quantum gases in previously inaccessible parameter regimes.

After examining the free evolution of the condensate for up to 1 s [1], we have now integrated a matter wave interferometer based on Bragg diffraction into our apparatus. In our talk we will describe the current setup and give an overview of recent experimental campaigns addressing the extension of the interrogation time of a Mach-Zehnder type interferometer to the realm of seconds.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 1135.

A 51.2 Fri 14:15 V53.01

MAIUS - a rocket-borne test of an atom interferometer with a chip-based atom laser — •Stephan Tobias Seidel, Ernst Maria Rasel, and The QUANTUS TEAM — Institut für Quantenoptik, LU Hannover

The test of the Einstein's equivalence principle with degenerate quantum matter is one the strategies to explore the frontier between quantum mechanics and gravity. A precise test for this equivalence is the comparisons of the free fall of ultra-cold clouds of different atomic species and its readout using atom interferometry. In order to increase the precision of such an interferometer the space-time-area enclosed in it has to be increased. This can be achieved by performing the experiments in a weightless environment that allows longer interrogation times.

As a next step towards the transfer of such a system to space, either on-board the international space station or as a dedicated satellite mission, a rocket-based atom interferometer is currently being build. With the launch of the rocket mission in November 2013 we plan to demonstrate and test such an apparatus in space for the first time. Its success would mark a major advancement towards a precise measurement of the equivalence principle with a space-borne atom interferometer.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM1131.

A 51.3 Fri 14:30 V53.01

Interferometry with δ-kick cooled atoms — •André Wenzlawski[1], Klaus Sengstock[1], and the QUANTUS-TEAM[1,2,3,4,5,6,7,8,9] — [1]Institut für Laser-Physik, Universität Hamburg — [2]Institut für Quantenoptik, Universität Hannover — [3]Institut für Physik, HU Berlin — [4]ZARM, Universität Bremen — [5]Institut für angewandte Physik, TU Darmstadt — [6]Institut für Quantenphysik, Universität Ulm — [7]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [8]FBH, Berlin — [9]MPQ, Garching

The observation of a freely expanding Bose-Einstein Condensate in microgravity [1] paved the way for realizing atom interferometers on unprecedented time scales.
To even further extend the available interrogation time for the interferometer the concept of delta kick cooling has been implemented in the experimental apparatus. By using pulsed magnetic fields we can manipulate the momentum distribution of the atoms which allows for the preparation of the atoms in a very narrow momentum distribution. With this method we are also able to use non velocity selected thermal atoms in an atom interferometer. In this talk I will report on recent results obtained with delta-kick cooled atoms.

The QUANTUS Project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM1133.
[1] T. van Zoest et al., Science **328**, 1540 (2010).

A 51.4 Fri 14:45 V53.01

Micro-integrated, narrow linewidth master-oscillator-power-amplifier laser system with 3 W output power — •Max Schiemangk[1], Achim Peters[1,9], and the QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Physik, HU Berlin — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Laserphysik, Uni Hamburg — [4]ZARM, Uni Bremen — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

We present an all-diode laser based, hybrid integrated laser module, that will be used within QUANTUS II at the Drop Tower Bremen. The 10×50 mm^2 module is based on a master oscillator power amplifier (MOPA) concept. A distributed feedback (DFB) laser diode is used as master oscillator (MO), that provides narrow linewidth emission. The output of the MO is collimated by micro-lenses, passed through a micro-optical isolator to supress feedback, and injected into a power amplifier (PA) chip. The PA consists of a ridge-waveguide pre-amplifier section, that serves as a mode filter, and a tapered section, that boosts the output power to about 3 W while preserving the spectral properties. The module's FWHM linewidth corresponds to approx. 1 MHz (10 μs time scale) and the intrinsic linewidth derived from the white noise floor of the frequency noise spectrum is below 200 kHz.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR 50WM1131-1137.

A 51.5 Fri 15:00 V53.01

Twin Matter Waves for Interferometry Beyond the Classical Limit — •Bernd Lücke[1], Manuel Scherer[1], Jens Kruse[1], Luca Pezze[2], Frank Deuretzbacher[3], Philipp Hyllus[3], Oliver Topic[1], Jan Peise[1], Wolfgang Ertmer[1], Jan Arlt[4], Luis Santos[3], Augusto Smerzi[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Istituto Nazionale di Ottica (INO), Consiglio Nazionale delle Ricerche (CNR), and European Laboratory for Non-Linear Spectroscopy (LENS), 50125 Firenze, Italy — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, 30167 Hannover, Germany — [4]Center for Quantum Optics (QUANTOP), Institut for Fysik og Astronomi, Aarhus Universitet, 8000 Århus C, Denmark

Interferometers with atomic ensembles are an integral part of modern precision metrology. However, these interferometers are fundamentally restricted by the shot noise limit, which can only be overcome by creating quantum entanglement among the atoms. We employ spin dynamics in Bose-Einstein condensates to create large ensembles of up to 10000 pair-correlated atoms and thus achieve this goal. The fluctuation of the population difference in the two output states is -6.9 dB below shot noise and is mainly limited by the detection noise of 30 atoms. Moreover we show that this twin state has an interferometric sensitivity -1.61 dB beyond the shot noise limit. Our proof-of-principle results point the way toward a new generation of atom interferometers.

A 51.6 Fri 15:15 V53.01

Matter-Wave Interferometry with Ions — •Georg Schütz[1], Alexander Rembold[1], Andreas Pooch[1], Franz Hasselbach[1], Ing-Shouh Hwang[2], and Alexander Stibor[1] — [1]Physikalisches Institut Tübingen, Auf der Morgenstelle 15, 72076 Tübingen — [2]Institute of Physics, Academia Sinica, Academia Rd., 11529 Nankang, Taipei

The big success of matter-wave experiments with neutral particles and electrons within the last 20 years encourage the development of a new type of interferometer for ions. We report on the present status in the construction of the first stable ion-interferometer.

Compared to neutral atomic or molecular interferometers, the additional parameter charge opens the door for fundamental quantum-mechanical experiments, such as the magnetic and electric Aharonov-Bohm effect.

In the development of this device the long term experience in the manipulation of electron-waves are utilized on ions. In our experimental approach a coherent matter-wave of charged particles gets separated and recombined by an extremely thin, charged biprism wire, resulting in an interference pattern in the detection plane. A novel technique allows for a stable ion emission from a single atom apex of a pyramidal shaped metal tip. The resulting charged matter-waves are highly monochromatic and coherent. Since ions or even charged molecules in this kind of interferometer are significantly heavier and slower compared to electrons, highly sensitive, compact sensors for rotation and acceleration come into reach of current technical possibilities.

A 51.7 Fri 15:30 V53.01

High resolution Sagnac atom interferometer — •Peter Berg, Christian Schubert, Gunnar Tackmann, Sven Abend, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Within the gyroscope experiment CASI (Cold Atom Sagnac Interferometer), a compact dual cold-atom interferometer for high resolution measurement of slow rotations is realised. Employing three separate beam-splitter light fields an area of 19 mm^2 is enclosed. We discuss the high demands of the relative beam-splitter light field alignment at the position of the atoms, which excludes standard optical alignment techniques. These are met by an alignment technique utilising the interferometer itself. The resulting gyroscope resolution of $5.3\ 10^{-7}\mathrm{rad/s}/\sqrt{\mathrm{Hz}}$ is mainly limited by environmental vibrations. This work is supported by the DFG, the cluster of excellence QUEST, and IQS.

A 51.8 Fri 15:45 V53.01

An ionizing time-domain matter-wave interferometer — •Nadine Dörre[1], Philipp Haslinger[1], Philipp Geyer[1], Jonas Rodewald[1], Stefan Nimmrichter[1], Klaus Hornberger[2], and Markus Arndt[1] — [1]University of Vienna, Vienna Center of Quantum Science and Technology, Vienna , Austria — [2]University of Duisburg-Essen, Duisburg, Germany

We present the concept and a recent setup of an all-optical matter-wave interferometer for clusters and complex molecules that combines absorptive ionization gratings with the advantages of interferometry in the time domain. In this setup, we use a sequence of three equally timed UV lasers pulses reflected from a single mirror to form standing wave gratings that diffract the particles in the time domain. These gratings can act as absorptive masks for matter waves, as soon as the absorption of a single photon leads to ionization of each particle in the vicinity of anti-nodes of the standing wave. In contrast to material grating setups, this experiment operates in a pulsed mode, which reduces the influence of the longitudinal particle motion. This turns the interferometer into a universal tool which, on the one hand, will allow us to explore the quantum wave nature of very massive particles. In combination with deflectometry and spectroscopy, on the other hand, it offers the possibility to determine properties of organic and metal clusters with high precision, among them polarizabilities, electric and magnetic moments, absorption and ionization cross sections.

A 52: SYQM 2: Quantum limited measurement applications 2

Time: Friday 14:00–16:15 Location: V47.01

Invited Talk A 52.1 Fri 14:00 V47.01

Nanoscale magnetic resonance imaging: Progress and challenges — •Daniel Rugar — IBM Research Division, San Jose, California, USA

Magnetic resonance imaging (MRI), based on the sensitive detection of nuclear spins, enables three dimensional imaging without radiation damage. Conventional MRI techniques achieve spatial resolution that is at best a few micrometers due to sensitivity limitations of conventional inductive detection. The advent of ultrasensitive nanoscale magnetic sensing opens the possibility of extending MRI to the nanometer scale. If this can be pushed far enough, one can envision taking 3D images of individual biomolecules and, perhaps, even solving molecular structures of proteins. In this talk we will discuss issues related to nanoscale magnetic resonance imaging, especially its implementation using magnetic resonance force microscopy (MRFM). MRFM is based on the detection of ultrasmall (attonewton) magnetic forces. While 3D spatial resolution below 5 nm has been demonstrated, further progress depends on overcoming poorly understood near-surface force noise effects. We will also consider the future possibility of using NV centers in diamond for detection of nanoMRI.

Invited Talk A 52.2 Fri 14:30 V47.01

Optical Far-Field Addressing of Single Spins Beyond the Diffraction Limit at Enhanced Collection Efficency — •Dominik Wildanger[1], Jero Maze[2], Benno Koberstein-Schwarz[1], Jan Meijer[3], Sébastien Pezzagna[3], Brian Patton[4], Jason Smith[4], and Stefan Hell[1] — [1]MPI for Biophysical Chemistry, Göttingen, GER — [2]PUC, Santiago, Chile — [3]Ruhr-Universität, Bochum, GER — [4]University of Oxford, Oxford, UK

The electron spin associated with charged nitrogen-vacancy (NV) centres in diamond is optically addressable, because it can be polarised via an optical excitation, while its spin information is encoded in its fluorescence signal and can be read-out by using a fluorescence microscope. Till recently fluorescence microscopy was limited by diffraction and thus the spins of close-by NV- centres could not be addressed individually. Today techniques are available to fundamentally overcome the diffraction limit in fluorescence microscopy and some of them could be successfully applied on the NV- centre.

Here we show how to address single electron spins in diamond with single digit nanometre resolution by combining STED (Stimulated Emission Depletion) with ODMR (Optically Detectable Magnetic Resonance) techniques. Furthermore we overcome the limitations on fluorescence efficiency and focus quality caused by the high index of refraction of diamond by employing a solid immersion lens (SIL). We demonstrate that SIL enhanced STED-ODMR provides a spin addressing resolution potential of 1.6 nm. Concurrently the collection efficiency is increased by a factor of 5.

A 52.3 Fri 15:00 V47.01

Beating the classical resolution limit via multi-photon interferences of independent light sources — Steffen Oppel[1], Thomas Büttner[1], Pieter Kok[2], and •Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Department of Physics and Astronomy, University of Shefield, Shefield, UK

Multi-photon interferences with indistinguishable photons from independent light sources are at the focus of current research due to their potential in optical quantum computing, creating remote entanglement and quantum metrology. The paradigmatic states for multi-photon interference are the highly entangled NOON states which can be used to achieve enhanced resolution in interferometry and lithography [1]. Multi-photon interferences from independent, uncorrelated emitters can also lead to enhanced resolution [2]. So far, such quantum interferences have been observed with maximally two emitters. Here, we report multi-photon interferences with up to five independent emitters, displaying interference patterns equivalent to those of NOON states. Experimental results with independent thermal light sources confirm this NOON-like modulation. The experiment is an extension of the landmark measurement by Hanbury Brown and Twiss who investigated intensity correlations of second order. Here we go beyond this level by measuring spatial intensity correlations up to fifth order to further increase the resolution.

[1] A. N. Boto et al., Phys. Rev. Lett. 85, 2733 (2000).
[2] C. Thiel et al., Phys. Rev. Lett. 99, 133603 (2007).

A 52.4 Fri 15:15 V47.01

High Dynamic Range Magnetometry with a Single Nuclear Spin in Diamond — •Gerald Waldherr[1], Johannes Beck[1], Philipp Neumann[1], Ressa S. Said[2], Matthias Nitsche[1], Jason Twamley[3], Fedor Jelezko[4], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, 70569 Stuttgart — [2]Institut für Quanten-Informationsverarbeitung, Universität Ulm, 89081 Ulm — [3]Centre for Engineered Quantum Systems, Faculty of Science, Macquarie University, Sydney, Australia — [4]Institut für Quantenoptik, Universität Ulm, 89073 Ulm

Sensors based on the nitrogen-vacancy (NV) defect in diamond are being developed to measure weak magnetic and electric fields at nanoscale. However, such sensors rely on measurements of a shift in the Lamor frequency of the defect, so an accumulation of quantum phase causes the measurement signal to exhibit a periodic modulation. This means that the measurement time is either restricted to half of one oscillation period, which limits accuracy, or that the magnetic field range must be known in advance. Moreover, the precision increases only slowly, as $T^{-0.5}$, with the measurement time T. We implement a quantum phase estimation algorithm on a single nuclear spin in diamond to combine both high sensitivity and high dynamic range. By achieving a scaling of the precision with time to $T^{-0.85}$, we improve the sensitivity by a factor of 7.4, for an accessible field range of 16 mT, or alternatively, we improve the dynamic range by a factor of 130 for a sensitivity of 2.5 μT/Hz$^{0.5}$. These methods are applicable to a variety of field detection schemes, and do not require entanglement.

A 52.5 Fri 15:30 V47.01

Enhancement of a single electron spin based magnetometer by utilizing a small nuclear spin quantum register — •Philipp Neumann[1], Gerald Waldherr[1], Matthias Nitsche[1], Sebastian Zaiser[1], Fedor Jelezko[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Institut für Quantenoptik, Universität Ulm

The negatively charged nitrogen-vacancy (NV) center in diamond and its associated nuclear spins form a versatile small quantum register. Apart from its potential applications in quantum information processing the susceptibility of its quantum coherence to external stimuli like magnetic and electric fields render the NV center a tiny quantum sensor. Its high spatial confinement allows to build very small sensing devices which lead to a sample-probe distance of only a few nanometer potentially enabling the detection of single electron or even nuclear spins.

Here we show how a small quantum register of proximal nuclear spins around the NV center can be used to drastically increase the performance of the NV electron spin as a magnetic field sensor.

A 52.6 Fri 15:45 V47.01

Sub shot-noise interferometry from measurements of the one-body density — Jan Chwedenczuk[1,2], •Philipp Hyllus[1,3], Francesco Piazza[1,4], and Augusto Smerzi[1,5] — [1]INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento, 38123 Povo, Italy — [2]Faculty of Physics, University of Warsaw, ul. Hȯza 69, 00-681 Warsaw, Poland — [3]Department of Theoretical Physics, The University of the Basque Country, P.O. Box 644, E-48080 Bilbao, Spain — [4]Physik Department T34,Technische Universität München, James-Franck-Straße, 85747 Garching, Germany — [5]INO-CNR and LENS, 50125 Firenze, Italy

We show that a sub shot-noise sensitivity – associated with the quantum correlations present in the state entering the interferometer – can be achieved with particle-position measurements using a new phase estimator which does not require *any* knowledge about these correlations, and is based on the single-body density. For the case of the estimation of the relative phase θ between two interfering wave-packets we demonstrate that the sensitivity can scale as $\Delta^2\theta \propto N^{-1.33}$ with the total number of particles N when phase-squeezed states are used. The necessary amount of squeezing could be created using a Bose-Einstein Condensate trapped in a double-well potential, and we argue that even with finite detection efficiency/resolution, sub shot-noise sensitivity can be preserved.

A 52.7 Fri 16:00 V47.01

Quantum State Tomography of Bipartite Bose Condensates — •Roman Schmied, Caspar Ockeloen, and Philipp Treutlein — Departement Physik, Universität Basel, Schweiz

The quantum-mechanical states of large systems are difficult to measure experimentally because of the exponentially large number of variables involved. Yet in systems of indistinguishable bosons, this number is dramatically reduced, and a tomographic reconstruction of the exchange-symmetric density matrix is feasible even for thousands of particles. We present a practical method for experimentally performing this tomography for two-component Bose–Einstein condensates,* and extend it to the tomographic determination of *correlations* between small numbers of particles within a condensate: such correlations can be stable even when the total atom number fluctuates between experimental runs. The tomographic reconstructions of Wigner functions, Glauber–Sudarshan P-representations, and Husimi-Q distributions on the Bloch sphere are compared.

As an application we present the quantum-state tomography of spin-squeezed states of a two-component ^{87}Rb Bose–Einstein condensate (see also SYQM 1.5).

* R. Schmied and P. Treutlein, New J. Phys. **13**, 065019 (2011)