Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture rooms: C/HSW, C/kHS, and M/HS1; Poster: C/Foyer)

Invited Talks

A 2.1	Mon	11:30–12:00	M/HS1	**Dynamic x-ray imaging of clusters in strong fields** — •Thomas Fennel
A 13.1	Tue	11:00–11:30	M/HS1	**Observation of wave function collapse and four-electron Auger process in inner-shell photoionization of atomic ions** — •Stefan Schippers
A 20.1	Wed	11:00–11:30	C/HSW	**Strong-field ionization of molecules in circularly polarized fields** — Ingo Petersen, Jost Henkel, •Manfred Lein
A 29.1	Thu	11:00–11:30	C/HSW	**Electronic structure in high-intensity x-ray fields** — •Robin Santra
A 32.1	Thu	14:30–15:00	C/HSW	**Time-Resolved Measurement of Interatomic Coulombic Decay in Ne_2** — •Kirsten Schnorr
A 38.1	Fri	11:00–11:30	C/HSW	**X-ray quantum optics: From Mössbauer to Fano** — Kilian P. Heeg, Christian Ott, Daniel Schumacher, Hans-Christian Wille, Ralf Röhlsberger, Thomas Pfeifer, •Jörg Evers

Invited talks of the joint symposium SYEP

See SYEP for the full program of the symposium.

SYEP 1.1	Mon	11:30–12:00	C/gHS	**Few-body physics with ultracold atoms: What we learned from cesium** — •Rudolf Grimm
SYEP 1.2	Mon	12:00–12:30	C/gHS	**Universality in halo nuclei** — •Daniel Phillips
SYEP 2.1	Mon	14:30–15:00	C/gHS	**Efimov Physics from Quantum Field Theory** — •Eric Braaten
SYEP 2.2	Mon	15:00–15:30	C/gHS	**Efimov physics with multiple spin substates** — •Chris H Greene

Invited talks of the joint symposium SYDM

See SYDM for the full program of the symposium.

SYDM 1.1	Tue	11:00–11:40	C/gHS	**Searching for New Physics Effects in the Muon g -Factor** — •B. Lee Roberts
SYDM 1.2	Tue	11:40–12:20	C/gHS	**Dedicated storage ring EDM methods** — •Yannis Semertzidis
SYDM 2.1	Tue	14:30–15:10	C/gHS	**The experimental search for the neutron electric dipole moment** — •Klaus Kirch
SYDM 2.2	Tue	15:10–15:50	C/gHS	**The muon g-2: where we are, what does it tell us?** — •Friedrich Jegerlehner

Invited talks of the joint symposium SYPS

See SYPS for the full program of the symposium.

SYPS 1.1	Tue	17:00–17:30	K/HS1	**Feshbach resonances and the production of ultracold molecules** — •Jeremy M. Hutson
SYPS 1.2	Tue	17:30–18:00	K/HS1	**New frontiers in quantum simulation with ultra-cold polar molecules** — •Ana Maria Rey

SYPS 1.3	Tue	18:15–18:45	K/HS1	**Ground-state molecules near quantum degeneracy: the nuts and bolts** — •Hanns-Christoph Nägerl
SYPS 1.4	Tue	18:45–19:15	K/HS1	**Prospects and future directions with quantum gases of ultracold polar molecules** — •Silke Ospelkaus

Invited talks of the joint symposium SYEM

See SYEM for the full program of the symposium.

SYEM 1.1	Wed	11:00–11:30	C/gHS	**Generation of Structure under Extreme Conditions: Ultracold Atoms meet Heavy-Ion Collissions** — •Jens Braun
SYEM 1.2	Wed	11:30–12:00	C/gHS	**Strongly Interacting Fermi Gases of Atoms and Molecules** — •Martin Zwierlein
SYEM 1.3	Wed	12:00–12:30	C/gHS	**Towards ultracold RbSr ground-state molecules** — •Florian Schreck
SYEM 1.4	Wed	12:30–13:00	C/gHS	**Multiflavor phenomena and synthetic gauge fields in strongly interacting quantum gases** — •Walter Hofstetter

Prize talks of the joint symposium SYAW

See SYAW for the full program of the symposium.

SYAW 1.1	Wed	14:30–15:15	C/gHS	**Warum einzelne kalte Atome?** — •Peter E. Toschek
SYAW 1.2	Wed	15:15–16:00	C/gHS	**Strongly interacting Rydberg gases in thermal vapor cells** — •Tilman Pfau

Invited talks of the joint symposium SYTL

See SYTL for the full program of the symposium.

SYTL 1.1	Fri	11:00–11:30	C/gHS	**Optical curl forces and beyond** — •Michael Berry
SYTL 1.2	Fri	11:30–12:00	C/gHS	**Quantum memories for twisted photons** — •Elisabeth Giacobino, Julien Laurat, Dominik Maxein, Lambert Giner, Lucile Veissier, Adrien Nicolas
SYTL 2.1	Fri	14:30–15:00	C/gHS	**Electron vortex beams: Twisted matter waves** — •Peter Schattschneider
SYTL 2.2	Fri	15:00–15:30	C/gHS	**Inelastic effects on the lateral wave function of electron beams** — •Javier García de Abajo

Sessions

A 1.1–1.7	Mon	11:30–13:15	C/HSW	**Precision spectroscopy of atoms and ions I (with Q)**
A 2.1–2.6	Mon	11:30–13:15	M/HS1	**Atomic clusters (with MO)**
A 3.1–3.5	Mon	11:30–12:45	G/gHS	**Precision Measurements and Metrology I (with Q)**
A 4.1–4.8	Mon	14:30–16:30	C/HSW	**Ultra-cold atoms, ions and BEC I (with Q)**
A 5.1–5.8	Mon	14:30–16:30	C/kHS	**Atomic systems in external fields**
A 6.1–6.7	Mon	14:30–16:30	P/H1	**Precision Measurements and Metrology II (with Q)**
A 7.1–7.8	Mon	17:00–19:00	C/Foyer	**Poster: Atomic systems in external fields**
A 8.1–8.6	Mon	17:00–19:00	C/Foyer	**Poster: Photoionization**
A 9.1–9.2	Mon	17:00–19:00	C/Foyer	**Poster: Interaction with VUV and X-ray light I**
A 10.1–10.17	Mon	17:00–19:00	C/Foyer	**Poster: Interaction with strong or short laser pulses**
A 11.1–11.8	Mon	17:00–19:00	C/Foyer	**Poster: Atomic clusters (with MO)**
A 12.1–12.8	Tue	11:00–13:00	C/kHS	**Ultra-cold plasmas and Rydberg systems I (with Q)**
A 13.1–13.8	Tue	11:00–13:15	M/HS1	**Precision spectroscopy of atoms and ions II (with Q)**
A 14.1–14.6	Tue	11:00–12:45	G/gHS	**Precision Measurements and Metrology III (with Q)**
A 15.1–15.8	Tue	14:30–16:30	C/HSW	**Ultra-cold atoms, ions and BEC II (with Q)**
A 16.1–16.8	Tue	14:30–16:30	C/kHS	**Interaction with strong or short laser pulses I**
A 17.1–17.8	Tue	14:30–16:30	P/H1	**Precision Measurements and Metrology IV (with Q)**
A 18.1–18.35	Tue	17:00–19:00	C/Foyer	**Poster: Ultra-cold atoms, ions and BEC (with Q)**
A 19.1–19.6	Wed	11:00–12:30	C/HSO	**Precision Measurements and Metrology V (with Q)**

A 20.1–20.7	Wed	11:00–13:00	C/HSW	**Interaction with strong or short laser pulses II**
A 21.1–21.7	Wed	11:00–12:45	C/kHS	**Ultra-cold plasmas and Rydberg systems II (with Q)**
A 22.1–22.8	Wed	11:00–13:00	M/HS1	**Ultra-cold atoms, ions and BEC III (with Q)**
A 23.1–23.8	Wed	14:30–16:30	C/HSW	**Ultra-cold atoms, ions and BEC IV (with Q)**
A 24.1–24.8	Wed	14:30–16:30	C/kHS	**Attosecond physics**
A 25.1–25.7	Wed	14:30–16:30	PH/SR106	**Clusters in Molecular Physics (with MO & MS)**
A 26.1–26.9	Wed	17:00–19:00	C/Foyer	**Poster: Collisions, scattering and recombination**
A 27.1–27.4	Wed	17:00–19:00	C/Foyer	**Poster: Attosecond physics**
A 28.1–28.15	Wed	17:00–19:00	C/Foyer	**Poster: Interaction with VUV and X-ray light II**
A 29.1–29.8	Thu	11:00–13:15	C/HSW	**Interaction with VUV and X-ray light I**
A 30.1–30.8	Thu	11:00–13:00	M/HS1	**Precision spectroscopy of atoms and ions III (with Q)**
A 31.1–31.5	Thu	11:00–12:30	P/H2	**Ultracold Atoms: Trapping and Cooling I (with Q)**
A 32.1–32.7	Thu	14:30–16:30	C/HSW	**Interaction with strong or short laser pulses III**
A 33.1–33.8	Thu	14:30–16:30	C/kHS	**Collisions, scattering and recombination**
A 34.1–34.7	Thu	14:30–16:15	P/H2	**Ultracold Atoms: Trapping and Cooling II (with Q)**
A 35.1–35.29	Thu	17:00–19:00	C/Foyer	**Poster: Precision spectroscopy of atoms and ions (with Q)**
A 36.1–36.9	Thu	17:00–19:00	C/Foyer	**Poster: Ultra-cold plasmas and Rydberg systems (with Q)**
A 37.1–37.4	Thu	17:00–19:00	C/Foyer	**Poster: Twisted light and particles (SYTL)**
A 38.1–38.8	Fri	11:00–13:15	C/HSW	**Interaction with VUV and X-ray light II**
A 39.1–39.8	Fri	11:00–13:00	C/kHS	**Precision spectroscopy of atoms and ions IV (with Q)**
A 40.1–40.8	Fri	11:00–13:00	B/SR	**Ultracold Atoms and Molecules (with Q)**
A 41.1–41.9	Fri	11:00–13:15	M/HS1	**Ultra-cold atoms, ions and BEC V (with Q)**
A 42.1–42.7	Fri	11:00–12:45	P/H2	**Ultracold Plasmas and Rydberg Systems III (with Q)**
A 43.1–43.6	Fri	14:30–16:00	P/H2	**Ultracold Plasmas and Rydberg Systems IV (with Q)**

Annual General Meeting of the Atomic Physics Division

Thursday 13:15–14:00 C/kHS

A 1: Precision spectroscopy of atoms and ions I (with Q)

Time: Monday 11:30–13:15 Location: C/HSW

A 1.1 Mon 11:30 C/HSW

The Detection System of the ALPHATRAP Experiment — •Andreas Weigel, Robert Wolf, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The Penning-trap experiment ALPHATRAP is currently being set up at the Max-Planck-Institut für Kernphysik in Heidelberg. It is the follow-up to the Mainz g-factor experiment, which has recently succeeded in the most stringent test of quantum electrodynamics in the regime of strong fields on hydrogen-like $^{28}Si^{13+}$ at the level of 10^{-11}. ALPHATRAP aims for g-factor measurements on even heavier highly charged ions up to $^{208}Pb^{81+}$, with simultaneously improved accuracy. This shall further contribute to the exploration of the limits of bound-state quantum electrodynamics.

The determination of the g-factor is based on the non-destructive determination of the electron spin state inside a magnetic bottle via the continuous Stern-Gerlach effect. For this purpose the ion eigenfrequencies have to be measured via the detection of image currents, which the ion induces into the trap electrodes. These currents are typically on the order of a few femto-Ampère. Therefore, special highly sensitive detection electronics consisting of superconducting tank circuits with extremely high Q-factors followed by ultra-low noise cryogenic amplifiers will be used. This shall allow for a higher signal-to-noise ratio resulting in an increased measurement precision. The ALPHATRAP detection system and electronics design will be presented.

A 1.2 Mon 11:45 C/HSW

Isotope shifts of ^{40,42,44,48}Ca$^+$ in the $4s_{1/2} \rightarrow 4p_{3/2}$ transition measured at TRIGA-LASER — •Christian Gorges for the TRIGA-SPEC-Collaboration — Institut für Kernphysik, TU Darmstadt

The TRIGA-LASER experiment at the TRIGA research reactor in Mainz is a collinear laser spectroscopy setup [1]. It is a prototype for the LaSpec-Experiment at FAIR [2] and will first be used to investigate short-lived radioactive isotopes which are produced by neutron induced fission of ^{235}U, ^{239}Pu or ^{249}Cf in the TRIGA reactor. For commissioning, we have measured the isotope shifts of the stable calcium isotopes ^{40,42,44,48}Ca in the $4s_{1/2} \rightarrow 4p_{1/2,3/2}$ transitions. This was motivated by the relatively large uncertainty of the isotope shifts in the $4s_{1/2} \rightarrow 4p_{3/2}$ transition, which are needed as reference for recent measurements of exotic short-lived $^{49-52}$Ca at COLLAPS (collinear laser spectroscopy at Isolde-CERN). Using precise isotope shifts in the $4s_{1/2} \rightarrow 4p_{1/2}$ transition from trap measurements for voltage calibration, we were able to reduce the uncertainties in this transition considerably.

[1] J. Ketelaer et al., Nucl. Instr. Meth. A 594, 162 (2008)
[2] D. Rodriguez et al., Eur. Phys. J. Special Topics 183, 1-123 (2010)

A 1.3 Mon 12:00 C/HSW

Determination of ground-state hyperfine splitting energies in highly charged bismuth ions — •Johannes Ullmann für die LIBELLE-Kollaboration — Institut für Kernphysik, Technische Universität Darmstadt, Germany — Helmholtz Institut Jena, Germany

While quantum electrodynamics (QED) is usually referred to as the most accurately tested theory, its consistency for bound electrons in strong fields is still to be tested more rigourosly. The strongest static magnetic fields available in the laboratory are experienced by ground-state electrons of highly charged, heavy ions which can be probed by hyperfine transition spectroscopy.

The transition in Li-like Bismuth was directly observed for the first time in 2011 at the experimental storage ring ESR located at GSI Darmstadt, the major improvement being an optimized detection system collecting the Doppler-shifted photons. Yet the accuracy of the result was limited by the calibration of the electron cooler voltage, determining the ion velocity which is required to transform the measured transition wavelength to the rest frame of the ion. We were able to reduce the uncertainties in nearly all experimental parameters in a second beamtime at the ESR in 2014. The continuous in-situ measurement of the electron cooler voltage using a precise high voltage divider provided by the Physikalisch-Technische Bundesanstalt minimized the main uncertainty of 2011. We will present results of the transition wavelength in H-like and Li-like ions and discuss the relevance for a test of strong-field bound-state QED.

A 1.4 Mon 12:15 C/HSW

ALIVE - Measuring High Voltage with ppm Accuracy using Collinear Laser Spectroscopy — •Jörg Krämer[1], Kristian König[1], Wilfried Nörtershäuser[1], Christopher Geppert[2], Ernst W. Otten[3], and Johannes Ullmann[1] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]Institut für Kernchemie, Universität Mainz — [3]Institut für Physik, Universität Mainz

Collinear laser spectroscopy has widely been used for the determination of nuclear properties like spins, moments and charge radii in radioactive beam facilities world wide. To extract these properties from the hyperfine structure of atoms, knowledge of the acceleration voltage is essential which is measured using classical voltage dividers.

In our experiment we will use the inverse approach: We will probe ions with well-known properties and by calculating the actual Doppler shift of the transition frequency, we can determine the high voltage that was used to accelerate the ions. With our two-chamber approach we envisage to reach an accuracy of <1 ppm which would exceed the performance of state-of-the-art high accuracy high voltage dividers.

We will present the basic outline of the experiment with the two-chamber pump/probe scheme and give a status update.

A 1.5 Mon 12:30 C/HSW

Cold highly charged ions for novel optical clocks and the search for α variation — •Lisa Schmöger[1,2], Oscar O. Versolato[1,2], Maria Schwarz[1,2], Matthias Kohnen[2], Tobias Leopold[2], Stefanie Feuchtenbeiner[1], Baptist Piest[1], Alexander Windberger[1], Joachim Ullrich[2], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik — [2]Physikalisch-Technische Bundesanstalt — [3]Institut für Quantenoptik, Leibniz Universität Hannover

Optical forbidden transitions in highly charged ions (HCIs) are both insensitive to external perturbations and extremely sensitive to possible drifts of the fine structure constant α. Thus, cold, strongly localized HCIs are of particular interest for the development of novel optical clocks and the search for a possible α variation. We have recently succeeded in the first preparation of Coulomb crystallized ultra-cold HCIs through sympathetic cooling in a cryogenic linear Paul trap. The ions (Ar^{13+}) produced in and extracted from an electron beam ion trap (EBIT) are decelerated and pre-cooled by means of two serrated and interlaced pulsed drift tubes before they are injected into the Paul trap. Subsequently, they are forced to interact multiple times with a Coulomb crystal of laser-cooled Be+ ions before they lose enough energy to become implanted in it and thermalize close to the Be+ crystal temperature. We investigated various cooling configurations of large mixed-species crystals and fluids, over strings of few ions down to a single HCI cooled by a single Be+ ion - a prerequisite for future quantum logic spectroscopy at a potential 10^{-19} level accuracy.

A 1.6 Mon 12:45 C/HSW

Spectroscopy of the hyperfine structure splitting and isotopic shift on $^{97-99}$Technetium — •Tobias Kron[1], Michael Franzmann[1], Jose-Luis Henares[2], Sebastian Raeder[3], Tobias Reich[4], Pascal Schönberg[4], and Klaus Wendt[1] — [1]Institute of Physics, Mainz University — [2]GANIL, Caen, France — [3]KU Leuven, Belgium — [4]Institute for Nuclear Chemistry, Mainz University

The radioactive trace element technetium is one of the dominant fission fragments and therefore might cause radio-toxic threat or, on the other hand, could serve as a long-term indicator of nuclear debris. Nuclear reactors and atomic bombs primarily create the isotope ^{99}Tc with a half-life time of $2.1 \cdot 10^5$ years. Measurements on dissemination in the environment correspondingly require highest significance and selectivity on samples containing only about 10^{10} atoms or less. Resonant laser ionization is the most suitable approach for this purpose, as it combines high elemental selectivity and highest ionization efficiency widely independent of chemical sample composition.

Successive optical excitation and subsequent ionization following strong unique dipole transitions serves as fingerprint for every element. For this purpose, the detailed knowledge of the hyperfine structure and isotopic shift in the different transitions along the excitation ladders is mandatory, in particular as ^{97}Tc serves as tracer for quantification of analytical results. We examined these parameters for the ground state and energetically higher lying levels in the spectrum of Tc I using a high repetition rate tunable narrow bandwidth titanium:sapphire laser system, to evaluate possible effects on the determined isotopic ratios.

A 1.7 Mon 13:00 C/HSW

ARTEMIS: Bound-Electron *g*-Factor Measurements by Double-Resonance Spectroscopy — •Marco Wiesel[1,2,4], David von Lindenfels[1,2,3], Sadegh Ebrahimi[1,2], Wolfgang Quint[1,2], Manuel Vogel[1,4], Alexander Martin[4], and Gerhard Birkl[4] — [1]GSI Darmstadt — [2]Universität Heidelberg — [3]MPI-K Heidelberg — [4]TU Darmstadt

Magnetic moments of electrons bound in highly charged ions provide access to effects of quantum electrodynamics (QED) in the extreme fields close to the ionic nucleus. The cryogenic Penning trap setup ARTEMIS is dedicated to determine the electronic *g*-factors of highly charged ions such as boron-like argon (Ar^{13+}) via the method of 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 excite transitions between Zeeman sublevels. With this Larmor frequency and the measurement of the ion cyclotron frequency the *g*-factor can be determined with an expected accuracy of 10^{-9} or better. Such measurements are also able to resolve higher-order contributions to the Zeeman effect. We report the commissioning of the novel half-open double trap with in-trap ion creation, characterization of the trap and first measurements performed at ARTEMIS which is part of the experimental program of the HITRAP facility. The double-resonance method can also be applied to *g*-factor measurements of the hyperfine structures of heavy hydrogen-like ions.

A 2: Atomic clusters (with MO)

Time: Monday 11:30–13:15 Location: M/HS1

Invited Talk A 2.1 Mon 11:30 M/HS1

Dynamic x-ray imaging of clusters in strong fields — •Thomas Fennel — University of Rostock, 18051, Rostock, Germany

Intense laser-cluster interactions allow the fundamental investigation of collective and correlated processes in nanoscale plasmas, including ionization avalanching, plasmon-assisted electron acceleration, attosecond plasma wave dynamics, and plasma expansion. With the rapidly developing capabilities of FELs, novel routes to the direct time-resolved imaging of the underlying dynamics are emerging [1]. I will discuss the feasibility of pump - probe scattering experiments for tracing cluster dynamics via diffractive imaging with (sub?)femtosecond resolution. The recently developed microscopic particle-in-cell approach (MicPIC) accounts simultaneously for both the correlated (classical) atomic scale plasma dynamics and electromagnetic wave propagation [2]. Complete MicPIC simulations of NIR pump - x-ray probe experiments on Hydrogen clusters are used to (i) identify relevant signatures in the scattering images and to (ii) benchmark a simplified reconstruction scheme to retrieve the (ultra)fast evolution of the cluster density profile [3]. The results suggest the potential to illuminate the dynamics of laser ablation and anisotropic plasma expansion with unprecedented detail. An outlook on routes to attosecond-resolved diffractive imaging and sub-cycle photonic streaking via inelastic x-ray scattering will be given.

[1] I. Barke *et al.*, Nat. Commun. (accepted)
[2] C. Varin *et al.*, Phys. Rev. Lett. **108**, 175007 (2012)
[3] C. Peltz *et al.*, Phys. Rev. Lett **113**, 133401 (2014)

A 2.2 Mon 12:00 M/HS1

Experimental determination of absolute cross sections for cluster-specific decay mechanisms — •Andreas Hans[1], André Knie[1], Marko Förstel[2], Philipp Schmidt[1], Uwe Hergenhahn[2], and Arno Ehresmann[1] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel — [2]Max-Planck-Institut für Plasmaphysik, c/o HZB-Bessy II, Albert-Einstein-Straße 15, 12489 Berlin

The knowledge of absolute values for cross sections of specific processes is of high interest in many fields of physics and especially for applications. In atomic clusters, decay mechanisms can differ significantly from those dominant in atoms. Absolute cross sections of these processes are attractive in many contexts, e.g. in astrophysics or applications of interatomic Coulombic decay (ICD). We present a new method to determine absolute cross sections for cluster-specific decay mechanisms using photon-induced fluorescence spectroscopy of a partially condensed gas jet. Once calibrated, this method also allows the characterization of cluster jets. In a first experiment, absolute cross sections of resonant ICD in Ne clusters and photon emission after inner-valence excitation in Ar clusters were measured.

A 2.3 Mon 12:15 M/HS1

Investigation of resonant interatomic coulombic decay in neon clusters by dispersed fluorescence spectroscopy — •Ltaief Ben Ltaief[1], Andreas Hans[1], Philipp Schmidt[1], Philipp Reiss[1], Marko Förstel[2], Uwe Hergenhahn[2], Till Jahnke[3], Reinhard Dörner[3], André Knie[1], and Arno Ehresmann[1] — [1]Universität Kassel, Heinrich-Plett Straß 40, D-34132 Kassel, Germany — [2]Max-Planck- Institut für Plasmaphysik, EURATOM Association, Wendelsteinstr. 1, 17491 Greifswald, Germany — [3]Institut für Kernphysik Goethe- Universität Max-von-Laue-Str.1 60438 Frankfurt am Main, Germany

Interatomic Coulombic Decay (ICD) in weakly bound systems, e.g. van-der-Waals clusters or hydrogen bonded clusters, has recently attracted much interest as an efficient and ultrafast process by which the excess energy of electronically excited atoms or molecules is transferred to a neighboring site, thereby, ionizing it. Since its discovery ICD is considered to be a relevant process in radiation chemistry and living tissues by producing low kinetic energy electrons and radical cations which may induce irreparable damage to DNA. So far, most of experiments aiming at ICD-processes used charged particles as probe of the process. Recently we have successfully demonstrated a first unambiguous proof of ICD by undispersed measurements of the emitted photons from neon clusters [1]. Here we report the use of dispersed-fluorescence spectrometry to investigate ICD after resonant excitation in neon clusters.

[1] Knie, A. *et al.* New. J. Phys. **16** 102002 (2014)

A 2.4 Mon 12:30 M/HS1

Tracing efficient autoionization processes in nanoplasmas — •Bernd Schütte[1,2], Mathias Arbeiter[3], Thomas Fennel[3], Ghazal Jabbari[4], Kirill Gokhberg[4], Alexander I. Kuleff[4], Jan Lahl[5], Tim Oelze[5], Maria Krikunova[5], Marc J. J. Vrakking[1], and Arnaud Rouzée[1] — [1]Max-Born-Institut, Berlin, Germany — [2]Imperial College London, United Kingdom — [3]Universität Rostock, Germany — [4]Universität Heidelberg, Germany — [5]Technische Universität Berlin, Germany

Nanoplasmas are generated during the interaction of clusters and large molecules with intense laser pulses from the NIR to the X-ray regime. It was shown that electron-ion recombination leads to a substantial excited state population in nanoplasmas. At sufficiently high laser intensities, multiply-excited atoms and ions can be formed and decay via autoionization. Here we demonstrate an efficient autoionization process in molecular oxygen and atomic clusters interacting with intense NIR pulses. In the case of oxygen clusters, superexcited atoms are formed during the cluster expansion that decay on a time scale of 1 ns. THz streaking reveals that a substantial portion of the electron emission is delayed, which is explained by autoionization processes on (sub-)ps to ns scales. Furthermore, we show that singly-excited Rydberg atoms decay by transferring the excess energy to an electron or to a second Rydberg atom in the environment that gets ionized, similar to interatomic Coulombic decay. The results demonstrate that autoionization processes are crucial for the understanding of nanoplasma dynamics and may strongly influence ion charge state distributions.

A 2.5 Mon 12:45 M/HS1

Laser-induced delayed electron emission of Co_4^- anions — •Christian Breitenfeldt[1,2], Klaus Blaum[2], Sebastian George[2], Jürgen Göck[2], Jonas Karthein[2], Thomas Kolling[3], Christian Meyer[2], Jennifer Mohrbach[3], Gereon Niedner-Schatteburg[3], Lutz Schweikhard[1], and Andreas Wolf[2] — [1]Institut für Physik, Ernst-Moritz-Arndt Universität, Felix-Hausdorff-

Str. 6, 17487 Greifswald, Germany — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Fachbereich Chemie, Universität Kaiserslautern, Germany

The Cryogenic Trap for Fast ion beams CTF located at the Max-Planck-Institut für Kernphysik is an electrostatic ion beam trap (EIBT) setup. It is well suited to investigate dynamical processes of stored ion beams. Vibrational electron autodetachment (also called delayed electron detachment) is followed by monitoring the rate of neutral particles escaping from the EIBT either as a function of storage time or, in case of laser-induced electron loss processes as a function of the time after laser excitation. Two different ion sources were used: First, a cesium ion sputter source, producing ions with vibrational temperatures up to several hundred Kelvin, second, a laser vaporization source with helium expansion to produce Co_4^- anions where the vibrational excitation levels correspond to cryogenic temperatures. The ions were stored in the CTF and the cooling and heating of the ions was probed by the change in the delayed electron detachment rate. The photo excitation measurements were performed as a function of storage time and wavelengths of the laser. Recent results are presented and discussed.

A 2.6 Mon 13:00 M/HS1

Wide angle X-ray scattering of silica nanoparticles — •Burkhard Langer[1], Christian Goroncy[1], Christopher Raschpichler[1], Felix Gerke[1], Toralf Lischke[2], Bernhard Wassermann[1], Christina Graf[1], and Eckart Rühl[1] — [1]Physikalische Chemie, Freie Universität Berlin — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle

Amorphous silica nanoparticles are widely used as model systems in materials and life sciences as well as in industrial and pharmaceutical applications. The structure of these particles consists of an amorphous network of SiO_2 containing pores in the nanometer range (1-10 nm). Chemically synthesized silica nanoparticles with a diameter between 150 and 350 nm which are prepared with porous layers are focused with an aerodynamical lens into the interaction region with synchrotron radiation from BESSY II. The experiments were performed in the energy range of the Si $2p$ regime ($E \approx 100$ eV), where the photon wavelength is comparable to the pore sizes. Deviations in the angle dependent scattering intensity compared to calculations obtained by pure Mie theory for spherical particles are attributed to Rayleigh scattering at the pores of the nanoparticles. Calculations using Discrete Dipole Approximation Scattering Theory (DDSCAT) and a modified Mie algorithm, both using realistic pore sizes and size distributions, are successfully applied to describe the wide angle X-ray scattering intensities.

A 3: Precision Measurements and Metrology I (with Q)

Time: Monday 11:30–12:45 Location: G/gHS

A 3.1 Mon 11:30 G/gHS

Testing the universality of free fall with very large baseline atom interferometry — •Christian Schubert, Jonas Hartwig, Sven Abend, Dennis Schlippert, Christian Meiners, Étienne Wodey, Holger Ahlers, Katerine Posso-Trujillo, Naceur Gaaloul, Wolfgang Ertmer, and Ernst Maria Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

The scaling factor of atom interferometers critically relies on its baseline. In case of a gravimeter, it defines the free evolution time and subsequently the response to gravity. For a gradiometer or strainmeter, the signal strength of differential acceleration signal depends on it. Therefore, very large baseline atom interferometers (VLBAI) at the scale of several meters and above are the next step to reach higher precision for advances in applied and fundamental sciences. The perspectives are to compete with superconducting gravimeters, to perform quantum tests of the weak equivalence principle in dual species set up with accuracies comparable to classical state-of-the-art tests, and to establish scalable atom optics for future strainmeters. Our VLBAI setup aims for interrogation of quantum degenerated Ytterbium and Rubidium ensembles in a 10 m vacuum setup. The simultaneous dual species operation will allow a test the universality of free fall. Choosing specifically this combination of atomic elements is motivated by the extensive experience from interferometry with cold and ultra cold atoms, and atomic clock experiments while it also constrains complementary violation parameters compared to existing tests. We will discuss the experimental implementation and the requirements to reach the targeted accuracy.

A 3.2 Mon 11:45 G/gHS

Quantum Test of the Universality of Free Fall with a Dual Species Atom Interferometer — •Logan Richardson, Henning Albers, Hendrik Heine, Jonas Hartwig, Dipankar Nath, Dennis Schlippert, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Possible violations of the universality of free fall would have deep implications on the current state of modern physics. Although the universality of free fall has been well tested classically, atom intereferometers allow access to tests of the principle from a uniquely quantum perspective. We present the results and developments from our experiment which simultaneously measures the gravitationally induced phase shift of ^{39}K and ^{87}Rb through the use of atom interferometery. With our current setup we were able to measure an Eötvös Ratio of $(0.3 \pm 5.4) \times 10^{-7}$. We here present our reasons for test mass choice, and the current limitations for our experiment. We further will discuss future developments, which will allow us to further constrain systematic uncertainty in comparison with previous published results.

A 3.3 Mon 12:00 G/gHS

Mobile Absolute Gravity Measurements with the Atom Interferometer GAIN — •Christian Freier, Matthias Hauth, Vladimir Schkolnik, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin

The gravimetric atom interferometer (GAIN) is a transportable experiment which was designed to perform measurements of local gravity at a range of interesting locations in the context of geodesy and geophysics. It is based on ensembles of laser cooled ^{87}Rb in an atomic fountain configuration and stimulated Raman transitions to implement a Mach-Zehnder type interferometer.

We report on mobile gravity measurements comparing GAIN with state-of-the-art falling corner-cube and super-conducting gravimeters. They also demonstrate the robustness and maturity of the instrument, enabling mobile long-term registrations of absolute gravity, something that is not feasible with commercially available absolute gravimeters.

The achieved sensitivity of $1.3\times10^{-8}\mathrm{g}/\sqrt{\mathrm{Hz}}$ without observable drift is comparable to other mobile atomic gravimeters and significantly better than that of falling corner-cube absolute gravimeters.

A remaining gravity value offset of less than 10^{-8}g is due to systematic effects which are discussed along with recent improvements of the set-up in order to further decrease this offset.

A 3.4 Mon 12:15 G/gHS

The effect of wavefront aberrations in atom interferometry — •Bastian Leykauf, Vladimir Schkolnik, Matthias Hauth, Christian Freier, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489 Berlin

Wavefront aberrations are a large source of uncertainty in current atom interferometers. We present the results of a numerical and experimental analysis based on measured aberrations of optical windows.

The numerical method is based on a simple model of atoms moving along classical trajectories and takes into account parameters such as the size and temperature of the atomic cloud. Despite its simplicity the method is able to faithfully predict the shift of the interferometer phase caused by wavefront aberrations of the beam.

Aberrations of several windows were analyzed with a Shack-Hartmann sensor and the phase bias numerically calculated for a range of experimental parameters. To verify these results, windows with known aberrations were inserted into the beam path of the atomic gravimeter GAIN and their effect on the measured value of the gravitational acceleration g was observed and compared with theory.

The method can be used to pre-select windows and reduce the error by one order of magnitude by post-correcting the measured value of g. We will also present our progress in characterizing the influence of the other contributing optics in the beam path on the wavefront.

Schkolnik et al. *The effect of wavefront aberrations in atom interferometry.* ArXiv pre-prints (arXiv:1411.7914). Nov. 2014.

A 3.5 Mon 12:30 G/gHS

Atom interferometry with Bose-Einstein condensate on sounding rockets — •Stephan Tobias Seidel, Dennis Becker, Maike Diana Lachmann, Jung-Bin Wang, Thijs Wendrich, Ernst Marial Rasel, and Wolfgang Ertmer for the QUANTUS-Collaboration — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

One of the fundamental principles of nature is the universality of free fall. A precise test for this postulate is the comparison 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.

As a step towards the transfer of such a system in space three rocket-based atom interferometer missions are currently being prepared. The launch of the first mission, aimed at the demonstration of a BEC in space for the first time and using this quantum degenerate matter as a source for atom interferometry is planned for May 2015. It is followed by two more missions that will include the creation of degenerate mixtures in space and simultaneous atom interferometry with two atomic species. Their success would mark a major advancement towards a precise measurement of the equivalence principle with a space-born atom interferometer.

QUANTUS is supported by the German Space Agency DLR under grant number DLR 50 1131-37.

A 4: Ultra-cold atoms, ions and BEC I (with Q)

Time: Monday 14:30–16:30 Location: C/HSW

A 4.1 Mon 14:30 C/HSW

Matter wave interference of a chiral superfluid — •Wen-Min Huang[1,2], Thorge Kock[1], Matthias Ölschläger[1], Arne Ewerbeck[1], Andreas Hemmerich[1,2], and Ludwig Mathey[1,2] — [1]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany

In a recent experiment[1], ultracold atoms were loaded into the second band of an optical lattice, and the resulting chiral superfluid order, that these atoms formed, were revealed by matter wave heterodyning technique: two independent, but coherent, condensates were created, then brought to interference in the time-of-flight expansion. Two classes of interference patterns are observed, and may be attributed to the same or the opposite chiral order spontaneously developed in two independent subsystems. In this work, we construct the interference contrast by computing the convolution of the Green's functions of the two condensates. We confirm that while the same chiral symmetry are developed in the two subsystems, the interference contrast between the two momenta at while the atoms are condensed is correlative. In contrast, if two opposite chiral symmetries are developed, an anti-correlative interference pattern is presented. Our simulations agree with the experimental observation and provide an unambiguous demonstration of two chiral time-reversal symmetry breaking superfluid order. —— [1] T. Kock, M. Ölschläger, A. Ewerbeck, W.-M. Huang, L. Mathey and A. Hemmerich, arXiv:1411.3483

A 4.2 Mon 14:45 C/HSW

Realizing effective state-dependent optical lattices by periodic driving — Gregor Jotzu, Michael Messer, Frederik Görg, Daniel Greif, •Rémi Desbuquois, and Tilman Esslinger — ETH Zurich, Zurich, Switzerland

Ultracold atoms in optical lattices offer the possibility to engineer specific Hamiltonians, with widely tunable properties. For example, the periodic modulation of the lattice potential yields an effective static Hamiltonian. While previous implementations relied on the physical motion of the lattice potential, this effect can also be realized by periodic modulation of a magnetic field gradient. As the coupling of an atom to this magnetic field gradient depends on its internal state, the effective Hamiltonian is state-dependant. For each internal state, the differing band structure can be characterized either by measuring the ballistic expansion of an atomic cloud in the lattice, or by a measurement of the effective mass through dipole oscillations. This method can be used to create novel situations, such as systems where one state is pinned to the lattice, while the other remains itinerant.

A 4.3 Mon 15:00 C/HSW

Saturation absorbtion imaging of dense atom clouds — •Bastian Höltkemeier, Henry Lopez, Julian Glässel, Pascal Weckesser, Stefan Paul, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, INF 226, 69120 Heidelberg

Imaging atomic samples with absorption imaging has become one of the standard techniques in atomic physics. Absorption imaging can be used for a wide range of atomic samples of very different densities. In this talk we will focus on imaging large and dense atom clouds with optical densities of about one hundred. In this case the sample becomes optically thick to the imaging transition which is a common problem of absorption imaging. In order to solve this problem we discuss possible approaches which can be used for such systems. The main idea is to decrease the atoms' absorption cross section and therefore reduce the measured optical thickness. The effective cross section is then characterized by saturated absorption imaging.

A 4.4 Mon 15:15 C/HSW

Goldstone mode in the quench dynamics of an ultracold BCS Fermi gas — •Peter Kettmann[1], Simon Hannibal[1], Mihail Croitoru[2], Alexei Vagov[3], Vollrath Martin Axt[3], and Tilmann Kuhn[1] — [1]Institute of Solid State Theory, University of Münster — [2]Condensed Matter Theory, University of Antwerp — [3]Theoretical Physics III, University of Bayreuth

Ultracold Fermi gases are a convenient testbed for complex interacting Fermi systems like, e.g., superconductors. They are on the one hand easily accessible in experiment. On the other hand they can form not only a BEC but a BCS phase as well. A study of this BCS phase and the crossover to the BEC is expected to give insight into other fields like high temperature superconductivity.

We investigate the BCS phase of an ultracold Fermi gas. In particular we calculate the nonequilibrium dynamics of a confined ^{6}Li gas after a quantum quench, i.e., a sudden change of the BCS coupling strength induced by the abrupt change of an external magnetic field. We find that the excitation leads to a vibration of the cloud with the spectrum containing one dominant low frequency and several higher frequencies. We show that the low frequency corresponds to the Goldstone mode of the order parameter while the higher frequencies result from the amplitude oscillation of the gap, i.e., the Higgs mode.

We study the Goldstone mode over a wide range of parameters. We find that the size-dependent superfluid resonances [1] have a strong impact on the frequency of the Goldstone mode and on its dependence on the size of the cloud. [1] Shanenko et al., PRA 86, 033612 (2012)

A 4.5 Mon 15:30 C/HSW

Anomalously long-range coherence in one dimensional Bose gases far from equilibrium — •Alexander Schnell[1,2], Daniel Vorberg[1], Roland Ketzmerick[1,2], and André Eckardt[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [2]Institut für Theoretische Physik, Technische Universität Dresden

As a consequence of the Mermin-Wagner theorem, a one-dimensional Bose gas in equilibrium at finite temperature does not feature Bose condensation in the thermodynamic limit (system size to infinity at constant density). The single-particle correlation function decays exponentially on a finite coherence length ℓ. Bose condensation can, however, occur in a system of finite length L, when for sufficiently large densities n or inverse temperatures β the ratio ℓ/L approaches one.

We investigate the situation where a one-dimensional ideal Bose gas of densisty n in contact with a heat bath of finite inverse temperature β is driven into a non-equilibrium steady state (NESS) by coupling it also to a second, population inverted heat bath described by a negative temperature. We find conditions where the NESS features fragmented

Bose condensation into three single-particle modes [1]. Remarkably, this form of non-equilibrium condensation occurs up to system sizes L that can be several orders of magnitude larger than those for which equilibrium Bose condensation occurs for the same β and n.

[1] Vorberg et. al., Phys. Rev. Lett. **111**, 240405 (2013)

A 4.6 Mon 15:45 C/HSW

Fermions in a harmonic trap with spin-imbalanced filling — Denis Morath, Stefan A. Söffing, and •Sebastian Eggert — OPTIMAS und Technische Universität Kaiserslautern

In recent experiments with ultra-cold fermions it was possible to prepare states with imbalanced pseudo-spin fillings, analogous to electrons in quantum dots. This offers the opportunity to make controlled studies on the influence of finite interactions, spin filling and temperature on the density of confined fermions. We now consider the situation in a one-dimensional trap theoretically and with numerical quantum simulations (quantum Monte Carlo and DMRG). Already for three particles in a trap there is a surprising alignment of spin up an down particles with a rather dramatic effect of the temperature. Naively an antiferromagnetic correlation between the spin species should be expected for repulsive interactions, i.e. density maxima of spin-up should correlate in space with spin-down minima and vice versa. However, already very low finite temperatures can induce *ferromagnetic* correlations. Based on the analysis of few-particle situations and symmetry considerations we can also explain the behaviour of many-particle systems.

A 4.7 Mon 16:00 C/HSW

Relaxation Dynamics of an Isolated Large-Spin Fermi Gas Far from Equilibrium — •Ulrich Ebling[1,2], Jasper Simon Krauser[3], Nick Fläschner[3], Klaus Sengstock[3,4], Christoph Becker[3,4], Maciej Lewenstein[2,5], and André Eckardt[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]ICFO - Institut de Ciències Fotòniques, Castelldefels, Spain — [3]Institut für Laserphysik, Universität Hamburg, Hamburg, Germany — [4]ZOQ - Zentrum für optische Quantentechnologien, Universität Hamburg, Hamburg, Germany — [5]ICREA - Instituciò Catalana de Recerca i Estudis Avançats, Barcelona, Spain

A fundamental question in many-body physics is how closed quantum systems reach equilibrium. We address this question experimentally and theoretically in an ultracold large-spin Fermi gas where we find a complex interplay between internal and motional degrees of freedom. The fermions are initially prepared far from equilibrium with only a few spin states occupied. The subsequent dynamics leading to redistribution among all spin states is observed experimentally and simulated theoretically using a kinetic Boltzmann equation with full spin coherence. The latter is derived microscopically and provides good agreement with experimental data without any free parameters. We identify several collisional processes that occur on different time scales. By varying density and magnetic field, we control the relaxation dynamics and are able to continuously tune the character of a subset of spin states from an open to a closed system.

A 4.8 Mon 16:15 C/HSW

High resolution ion microscopy of cold atoms — •Markus Stecker, Hannah Schefzyk, Peter Federsel, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

We develop a novel quantum gas microscope based on ionization of atoms and high resolution ion optics. The system allows for a magnification up to 1000 and a spatial resolution below the optical diffraction limit. The detection method enables continuous real time observation of trapped quantum gases with single atom sensitivity and high temporal and spatial resolution. In such a system, local statistics like temporal and spatial correlations could be studied as well as global cloud properties and dynamical processes.

We present the ion optics setup and the corresponding simulations, which reveal the principal limits of the system in terms of magnification and resolution. Furthermore, we show the first experimental realization. The current ionization scheme uses a 480nm laser to ionize directly out of a magneto-optically trapped cloud of atoms. In order to experimentally characterize the imaging quality, we imprint test patterns with the ionization laser onto the MOT. This data is used to verify the simulations and find the experimentally achievable resolution limits.

A 5: Atomic systems in external fields

Time: Monday 14:30–16:30 Location: C/kHS

A 5.1 Mon 14:30 C/kHS

Generalized Spin Precession Equations — •Hans-Jürgen Stöckmann[1] and Dirk Dubbers[2] — [1]Fachbereich Physik der Philipps-Universität Marburg, Renthof 5, 35032 Marburg, Germany — [2]Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

The Bloch equations, which describe spin precession and relaxation in external magnetic fields, can be generalized to include the evolution of polarization tensors of various ranks in arbitrary multipole fields [1]. We show applications of the generalized spin precession equations with simple examples from atomic, nuclear, and condensed matter physics, and compare the various approaches to the problem found in the literature. The derivation of the generalized Bloch equations can be considerably simplified by using a particular bra-ket notation for irreducible tensors.

[1] H.-J. Stöckmann, D. Dubbers, New J. of Phys. 16, 053050 (2014)

A 5.2 Mon 14:45 C/kHS

The effect of bound state dressing on laser assisted radiative recombination — •Robert A. Müller[1,2], Andrey Surzhykov[2], Daniel Seipt[2], and Stephan Fritzsche[1,2] — [1]Friedrich-Schiller-University Jena, Germany — [2]Helmholtz-Institute Jena, Germany

Radiative recombination is the capture of a continuum-state electron into a bound state of an ion, accompanied by the emission of a photon. If the system is exposed to an external laser field the process is commonly called *laser assisted radiative recombination* (LARR). LARR is mainly discussed as a part of the so called *three step model* in high harmonic generation and as a process to stimulate the formation of antihydrogen [1]. During the recent years a number of theoretical studies have been performed aiming for an analytical description of the laser assisted capture of an electron [2]. In most of these works either (i) the interaction between the continuum electron and the nucleus or (ii) the laser dressing of the bound state is neglected. In this contribution, therefore, we present a theoretical study of laser assisted radiative recombination accounting for both effects in an approximate way. Calculations are performed for bare low-Z ions and optical laser fields up to 10^{14}W/cm^2. Based on our calculations we found that the dressing of the bound state introduces additional asymmetries in the spectrum of the emitted photons. Moreover we could show that differences in the total cross section of LARR and the laser free process can be explained by the pertubation of the ionic wave function.

[1] D.B. Milošević and F. Ehlotzky, Phys. Rev. A **65**, 042504 (2002)
[2] G. Shchedrin and A. Volberg, J. Phys. A **44**, 245301 (2011)

A 5.3 Mon 15:00 C/kHS

^{3}He magnetometer for extreme precision measurement of high magnetic field — •Andreas Maul[1], Anna Nikiel[1], Peter Blümler[1], Werner Heil[1], Ernst Otten[1], Sergej Karpuk[2], Manfred Hehn[3], Laura Schreiber[4], and Maxim Terekhov[4] — [1]Institute of Physics, Johannes Gutenberg-Universität Mainz — [2]Institute for Nuclear Chemistry, Johannes Gutenberg-Universität Mainz — [3]MPI for Polymer Research, Mainz — [4]University Medical Center Mainz

Precise measurements and monitoring of high magnetic field are required for instance in high resolution mass spectroscopy using Penning traps or in the g-2 muon experiment. Our approach uses nuclear magnetic resonance detection on gaseous, nuclear spin-polarized ^{3}He. The nuclei of the ^{3}He gas are spin-polarized in-situ using a new, non-standard variant of the Metastability Exchange Optical Pumping (MEOP). The essential point is that coherent spin-precession times (T_2^*) of several minutes can be obtained in fields of > 1 Tesla [1]. From the measured Larmor frequency the local magnetic field can be determined with an relative accuracy better than 10^{-12}. Such a device can be miniaturized to fit next to a Penning trap in order to monitor and determine magnetic fields even at low temperatures and ultrahigh vacuum conditions. The current status and first results of the experiment will be presented.

[1] A. Nikiel, P.Blümler, W.Heil, M.Hehn, S.Karpuk, A.Maul, E.Otten, L.M.Schreiber, and M.Terekhov, Eur. Phys. J. D, 68 (2014), 330

A 5.4 Mon 15:15 C/kHS

Controlling the magnetic-field sensitivity of atomic-clock states by microwave dressing — •Lörinc Sárkány, Helge Hattermann, and József Fortágh — CQ Center for Collective Quantum Phenomena and their Applications, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

The sensitivity of atomic transitions to external field perturbations represents a major limitation for the accuracy and stability of atomic clocks and for the time of quantum-information storage in ultracold atoms and atomic gases. Electromagnetic field fluctuations and inhomogeneous trapping potentials give rise to temporal and spatial variations of atomic transition frequency.

We demonstrate control of the differential Zeeman shift between clock states of ultracold rubidium atoms by means of nonresonant microwave dressing. By dressing the state pair $5S_{1/2}F = 1, m_F = -1$ and $F = 2, m_F = 1$, a residual frequency spread of $<0.1\,\mathrm{Hz}$ in a range of $100\,\mathrm{mG}$ around a chosen magnetic offset field can be achieved [1].

We further identify *double magic* points, around which the clock frequency is insensitive to fluctuations both in the magnetic field and the dressing Rabi frequency. The technique is compatible with chip-based cold atom systems and allows the creation of clock and qubit states with reduced sensitivity to magnetic field noise.

[1] L. Sárkány *et al.*, Phys. Rev. A **90**, 053416 (2014)

A 5.5 Mon 15:30 C/kHS

Strong-field ionization with semi-classical trajectories: the role of the initial conditions — •Thomas Keil and Dieter Bauer — Universität Rostock, Institut für Physik

Photoelectron spectra for atoms in $7\,\mu$m laser fields [1] are calculated using so-called 'quantum orbits'. In the semi-classical limit, the method is known to yield good results in atomic [1-3] and cluster [4] ionization (see [5] for a review). Moreover, it is computationally less demanding than corresponding TDSE calculations, especially for very long laser wavelengths and high intensities where the ab initio solution of the TDSE is expensive, if not prohibitive. In this work, we analyze trajectory-based Coulomb-corrected strong-field approximation (CCSFA) calculations for momentum-resolved photoelectron spectra with respect to the influence of the choices for (i) the ionization rate and (ii) the initial conditions (i.e., momentum and tunnel exit).

[1] Y. Huismans, Science 331, 61 (2011)
[2] T.-M. Yan et al., Phys. Rev. Lett. 105, 253002 (2010)
[3] T.-M. Yan et al., Springer Series in Chem. Phys. vol. 104 (2013)
[4] Th. Keil et al., J. Phys. B 47, 124029 (2014)
[5] S.V. Popruzhenko, J. Phys. B 47 204001 (2014).

A 5.6 Mon 15:45 C/kHS

Exciton-phonon coupling in external fields — •Frank Schweiner, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, 70550 Stuttgart, Germany

Starting from the most simple description of an exciton as being a hydrogen-like system we construct an interaction Hamiltonian in first quantization, which describes a coupling of the exciton to acoustic and optical phonons. This is done using the descriptions of deformation potential coupling and Fröhlich interaction already known from electron-phonon interaction. By numerical investigation of the coupled system we try to reproduce a broadening of the lines of the hydrogen-like spectrum, which has recently been observed in experiments of the group of Fröhlich on cuprous oxide for quantum numbers up to n=25 (T. Kazimierczuk, Nature 514, 343, 2014). A further inclusion of external electric and magnetic fields shall prove the existence of exceptional points in the spectra.

A 5.7 Mon 16:00 C/kHS

Charge-resolved ion energy spectra of cluster coulomb explosion — •Dzmitry Komar, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universität Rostock, Institut für Physik, Universitätsplatz 3, D-18051 Rostock

Small silver metal particles of about 2000 atoms are produced by a magnetron sputtering gas aggregation cluster source. Directly in front of the nozzle the clusters are exposed to intense 100 fs dual pulses of about 10^13-10^14 W/cm^2. For the analysis of the charge-resolved ion energy spectra a modified Thomson parabola spectrometer is used. The new design features an improved energy resolution and a higher transmission compared to other setups. Optical delay studies show the impact of nanoplasmonic oscillations on the ion charge states as well as the recoil energies. Under optimized conditions charge states of up to q=19 and recoil energies of 300 keV are observed at moderate laser intensities. The results on the ions agree well with our recent studies on the electron emission under comparable conditions [1]. In particular at the Mie resonance the highly charged ions are predominantly emitted along the laser polarization axis.

[1] J. Passig, R. Irsig, N. X. Truong, T. Fennel, J. Tiggesbäumker, and K. H. Meiwes-Broer, New J. Phys. 14, 085020 (2012).

A 5.8 Mon 16:15 C/kHS

Evolution of very low energy states crossing the ionization threshold in strong mid-infrared fields — •Benjamin Wolter[1], Christoph Lemell[2], Matthias Baudisch[1], Michael G. Pullen[1], Xiao-Min Tong[3], Arne Senftleben[4], Claus Dieter Schröter[5], Joachim Ullrich[5,6], Robert Moshammer[5], Joachim Burgdörfer[2], and Jens Biegert[1,7] — [1]ICFO - Institut de Ciències Fotòniques, Mediterranean Technology Park, Castelldefels (Barcelona), Spain — [2]Institute for Theoretical Physics, Vienna University of Technology, Vienna, Austria — [3]Center for Computational Sciences, University of Tsukuba, Ibaraki, Japan — [4]Universität Kassel, Institut für Physik and CINSaT, Kassel, Germany — [5]Max - Planck - Institut für Kernphysik, Heidelberg, Germany — [6]Physikalisch - Technische Bundesanstalt, Braunschweig, Germany — [7]ICREA - Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

Intense long wavelength ($\lambda \geq 2\,\mu$m) laser pulses enable experiments in the tunneling ionization regime ($\gamma \ll 1$) and reveal surprising low electron energy features, which can not be described with the strong-field approximation (SFA). These features, universal for all target species, include the low-energy structure (LES), the very-low-energy structure (VLES) and the zero-energy structure (ZES). Using full 3D electron-ion coincidence detection in combination with our ultrafast 160 kHz mid-IR source, we reveal the entire 3D momentum spectrum well below 1 eV. Quantum and classical simulations allow for an interpretation of the LES, VLES and of the newly identified ZES.

A 6: Precision Measurements and Metrology II (with Q)

Time: Monday 14:30–16:30 Location: P/H1

Group Report A 6.1 Mon 14:30 P/H1

Quantum atom optics: states, schemes and applications — •Helmut Strobel, Daniel Linnemann, Arno Trautmann, Tobias Rentrop, Wolfgang Muessel, Philipp Kunkel, Sören Bieling, Fabian Olivares, Marcell Gall, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, Heidelberg

We report on the generation of non-Gaussian (NG) spin states via unstable fixed point dynamics in mesoscopic ^{87}Rb spinor Bose-Einstein condensates. We present a general method to extract the Fisher information, which reveals entanglement in a regime where no spin squeezing is present. The applicability of the detected quantum resource is explicitly confirmed by the implementation of a Bayesian phase estimation protocol [1].

A different class of NG spin states is generated via spin changing collisions involving three Zeeman sublevels, analogous to parametric down-conversion in quantum optics. Since this process is coherent, it can be utilized as active beam splitters in an interferometer. We characterize the phase-dependent output signal and find a phase sensitivity beyond the classical limit for average atom numbers as small as ~ 1 per side mode inside the interferometer.

We also present recent results in motional interferometry of Lithium impurities immersed in a background of Bose-condensed Sodium for the extraction of small changes of their effective mass. We confirm predicted Feshbach resonances for the interaction of ^{23}Na with ^{7}Li which is a prerequisite for systematic studies of the impurity mass.

[1] H. Strobel *et al.* Science **345** 424-427 (2014)

A 6.2 Mon 15:00 P/H1

Ultrasensitive magnetometer using a single atom — •Ingo Baumgart[1], Jianming-M. Cai[2], Alex Retzker[3], Martin B. Plenio[4], and Christof Wunderlich[1] — [1]Department Physik, Naturwissenschaftlich-Technische Fakultät, Universität Siegen, 57068 Siegen, Germany — [2]School of Physics, Huazhong University of Science and Technology, Wuhan 430074, China — [3]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Givat Ram, Israel — [4]Institut für Theoretische Physik, Universität Ulm, 89069 Ulm, Germany

Precision sensing [1], and in particular high precision magnetometry [2], is a central goal of research into quantum technologies. The precision, and thus the sensitivity of magnetometry scales as $1/\sqrt{T_2}$ with the phase coherence time, T_2, of the sensing system playing the role of a key determinant. Adapting a dynamical decoupling scheme that allows for extending T_2 by orders of magnitude [2] and merging it with a magnetic sensing protocol, we achieve a measurement sensitivity close to the standard quantum limit. Using a single atomic ion as a sensor, we experimentally attain a sensitivity of 4 pT Hz$^{-1/2}$ for an alternating-current (AC) magnetic field near 14 MHz. Based on the principle demonstrated here, this unprecedented sensitivity combined with spatial resolution in the nanometer range and tuneability from direct-current to the gigahertz range could be used for magnetic imaging in as of yet inaccessible parameter regimes. [1] Giovannetti, V. et al. *Nat. Photon.* **5,** 222 (2011). [2] Balasubramanian, G. et al. *Nature* **455,** 648 (2008). [3] Timoney, N. et al. *Nature* **476,** 185 (2011).

A 6.3 Mon 15:15 P/H1

Nanoscale magnetic field sensing enhanced by repeated quantum error correction — •Thomas Unden[1], Priya Balasubramanian[1], Daniel Louzon[1,4], Yuval Vinkler[4], Martin B. Plenio[2], Matthew Markham[5], Daniel Twitchen[5], Mikhail D. Lukin[3], Alex Retzker[4], Boris Naydenov[1], and Fedor Jelezko[1] — [1]Institut für Quantenoptik, Universität Ulm, 89089 Ulm — [2]Institut für theoretische Physik, Universität Ulm, 89089 Ulm — [3]Quantum Optics Laboratory , Harvard University, 02138 Cambridge — [4]The Racah Institute of Physics, Hebrew University of Jerusalem, 91904 Jerusalem — [5]Element 6

Coherent control of quantum systems offers unique possibilities for precise sensing and metrology. Examples of such well controlled systems are spins associated with single colour centers in diamond that were shown to be promising electric and magnetic field sensors at the nanoscale. The performance of a sensing technique is related to its ability to acquire a phase and to its capacity to reduce perturbations caused by environmental noise. State of the art techniques, however, can only tackle low frequency noise and are thus unable to support sensing of signals in a wide range of settings. Here we experimentally demonstrate for the first time a novel technique of magnetic field sensing enhanced by quantum error correction protocols, which can tackle noise at any frequency, using an electron spin in diamond associated with a single nitrogen-vacancy (NV) center.

A 6.4 Mon 15:30 P/H1

Highly sensitive magnetic fields sensing with the nitrogen vacancy center in diamond by using the rotary echo scheme — •Alexander Stark[1,3], Xi Kong[1], Vagharsh Mkhitaryan[2], Viatcheslav Dobrovitski[2], Ulrik L. Andersen[3], and Fedor Jelezko[1] — [1]Institut für Quantenoptik, Universität Ulm, 89081 Ulm, Germany — [2]Ames Laboratory, Iowa State University, Ames, Iowa 50011, USA — [3]Department of Physics, Technical University of Denmark, Fysikvej, 2800 Kgs. Lyngby, Denmark

Single defect centres in diamond and especially the nitrogen-vacancy (NV) show remarkable physical properties making them ideal candidates for single photon sources, qubits and nano-scale magnetic field sensors [1]. In a continuous decoupling protocol [2] the electron spin of the NV center is subjected to continuous Rabi driving with a periodically alternating phase forming the Rotary Echo (RE) scheme [3]. We show that this technique improves greatly the resolution for magnetic field sensing (by a factor of 10) compared to conventional dynamical decoupling techniques [4]. We believe, that RE is one of the promising candidates for the detection of individual nuclear spins in the emerging field of diamond magnetometry.

[1] M. Doherty et al., *Physics Reports* **528**, 1 (2013)
[2] M. Hirose et al., *Physical Review A* **86**, 062320 (2012).
[3] V.V. Mkhitaryan et al., *arXiv*:**1403**.6446 (2014).
[4] C. D. Aiello et al., *Nature Communications* **4**, 1419 (2013).

A 6.5 Mon 15:45 P/H1

Coherent Quantum Noise Cancellation — •Daniel Steinmeyer[1,3], Maximilian H. Wimmer[1,3], Klemens Hammerer[1,2], and Michèle Heurs[1,3] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover, Hannover, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany — [3]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Hannover, Germany

Optomechanical detectors have reached the standard quantum limit in position and force sensing where measurement backaction noise starts to be the limiting factor for the sensitivity. A strategy to circumvent measurement backaction and surpass the standard quantum limit has been suggested by M. Tsang and C. Caves [Phys. Rev. Lett. 105, 123601 (2010)]. We provide a detailed analysis of this method and assess its benefits, requirements, and limitations. We conclude that a proof-of-principle demonstration based on a micro-optomechanical system is demanding but possible. First steps towards such an experiment will be reported.

A 6.6 Mon 16:00 P/H1

Investigation of high-precision phase estimation in the presence of noise. — •Sanah Altenburg, Sabine Wölk, and Otfried Gühne — Department Physik, Universität Siegen, Siegen, Germany

Quantum correlation based measurement strategies can overcome classical precision bounds. However, quantum correlation are affected by noisy environments, which ruin the enhancement in precision.

In this talk, we discuss the effect of noisy environments in quantum metrology for different initial preparations of the measurement apparatus. We will concentrate on trapped ions as measurement apparatus. Typical decoherence processes in such systems are collective and distance dependent phase noise. For such decoherence processes, we investigate the maximally reachable precision and determine optimal probe states. Our results can help to improve the precision of experimental setups.

A 6.7 Mon 16:15 P/H1

Setup to Measure the Coefficient of Thermal Expansion (CTE) of Ultra Stable Materials at Temperature Range from 100K to 300K — •Rick Burow[1], Ruven Spannagel[1], Thilo Schuldt[1], Jose Sanjuan[1], Martin Gohlke[1], Ewan Fitzsimons[2], Ulrich Johann[2], Dennis Weise[2], and Claus Braxmaier[3] — [1]DLR German Aerospace Center, Institute of Space Systems, 28359 Bremen, Germany — [2]Airbus Defence & Space, 88039 Friedrichshafen, Germany — [3]University of Bremen, ZARM Center of Applied Space Technology and Microgravity, 28359 Bremen, Germany

For space and terrestrial applications dimensionally highly stable materials are needed, e.g. to enable precise measurements. This property of the ultra stable materials, like glass-ceramics or composite materials, is characterized by the Coefficient of Thermal Expansion (CTE). Space applications, like optical systems or sensors, often have a wide operating temperature range, where the CTEs of used materials have to be determined also at cryogenic temperatures. The basic of our setup is a heterodyne laser interferometer, that measures length variations of the sample caused by temperature changes. Our setup is an improvement of the existing facility at room temperature and allows to define CTEs at the temperature range from 100K to 300K. The mechanical and thermal design were improved, due to new requirements. The reached accuracy at room temperature is 10ppb/K, which is also the goal for the new setup.

A 7: Poster: Atomic systems in external fields

Time: Monday 17:00–19:00 Location: C/Foyer

A 7.1 Mon 17:00 C/Foyer

Testing equivalence principle for antimatter through dynamics in gravitational field — •Oliver Köhn[1] and Giovanni Manfredi[2] — [1]Universität des Saarlandes, Saarbrücken, Deutschland — [2]Centre National de la Recherche Scientifique, Strasbourg, Frankreich

We propose a test for the equivalence principle for antimatter. We consider the dynamics of a particle bouncing on a solid surface and predict an autoresonance phenomenon suitable for testing the equivalence principle. With the surface oscillating independently of the particle position, we calculate the bouncing amplitude of the particle as a function of time, and demonstrate a resonance phenomenon in the dynamics of the particle. The amplitude of the bouncing particle depends on its acceleration under the gravity of the earth and would be affected by the difference in the gravitational and inertial masses of the particle. Measurement of the autoresonance phenomenon therefore provides a test for the equivalence principle for antimatter.

A 7.2 Mon 17:00 C/Foyer

Calculating Tunnel Ionization Time by using a Quantum clock — •Nicolas Teeny, Heiko Bauke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik Saupfercheckweg 1, 69117 Heidelberg

Tunnel ionization belongs to the fundamental processes of atomic physics and has been investigated in-depth experimentally as well as theoretically. The question, however, how long it takes for an electron to escape from an attractive potential could not yet be answered conclusively. In our contribution, we solve the time-dependent Schrödinger equation numerically [1], in order to determine time-dependent ionization rates and to extract tunneling times. Additionally, we couple a Salecker-Wigner-Peres quantum clock [2, 3] to the tunneling electron and solve the coupled system numerically to explain the calculated tunneling times.

[1] Proc. of SPIE, **8780**, 87801Q (2013)

[2] Phys. Rev., **109**, 571, (1958)

[3] Am. J. Phys., **48**, 552, (1980)

A 7.3 Mon 17:00 C/Foyer

Following the evolution of ICD in time — •Fawad Karimi, Martin Ranke, Markus Pfau, Thomas Gebert, and Ulrike Frühling — Institute of experimental physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Interatomic Coulombic Decay (ICD) is a non-local auto-ionization process that was predicted by Lorenz Cederbaum in 1997. It is an efficient decay channel used by atoms in loosely bound van der Waals rare gas molecules and clusters. We aim to investigate the ICD lifetime in Neon-Krypton dimers.

The dimers are formed in a co-expansion of a NeKr gas mixture under high pressure through a small aperture in vacuum. In Ne-Kr dimer an ultrashort XUV initiates the ICD by ionizing an inner valence electron of Ne. The relaxation energy of Ne is transferred to Kr atom in form of a virtual photon, which in turn ionizes a 2p Kr electron. The whole process leaves two ionized atoms in a dimer which consequently undergoes a coulomb explosion.

The continuum electron wave packet can be probed with an intense terahertz field, which is superimposed with the XUV pulses (THz-streaking). The change in momentum of electrons due to acceleration in streaking field is proportional to the vector potential of the streaking field at the time of ionization. Thus, the temporal shape of the electron wavepacket is mapped onto changes of electron momenta.

A 7.4 Mon 17:00 C/Foyer

Exciton Interactions in Two Dimensions — •Valentin Walther, Robert Johne, and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Dresden

Recent experiments have shown that excitons with binding energies of up to 1 eV can be produced in a special class of two-dimensional semiconductors known as TMDCs (transition metal dichalogenides) [1].

We study the excited level structure of such excitons accounting for two-dimensional screening effects. Based on these results we explore the possibility to manipulate the properties by external fields. We determine the resulting interactions at asymptotic distances and discuss the importance of non-adiabatic effects.

[1] A. Chernikov et al., Phys. Rev. Lett. 113, 076802 (2014)

A 7.5 Mon 17:00 C/Foyer

Impact of subwavelength nanofocussing on the carrier-envelope phase controlled strong-field photoemission from nanospheres — •Lennart Seiffert[1], Frederik Süssmann[2], Matthias Kling[2], and Thomas Fennel[1] — [1]Universität Rostock, Universitätsplatz 3, 18051 Rostock, Germany — [2]Max-Planck Institut für Quantenoptik, 85748 Garching, Germany

Localized near-fields at laser-excited nanostructures have opened up a new dimension in attosecond science to enhance, fundamentally modify, and control electronic strong-field processes [1, 2]. Here we consider sub-wavelength nanofocussing in unsupported dielectric nanospheres to generate tailored near-fields and study the resulting strong-field electron dynamics via the angle-resolved photoemission [3]. To further investigate the electron acceleration process we modelled the dynamics using a quasi-classical trajectory-based mean field Monte-Carlo approach, which is extended to account for propagation effects of the near-fields. We demonstrate symmetry breaking and directional controllability of the carrier-envelope-phase dependent emission of recollision electrons due to the propagation-induced near-field deformation. We show that directionality of the photoemission remains largely unaffected by local field ellipticity and nonlinear many-particle charge interaction, even if the latter results in a significant boost of the final electron energies.

[1] M. Krüger et al., Nature 475 (2011)

[2] S. Zherebtsov et al., Nature Phys. 7 (2011)

[3] F. Süßmann et al., submitted

A 7.6 Mon 17:00 C/Foyer

Low-energy electrons in strong high frequency pulses — •Qi-Cheng Ning, Koudai Toyota, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany

In the tunneling ionization regime atoms and molecules, singly ionized by strong mid-infrared laser pulse, produce an unexpected low-energy structure [1], which can be explained by classical soft recollisions [2].

Surprisingly, low-energy electrons have been found numerically also in a higher-frequency regime, where they originate from a pure quantum effect [3]. Its physical picture can now be depicted by the non-adiabatic evolution of the system in a short pulse with duration comparable to the characteristic time scale of the bound electron [4]. We study this case also in a two-electron system. There a low-energy peak structure in the doubly-ionized electron spectrum has been confirmed and studied in terms of electron correlation.

[1] C. I. Balga et al., Nat. Phys. 5, 335 (2009). [2] A. Kastner, U. Saalmann, and J. M. Rost, Phys. Rev. Lett. 108, 033201 (2012). [3] K, Toyota, O. I. Tolstikhin, T. Morishita, and S. Watanabe, Phys. Rev. Lett. 103, 153003 (2009). [4] K. Koudai, U. Saalmann, and J. M. Rost, arXiv.1408.4541.

A 7.7 Mon 17:00 C/Foyer

Magnetometry with NV center ensembles — •Nathan Leefer[1], Kasper Jensen[2], Arne Wickenbrock[3], Dionysis Antypas[1], Yannick Dumeige[4], Mariusz Mrózek[5], and Dmitry Budker[1,2] — [1]Helmholtz Institut-Mainz, Mainz, Germany — [2]Niels Bohr Institute, Copenhagen, Denmark — [3]Johannes Gutenberg-Universität Mainz, Mainz, Germany — [4]Université de Rennes 1, Rennes, France — [5]Jagiellonian University, Kraków, Poland

We recently reported a cavity-enhanced room-temperature magnetic field sensor based on nitrogen-vacancy (NV) centers in diamond. The demonstrated sensitivity was 2.5 nT/$\sqrt{\text{Hz}}$ for a sensing volume of ~ 90 μm $\times$ 90 μm $\times$ 200 μm, with an estimated quantum projection-noise limit of 250 fT/$\sqrt{\text{Hz}}$. Magnetic resonance was detected using absorption of light resonant with the 1042-nm spin-singlet transition. The diamond was placed in an external optical cavity to enhance the absorption, providing significant absorption even at room temperature. We present new progress on improving the sensitivity of this device, some applications for such a miniaturized magnetometer, and new approaches for enhancing infrared absorption by NV centers in diamond without a resonant cavity.

A 7.8 Mon 17:00 C/Foyer

Exploiting light-shift effects for atomic magnetometry — •Arne Wickenbrock[1], Elena Zhivun[2], Brian Patton[2,3], and Dmitry Budker[1,4,5] — [1]Johannes Gutenberg Universität, Mainz, Germany — [2]University of California, Berkeley, California, USA — [3]Technische Universität München, Garching, Germany — [4]Helmholtz Institut Mainz, Mainz, Germany — [5]Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California, USA

We demonstrate a selection of experiments exploiting vector light shift effects for atomic magnetometry. The fictitious magnetic fields of two circular polarized laser beams are used to transform a scalar magnetometer with fT sensitivity to an all-optical vector magnetometer. The sensor exhibits a projected sensitivity of 12 $fT/Hz^{1/2}$ and 5 $microrad/Hz^{1/2}$. A second experiment demonstrates a novel approach to all-optical magnetometry with potential advantages for magnetometer arrays and magnetically sensitive fundamental physics experiments. Intensity modulation of a laser beam at the Larmor frequency directly drives a narrow magnetic resonance in alkali vapor. As a magnetometer the setup achieves a projected shot-noise-limited sensitivity of 1.7 $fT/Hz^{1/2}$ and measures a technical noise floor of 40 $fT/Hz^{1/2}$. These results are essentially identical to a coil-driven scalar magnetometer using the same setup.

A 8: Poster: Photoionization

Time: Monday 17:00–19:00 Location: C/Foyer

A 8.1 Mon 17:00 C/Foyer

Segmentierte Anode für MCP-Detektoren — •Christian Janke, Dennis Schmidt, Achim Czasch und Reinhard Dörner — Goethe Universität, Frankfurt

Für die Messungen mit der COLTRIMS-Technik wird ein Detektor benötigt, der Elektronen und Ionen auf $100\mu m$ und $500ps$ genau messen kann. Die in der Frankfurter Atomphysik-Gruppe benutzen Delay-Line-Detektoren können das sehr gut.

Delay-Line-Detektoren haben aber ein Problem, wenn mehrere Teilchen innerhalb eines kurzen Zeitfensters auf den Detektor treffen.

Um dieses Problem zu umgehen wird der Aufbau einer neuartigen Anode vorgestellt, die die Elektronenwolke der MCPs auf einer schachbrettähnlichen Struktur auffängt. Die einzelnen Signale werden hierbei mithilfe von ADCs aufgezeichnet.

A 8.2 Mon 17:00 C/Foyer

Calculation of Atomic properties by means of the MCDHF method — •Randolf Beerwerth[1] and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Universität Jena, 07743 Jena, Germany

The multi-configuration Dirac-Hartree-Fock (MCDHF) method can be applied to obtain numerical approximations of atomic multi-electron wave functions. The MCDHF method is based on the Dirac equation with added Breit-corrections, such that fully relativistic results are computed.

We use MCDHF wave-functions in order to analyze various atomic properties, such as transition rates, lifetimes and oscillator strengths. This can be done for optical transitions as well as auto ionization processes, including Auger and Coster-Kronig transitions. Detailed computations have been performed, for example, to explore and understand the electron spectra of multiply charged cadmium and to obtain further insight into the Auger cascades following inner-shell photoionization.

A 8.3 Mon 17:00 C/Foyer

Radiative and Auger transition rates of K-shell excited few-electron iron ions — •René Steinbrügge[1], Sven Bernitt[1], Sascha W. Epp[2], Jan K. Rudolph[1,3], Christian Beilmann[5], Hendrik Bekker[1], Sita Eberle[1], Alfred Müller[3], Joachim Ullrich[6], Oscar O. Versolato[1], Hasan Yavaş[4], Hans-Christian Wille[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg — [3]Institut für Atom- und Molekülphysik, Gießen — [4]DESY, Hamburg — [5]Physikalisches Institut, Heidelberg — [6]PTB, Braunschweig

The spectrum of highly charged iron ions provides rich information about the dynamics in X-ray binary stars and active galactic nuclei. To model measured spectra, a precise knowledge of the transition rates is needed. We present a measurement of radiative and Auger rates for K-shell transitions in Li-like to C-like iron ions. These were produced and trapped in the transportable electron beam ion trap FLASH-EBIT and resonantly excited with X-ray photons at PETRA III. By taking ratios of the photoionization yield and the simultaneous recorded fluorescence, we suppress setup-dependent uncertainties. Together with natural line widths [1], this allows us to determine absolute values for the radiative and Auger transition rates, with a better-than-10 % accuracy in the Li-like system. Furthermore, by analyzing the angular distribution of the fluorescence photons, we resolved different radiative decay channels in the Be-like and C-like system.

[1] J. K. Rudolph et al., Phys. Rev. Lett. **111**, 103002 (2013)

A 8.4 Mon 17:00 C/Foyer

Photoionizing ^{174}Yb^{+} to ^{174}Yb^{2+} — •Martin Fischer[1,2], Simon Heugel[1,2], Vladimir Elmann[1], Markus Sondermann[1,2], and Gerd Leuchs[1,2,3] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander University Erlangen-Nürnberg (FAU), Department of Physics, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Canada

We report on the photoionization of $^{174}Yb^{+}$ ions trapped inside a radio-frequency ion-trap. The photoionization is realized in a three-step scheme. In the second intermediate step the $4f^{14}7p_{1/2}$ level in $^{174}Yb^{+}$ is excited via the transition from the $4f^{14}5d_{3/2}$ level with a cw-laser at 245 nm. Another photon at 245 nm finally provides the energy for the ionization. A laser at 976 nm is applied continuously in order to clear the long-lived $4f^{14}5d_{5/2}$ level. The photoionization is typically achieved with intensities of 10 W/cm^2 at 245 nm. Effects from stray charges created by this laser can thereby be minimized. The $^{174}Yb^{2+}$ ions are identified using crystallized mixed species ion-pairs: The effect of a $^{174}Yb^{2+}$ 'guest' ion onto the position of a $^{174}Yb^{+}$ 'host' ion as well as the motional resonance-frequencies of this two-ion crystal are detected, unambiguously indicating for the successful ionization.

A 8.5 Mon 17:00 C/Foyer

Numerical Simulations of Single and Double Photoionization of the Helium Dimer — •Hongcheng Ni[1], Camilo Ruiz[2], Reinhard Dörner[3], and Andreas Becker[4] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [2]Centro de Láseres Pulsados (CLPU), Edificio M3 Parque Científico C/ Adaja, s/n 37185 Villamayor, Spain — [3]Institut für Kernphysik, J.W. Goethe Universität Frankfurt, Max-von-Laue-Straße 1, 60438 Frankfurt, Germany — [4]JILA and Department of Physics, University of Colorado, Boulder, Colorado 80309-0440, USA

We first study the double photoionization of the helium dimer, and the knockout mechanism is identified in the process. We further use the Hamiltonian reduction method to identify the role of the Coulomb interactions between the electrons and between the electrons and the nuclei for the primary as well as the knockout (secondary) electron in the processes.

A 8.6 Mon 17:00 C/Foyer

Experimentelle Messung absoluter ICD-Zerfallsraten in Argon-Dimeren — •Jonas Rist[1,2], Till Jahnke[1], Markus Schöffler[1], Ali Moradmand[3], Bishwanath Gaire[2], Allen Landers[3], Thorsten Weber[2], Premysl Kolorence[4], Kirill Gokhberg[5] und Reinhard Dörner[1] — [1]Institut für Kernphysik, Goethe-Universität, Max-von-Laue-Str.1, 60438 Frankfurt am Main, Germany — [2]Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA — [3]Department of Physics, Auburn University, AL 36849, USA — [4]Institute of Theoretical Physics, Charles University in Prague, Prague 116 36, Czech Republic — [5]Theoretical Chemistry Group, Heidelberg University, 69117 Heidelberg, Germany

Es wird eine Methode zur experimentellen Bestimmung der Zerfallsbreite $\Gamma(r)$ von Intermolekularen Coulombschen Zerfallskanälen (ICD-Kanälen) in Dimer-Systemen anhand ihrer KER-Verteilung (Kinetic Energy Release) vorgestellt. Als Beispiel wurde der $(^1D)4d(^2S)$ Zwischenzustand des Argon-Dimers gewählt, der durch Einzelphotonenionisation erzeugt werden kann. Die angewandte Methode basiert auf einem klassischen Ansatz für die Kernbewegung bei intermolekularen Kernabständen größer 5 *au*. Für die Aufnahme der Daten wurde eine COLTRIMS-Apparatur verwendet, mit der die koinzidente Messung aller am Zerfall beteiligter Fragmente und ihrer Impulse möglich ist.

A 9: Poster: Interaction with VUV and X-ray light I

Time: Monday 17:00–19:00 Location: C/Foyer

A 9.1 Mon 17:00 C/Foyer

Time-resolved nanoplasma formation by resonant XUV radiation — •Aaron LaForge[1], Alessandra Ciavardini[2], Mike Ziemkiewicz[3], Yevheniy Ovcharenko[4], Oksana Plekan[5], Paola Finetti[5], Robert Richter[5], Kevin Prince[5], Paolo Piseri[6], Michele Di Friaia[7], Arik Mika[8], Marcel Drabbels[8], Carlo Callegari[5], Thomas Moeller[4], Frank Stienkemeier[1], Patrick O'Keeffe[2], and Marcel Mudrich[1] — [1]Universität Freiburg, 79104 Freiburg, Germany — [2]CNR-IMP , 00016 Monterotondo Scalo, Italy — [3]University of California, Berkeley, California 94720, USA — [4]TU Berlin, 10623 Berlin, Germany — [5]Elettra, Basovizza, 34149 Trieste, Italy — [6]Università degli Studi di Milano, 20133 Milano, Italy — [7]University of Trieste, 34128 Trieste, Italy — [8]EPFL, CH-1015 Lausanne, Switzerland

The ionization dynamics of helium droplets resonantly excited by intence XUV radiation (10^12 W/cm^2) has been investigated. In this regime, a network of excited atoms is formed leading to all excited states collectively autoionizing where interesting effects such as nanoplasma and low energy electron formation and enhanced ionization rates were observed[1,2]. Here, we will present the first time-resolved measurements of such a system via XUV-UV pump-probe measurements where we see a clear time dependence on the nanoplasma formation. [1] Ovcharenko et al., Phys. Rev. Lett. 112, 073401 (2014) [2] LaForge et al., Sci. Rep. 4, 3621 (2014)

A 9.2 Mon 17:00 C/Foyer

X-ray movie of light induced dynamics in free nano particles — •Mario Sauppe[1], Leonie Flückiger[1], Jan P. Müller[1], Tais Gorkhover[1,2], Daniel Rolles[3], Benjamin Erk[3], Rolf Treusch[3], Authors as in[4], Thomas Möller[1], and Daniela Rupp[1] — [1]IOAP, TU Berlin — [2]LCLS, SLAC — [3]DESY — [4]see [2]

Naturally grown nanostructures like biological particles and clusters have an individual, complex and often non-reproducible structure. By using brilliant light pulses from short wavelength free-electron lasers, coherent diffraction imaging of single particles opens a new route to reveal the structures of such non-crystallizables targets [1].
We introduce a novel method to directly image the structural changes of the particles by recording a "two-frame movie ". Two separate images show the intact particle as well as the same particle at a later stage with the induced structural changes. The required double x-ray pulses are produced by a novel delay stage *DESC* soon available for users at the free-electron laser FLASH in Hamburg. The multilayer-based unit will be able to deliver x-ray double pulses with delays from 0 fs up to 600 ps. DESC will be set up as a part of the permanent endstation at FLASH, *CAMP* [2] including also KB optics for extremely tight focusing.

[1] M. M. Seibert et al., Nature 470, 78 (2011).
[2] L. Strüder et al., Nucl. Instr. Meth. Phys. Res. A 614 (2010) 483.

A 10: Poster: Interaction with strong or short laser pulses

Time: Monday 17:00–19:00 Location: C/Foyer

A 10.1 Mon 17:00 C/Foyer

Resonant Auger decay of the $4d \to 6p$ excitation in Xe driven by short intense coherent soft x-ray pulses — •Anne D Müller and Philipp V Demekhin — Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

The dynamics of the resonant Auger decay of the $\mathrm{Xe}^*\ 4d^9_{5/2}6p_{3/2}(J=1)$ excited state induced by a short coherent and intense soft x-ray laser pulse is investigated theoretically. The present approach includes (i) the non-Hermitian coupling between the ground state and the resonance caused by the driving pulse, (ii) the interference between the coherent populations of the final ionic states by the decay of the resonance and by the direct photoionization of the ground state, and (iii) the direct ionization of the resonance itself. The individual influence of the different competing physical processes on the total ion yield and on the electron spectrum of the most intense $\mathrm{Xe}^+\ 5p^4(^3P)6p\ ^2P_{3/2}$ spectator Auger decay line is examined. The present numerical spectra are interpreted analytically in terms of the dynamic interference of the electron waves emitted on the rising and falling sides of the driving pulse. Our results provide a theoretical basis for experiments on the verification of the dynamic interference at currently available sources of intense high-frequency laser pulses.

A 10.2 Mon 17:00 C/Foyer

Feasibility of electron cyclotron auto-resonance acceleration by a short terahertz pulse — Yousef Salamin[1], •Jian-Xing Li[2], Benjamin Galow[3], and Christoph Keitel[2] — [1]Department of Physics, American University of Sharjah, United Arab Emirates — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69029 Heidelberg, Germany — [3]Gaisbergstraße 61, 69115 Heidelberg, Germany

We investigate conditions for an electron vacuum auto-resonance accelerator scheme that would employ circularly polarized terahertz (THz) radiation and currently available laboratory magnetic fields. The system is an electron (or electron bunch) injected in the common directions of radiation pulse propagation and a uniform magnetic field B_s. Parameter values, which could make the scheme experimentally feasible, are identified and discussed. We consider a 1000 ensemble of electrons, initially, distributed randomly within a cylinder of radius 0.232 μm and height 4.642 μm, and centered at the origin of coordinates. The ensemble is injected with kinetic energy that follows a normal distribution of mean $\bar{K}_0 = 1.022$ MeV and spread $\Delta K_0 = 0.1\%$. We used the parameter set: pulse power P = 100 TW, frequency f = 4 THz ($\lambda = 75$ μm, period $T_0 = 250$ fs = FWHM), a waist radius at focus $w_0 = 17\lambda \simeq 1.27$ mm, and $B_s = 39.6$ T. Our simulations yield a mean exit kinetic energy $\bar{K}_{exit} = 396.253 \pm 0.003$ MeV, without electron-electron Coulomb interactions, and $\bar{K}_{exit} = 396.256 \pm 0.168$ MeV, with Coulomb interactions properly taken into account. The single-particle calculations yield $\bar{K}_{exit} = 396.260$ MeV. Acceleration from rest is possible, but $B_s \simeq 300$ T, in this case.

A 10.3 Mon 17:00 C/Foyer

Collisionless shocks in laboratory plasmas — •Shikha Bhadoria, Naveen Kumar, and Christoph H. Keitel — Max-Planck-Institut fuer Kernphysik, Saupfercheckweg 1, 69117, Heidelberg, Germany

Collisionless shocks are formed when two counter-propagating streams of plasmas are collided. This situation occurs quite often in astrophysical settings e.g when the supernova remnant blast shell hits the interstellar medium etc. In a laboratory this could be easily envisaged by irradiating two energetic laser pulses on thin-foil targets placed opposite to each other. These collisionless shocks are responsible for extreme acceleration of charged particles (e.g. cosmic rays) by Fermi acceleration mechanism, however little is known about their formation process. We present results of collisionless shock formation in a laboratory and discuss their implications for the astrophysical scenario.

A 10.4 Mon 17:00 C/Foyer

Double-slit electron interference in strong-field ionization of

argon dimers — Kevin Henrichs, Nikolai Schlott, •Alexander Hartung, Maksim Kunitski, and Reinhard Dörner — Institut für Kernphysik, Goethe Universität Frankfurt, Max-von-Laue-Str. 1, D-60438 Frankfurt am Main, Germany

Wave-like behavior of particles, e.g. interference, is *"the mystery"*, as stated by Feynman, *"which is impossible, absolutely impossible, to explain in any classical way, and which has in it the heart of quantum mechanics"*. In the 1960s it was realized that the double-slit experiment can be performed at the molecular level by exploiting two sites of a diatomic molecule as coherent electron emitters [1]. Several such experiments have been reported so far [2-6].

Here we report the observation of photo-electron double-slit interference in single ionization of argon dimer by a strong ultra-short laser field (40 fs, 790 nm, $1.8{\cdot}10^{14}$ W/cm^2). An electron and a single Ar ion resulting from break-up of $Ar_2{}^+$ along the repulsive $II(1/2)_g$ potential were measured in coincidence by means of COLd Target Recoil Ion Momentum Spectroscopy (COLTRIMS) [7]. The molecular axis of Ar_2 upon ionization was deduced from the momentum direction of the detected Ar ion. [1] H. D. Cohen, U. Fano, Phys Rev 150, 30-33 (1966) [2] D. Rolles et al., Nature 437, 711-715 (2005) [3] X.-J. Liu et al., J. Phys. B At. Mol. Opt. Phys. 39, 4801 (2006) [4] D. Akoury et al., Science 318, 949-952 (2007) [5] Z. Ansari et al., New J. Phys. 10, 093027 (2008) [6] S. E. Canton et al., Proc. Natl. Acad. Sci. 108, 7302-7306 (2011) [7] J. Ullrich et al., Rep. Prog. Phys. 66, 1463 (2003).

A 10.5 Mon 17:00 C/Foyer

Spin polarization of electrons in a strong laser field — Alexander Hartung, •Alina Laucke, Maksim Kunitski, and Reinhard Dörner — Institut für Kernphysik, Goethe-Universität Frankfurt am Main

Atoms exposed to a strong laser field (intensities in the range of $10^{14}\,W/cm^2$ and higher at $800\,nm$) are efficiently ionized. I. Barth and O. Smirnova predicted that electrons which are created by strong-field-tunnelionization from rare gas atoms are spin polarized [1]. They propose two effects to be responsible for the spin selectivity: first, they argue that the probability for tunnelionization by circular light depends on the sign of the magnetic quantum number m of the electron [2]. Second, there are different strong-field-tunnelionization probabilities for different electron spins because the spin-orbit-interaction makes electrons with spin parallel to m more weakly bound than those with spin antiparallel to m.

We have performed a first experiment on Xenon, ionized by a circularly polarized $800\,nm$ laser pulse at peak intensities of 4.4 and $6.6 \cdot 10^{14}\,W/cm^2$ [3]. We used a Spin Mott detector in order to measure the spin polarization of the photo-electrons. The preliminary results strongly indicate the existence of this theoretically predicted spin-polarization. The experimentally measured strength of the effect as well as the electron energy and intensity dependences are in good agreement with the theory. [1] I. Barth, O. Smirnova; Phys. Rev. A 88, 013401 (2013) [2] I. Barth, O. Smirnova; Phys. Rev. A 84, 063415 (2011) [3] A. Hartung; Master Thesis, University Frankfurt (2014)

A 10.6 Mon 17:00 C/Foyer

Spin effects in elliptically polarized laser fields in tunnel-ionization — •Enderalp Yakaboylu, Michael Klaiber, and Karen Z. Hatsagortsyan — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Spin effects in the tunneling regime of strong field ionization of hydrogenlike highly charged ions in a laser field of elliptical polarization are investigated. The spin-resolved differential ionization rates are calculated employing the dressed relativistic strong-field approximation (SFA), which takes into account the laser driven spin dynamics in the bound state. Analytical expressions for spin asymmetries as well as for the differential probabilities of spin transitions are obtained for the photoelectron momentum corresponding to the maximal tunneling probability. Intuitive explanations for the spin dynamics are provided introducing a simpleman model. The physical relevance of the applied dressed SFA, which is based on a non-standard partition of the total Hamiltonian, is discussed versus the standard SFA.

A 10.7 Mon 17:00 C/Foyer

Ionization of atoms and molecules in a strong two-color field — •Yonghao Mi, Nicolas Camus, Martin Laux, Lutz Fechner, Robert Moshammer, and Thomas Pfeifer — Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany

We experimentally investigated the asymmetry of photo-ion and photoelectron momentum spectra of argon and nitrogen. The spectra are obtained by using reaction microscope(COLTRIMS), in which an argon-nitrogen gas mixture is ionized in a strong two-color (400 nm + 800 nm) laser field. By changing the time delay t between the 400 nm laser pulse and the 800 nm pulse, the fan-like stripes in low-energy electron momentum shift from negative momentum to positive for both argon and nitrogen. A phase difference of asymmetric electron emission between Ar and N2 is observed.

A 10.8 Mon 17:00 C/Foyer

Vlasov simulation for laser-plasma interaction — •Suo Tang, Naveen Kumar, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69126, Heidelberg, Germany

Vlasov simulation of laser-plasma interaction has an inherent advantage of low-noise over the well-known method of particle-in-cell (PIC) simulation. In addition to studying the nonlinear physics of laser-plasma interaction, cross section of certain quantum processes can be included in the Vlasov equation as the source term, making it a versatile tool to study the intense laser-matter interaction. Results of the intense laser-matter interaction physics including some quantum effects from a recently developed 1D Vlasov code are presented.

A 10.9 Mon 17:00 C/Foyer

Strong bichromatic laser field ionization of atoms and "the phase of the phase" in the photoelectron yield — •Mohammad Adel Almajid and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

There have been various attempts to include Coulomb effects into the plain strong field approximation (SFA), one of them being the Coulomb-Volkov approximation (CVA). In our work, we consider two-color, colinearly polarized laser pulses. The relative phase between the two field components affects the photoelectron dynamics. A pronounced disagreement between exact TDSE and CVA-SFA photoelectron spectra is found for low energies. The rescattered electrons instead are well described already by the SFA (extended for the rescattering matrix element). We analyze the photoelectron spectra by Fourier-transforming the momentum-dependent yield as a function of the relative phase between the two pulses, thus obtaining "the phase of the phase". Plotted vs the momenta parallel and perpendicular to the laser polarization direction, this entity tells how the yield of photoelectrons with a certain final momentum is synchronized with respect to changes of the relative phase. The overall structure of these phase-of-the-phase spectra can be understood in terms of quantum trajectories while details are target-sensitive.

A 10.10 Mon 17:00 C/Foyer

Ion emission from argon microdroplets exposed by ultrashort intense laser pulses — •Lev Kazak, Robert Irsig, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Insitute of Physics, University of Rostock, Universitätsplatz 3, 18051 Rostock, Germany

The liquid jets are attractive targets for laser-generated plasma investigation. From the one side it gives a great opportunity to study the properties of warm dense matter, from the other side they are interesting as possible candidate of X-ray and extreme ultraviolet (XUV) light sources. In the present study we concentrate on the ionization and heating of the microdroplets. The kinetic energies of the ions emitted from the droplets are simultaneously measured by field-free time-of-flight spectrometers located in laser propagation and counter-propagation directions. First results show a strong asymmetry. Ions with higher recoil energy are emitted predominately in the direction opposite to the laser propagation. The impact of the laser pulse parameters will be discussed.

A 10.11 Mon 17:00 C/Foyer

Exploring quantum dynamics without time propagation — •Mehrdad Baghery, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

According to Schrödinger equation, the dynamics of a quantum system is obtained by successively applying the time evolution operator to the wavefunction. This procedure, thought seemingly simple, is not parallel in general, and this may become an obstacle as the size of the system increases.

In this study, time and space are treated on an equal footing, i.e. basis functions are used in both time and space to describe the evolution of the system. This way, one can find a system of sparse linear equations whose solution gives the evolution of the wavefunction as function of time. Considering the fact that solving a system of sparse linear equations may be parallel, the hope is to find a method to calculate the evolution of a quantum system using a parallel algorithm.

A 10.12 Mon 17:00 C/Foyer

Charge Transfer in XFEL Irradiated Biomolecules — •Abraham Camacho Garibay, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden

The possibility of single-molecule-diffractive imaging using intense XFEL pulses was suggested [1] long before these machines were operational. In this pioneering work the possibility of "diffraction before destruction" was demonstrated to be feasible, yet requiring rather high intensities and very short pulses. The important effect of charge transfer [2], neglected in this first approach, has been proven to drive a coulomb explosion were different elements escape the molecular environment in a non-homogeneous way. Here we calculate the electron and ion dynamics for molecules in an XFEL pulses, where we observe a systematic electron migration from hydrogen atoms (intrinsically abundant in biological environments) to heavier, more absorbing and scattering elements. This gives rise to the stabilization of the molecular backbone which allows the use of longer pulses and/or weaker intensities in imaging experiments.

[1] Neutze et. al., Nature 406, 2000
[2] DiCintio et. al., PRL 111, 2013

A 10.13 Mon 17:00 C/Foyer

Molecular wave-packet dynamics on laser controlled transition states — •Andreas Fischer[1], Martin Gärttner[1], Philipp Cörlin[1], Alexander Sperl[1], Michael Schönwald[1], Tomoya Mizuno[1], Giuseppe Sansone[2], Arne Senftleben[3], Joachim Ullrich[4], Bernold Feuerstein[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Dipartimento di Fisica, Politecnico Milano, Piazza Leonardo da Vinci 32, 20133 Milano , Italy — [3]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [4]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Using a kinematically complete XUV-pump IR-probe experiment, we have studied the dissociation dynamics of molecular hydrogen induced by ultra-short extreme-ultraviolet (XUV) and near-infrared (IR) laser pulses by varying the time delay between these pulses. The measured fragment velocities are time-delay dependent, showing that the reaction kinematics can be controlled by varying the retardation of the control pulse. A semi-classical model, supported by a quantum dynamics simulation, provides an intuitive understanding of the underlying mechanism in terms of particle motion on laser-induced potential energy surfaces.

A 10.14 Mon 17:00 C/Foyer

Strong Field Ionization of atoms with elliptically polarized light — •Nicolas Camus[1], Lutz Fechner[1], Andreas Krupp[1], Lukas Heizmann[1], Joachim Ullrich[2], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

We present kinematically complete strong field ionization of atoms by elliptically polarized light.

We experimentally produce arbitrary elliptically polarized light using a Mach-Zehnder interferometer. This optical setup allows shaping the polarization state of femtosecond pulses for a broad range of wavelengths. Using a Reaction Microscope, we are able to measure the three-dimensional momentum vector of all ionization fragments in coincidence.

Analyzing their momentum distribution allows to test current theories about tunneling of electron in elliptical/circular strong laser fields. More important, the dependence of these theories on the Keldysh parameter (describing which ionization picture is more relevant: tunneling or multi-photon) is investigated through the variation of target, intensity and wavelength of the laser used in the experiment.

A 10.15 Mon 17:00 C/Foyer

Seeded resonant Ionization of Xenon Doped Helium Droplets — •Michael Kelbg, Lev Kazak, Robert Irsig, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Instut für Physik, Universität Rostock, Germany

The interaction of doped helium droplets with intense, short laser pulses is studied. Colored double pulse fitness landscape is used to control the ionization of minimally Xenon-doped helium droplets resulting in mie-resonant enhanced absorbtion. Dependencies on delay and energy distribution as well as amount of dopant atoms have been further investigated, revealing an avalanchelike two step ionization process.

A 10.16 Mon 17:00 C/Foyer

Tracing the nano-plasma evolution in clusters induced by intense FEL and NIR pulses — •M. Müller[1], D. Rupp[1], L. Flückiger[1], M. Sauppe[1], J.-P. Müller[1], A. Ulmer[1], B. Langbehn[1], S. Toleikis[2], Y. Ovcharenko[1], and T. Möller[1] — [1]TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]DESY, Notkestr. 85, 22607 Hamburg

The interaction of short and intense light pulses with nano-particles results in the formation of spatial confined, solid density nano-plasmas. To understand the processes creating and driving the nano-plasma can be important for ultrafast strong field nano-plasmonics [1] as well as all experiments where the plasma formation as a byproduct cannot be avoided. We investigate the evolution of the nano-plasma time dependently in a two color pump probe scheme with scattering images and ion-spectroscopy. A short wavelength free electron laser(FEL) pulse from FLASH at DESY images the initial state and starts the nano-plasma formation while the plasma is probed with near infrared (NIR) pulses. In addition, in a second type of experiment with reversed order of the pulses the process of plasma formation and disintegration induced by a NIR pulse can be traced by recording scattering patterns with FEL pulses. The poster will give an overview on initial experiment and present first results. [1]: Kim et al., Nature 453, 757-760 (5 June 2008)

A 10.17 Mon 17:00 C/Foyer

In-flight-holography – a novel approach to image single nanoparticles with highly intense X-ray pulses — •A. Ulmer[1], J. Andreasson[2], A. Barty[2], J. Bielecki[2], M. Bucher[3], B. Daurer[2], D. DePonte[3], T. Ekeberg[2], G. Faigel[5], K.R. Ferguson[3], M.F. Hantke[2], D. Hasse[2], F. Maia[2], A.J. Morgan[4], K. Mühlig[2], M. Müller[1], C. Nettelblad[2], K. Okamoto[2], A. Pietrini[2], M. Sauppe[1], M.M. Seibert[2], J.A. Sellberg[2], M.S. Svenda[2], E.N. Timneanu[2], G. van der Schot[2], A. Zani[2], H.N. Chapman[4], J. Hajdu[2], C. Bostedt[3], T. Möller[1], and T. Gorkhover[3] — [1]TU Berlin — [2]LCLS@SLAC — [3]Uppsala University — [4]CFEL@Desy Hamburg — [5]Hungarian Academy of Sciences

Free-Electron Lasers provide coherent highly intense and short pulses which make it possible for the first time to analyze the morphology of non-periodic or non-crystallizable nanoparticles by elastic light scattering. As the phase information is lost due to the imaging process it has to be retrieved to extract full structural information. In former approaches sophisticated techniques were necessary in order to regain the phase. For solid targets holographic methods were applied successfully which retrieve the phase information in a much faster and less expensive way. We recently developed single-shot in-flight-holography using pulses from the Linac Coherent Light Source (LCLS) to image undistorted viruses in water droplets using the scattered light from xenon nanoclusters as a reference wave. First results and resolution limits through experimental constraints will be discussed.

A 11: Poster: Atomic clusters (with MO)

Time: Monday 17:00–19:00 Location: C/Foyer

A 11.1 Mon 17:00 C/Foyer

Radio-frequency buncher for core-level photoelectron spectroscopy of metal clusters at FLASH — •Franklin Martinez, Patrice Oelssner, Michael Köther, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universität Rostock, Institut für Physik, 18055 Rostock

XUV radiation of high brilliance from the free electron laser facility FLASH (Hamburg) allows to access electronic core levels of free metallic clusters by photo-electron spectroscopy (PES). Recent experiments on lead cluster anions revealed a systematic shift of 5d and of 4f level energies as a function of cluster size. For small clusters, a variation of the electron binding energy from the metallic sphere model due to reduced core-hole screening is observed [1,2]. However, with decreasing cluster size and also with increasing photon energies, the photoionization cross sections decrease rapidly, thus limiting the photo-electron yield. To increase the target density of size-selected clusters, and hence the electron yield, a new apparatus with a linear radiofrequency ion trap is currently under construction. Perspectively, the ion trap is to be combined with a radio-frequency ion buncher to increase the cluster density in the laser interaction region even further. With this setup many-electron dynamics due to x-ray photon absorption and highlycorrelated phenomena on ultrashort timescales in clusters will be addressed in future experiments. This contribution reports about design and simulations of the rf-buncher. The work is funded by the bmbf (FSP302), and supported by the DFG (SFB 652). [1] V. Senz et al., PRL 102, 138303 (2009). [2] J. Bahn et al., NJP 14, 075008 (2012).

A 11.2 Mon 17:00 C/Foyer

Investigation of a ring ion trap for the produdtion of multiply-charged cluster anions — •Stefan Knauer, Gerrit Marx, and Lutz Schweikhard — Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

A multipole ring trap was built for systematic studies of cluster anions. The Coulomb barrier and electron binding energies of multiply-charged metal clusters are experimentally mostly uninvestigated. Because polyanionc metal-clusters do not exist in nature, they have to be produced in laboratories by cluster electron collision. This can be achieved by combinations of cluster sources and ion traps [1]. A method to investigate the Coulomb barrier is the production of negative charge states with precise electron energies. To do so, one needs a field free region for the cluster-electron interaction where, simultaneously, the cluster ions are trapped. For this purpose a multipole ring electrode trap [2] was built. The experiment consists of a magnetron sputter source [3], a quadrupole bender, the ring electrode trap and a section for time-of-flight mass spectrometry (ToF MS). The sputter source is used to produce singly-charged negative metal clusters, which are guided into the trap. Cooled cluster ions can gain multiple charge states by cluster-electron collisions. For those collisions the cluster and electrons have to interact in a field free region, which a ring-electrode trap provides. In a next step, the experiment should provide defined charge states for laser interaction experiments. The contribution will discuss the principle and design of the ring electrode trap, preliminaryion-confinement tests and corresponding mass spectra.

A 11.3 Mon 17:00 C/Foyer

Linear Paul-trap for core-level photoelectron spectroscopy of Metal Clusters at FLASH — •Michael Köther, Franklin Martinez, Patrice Oelssner, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universität Rostock, Institut für Physik, 18055 Rostock

Previous photoelectron spectroscopy experiments at the free electron laser in Hamburg (FLASH) have shown distinct changes in the binding energy of lead 5d and 4f levels as a function of cluster size[1,2]. With higher photon energies available it is now possible to excite even deeper core electrons. On the other hand photoionization cross sections decrease rapidly. For compensation higher target densities are necessary and will be achieved by a new setup currently under construction. The main changes include a cryogenic, linear Paultrap and a radio frequency ion buncher. In the trap, cluster ions from a continuous source are cooled and accumulated, thus approaching a structural ground state, before pulsed extraction into the FEL interaction region. This contribution reports about simulations and first test runs of the Paultrap. The work is funded by the BMBF FSP 302, and supported by the DFG (SFB 652). [1] V. Senz et al., Phys.Rev.Lett.,102, 138303 (2009). [2] J. Bahn et al., New J. Phys., 14, 075008 (2012).

A 11.4 Mon 17:00 C/Foyer

Electron re-localization dynamics in Xenon clusters under intense XUV pump-probe excitation — •Mathias Arbeiter, Christian Peltz, and Thomas Fennel — University of Rostock, Germany

Intense and temporally structured X-ray - light fields enable the controlled generation of strongly coupled nonequilibrium cluster nanoplasma. Sub-picosecond relaxation dynamics within the cluster are revealed via the delay dependent charge states as demonstrated in recent femtosecond soft x-ray pump-probe experiments [1]. Here we report a scheme based on local electron single-particle energy spectra that enables microscopic tracing of the underlying electron-relocalization processes in molecular dynamics simulations up to the strong-coupling regime [2]. We show that recombination dynamics strongly depend on temperature and density of the system leading to a rapidly converging electron relocalization within a few picoseconds and most efficient recombination in the cluster core. A systematic pump-probe analysis reveals that electron re-localization provides a fingerprint of electron cooling and nanoplasma rarefaction through cluster expansion and yield delay-dependent ion charge states in good agreement with experiments[1]. The applied analysis is not restricted to soft x-ray excitation of clusters but essential also for the infrared regime and high harmonic light sources.

A 11.5 Mon 17:00 C/Foyer

Microscopic description of single-shot diffractive imaging of atomic clusters — •Katharina Sander, Christian Peltz, and Thomas Fennel — Institute of Physics, University of Rostock

The availability of intense femtosecond laser pulses in the XUV and soft x-ray spectral range from free-electron lasers has made it possible to investigate the structure and dynamics of nanosystems via single-shot diffractive imaging experiments, as recently demonstrated with single clusters [1]. To study the linear light scattering in clusters theoretically we employ the discrete dipole approximation (DDA) [2]. The DDA method relies on a dyadic Greens function approach and allows to model arbitrarily shaped targets down to the atomic level. We propose a modified complex mixing scheme to increase convergence of the iterative DDA model. As a first application, we examine the possibility of imaging the recently predicted IR induced nonlinear internal plasma waves in clusters [3]. Our analysis supports that distinct features of the sub-fs dynamics can be extracted from time-resolved scattering pictures. Second, we investigate the scattering of strongly absorbing silver clusters. A comparison with experimental results highlights the necessity to include absorption, which is neglected in the regularly applied treatment of x-ray scattering (Born approximation). Finally, we analyze the limits for the applicability of the single-frequency approximation in the modelling of scattering images.

[1] T. Gorkhover *et al.*, Phys. Rev. Lett. **108**, 245005, (2012)
[2] E. M. Purcell *et al.*, Astrophys. J. **186**, 705-714, (1973)
[3] C. Varin *et al.*, Phys. Rev. Lett. **108**, 175007, (2012)

A 11.6 Mon 17:00 C/Foyer

Time-resolved X-ray Imaging of Anisotropic Nanoplasma Expansion — •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

We investigate the time-dependent evolution of laser-heated R = 25 nm solid-density hydrogen clusters via coherent diffractive imaging for an infrared pump / x-ray probe scenario. Our microscopic particle-in-cell analysis provides a full self-consistent electromagnetic description of both the droplet ionization and expansion induced by the intense few-cycle pump pulse as well as the elastic and inelastic light scattering by the x-ray probe in the expanding nano-plasma [1]. Our analysis reveals that continuous ion ablation on the cluster surface generates an anisotropic nanoplasma expansion that can be accurately described by a simple self-similar radial density profile. It's time evolution can be reconstructed precisely by fitting the time-resolved scattering images using a simplified scattering model in Born approximation. Our findings suggest, that time-resolved diffractive imaging experiments on nano-droplets will provide unprecedented insights into the physics of ion expansion and surface ablation in laser-driven plasmas [2].

[1] C. Varin, C. Peltz, T. Brabec and T. Fennel , Phys. Rev. Lett. **108**, 175007 (2012)

[2] C. Peltz, C. Varin, T. Brabec and T. Fennel , Phys. Rev. Lett. **113**, 133401 (2014)

A 11.7 Mon 17:00 C/Foyer

Commissioning the Microfocus Optics for the CAMP Chamber at FLASH — •Jan P. Müller[1], Benjamin Erk[2], Rebecca Boll[2], Cedric Bomme[2], Evgeny Savelyev[2], Günter Brenner[2], Siarhei Dziarzhytski[2], Barbara Keitel[2], Marion Kuhlmann[2], Elke Plönjes[2], Kai Tiedke[2], Rolf Treusch[2], Mario Sauppe[1], Angad Swiderski[2], Lars Gumprecht[3], Thomas Tilp[3], Frank Siewert[4], Thomas Zeschke[4], Daniel Rolles[2], and Thomas Möller[1] — [1]TU Berlin/ IOAP, AG M"oller, 10623 Berlin — [2]DESY, 22607 Hamburg — [3]CFEL, 22607 Hamburg — [4]HZB, 12489 Berlin

Free electron lasers provide a high photon flux combined with ultrashort pulse durations. A tightly foucussed radiation beam enables to study atoms, molecules, clusters and particles with nonlinear effects, particularly light scattering. A focus smaller than 8 x 9 μm^2 has been reached by a newly set-up Kirkpartrick-Baez optics at the BL1 of FLASH. In combination with the permanently installed CAMP chamber [1], a multi-purpose instrument for electron and ion spectroscopy, pump-probe, and imaging experiments, it founds the base for user-experiments at high light intensities in a versatile and well-proven experimental chamber. In a first experiment very high charge states of ions from a rare gas target could be generated.

[1] L. Strüder et al., Large-format, high-speed, x-ray pnCCDs combined with electron and ion imaging spectrometers in a multipurpose chamber for experiments at 4th gen. light sources, Nucl. Instr. and Meth. in Phys. Res. A 614, 483–496 (2010)

A 11.8 Mon 17:00 C/Foyer

First-principles simulation of alkali-doped liquid helium at zero temperature — •Stefan Hempel, Yaroslav Lutsyshyn, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Alkali-doped helium droplets reveal unexpected physical features [1,2] and present testing grounds for first-principles quantum many-body methods [3]. In particular, multiple Mg dopants are known to form metastable structures in helium droplets [2]. We use first-principles projector Monte Carlo methods to study how the presence of the alkali atoms affects the surrounding superfluid. We will report the implications for the interpretation of the metastable structures of Mg atoms in the droplets.

[1] M. Mudrich , F. Stienkemeier, Int. Rev. Phys. Chem. 33, 301-339, (2014); J. Reho, U. Merker, M. R. Radcliff, K. K. Lehmann, G. Scoles, J. Chem. Phys. 112, 8409 (2000).

[2] A. Przystawik, S. Göde, T. Döppner, J. Tiggesbäumker, and K.-H. Meiwes-Broer, Phys. Rev. A 78, 021202(R) (2008); S Göde, R Irsig, J Tiggesbäumker and K-H Meiwes-Broer, New J. Phys. 15, 015026 (2013).

[3] R. Rodríguez-Cantano, T. González-Lezana, P. Villarreal, D. López-Durán, F. A. Gianturco, G. Delgado-Barrio, Int. J. Quantum Chem. 114, 1318 (2014); A. Nakayama, K. Yamashita, J. Chem. Phys. 114, 780 (2001).

A 12: Ultra-cold plasmas and Rydberg systems I (with Q)

Time: Tuesday 11:00–13:00 Location: C/kHS

A 12.1 Tue 11:00 C/kHS

Quantum simulation of energy transport with embedded Rydberg aggregates — •David W. Schönleber[1], Alexander Eisfeld[1], Michael Genkin[1], Shannon Whitlock[2], and Sebastian Wüster[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden — [2]Physikalisches Institut, Universität Heidelberg, 69120 Heidelberg

We show that an array of ultracold Rydberg atoms embedded in a laser driven background gas can serve as an artificial molecular aggregate for simulating exciton dynamics and energy transport with a controlled environment. Spatial disorder and decoherence introduced by the interaction with the background gas atoms can be controlled by the laser parameters. This allows for an almost ideal realization of a Haken-Reineker-Strobl type model for energy transport, providing a possible platform for quantum simulation of photosynthetic light harvesting complexes. Physics can be monitored using the same mechanism that provides control over the environment. The degree of decoherence is traced back to information gained on the excitation location through the monitoring, turning the setup into an experimentally accessible model system for studying the effects of quantum measurements on the dynamics of a many-body quantum system.

A 12.2 Tue 11:15 C/kHS

Signatures of directed percolation in strongly-dephased Rydberg atoms — •Matteo Marcuzzi, Emanuele Levi, Beatriz Olmos, Weibin Li, Juan Garrahan, and Igor Lesanovsky — School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

The directed percolation universality class possibly represents the simplest instance of a genuine non-equilibrium phase transition from an absorbing state to a fluctuating active phase and is typically thought to be as fundamental as the Ising universality class is for equilibrium. However, until rather recently, no clear evidence of this transition had been found in experiments. This presentation aims to show that signatures of directed percolation can be observed in a strongly interacting ensemble of Rydberg atoms subject to intense dephasing noise. Thanks to the high degree of tunability offered by cold atomic techniques, this approach should allow for the experimental probing of directed percolation in all physical dimensions.

A 12.3 Tue 11:30 C/kHS

Universal Nonequilibrium Properties of Dissipative Rydberg Gases — Matteo Marcuzzi[1], •Emanuele Levi[1], Sebastian Diehl[2,3], Juan. P. Garrahan[1], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom — [2]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

We investigate the out-of-equilibrium behavior of a dissipative gas of Rydberg atoms that features a dynamical transition between two stationary states characterized by different excitation densities.

We determine the structure and properties of the phase diagram and identify the universality class of the transition, both for the statics and the dynamics. We show that the proper dynamical order parameter is in fact not the excitation density and find evidence that the dynamical transition is in the "model A" universality class.

This sheds light on some relevant and observable aspects of dynamical transitions in Rydberg gases. In particular it permits a quantitative understanding of a recent experiment [C. Carr, Phys. Rev. Lett. 111, 113901 (2013)] which observed bistable behavior as well as power-law scaling of the relaxation time. The latter emerges not due to critical slowing down in the vicinity of a second order transition, but from the nonequilibrium dynamics near a so-called spinodal line.

A 12.4 Tue 11:45 C/kHS

Hybridization of Rydberg orbitals by molecule formation — •Anita Gaj, Alexander T. Krupp, Philipp Ilzhöfer, Thomas Schmid, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — University of Stuttgart, Stuttgart, Germany

The bond in ultralong-range Rydberg molecules results from scattering between a Rydberg electron and ground state atoms in an ultracold gas. In our setup we can selectively excite rovibrational states of D-state molecules. We study their binding energies and the shape of the binding potential at the crossing of two m_j states in an external electric field. The degeneracy of the electronic orbitals leads to stronger binding energies and new symmetries of the bound molecular states.

As a consequence the Rydberg orbitals hybridize due to the molecular bond.

A 12.5 Tue 12:00 C/kHS

Quantum magnetism and topological ordering via Rydberg-dressing near Förster-resonances — •Rick van Bijnen and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden

We devise a cold-atom approach to realizing a broad range of bi-linear quantum magnets [1]. Our scheme is based on off-resonant single-photon excitation of Rydberg P-states, whose strong interactions and state-mixing are shown to yield controllable XYZ-interactions between effective spins, represented by different atomic ground states. Exploiting distinctive features of Förster-resonant Rydberg atom interactions, we obtain large spin-interactions, up to three orders of magnitude in excess of corresponding decoherence rates. We illustrate the concept on a spin-1 chain implemented with cold Rubidium atoms, and demonstrate that this permits the dynamical preparation of topological magnetic phases. Generally, the described approach provides a viable route to exploring quantum magnetism with dynamically tuneable (an)isotropic interactions as well as variable space- and spin-dimensions in cold-atom experiments.

[1] arXiv:1411.3118

A 12.6 Tue 12:15 C/kHS

State-selective all-optical population detection of Rydberg atoms — •Florian Karlewski[1], Markus Mack[1], Jens Grimmel[1], Nóra Sándor[2,3], and József Fortágh[1] — [1]Physikalisches Institut der Universität Tübingen — [2]Department for Quantumoptics and Quantuminformatics, Wigner Research Center for Physics, Budapest — [3]Laboratoire de Physique Quantique, Strasbourg, France

We present an all-optical protocol for detecting population in a selected Rydberg state of alkali atoms. The detection scheme is based on the interaction of the atoms with two laser pulses: one weak probe pulse which is resonant with the transition between the ground state and first excited state, and a relatively strong pulse which couples the first excited state to the selected Rydberg state. We show that by monitoring the absorption signal of the probe laser over time, we can imply the initial population of the Rydberg state. We also present the results of a proof-of-principle measurement performed on a cold gas of ^{87}Rb atoms, as well as applications in studies of the lifetimes of Rydberg states under various environment conditions.

A 12.7 Tue 12:30 C/kHS

Aggregation of Rydberg excitations in a dense thermal vapor cell — •Alban Urvoy[1], Fabian Ripka[1], Igor Lesanovsky[2], Tilman Pfau[1], and Robert Löw[1] — [1]5. Physikalisches Institut , Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

Rydberg atoms in dense gases are of growing interest, due to the rich many-body physics enabled by the strong interactions. In particular, the effect of Rydberg aggregation, which relies on off-resonant excitation to spatially correlated ensembles of atoms, is currently studied [1,2] as it exhibits interesting correlations, as e.g. in soft-matter systems [3].

We present our experimental results on the excitation dynamics of such Rydberg aggregates in a vapor cell at room temperature [4]. The scaling laws for the characteristic timescale of the excitation process are consistent with a model based on an effective Master equation. Moreover we show that our measurements are very sensitive to the interaction potentials. We are able to observe the influence dipole-quadrupole interactions.

We will also discuss the use of this sensitivity to probe various interactions of the Rydberg atoms.

[1] H. Schempp et al., PRL **112**, 013002 (2014)
[2] N. Malossi et al., PRL **113**, 023006 (2014)
[3] I. Lesanovsky and J.P. Garrahan, PRA **90**, 011603(R) (2014)
[4] A. Urvoy et al., arXiv:1408.0039 [physics.atom-ph] (2014)

A 12.8 Tue 12:45 C/kHS

Measurements and numerical calculations of ^{87}Rb Rydberg Stark Maps — •Jens Grimmel[1], Markus Mack[1], Florian Karlewski[1], Florian Jessen[1], Malte Reinschmidt[1], Ahmad Rizehbandy[1], Nóra Sándor[2,3], and József Fortágh[1] — [1]Physikalisches Institut der Universität Tübingen — [2]Department of Quantumoptics and Quantuminformatics, Wigner Research Center for Physics, Budapest, Hungary — [3]Laboratoire de Physique Quantique, ISIS, Strasbourg, France

Rydberg atoms are extremely sensitive to electric fields and consequently have a rich Stark spectrum. We present measurements and numerical calculations of Stark shifts for Rydberg states of 87Rb. We extended the numerical method of [M. Zimmerman et al., Phys. Rev. A 20, 2251-2275 (1979)] to allow for a calculation of the transition strength from low lying states to Stark shifted Rydberg states. The results from these calculations are compared to high precision measurements of Stark Maps for Rubidium Rydberg atoms with principal quantum numbers up to 70 and electric fields ranging beyond the classical ionization threshold. An electromagnetically induced transparency measurement scheme is used to detect Rydberg states inbetween two electrodes of a capacitor in a glass vapor cell.

A 13: Precision spectroscopy of atoms and ions II (with Q)

Time: Tuesday 11:00–13:15 Location: M/HS1

Invited Talk A 13.1 Tue 11:00 M/HS1

Observation of wave function collapse and four-electron Auger process in inner-shell photoionization of atomic ions — •Stefan Schippers — IAMP, Justus-Liebig-Universität Gießen, Germany

Inner-shell ionization of atomic ions is an important process in astrophysical and man-made plasmas. The creation of an inner-shell vacancy leads to the formation of multiply excited states which deexcite via many competing channels, some of which are quite exotic. Recently, the study of inner-shell photoionization of ions has become feasible at the PETRA III synchrotron radiation facility at DESY in Hamburg, Germany. There, the Photon-Ion spectrometer at PETRA III (PIPE) [1] was set up at the beam line P04 [2] which provides photons in the 250–3000 eV energy range. First results were obtained on the $3d$ ionization of multiply charged xenon ions where the formation of resonances via the collapse of nf wave functions was studied as a function of the primary ion charge [3]. Further experiments with singly charged carbon ions gave a compelling evidence of the new experimental capabilities of the PIPE setup. For the first time, multiple ionization by K-shell excitation of an atomic ion could be studied. As one of the de-excitation channels, the long sought-after triple Auger process — mediated by a four-body interaction — could be unambiguously identified [4].

[1] S. Schippers et al., J. Phys. B 47, 115602 (2014).
[2] J. Viefhaus et al., Nucl. Instrum. Methods A 710 (2013) 151.
[3] S. Schippers et al., J. Phys. B (in print).
[4] A. Müller et al., Phys. Rev. Lett. (in print).

A 13.2 Tue 11:30 M/HS1

Laser spectroscopy of the heaviest elements at GSI — •Premaditya Chhetri[1], MIchael Block[2,3], Harmut Backe[4], Peter Kunz[5], Fritz-Peter Hessberger[2,3], Mustapha Laatiaoui[2], Werner Lauth[4], Felix Lautenschläger[1], Sebastian Raeder[7], Thomas Walther[1], and Calvin Wraith[6] — [1]TU Darmstadt, Darmstadt — [2]Helmholtzinstitut Mainz, Mainz — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [4]JGU Mainz, Mainz — [5]TRIUMF, Vancouver, Canada — [6]University of Liverpool, Liverpool, United Kindom — [7]KU Leuven, Leuven, Belgium

Laser spectroscopy of the heaviest elements allows the study of the evolution of relativistic effects on their atomic structure. In addition, nuclear properties such as spins and nuclear moments can be obtained. In our experiments at the GSI we exploit the Radiation Detected Resonance Ionization Spectroscopy in a buffer-gas filled stopping cell and use a two step photoionization process to search for the $^1P_1$ level in ^{254}No. Yb, a chemical homolog of No, can be produced at a higher rate and is used for optimizing the system. In this talk a general overview of our experimental setup and some results from a recent online experiment on ^{155}Yb will be presented.

A 13.3 Tue 11:45 M/HS1

The *g*-factor of the proton and progress towards the antiproton — •Andreas Mooser for the BASE-Collaboration — RIKEN Advanced Science Institute, Japan

By measuring the ratio of the Larmor and the cyclotron frequency of a single trapped proton with a fractional precision of 3.3 ppb we succeeded to perform the most precise and first direct high-precision measurement of the *g*-factor of the proton [1]. This was possible by recent advances in the quantum control of a single proton in a Penning trap [2]. As a next step, we currently pursue the application of our techniques towards a measurement of the *g*-factor of the antiproton [3], which will result in one of the most precise tests of CPT invariance on the baryionic sector. Pushing our limits even further, we are exploring experimental techniques, which will allow significantly accelerated measurement cycles using sophisticated Penning traps, detection systems and sympathetic laser cooling of single protons/antiprotons. This shall open up the possibility for a search of diurnal variations of the Larmor frequency caused by CPT- and Lorentz violating contributions beyond the Standard Model. In the talk our recent results on the measurement of the *g*-factor of the proton and an outlook regarding our future developments are given.

[1] A. Mooser *et al.*, Nature **509**, 596 (2014).
[2] A. Mooser *et al.*, Phys. Rev. Lett. **110**, 140405 (2013).
[3] C. Smorra *et al.*, Hyperfine Interact. **228**, 31 (2014).

A 13.4 Tue 12:00 M/HS1

Microwave Electrometry with Rydberg Atoms in a Vapor Cell — •Harald Kübler[1,2], Jonathan A. Sedlacek[1], Haoquan Fan[1], Santosh Kumar[1], Renate Daschner[2], Robert Löw[2], Tilman Pfau[2], and James p. Shaffer[1] — [1]Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, 440 W. Brooks St. Norman, Oklahoma 73019, USA — [2]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany

Quantum based standards of length and time as well as measurements of other useful physical quantities, ex. magnetic fields, are important because quantum systems, like atoms, show clear advantages for providing stable and uniform measurements. We demonstrate a new method for measuring microwave electric fields based on quantum interference in a Rubidium atom. Using a bright resonance prepared within an electromagnetically induced transparency window we are able to achieve a sensitivity of $30\,\mu\mathrm{V\,cm^{-1}}\sqrt{\mathrm{Hz}}^{-1}$ with a modest setup [1]. This method can be used for vector electrometry with a precision below 1° [2] and microwave field imaging with a sub-wavelength resolution [3]. Furthermore we show first results on exploiting the dispersive features of the system.

[1] J.A. Sedlacek, et al. *Nature Physics* **8**, 819 (2012)
[2] J.A. Sedlacek, et al. *Phys. Rev. Lett.* **111**, 063001 (2013)
[3] H. Q. Fan, et al. *Opt. Lett.* **39**, 3030-3033 (2014)

A 13.5 Tue 12:15 M/HS1

A high-precision measurement of the isotope effect in the magnetic moment of highly charged ^{40,48}Ca^{17+} ions — •Jiamin Hou[1], Florian Köhler[1,2], Sven Sturm[1], Anke Wagner[1], Wolfgang Quint[2], Günter Werth[3], and Klaus Blaum[1] — [1]MPIK, Heidelberg, Germany — [2]GSI, Darmstadt, Germany — [3]JGU, Mainz, Germany

To achieve a comprehensive understanding of the fundamental properties of nature, high-precision experiments with trapped charged particles are one of the most promising methods. In this experiment, the magnetic moments, i.e. *g*-factors, of the bound electrons for lithium-like ^{40}Ca and ^{48}Ca ions in the medium Z region (Z=20) have been measured for the first time with a relative uncertainty of $7 \cdot 10^{-10}$, giving rise to a stringent test of the isotope effect. We determine the bound-state electron magnetic moment by measuring the ratio of the electron spin-precession frequency and the ion's cyclotron frequency[1,2] in a cryogenic Penning-trap apparatus. The final result is obtained by combining our results with state-of-the-art QED calculations and an independent Penning-trap mass measurement. In the next step, hydrogen-like ^{40,48}Ca^{19+} will be studied. The comparison with the lithium-like system allows us to separate nuclear and inter-electronic effects. Furthermore, a novel trap system is under development which will push the achievable precision into the 10^{-12} regime and thus will open new possibilities for the determination of fundamental constants.

[1] A.Wagner et al. Phys. Rev. Lett. 110, 033003 (2013)
[2] S. Sturm et al. Phys. Rev. Lett. 107, 023002(2011)

A 13.6 Tue 12:30 M/HS1

Spin noise spectroscopy beyond thermal equilibrium and linear response — •Dibyendu Roy[1,2,3], Philipp Glasenapp[4], Luyi Yang[5], Dwight G. Rickel[5], Alex Greilich[4], Manfred Bayer[4], Nikolai A. Sinitsyn[2], and Scott A. Crooker[5] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [3]Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [4]Experimentelle Physik 2, Technische Universitat Dortmund, D-44221 Dortmund, Germany — [5]National High Magnetic Field Lab, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Per the fluctuation-dissipation theorem, the information obtained from spin fluctuation studies in thermal equilibrium is necessarily constrained by the system's linear response functions. However, by including weak radiofrequency magnetic fields, we demonstrate that intrinsic and random spin fluctuations even in strictly unpolarized ensembles can reveal underlying patterns of correlation and coupling beyond linear response, and can be used to study non-equilibrium and even multiphoton coherent spin phenomena [arXiv:1407.2895]. We demonstrate this capability in a classical vapor of 41K alkali atoms, where spin fluctuations alone directly reveal Rabi splittings, the formation of Mollow triplets and Autler-Townes doublets, ac Zeeman shifts, and even nonlinear multiphoton coherences.

A 13.7 Tue 12:45 M/HS1

Frequency metrology of ultracold ^{3}He and ^{4}He in the framework of the proton radius puzzle — •Robert J. Rengelink, Remy P.M.J.W. Notermans, and Wim Vassen — LaserLaB, Department of Physics and Astronomy, VU University, Amsterdam, the Netherlands

Ultracold gases can be probed with long interrogation times which allows very weak optical transitions to be made. In helium narrow transitions involving S-states are of interest from the perspective of testing QED and as a sensitive probe of the nuclear charge radius. At VU university we study the doubly forbidden $2\ ^3S \rightarrow 2\ ^1S$ transition at 1557 nm, which allows an accurate determination of the ^{3}He-4He differential nuclear charge radius. Previously, this transition was measured to kHz accuracy in our group (van Rooij *et. al*, Science **333**,196 (2011)). To achieve a level of accuracy comparable to the projected accuracy of muonic helium experiments currently being performed at the Paul Scherrer Institute (Nebel *et. al*, Hyperfine Interact. **212**, 195-201(2012)) we intend to push the accuracy to the 0.1 kHz level.

In this contribution, I will discuss the improvements currently being implemented in our experiment. These include an improved laser frequency stabilization scheme, a better determination of the Zeeman shift and, most importantly, the implementation of a magic wavelength dipole trap at 320 nm (Notermans *et. al*, Phys. Rev. A **90**, 052508 (2014)) to eliminate the AC-stark shift. For this purpose a laser system has been built with a continuous output power of 2W at this challenging UV wavelength.

A 13.8 Tue 13:00 M/HS1

A novel permanent magnetic EBIT — •Peter Micke[1,2], Sven Bernitt[1,3], James Harries[4], Lisa F. Buchauer[1], Thore M. Bücking[1], Steffen Kühn[1], Piet O. Schmidt[2,5], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Friedrich-Schiller-Universität Jena, Germany — [4]SPring-8, Hyogo, Japan — [5]Leibniz Universität Hannover, Germany

Research on moderately and highly charged ions (HCIs) is of great interest not only for atomic physics but also fundamental studies. Electron beam ion traps (EBITs) have proven to be versatile and indispensable tools for the production and study of such ions. In an EBIT, an electron beam is compressed by a strong, inhomogeneous magnetic field to breed the ions efficiently. Usually the field is generated by superconducting magnet coils. To ease operation we introduce a novel magnetic design based on permanent magnets for a 0.74 tesla EBIT. It allows operation at room temperature, resulting in a low-cost and low-maintenance apparatus. An open trap design offers a large solid angle access to the trap center. Our EBIT is intended to serve as a reliable source for HCIs. Additionally a new off-axis gun is under construction, to be used at synchrotron and free-electron laser light sources for energy calibration by spectroscopy on HCIs. By using this off-axis gun the photon beam can pass through the EBIT and is available for beamline users. Currently, first experiments with a prototype are carried out regarding trapping and extraction of HCIs.

A 14: Precision Measurements and Metrology III (with Q)

Time: Tuesday 11:00–12:45 Location: G/gHS

Group Report A 14.1 Tue 11:00 G/gHS
Laser Ranging Interferometer for GRACE Follow-On — •Christina Bogan, Gerhard Heinzel, and On behalf of the LRI team — Max-Planck-Institute for Gravitational Physics, Hannover, Germany

The GRACE satellite mission is measuring the earth's gravity field and its temporal variations since March 2002. What was planned to be a five year mission is still collecting data which show e.g. the drastic climate change all over the planet. However, the fuel of the two satellites is limited and anytime soon they will have to stop operations. Therefore, it was decided to launch a following mission as soon as possible, GRACE Follow On (GFO), with a scheduled launch date of August 2017. Like GRACE the GFO mission is a joint US/German project. This new mission will be an almost identical copy of the former mission but with an additional science instrument on board. The Laser Ranging Interferometer (LRI) will demonstrate for the first time the high precision inter-satellite distance measurement using a heterodyne interferometer. This will increase the accuracy of the distance measurement compared to the main science instrument which uses microwave radiation by a factor of 25. In this talk we will present the concept of the LRI, introduce the different subsystems and give an overview about the current status.

A 14.2 Tue 11:30 G/gHS
Test-bed development to experimentally investigate tilt-to-length coupling for eLISA — •Sönke Schuster[1], Ewan Fitzsimons[2], Gerhard Heinzel[1], Christian Killow[3], Maike Lieser[1], Michael Perreur-Lloyd[3], David Robertson[3], Michael Tröbs[1], Henry Ward[3], and Karsten Danzmann[1] — [1]Albert-Einstein-Institute — [2]Airbus Defence and Space — [3]University of Glasgow

eLISA (evolved Laser Interferometer Space Antenna) is a planned space-based GW detector consisting of three satellites separated by millions of kilometers. It measures with laser interferometry distance variations between free-floating test masses inside the satellites to detect gravitational waves. The coupling from angular misalignment between the satellites, laser links and test masses into the pathlength readout (tilt-to-length coupling) is currently the second largest entry in the eLISA metrology error budget (after shot noise). Here we give an overview over a test-bed development to experimentally investigate tilt-to-length coupling and test if suitable imaging systems can suppress this coupling to the required level.

A 14.3 Tue 11:45 G/gHS
An optical testbed for the eLISA Phasemeter — •Thomas Schwarze, Germán Fernández Barranco, Gerhard Heinzel, and Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) und Institut für Gravitationsphysik der Leibniz Universität Hannover

The planned spaceborne gravitational wave detector eLISA will allow the detection of gravitational waves at frequencies between 0.1 mHz and 1 Hz. It uses high-precision heterodyne laser interferometry as the main measurement technology. A breadboard model for the phase readout system of these interferometers (Phasemeter) was developed in the scope of an ESA technology development project by a collaboration between the Albert Einstein Institute, the Technical University of Denmark and the Danish industry partner Axcon Aps. This project was completed successfully fulfilling all performance requirements in an electrical two-signal test. Here we present the planning and advances in the implementation of an optical testbed for the Phasemeter. It is based on an ultra-stable hexagonal optical bench. This bench allows the generation of three unequal heterodyne beatnotes, thus providing the possibility to probe the Phasemeter for non-linearites in an optical three-signal test. The final goal is to show 1 microcycle/sqrt(Hz) performance between 2 and 25 MHz with a dynamic range of 10 orders of magnitude. Furthermore, other components of the eLISA metrology chain can be tested in this setup. This includes clock noise transfer and removal, inter-satellite ranging and communication, as well as laser frequency control and acquisition.

A 14.4 Tue 12:00 G/gHS
Highspeed multiplexed heterodyne interferometry — •Katharina-Sophie Isleif, Oliver Gerberding, Sina Köhlenbeck, Gerhard Heinzel, and Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationspyhsik und Institut für Gravitationsphysik der Universität Hannover

Digitally enhanced heterodyne interferometry is a promising new metrology technique for high-precision displacement measurements using free beams [Shaddock, 2007]. This technique uses pseudo-random noise codes for modulating the phase of the laser light. A digital decoding mechanism allows us to isolate multiple interferometric signals from the same beam based on their propagation delay. This results in more flexibility in optical layouts and finds application in multichannel interferometry and spatial investigation of stray light. Since space-based interferometers require compact optical set-ups, this technique is an attractive alternative for future missions like eLISA and LISA Pathfinder.

This talk presents the current status of the digital interferometer experiments at the AEI. Using a high modulation rate of 1.25GHz we are able to demonstrate multiplexing between targets separated by only 36cm and we achieve a displacement measurement noise floor of <3pm/sqrt(Hz) at 10 Hz for the distance between two targets along the same beam axis. A source of excess low frequency noise was identified and is probably caused by the finite bandwidth of our experimental set-up. An additional delay lock loop was implemented to reduce this noise by one order of magnitude.

A 14.5 Tue 12:15 G/gHS
Characterization and stabilization of a high-power fiber amplifier — •Patrick Oppermann, Fabian Thies, and Benno Willke — Max-Planck-Institut für Gravitationsphysik und Leibniz Universität Hannover (AEI)

We present a detailed beam characterization of continuous-wave single frequency fiber amplifier with an output power of more than 180 W at a wavelength of 1064 nm. The power noise, frequency noise, beam pointing fluctuations and spatial beam quality were measured with an optical ring resonator. The results are compared with the Advanced LIGO Pre-Stabilized Laser system. The advantage of this laser system is the use of new actuators for power stabilization of each amplifier stage with a power-shunt and an EO-AM to modulate the seed laser. First, stabilization of the pre-amplifier with 20 W to an over all relative power noise of 1*10e-8/sqrt(HZ) is shown. Then the main amplifier is stabilized with a second power-shunt.

A 14.6 Tue 12:30 G/gHS
iSense: A portable ultracold atom based gravimeter — •Lingxiao Zhu, Jonathan Malcolm, Clemens Rammeloo, Michael Holynski, Vincent Boyer, and Kai Bongs — West Midlands Ultracold Atom Research Centre, School of Physics and Astronomy, University of Birmingham, UK

The iSense project aims to be a bridge between the latest developments in ultracold atom science and practical applications, turning laboratory-based experiments into portable and robust quantum sensors. Expertise from the iSense consortium has been brought together to achieve significant reductions in the size and power consumption of all major components. The integrated device, iSense, will form a portable compact gravity sensor. This is under construction at the University of Birmingham. The current status and recent results are presented.

The iSense consortium is comprised of:
University of Birmingham;
University of Nottingham;
Ferdinand-Braun-Institut;

Centre national de la recherche scientifique;
Università degli Studi di Firenze;
Leibniz Universität Hannover;
Universität Hamburg;
Österreichische Akademie der Wissenschaften;
Institute d'Optique Graduate School;
Observatoire de Paris - SYRTE

A 15: Ultra-cold atoms, ions and BEC II (with Q)

Time: Tuesday 14:30–16:30 Location: C/HSW

A 15.1 Tue 14:30 C/HSW

Structural transitions of nearly second order in classical dipolar gases — •Florian Cartarius[1,2,3], Giovanna Morigi[3], and Anna Minguzzi[1,2] — [1]Laboratoire de Physique et Modélisation des Milieux Condensés, Université Grenoble Alpes, F-38000 Grenoble, France — [2]Laboratoire de Physique et Modélisation des Milieux Condensés, CNRS, F-38000 Grenoble, France — [3]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany

Particles with repulsive power-law interactions undergo a transition from a single to a double chain (zigzag) by decreasing the confinement in the transverse direction. We theoretically characterize this transition when the particles are classical dipoles, polarized perpendicularly to the plane in which the motion occurs, and argue that this transition is of first order, even though weakly. The nature of the transition is determined by the coupling between transverse and axial modes of the chain and contrasts with the behavior found in Coulomb systems, where the linear-zigzag transition is continuous and belongs to the universality class of the ferromagnetic transition. Our results hold for classical systems with power-law interactions $1/r^\alpha$ when $\alpha > 2$ and show that structural transitions in dipolar systems and Rydberg atoms can offer a test bed for simulating the critical behavior of magnets with lattice coupling.

A 15.2 Tue 14:45 C/HSW

Noise spectroscopy with quantum gases — •Peter Federsel, Carola Rogulj, Tobias Menold, Malte Reinschmidt, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

Local measurements of electric and magnetic field noise are fundamentally important for understanding charge transport in nanoscaled systems. Using a quantum gas, classical and even quantum noise, might be locally detected via magnetic and electric dipole transitions. This way, a quantum galvanometer for measuring current and current noise comes into direct reach[1].

Here we present a state- and energy-selective single atom detection scheme, which can be used to sense magnetic field fluctuations at the atoms' hyperfine and Zeeman transition frequencies. Therefore, atoms which have undergone a transition are ionized and individually detected on a channel electron multiplier. We characterize the bandwidth and sensitivity of this spectrometer by applying external magnetic field fluctuations and find good agreement with theoretical predictions. Using correlation analysis of the time-resolved ion signal, the resolution of the spectrometer can be further increased.

[1] Kalman et al., Nano Letters **12**, 435-439 (2012)

A 15.3 Tue 15:00 C/HSW

Interferometric Measurement of the Current-Phase Relationship of a Superfluid Weak Link — •Fred Jendrzejewski, Steve Eckel, Avinash Kumar, Christopher J. Lobb, and Gretchen K. Campbell — Joint Quantum Institute, National Institute of Standards and Technology and University of Maryland

Weak connections between superconductors or superfluids can differ from classical links due to quantum coherence, which allows flow without resistance. Transport properties through such weak links can be described with a single function, the current-phase relationship, which serves as the quantum analog of the current-voltage relationship. Here, we present a technique for inteferometrically measuring the current-phase relationship of superfluid weak links. We interferometrically measure the phase gradient around a ring-shaped superfluid Bose-Einstein condensate containing a rotating weak link, allowing us to identify the current flowing around the ring. While our Bose-Einstein condensate weak link operates in the hydrodynamic regime, this technique can be extended to all types of weak links (including tunnel junctions) in any phase-coherent quantum gas. Moreover, it can also measure the current-phase relationships of excitations. Such measurements may open new avenues of research in quantum transport.

A 15.4 Tue 15:15 C/HSW

Hybrid Quantum Systems of Ultracold Atoms and Superconductors — •Helge Hattermann, Lörinc Sárkány, Patrizia Weiss, Simon Bernon, Daniel Bothner, Benedikt Ferdinand, Matthias Rudolph, Reinhold Kleiner, Dieter Koelle, and József Fortágh — CQ Center for Collective Quantum Phenomena and their Applications, Physikalisches Institut Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

We present recent experimental progress towards coupling between cold atoms and superconducting quantum circuits. We show that atomic ensembles can be trapped magnetically in a superconducting coplanar waveguide resonator, where long-lived atomic superposition states with coherence times on the order of seconds can be prepared. The next research goal will be the resonant coupling between trapped atoms and the superconducting microwave cavity.

Furthermore, we demonstrate the sensitivity of ultracold atomic ensembles to quantized flux in a superconducting ring.

A 15.5 Tue 15:30 C/HSW

Photoassociation of Chromium — •Jahn Rührig, Tobias Bäuerle, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, Stuttgart, 70569 , Germany

We report the homonuclear photoassociation (PA) [1] of ^{52}Cr atoms while demagnetization cooling [2] in an optical dipole trap. This constitutes the first measurement of PA in an high spin element. Although Cr, with the $^7S_3$ ground and $^7P_3$ excited states, is expected to have a complicated PA spectrum the spin polarized cloud, the applied σ^- light and the absence of hyperfine-splitting lead to a remarkably simple PA spectrum. Within the scan range of 20 GHz we observe two distinct PA series each following a LeRoy-Bernstein law [3] with excellent agreement. We determine the C_3 coefficients of the Hund's case c) [4] adiabatic potentials to be 1.9 a.u. and 1.5 a.u.. Due to the strong spin orbit coupling we compute the full adiabatic potentials [5] to explain the observed C_3 coefficients. In a different set of experiments we can lift the spin-polarization of the cloud by tilting the magnetic field which leads to additional PA series.

[1]:K. M. Jones, Rev. Mod. Phys. 78, 483-535 (2006)
[2]:M. Fattori et al. , Nature Physics 2, 765 (2006).
[3]:R. J. LeRoy et al., J. Chem. Phys. 52, 3869 (1970).
[4]:F. Hund, Zeitschrift für Physik 36, 657-674 (1926).
[5]:M. Movre et al.,J. Phys. B: At. Mol. Phys. 10, 2631 (1977).

A 15.6 Tue 15:45 C/HSW

Suppression and Revival of Weak Localization through Control of Time-Reversal Symmetry — •Kilian Müller[1], Jérémie Richard[1], Valentin Volchkov[1], Vincent Denechaud[1], Philippe Bouyer[2], Alain Aspect[1], and Vincent Josse[1] — [1]Institut d'Optique, Université Paris Sud 11, Palaiseau, France — [2]Institut d'Optique, Université Bordeaux 1, Talence, France

Phase coherence can have an important effect on the propagation of waves in disorder. Emblematic phenomena are weak localization and coherent backscattering (CBS). At their heart they rely on the constructive interference between time-reversed multiple scattering paths.

We report on the observation of suppression and revival of CBS of ultra-cold atoms launched in an optical disorder and submitted to a short dephasing pulse [1], as proposed in a recent paper of T. Micklitz et al. [2]. This observation, in a quasi-2D geometry, demonstrates a novel and general method to study weak localization by manipulating time reversal symmetry in disordered systems. In future experiments, this scheme could be extended to investigate higher order localization processes at the heart of Anderson (strong) localization.

[1] K. Müller, J. Richard, V.V. Volchkov, V. Denechaud, P. Bouyer, A. Aspect, and V. Josse, arXiv:1411.1671 [2] T. Micklitz, C. A. Müller,

and A. Altland, arXiv:1406.6915

A 15.7 Tue 16:00 C/HSW

Controlling a $\mathcal{PT}$-symmetric double well by an additional well — •Daniel Haag, Dennis Dast, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Non-Hermitian Hamiltonians provide an efficient way to describe in- and outcoupling of atoms in Bose-Einstein condensates. Of special interest are $\mathcal{PT}$-symmetric Hamiltonians which often provide $\mathcal{PT}$-symmetric eigenstates with real eigenvalues. These states are truly stationary even though the particles are removed and injected at different locations. We implement such a Hamiltonian for a three-mode system, where one additional well is coupled to a $\mathcal{PT}$-symmetric double well. The influences of the third well on the well known behaviour of the two-well system is studied.

A 15.8 Tue 16:15 C/HSW

Quantum master equation for a BEC with balanced gain and loss — •Dennis Dast, Daniel Haag, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

BECs with balanced gain and loss have been extensively studied in the mean-field limit using a non-Hermitian but $\mathcal{PT}$-symmetric Gross-Pitaevskii equation. However, a microscopic description is desirable since the only physical process capable of describing a gain and loss of the condensate's wave function is the injection and removal of single particles. We present a quantum master equation in Lindblad form whose mean-field limit is a $\mathcal{PT}$-symmetric Gross-Pitaevskii equation. The master equation supports the characteristic properties of $\mathcal{PT}$-symmetric systems such as the existence of stationary states even for a relatively small number of particles. Furthermore it allows us to investigate many-particle effects of systems with balanced gain and loss which are not accessible in the mean-field limit.

A 16: Interaction with strong or short laser pulses I

Time: Tuesday 14:30–16:30 Location: C/kHS

A 16.1 Tue 14:30 C/kHS

Stark dynamics revealed by the zero-energy-structure in strong-field photoelectron spectra — •Elias Diesen, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Dresden

A pronounced feature ("zero-energy-structure") at the meV scale has been observed [1] in photoionization spectra in the IR, high-intensity tunneling regime. We show that this peak is formed by a general mechanism: the constant electric field in the detector apparatus ionizes Rydberg states created by frustrated tunneling ionization [2]. The detailed structure of the peak is revealed using classical calculations, giving interesting general results on the Stark problem in this unusual regime and showing excellent agreement with experiments.

[1] Dura et al, Sci. Rep. 3, 2675 (2013)
[2] Nubbemeyer et al., Phys. Rev. Lett. 101, 233001 (2008)

A 16.2 Tue 14:45 C/kHS

Population of doubly excited states in the tunneling regime — •Lutz Fechner[1], Nicolas Camus[1], Andreas Krupp[1], Joachim Ullrich[2], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

The mechanism of frustrated tunneling ionization (FTI) has been identified recently as being responsible for the population of Rydberg states in strong laser fields in the tunneling regime [1]. Using a Reaction Microscope we obtained highly resolved electron momentum distributions resulting from ionization of noble gases at various wavelengths from 400 to 1600 nm. We present unique features visible in the low momentum regions that arise from autoionizing doubly excited states. Possible population scenarios include the excitation of the electronic core by the resonant recapturing of a slow, recolliding electron and thus a possible connection to dielectronic recombination processes [2, 3].

[1] T. Nubbemeyer et al., *Phys. Rev. Lett.* **101**, 233001 (2008)
[2] J.B.A. Mitchell et al., *Phys. Rev. Lett.* **50**, 335 (1983)
[3] D.S. Belic et al., *Phys. Rev. Lett.* **50**, 339 (1983)

A 16.3 Tue 15:00 C/kHS

Strong Field Ionization in ω-2ω Laser Pulses: Phase-of-the-Phase Spectroscopy — •Slawomir Skruszewicz, Josef Tiggesbäumker, Karl-Heinz Meiwes-Broer, Mathias Arbeiter, Thomas Fennel, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Coherent superposition of fundamental 800 nm (ω) laser beam with its second-harmonic (2ω) creates laser pulses with asymmetrical electric field distribution [1]. Controlling of the relative phase between them with sub-fs precision enables obtaining the relative-phase-tagged photoelectron spectra. Thus, the electron recollision dynamics can be studied in more details than conventional photoelectron spectroscopy. Here, we propose 'phase-of-the-phase spectroscopy' which applied to rare gas atoms and CO_2 unambiguously identifies photoelectrons that rescatter during first and second re-encountering their parent ion. Simple modelling in terms of Simple Man's Theory shows universality of the rescattering features. However closer inspection reveals finer details which are target sensitive and can be used to imaging electronic structure of the scattering center.

References: [1] N. Dudovich et al., Nature Physics **2**, 781 (2006) [2] S. Skruszewicz et. al., Int. J. Mass. Spectr. **365**, 338 (2014) [3] S. Zherebtsov et. al., New. J. Phys. **14**, 075010 (2012)

A 16.4 Tue 15:15 C/kHS

Measurements and Semi-classical analysis of Above Threshold Ionization Spectra in Orthogonal Two Color Fields — •Daniel Würzler[1,2], Max Möller[1,2], Max Sayler[1,2], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena, Germany — [2]Helmholtz Institute Jena, Germany

Recent research shows that orthogonally polarized two color laser (OTC) fields can be used to gain control over sub-cycle electron dynamics in strong-laser ionization. While existing studies mainly focus on high harmonic spectra or electron-ion coincidence measurements done with a COLTRIMS, here we present electron spectra for Ne and Xe in OTC fields measured via velocity map imaging. To analyze these spectra, a semi-classical model is used to describe changes in the electron interference pattern and map the electron dynamics introduced by changing the phase between the two field components.

A 16.5 Tue 15:30 C/kHS

Exact correlated electron dynamics in full dimensionality: Applying time-dependent renormalized-natural-orbital theory (TDRNOT) to 3D He — •Julius Rapp, Martins Brics, and Dieter Bauer — Universität Rostock, Germany

A numerically affordable exact two-body scheme is desirable not only for describing driven He but any process where the single-active-electron picture breaks down due to two-body correlations.

In this talk we discuss the conceptual challenges when applying the recently introduced [1-3] TDRNOT scheme to He in full dimensionality. After expanding both the natural orbitals and their effective potentials in spherical harmonics we find that compared to the 1D-model case additional degeneracies in the occupation numbers can occur. As a result, one has to employ a suitable propagation scheme that is capable of handling these possible degeneracies. Moreover, we present several techniques to keep the numerical effort manageable. Finally, the practicability of TDRNOT implemented on a desktop computer for the exact treatment of both electrons in 3D He, subject to a strong laser field, is analyzed.

[1] M. Brics and D. Bauer, Phys. Rev. A **88**, 052514 (2013).
[2] J. Rapp, M. Brics, and D. Bauer, Phys. Rev. A **90**, 012518 (2014).
[3] M. Brics, J. Rapp, and D. Bauer, Phys. Rev. A **90**, 053418 (2014).

A 16.6 Tue 15:45 C/kHS

Nonsequential double ionization and radiation/absorption spectra with time-dependent renormalized-natural-orbital

theory — •Martins Brics, Julius Rapp, and Dieter Bauer — Universität Rostock, Rostock, Germany

Time-dependent renormalized-natural-orbital theory (TDRNOT) is a promising approach to describe correlated electron quantum dynamics, even beyond linear response. It has been shown in [1] that TDRNOT with only two renormalized natural orbitals (RNOs) per spin is capable of describing correlated phenomena such as doubly excited states, autoionization, and Fano profiles in the photoelectron spectra for He. Here we go one step further and investigate the performance of TDRNOT for processes which involve more than two RNOs.

As the first test case we consider nonsequential double ionization (NSDI) as it is a very correlated process and therefore many RNOs are needed to describe it. Our two main observables for NSDI are the double-ionization probability and correlated photoelectron spectra. It is found that TDRNOT reproduces the celebrated NSDI "knee," i.e., a many-order-of-magnitude enhancement of the double-ionization yield (as compared to purely sequential ionization) with only the ten most significant natural orbitals (NOs) per spin. Correlated photoelectron spectra—as "more differential" observables—require more NOs [2].

The second test case is radiation/absorption spectra. Here we look at absorption line-shapes showing Lorentz/Fano profiles and ATI spectra.

[1] M. Brics, D. Bauer, Phys. Rev. A **88**, 052514 (2013).
[2] M. Brics, J. Rapp, D. Bauer, Phys. Rev. A **90**, 053418 (2014).

A 16.7 Tue 16:00 C/kHS

Spin Effects in Strong-Field Breit-Wheeler Pair Production — •Martin J.A. Jansen and Carsten Müller — Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

As predicted by Breit and Wheeler in 1934, highly energetic photons can materialize upon collision into electron-positron pairs. Owing to the ever increasing photon densities in current laser systems, this fundamental effect comes into reach of experimental capabilities and has actually been seen for the first time in the SLAC E144 experiment [1].

In this contribution, we investigate spin effects in Breit-Wheeler pair production induced by the collision of a laser field and high-energy gamma quanta. We present detailed calculations within the framework of strong-field QED. The laser field is modelled by a plane wave of either infinite or finite duration, where the latter allows for a more realistic description of typical high-intensity laser fields. By comparing results obtained for scalar and spinor particles, respectively, we extend a previous study on the subject [2] and gain new insights into the fundamental role played by the particle spin in the pair production process.

[1] D. Burke et al., Phys. Rev. Lett 79, 1626 (1997)
[2] S. Villalba-Chavez and C. Müller, Phys. Lett. B 718, 992 (2013)

A 16.8 Tue 16:15 C/kHS

Narrowband inverse Compton scattering x-ray sources at high laser intensities — •Daniel Seipt[1], Sergey Rykovanov[1], Andrey Surzhykov[1], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena — [2]Universität Jena, Institut für Theoretische Physik, 07743 Jena

Narrowband x- and gamma-ray sources based on inverse Compton scattering of laser light suffer from a limitation of the allowed laser intensity due to the onset of nonlinear effects, which limits the photon yield. At high laser intensity the ponderomotive force changes the electrons' longitudinal velocity and leads to a variable red-shift during the scattering such that the scattered radiation's spectral bandwidth increases. In this talk I will discuss the possibilities to use chirped laser pulses to compensate this ponderomotive broadening and to reduce the bandwidth of the spectral lines, which would allow to operate narrowband Compton sources in the high-intensity regime [1]. The optimal frequency modulation of the initial laser pulse is derived from the strong-field QED scattering matrix element for nonlinear Compton scattering in the Furry picture, where the electron recoil and spin are taken into account [2].

[1] B. Terzić et. al., Phys. Rev. Lett. **112**, 074801 (2014).
[2] D. Seipt et. al., to appear.

A 17: Precision Measurements and Metrology IV (with Q)

Time: Tuesday 14:30–16:30 Location: P/H1

A 17.1 Tue 14:30 P/H1

Recent results of the Space Optical Clock 2 EU project (SOC2). A compact, transportable optical lattice clock. — •Lyndsie Smith[1], Stefano Origlia[2], Joshua Hughes[1], Wei He[1], Ole Kock[1], Dariusz Świerad[1], Yeshpal Singh[1], Kai Bongs[1], Soroosh Alighanbari[2], Stephan Schiller[2], Stefan Vogt[3], Uwe Sterr[3], Christian Lisdat[3], Rudolphe Le Targat[4], Jèrôme Lodewyck[4], David Holleville[4], Bertrand Venon[4], Sébastien Bize[4], Geoffrey P Barwood[5], Patrick Gill[5], Ian R Hill[5], Yuri B Ovchinnikov[5], Nicola Poli[6], Guglielmo M Tino[6], Jürgen Stuhler[7], Wilhelm Kaenders[7], and and the SOC2 team[7] — [1]University of Birmingham (UoB), Edgbaston, Birmingham B15 2TT, UK — [2]Institut für Experimentalphysik,Heinrich-Heine-Universität Düsseldorf (HHUD),40225 Düsseldorf, Germany — [3]Physikalisch-Technische Bundesanstalt (PTB), 38116 Braunschweig, Germany — [4]SYRTE, Observatoire de Paris, 75014 Paris, France — [5]National Physical Laboratory (NPL), Teddington TW11 0LW, UK — [6]Università di Firenze (UNIFI) and LENS, Firenze, Italy — [7]TOPTICA Photonics AG, 82166 Gräfelfing, Germany

With timekeeping being of paramount importance for modern life, much research and major scientific advances have been undertaken in the field of frequency metrology, particularly over the last few years. New Nobel-prize winning technologies have enabled a new era of atomic clocks; namely the optical clock. These have been shown to perform significantly better than the best microwave clocks reaching an inaccuracy of $1.6{\cdot}10^{-18}$ (doi:10.1038/nature12941). With such results being found in large lab based apparatus, the focus now has shifted to portability - to enable the accuracy of various ground based clocks to be measured, and compact autonomous performance - to enable such technologies to be tested in space. This could lead to a master clock in space, improving not only the accuracy of technologies on which modern life has come to require such as GPS and communication networks. But also more fundamentally, this could lead to the redefinition of the second and tests of fundamental physics. Within the European collaboration, Space Optical Clocks 2 (SOC2) consisting of various institutes and industry partners across Europe we have tried to tackle this problem of miniaturisation whilst maintaining stability, accuracy ($5{\cdot}10^{-17}$) and robustness whilst keeping power consumption to a minimum - ideal for space applications. I will present the most recent results of the Sr optical clock in SOC2 and also the novel compact design features for reducing BBR, new methods employed and outlook.

A 17.2 Tue 14:45 P/H1

Absolute frequency measurement of the ^{87}Sr lattice clock at PTB — Ali Al-Masoudi, •Sören Dörscher, Vladislav Gerginov, Stefan Weyers, Christian Grebing, Burghard Lipphardt, Sebastian Häfner, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig

Comparisons of optical clocks to microwave or other optical clocks are of great importance e.g. for the search for drifts of fundamental constants, and they also serve to ascertain the correctness and completeness of their error budgets. We report on a recent measurement of the absolute frequency of the $^1S_0$–$^3P_0$ transition in ^{87}Sr against a Cs fountain clock. The result is in excellent agreement with recent measurements in other laboratories as well as our own previous measurements. The preliminary fractional uncertainty of this measurement is 4×10^{-16}, to which the statistical uncertainty due to the measurement time of 267000 s still contributes considerably. However, this uncertainty can be reduced to below the systematic uncertainty of the Cs clock by an extension of the effective total measurement time through interpolation, which is currently under investigation. Finally, we present recent improvements of the lattice clocks at PTB for this measurement and towards a direct comparison of two separate ^{87}Sr clocks. This work is supported by QUEST, the DFG within CRC 1128 (geo-Q) and RTG 1729, and the EMRP within IND14, ITOC, and QESOCAS. The EMRP is jointly funded by the EMRP-participating countries within EURAMET and the European Union.

A 17.3 Tue 15:00 P/H1

Lifetime of the $5s4d$ ^{3}D$_1$ transition in neutral strontium — •Joshua Hughes[1], Marco Menchetti[1,2], Yeshpal Singh[1], Kai Bongs[1], Ian Hill[2], Richard Hobson[2,3], Anne Curtis[2], Ross Williams[2], and Patrick Gill[2,3,4] — [1]University of Birmingham, Birmingham, UK — [2]National Physical Laboratory, Teddington, UK — [3]Clarendon Laboratory, University of Oxford, Oxford, UK — [4]Imperial College London, London, UK

Atomic clocks based on neutral strontium have now reached both accuracies and stabilities at the 10^{-18} level. The accuracy is currently limited by the uncertainty of the blackbody radiation (BBR) shift in neutral strontium at room temperature. Improved measurements of the strontium $5s4d$ ^{3}D$_1$ lifetime, which contributes to 98% of the uncertainty in the dynamic correction term to the BBR shift, will lead to a further reduction of the overall systematic uncertainty in room temperature strontium lattice clocks. I will present an update on the status of the strontium lattice clock at NPL as well as measurements we have made of the ^{3}D$_1$ state lifetime.

A 17.4 Tue 15:15 P/H1

Miniaturised optical lattice clock — •Ole Kock, Wei He, Lyndsie Smith, Dariusz Swierad, Qasim Ubaid, Sruthi Viswam, Yeshpal Singh, and Kai Bongs — University of Birmingham (UoB), Edgbaston, Birmingham B15 2TT, UK

A major scientific development over the last decade, namely clocks based on optical rather than microwave transitions, has opened a new era in time/frequency metrology. Several Physics Nobel prizes (1997, 2001, 2005, 2012) were awarded for methods that have enabled optical clocks showing the significance of their development. Optical clocks have now achieved a performance significantly beyond that of the best microwave clocks, down to a fractional frequency inaccuracy of $1.6 \cdot 10^{-18}$. The advances in this field open up a multitude of new applications. One can envision optical clocks improving the accuracy of GNSS receivers and the resilience of high speed communication networks as well as enabling the operation of a master clock in space. For such endeavours great work has to be done to miniaturise optical clocks and increase their robustness. I will present our design of a portable miniaturised optical lattice clock which aims at a stability of one part in 10^{16} or better. As part of the miniaturisation efforts a novel method of a very compact atomic source which greatly reduces effects of the blackbody shift on the clock transition and new technologies for a miniature self-contained vacuum chamber will be introduced.

A 17.5 Tue 15:30 P/H1

Magic wavelength for the clock transition in Magnesium-24 — •Dominika Fim, André Kulosa, Steffen Rühmann, Klaus Zipfel, Nandan Jha, Steffen Sauer, Wolfgang Ertmer, and Ernst M. Rasel — Gottfried Wilhelm Leibniz Universität

For this purpose we trap 10^4 magnesium-24 atoms in a power enhanced linear optical lattice near the magic wavelength. We succeeded to directly excite the spin forbidden clock transition $^1S_0 \rightarrow {}^3P_0$ by using the magnetic field induced spectroscopy [1]. The interrogation laser has an instability of $5 \cdot 10^{-16}$ at 1 s. A spectroscopy of the blue and red sideband and the carrier give access to important parameters. First, a measurement of the shift of the carrier frequency as a function of trap depth gives insight in the differential AC stark shift. Here from we could determine the magic wavelength to 468.4(0.1) nm which is in a good agreement with theoretical calculations. By means of the difference in height of the sidebands we could evaluate the temperature of the atoms to 7 μK.
Currently, we are investigating systematic shifts of the clock transition (e.g. 2nd order Zeeman shift).

[1] A. V. Taichenachev et al., Phys. Rev. Lett. 96, 083001 (2006)

A 17.6 Tue 15:45 P/H1

Optical Bloch band spectroscopy with laser cooled magnesium atoms — •André Kulosa, Steffen Rühmann, Dominika Fim, Klaus Zipfel, Nandan Jha, Steffen Sauer, Wolfgang Ertmer, and Ernst Rasel — Leibniz Universität Hannover, Institut für Quantenoptik, Hannover

Here we report on optical Bloch band spectroscopy of laser cooled magnesium atoms trapped in a magic wavelength lattice. Phenomena observed with atoms in lattices show close analogies to those known for electrons in solid state physics as the periodic light field potential can be directly related to a periodic crystal structure. Moreover, tunneling between the lattice sites leads to delocalization of atoms with a resulting band structure in the atomic energy spectrum. We employ spectroscopy of the band structure to gather information about the atomic polarizabilities of the involved electronic states.

Atoms are probed on the spin-forbidden $^1S_0 \rightarrow {}^3P_0$ clock transition at 458 nm with a spectroscopic linewidth of about 3 kHz. Lowering the trap depth to less than 10 recoil energies, we expect a bandwidth resulting from the energy dispersion of the lower and upper band to be larger than the spectroscopic linewidth and a line shape reflecting the band structure of the lower and upper electronic state. For an increasing trap depth and as a consequence a decreasing ground state bandwidth, we see the corresponding decreasing in the carrier frequency shift as it has been postulated by P. Wolf and P. Lemonde [1].

[1] P. Lemonde and P. Wolf, *Phys. Rev. A* **72**, 033409 (2005)

A 17.7 Tue 16:00 P/H1

Precision isotope shift measurements of calcium ions using photon recoil amplification schemes — •F. Gebert[1], Y. Wan[1], J. C. Heip[1], F. Wolf[1], J. Berengut[2], and P. O. Schmidt[1,3] — [1]QUEST Institut, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig — [2]School of Physics, University of New South Wales, Sydney — [3]Institut für Quantenoptik, Leibniz Universität Hannover

We present isotope shift measurements of the $^2D_{3/2}$-$^2P_{1/2}$ and $^2S_{1/2}$-$^2P_{1/2}$ transitions in calcium ions using the photon recoil spectroscopy technique (PRS). In PRS, a spectroscopy ion is trapped and sympathetically cooled by a cooling ion. Photon recoil from absorption on a spectroscopy transition results in motional excitation probed by the cooling ion using quantum logic techniques. In a new approach single-photon repumping from the meta-stable $^2D_{3/2}$ state via the $^2D_{3/2}$-$^2P_{1/2}$ transition serves as the spectroscopy signal, which is efficiently translated into motion of the two ion crystal, through amplification via recoil from absorption of photons resonant with the $^2S_{1/2}$-$^2P_{1/2}$ transition. The residual motional ground state population is then probed using a stimulated Raman adiabatic passage pulse driving a motional sideband on the 25Mg+ logic ion. We present isotope shift measurements using the new technique with an accuracy improved by up to two orders of magnitude. We performed a multidimensional King plot analysis and extracted important nuclear constants from the optical data.

A 17.8 Tue 16:15 P/H1

Suppressing high-frequency noise in phase-locks to fiber frequency combs — •Nils Scharnhorst, Jannes B. Wübbena, Stephan Hannig, Ian D. Leroux, and Piet O. Schmidt — QUEST Institute of Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt and Leibniz Universität Hannover, Bundesallee 100, D-38116 Braunschweig, Germany

We demonstrate a high-bandwidth transfer-lock scheme which is capable of transferring short-term stability from a stable master laser to an otherwise free-running diode laser at 729 nm via a frequency comb.

Limited by the intrinsic noise of the comb at high Fourier-frequencies and the available feddback bandwidth, we synthesize a virtual beat signal for the 729 nm laser in which the effect of the comb noise is suppressed by microwave feed-forward electronics, a so-called transfer-oscillator lock [1], circumventing a tight comb lock.

By eliminating the need for auxiliary reference cavities for laser prestabilization at each wavelength, this capability allows a substantial simplification of experimental setups requiring multiple stable lasers, such as high-accuracy frequency standards based on quantum logic spectroscopy, experiments in Rydberg spectroscopy, or coherent photoassociation and control of molecules with Raman pulses.

[1] J.Stenger et al., Phys. Rev. Lett. **88**, 073601 (2002)

A 18: Poster: Ultra-cold atoms, ions and BEC (with Q)

Time: Tuesday 17:00–19:00 Location: C/Foyer

A 18.1 Tue 17:00 C/Foyer

Interacting bosons in an optical cavity — •Dandan Su[1], Yongqiang Li[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Department of Physics, National University of Defense Technology, Changsha 410073, People's Republic of China

We numerically simulate strongly correlated ultracold bosons coupled to a high-finesse optical cavity. Assuming that a weak classical optical lattice is added in the cavity direction, we describe this system by a generalized Bose-Hubbard model, which is solved by means of bosonic dynamical mean-field theory. For a single-mode cavity, pumped by a laser beam in the transverse direction, the complete phase diagram is established, which contains two novel self-organized quantum phases, lattice supersolid and checkerboard solid, in addition to conventional phases such as superfluid and Mott insulator [1]. At finite but low temperature, thermal fluctuations are found to enhance the buildup of these self-organized phases. We demonstrate that cavity-mediated long-range interactions can give rise to stable lattice supersolid and checkerboard solid phases even in the regime of strong s-wave scattering. In the presence of a harmonic trap, we discuss the coexistence of these self-organized phases, as relevant to experiments. Furthermore, we investigate a system of bosons coupled to two crossed cavity modes, whose axes' angle is 60 degree. We study self-organization phenomena in the resulting hexagonal lattice.

[1] Yongqiang Li, Liang He, and Walter Hofstetter, Phys. Rev. A 87, 051604(R) (2013).

A 18.2 Tue 17:00 C/Foyer

Realizing a hybrid atom-ion trap for Li and Yb^+ — •Jannis Joger, Henning Fürst, Norman Ewald, and Rene Gerritsma — Institut für Physik, Johannes Gutenberg-Universität, D-55099 Mainz, Germany

Mixtures of ultracold atomic gases and trapped ions have become a promising application for studying cold chemistry, ultra-cold collisions and quantum many-body physics [1]. Recent analysis has shown that the time-dependent trapping field of the Paul trap can cause heating in these systems. One proposed way to mitigate this problem is to employ ion-atom combinations with a large mass ratio [2]. The highest convenient mass ratio - for species that still allow for straightforward laser cooling - is $\sim$29, and is achieved by using the combination Yb^+ and Li. Combining ultracold Li atoms with trapped ions poses particular technical challenges. Also the application of different sub-Doppler cooling techniques for Li such as gray molasses [3] is of particular importance to produce a dense gas in the deep quantum regime. We present a hybrid atom-ion experiment for Yb^+ and Li that we are currently building up. We discuss the magnetic field coils, ion trap and dipole trap, as well as the Zeeman slower and atomic loading platform. We also introduce a two-ion-atom detector we plan to implement in the experiment.

[1] A. Härter and J. Hecker Denschlag, Contemporary Physics 55, 33 (2014)

[2] M. Cetina et al., Phys. Rev. Lett. 109, 253201 (2012)

[3] A. Grier et al., Phys. Rev. A 87, 063411 (2013)

A 18.3 Tue 17:00 C/Foyer

Ultracold bosons in lattices with long range hopping — •Jan Stockhofe[1] and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging

We study ultracold bosonic atoms in a tight-binding lattice with long range hopping terms. A helix lattice setup is proposed where such hoppings to far neighbors can be experimentally tuned to sizable values. In a first step, we discuss the noninteracting Bloch dynamics under the influence of a constant force [1]. A closed expression for the propagator is given, based on which we analyze the dynamics of initially Gaussian wave packets. Our findings capture the anharmonic Bloch oscillations recently observed in photonic zigzag lattices and furthermore provide a detailed quantitative description of the crossover between center of mass oscillations for wide wave packets and left-right symmetric width oscillations for narrow single site excitations. We then turn to on-site interaction effects within a bosonic mean field framework. The long range hopping in the ensuing discrete nonlinear Schrödinger model is demonstrated to severely affect the structural and stability properties of localized excitations, such as discrete breathers.

[1] J. Stockhofe, P. Schmelcher, arXiv:1411.2784 (2014).

A 18.4 Tue 17:00 C/Foyer

Degeneracy and inversion of band structure for Wigner crystals on a closed helix — •Alexandra Zampetaki[1], Jan Stockhofe[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

Constraining long-range interacting particles to move on a curved manifold can drastically alter their effective interactions. As a prototype we explore the structure and vibrational dynamics of crystalline configurations formed on a closed helix. We show that the ground state undergoes a pitchfork bifurcation from a symmetric polygonic to a zig-zag-like configuration with increasing radius of the helix.

Remarkably, we find that for a specific value of the helix radius, below the bifurcation point, the vibrational frequency spectrum collapses to a single frequency. This allows for an essentially independent small-amplitude motion of the individual particles and consequently localized excitations can propagate in time without significant spreading. Increasing the radius beyond the degeneracy point, the band structure is inverted, with the out-of-phase oscillation mode becoming lower in frequency than the mode corresponding to the centre of mass motion.

A 18.5 Tue 17:00 C/Foyer

Positive and negative quenches induced excitation dynamics for ultracold bosons in one-dimensional lattices — •Simeon Mistakidis[1], Lushuai Cao[1,2], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The correlated non-equilibrium dynamics of few-boson systems in one-dimensional finite lattices is investigated. Focusing on the low-lying modes of the finite lattice we observe the emergence of density-wave tunneling, breathing and cradle-like processes. In particular, the tunneling induced by the quench leads to a global density-wave oscillation. The resulting breathing and cradle modes are inherent to the local intrawell dynamics and related to excited-band states. Positive interaction quenches couple the density-wave and the cradle modes allowing for resonance phenomena. Moreover, the cradle mode is associated with the initial delocalization and following a negative interaction quench can be excited for incommensurate setups with filling larger than unity. For subunit and commensurate fillings it can be accessed with the aid of a negative quench of the optical lattice depth. Finally, our results shed light to possible controlling schemes for the cradle and the breathing modes in terms of the tunable parameters of the Hamiltonian. The evolution of the system is obtained numerically using the ab-initio multi-layer multi-configuration time-dependent Hartree method for bosons.

A 18.6 Tue 17:00 C/Foyer

A High-Resolution Imaging System for Ultracold Dysprosium Atoms — •Matthias Wenzel, Thomas Maier, Holger Kadau, Matthias Schmitt, Clarissa Wink, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Strongly dipolar quantum gases enable the observation of many-body phenomena with anisotropic, long-range interaction. Rotonic features, 2D stable solitons and the supersolid state are some of the exotic many-body phenomena predicted for dipolar quantum gases.

Recently quantum degeneracy of dysprosium, the element with the strongest magnetic dipole moment, was achieved. After preparation of a dysprosium condensate we plan to use a diffraction-limited custom objective with high numerical aperture for in-situ imaging. This allows to reveal the structure of the quantum gas on a sub-micron level. Combined with an electro-optical deflector system and a Pockels cell the objective is used to create tailored potentials. With this setup we want to investigate multi-well potentials [1] or ring-shaped potentials [2].

[1] D. Peter, K. Pawłowski, T. Pfau and K. Rzażewski, J. Phys. B, 45, 225302 (2012)
[2] M. Abad, M. Guilleumas, R. Mayol, M. Pi and D. M. Jezek, EPL, 94, 10004 (2011)

A 18.7 Tue 17:00 C/Foyer

Future prospects for trapping a single ion in Bose-Einstein condensates — •Kathrin Kleinbach, Karl Magnus Westphal, Michael Schlagmüller, Huan Nguyen, Fabian Böttcher, Tara Cubel Liebisch, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany

Creating hybrid systems of ions and neutral atoms is of great interest in order to study controlled collision and chemical processes in ultracold temperature regime. There has been exciting progress made with combining ion traps with neutral atom traps, but due to the micromotion of the ion in trap, the ultralow temperature regimes of these hybrid systems still remains out-of-reach. We propose two methods for realizing an ion-neutral hybrid system with Rydberg atoms excited in a Bose-Einstein condensate. The first approach is to excite a single Rydberg atom in the BEC and then promote it into a circular state with a radius on the order of $2\mu m$, via fast electric field pulses. The electron would then orbit outside of the BEC created with appropriate trap frequencies. The second approach would be to create the single Rydberg impurity in the BEC and then shine focused magic wavelength light on the Rydberg atom, thereby ionizing the electron and trapping the ion. The advantage of the second approach is that the ion could be held for long times and dragged through the BEC to sample various density regimes.

A 18.8 Tue 17:00 C/Foyer

Magnetic Quantum Phases of Ultracold Dipolar Gases in an Optical Superlattice — •Xiangguo Yin[1], Lushuai Cao[1,2], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging,Luruper Chaussee 149,D-22761 Hamburg, Germany

We propose an effective Ising spin chain constructed with dipolar quantum gases confined in a one-dimensional optical superlattice. Mapping the motional degrees of freedom of a single particle in the lattice onto a pseudo-spin results in effective transverse and longitudinal magnetic fields. This effective Ising spin chain exhibits a quantum phase transition from a paramagnetic to a single-kink phase as the dipolar interaction increases. Particularly in the single-kink phase, a magnetic kink arises in the effective spin chain and behaves as a quasi-particle in a pinning potential exerted by the longitudinal magnetic field. Being realizable with current experimental techniques, this effective Ising chain presents a unique platform for emulating the quantum phase transition as well as the magnetic kink effects in the Ising-spin chain and enriches the toolbox for quantum emulation of spin models by ultracold quantum gases.

A 18.9 Tue 17:00 C/Foyer

Out-of-equilibrium dynamics of two interacting bosons — •Tim Keller[1], Thomás Fogarty[1,2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Quantum Systems Unit, Okinawa Institute of Science and Technology Graduate University, Okinawa, Japan

Small systems of ultracold quantum gases are a leading candidate for studying interesting quantum phenomena in interacting many-body systems. To this end we study the out-of-equilibrium dynamics of two interacting bosons in a one-dimensional harmonic trap after a quench by a delta-shaped potential located in the centre of the trap. We make use of an approximate variational calculation called Lagrange-mesh method to solve the Schrödinger equation. We examine the dynamics by calculating the single particle density and calculate the correlations between the particles via the von Neumann entropy. We investigate the irreversibility of the quenched system by calculating the Loschmidt echo. This is related to the spectral function, with which one can discern distinct scattering states created by the quench and the emergence of the orthogonality catastrophe. We show that a thorough examination of the parameter space leads to the excitation of distinct separate or collective oscillations and also the creation of NOON states depending on the interaction and strength of the quench. We also show that the distribution of the Loschmidt echo over large time scales can be used to identify different distinct regimes, which are heavily dependent on the interaction strength between the atoms.

A 18.10 Tue 17:00 C/Foyer

Sympathetic cooling of OH$^-$-ions using Rb atoms in a MOT — •Stefan Paul[1], Bastian Höltkemeier[1], Henry Lopez[1], Pascal Weckesser[1], Matthias Weidemüller[1], Eric Endres[2], and Roland Wester[2] — [1]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Institut f. Ionenphysik und Angewandte Physik Universität Innsbruck Technikerstraße 25/3 A-6020 Innsbruck, Austria

We report on the current status of our experiment employing a hybrid atom-ion trap for investigating the interaction between OH$^-$ anions and rubidium atoms. The experimental configuration consists of an octupole rf ion trap with thin wires. The design provides a large field-free center as well as sufficient optical access to combine the ion trap with a magneto optical trap (MOT) for the atoms. The MOT can be extended to a Dark Spontaneous Force Optical Trap.

A 18.11 Tue 17:00 C/Foyer

Bose-Einstein condensation in a hybrid trap for photoionization experiments — •Harry Krüger[1], Bernhard Ruff[2,3], Maik Schröder[1], Jasper Krauser[1], Philipp Wessels[1,2], Juliette Simonet[1], Markus Drescher[2,3], and Klaus Sengstock[1,2] — [1]Zentrum für optische Quantentechnologien, Hamburg, Germany — [2]Centre for Ultrafast Imaging, Hamburg, Germany — [3]Institut für Experimentalphysik, Hamburg, Germany

Local photoionization of ultracold atoms shall offer insight into the coherence properties of a Bose-Einstein condensate (BEC). To access the corresponding quantum effects, we are setting up an experiment to observe correlations among electrons originating from a BEC ionized by a femtosecond laser pulse.

We present the design of our vacuum system consisting of a preparation and a science chamber with the atom transport provided by an optical tweezers approach. The transport is necessary because usual cooling techniques are difficult to implement in the science chamber where the particle detectors have to be shielded against stray fields. To realize quantum degeneracy in the preparation chamber, we perform forced evaporative cooling in a hybrid trap consisting of a magnetic quadrupole trap combined with a red-detuned optical dipole trap. We show experimental results for the evaporation efficiency and support these data by numerical simulations of the hybrid trap potential as well as the evaporation process itself.

A 18.12 Tue 17:00 C/Foyer

An analytical approach to confinement-induced resonances in multichannel collisions — •Benjamin Hess[1], Panagiotis Giannakeas[2], and Peter Schmelcher[1,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Department of Physics and Astronomy, Purdue University, West Lafayette, Indiana 47907, USA — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We perform an analytical investigation within the framework of generalized K Matrix theory of the scattering problem in tight isotropic and harmonic confinement allowing for open trap modes. The scattering behavior is explored for identical bosons and fermions, as well as for distinguishable particles, the main aspect being the confinement-induced resonances (CIR) which are attributed to different partial waves. In particular we present the unitarity bounds which emerge when considering a quasi one dimensional system. Unitarity bounds are also given for the transition coefficients, which show the limitations for efficient transversal de-excitations by means of CIRs. Furthermore, we analyze the CIR for d-waves and find the intriguing phenomenon of a strong transmission suppression in the presence of more than one open channel, which represents an interesting regime for the corresponding many-particle systems. The corresponding channel threshold singularities are studied and it is shown that these are solely determined by the symmetry class of the partial wave.

A 18.13 Tue 17:00 C/Foyer

Cavity-Optomechanics with Cold Atoms: Coupled Quantum Oscillators and Quantum Limited Force Sensing — •Nicolas Spethmann[1,2], Jonathan Kohler[1], Sydney Schreppler[1], Lukas Buchmann[1], and Dan Stamper-Kurn[1] — [1]University of California, Berkeley — [2]Universität Kaiserslautern

Cavity opto-mechanics with cold atoms provides a system with unique properties for studying quantum physics: Highly tunable and controllable oscillators, close to their thermal groundstate, with excellent isolation from the environment and quantum-limited optical detection.

The limit of sensitivity of a force measurement dictated by quantum mechanics, the standard quantum limit, is reached when measurement imprecision from photon shot-noise is balanced against disturbance from measurement back-action. To observe this quantum limit, we apply a known external force to the center-of-mass motion of an ultracold atom cloud in a high-finesse optical cavity. We achieve a sensitivity of $(42\pm13\text{yN})^2/\text{Hz}$, consistent with theoretical predictions and a factor of 4 above the absolute standard quantum limit.

The flexibility of our approach furthermore allows us to study cavity-optomechanics with multiple, coupled oscillators. We demonstrate cavity mediated coupling between two near-groundstate oscillators. We observe the oscillating coherent transfer of excitation between the oscillators. At the same time, we detect the motional noise of the oscillators to monotonously increase due to back-action caused by the coupling. Our results point to the potential, and also the challenge, of coupling quantum objects with light.

A 18.14 Tue 17:00 C/Foyer

Light induced spin-orbit coupling for ultracold neutral atoms — •Felix Kösel, Sebastian Bode, Holger Ahlers, Katerine Posso Trujillo, Naceur Gaaloul, and Ernst M. Rasel — Institut für Quantenoptik, Hannover, Germany

We present the status of our experiment for engineering 2D spin-orbit coupling [1] of a neutral Rubidium Bose-Einstein condensate. Using Raman transitions to couple cyclically three hyperfine Zeeman states of the atoms, an effective gauge field is predicted to be created which resembles the one occurring in spintronic systems [2]. Such an artificial interaction could be used to build advanced solid state simulators with non-Abelian character in a versatile cold-atom system.

[1] Y.-J. Lin, K. Jiménez-García, and I. B. Spielman, Nature (London) 471, 83-86 (2011).

[2] H. C. Koo et al., Science 325, 1515 (2009).

A 18.15 Tue 17:00 C/Foyer

Quench Dynamics of a Superfluid Fermi Gas in the BCS-BEC Crossover Regime — •Simon Hannibal[1], Peter Kettmann[1], Mihail Croitoru[2], Alexei Vagov[3], Vollrath Martin Axt[3], and Tilmann Kuhn[1] — [1]Institute of Solid State Theory, University of Münster — [2]Condensed Matter Theory, University of Antwerp — [3]Theoretical Physics III, University of Bayreuth

Ultracold Fermi gases in optical traps provide a unique system to study the many body physics of systems composed of fermionic constituents. Both, the BEC and the BCS superfluid state are observed in these systems. Furthermore, the transition between these two states is well controllable by means of a Feshbach resonance, which allows one to tune the interaction strength over a wide range from negative to positive scattering lengths. The divergence of this quantity marks the unitary point associated with the BCS-BEC crossover.

We calculate the dynamics of the BCS gap of a confined ultracold Fermi gas after a quantum quench, i.e., a sudden change of the coupling constant induced by switching the magnetic field. We show that the excitation induces an oscillation of the BCS gap which can be classified into the Higgs and Goldstone mode. Here we concentrate on the Higgs mode in the BCS-BEC crossover regime.

We find damped collective amplitude oscillations of the gap breaking down after a certain time. Afterwards rather irregular dynamics occur. The obtained frequencies are connected to the BCS gap and the size of the gas cloud. A linearization of the equations of motion is exploited to understand the origin of the observed behavior.

A 18.16 Tue 17:00 C/Foyer

Optimizing the production of RbCs ground-state molecules with high phase-space density — •Lukas Reichsöllner[1], Tetsu Takekoshi[1,2], Andreas Schindewolf[1], Silva Mezinska[1], Francesca Ferlaino[1,2], Rudolf Grimm[1,2], and Hanns-Christoph Nägerl[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation IQOQI, Innsbruck, Austria

Ultracold dipolar systems are of high interest for quantum chemistry, precision spectroscopy, quantum many-body physics, and quantum simulation. Our goal is the production of dipolar RbCs rovibronic ground-state molecules with full control of all degrees of freedom and with high phase-space density. We first produce two spatially separated BECs of Rb and Cs. We use an optical lattice similar to the work in Ref. [1] to prevent three-body loss to create a Cs Mott insulator (MI) with single occupancy while having Rb spatially separated and superfluid (SF). We tune the interspecies interactions by using an interspecies Feshbach resonance and we move Rb on top of Cs with the aim to form a pair state with exactly one Rb and one Cs atom at each lattice site. Feshbach association and STIRAP transfer drive the Rb-Cs precursor pairs into the rovibronic ground-state. We present our work on the STIRAP ground-state transfer [2] and show data of the coexisting Rb SF and Cs MI phase in the same optical lattice as well as the Rb transport and merging of the two ultracold ensembles.

[1] J.G. Danzl et al., Nature Physics 6, 265 (2010) [2] T. Takekoshi et al., Phys. Rev. Lett. 113, 205301 (2014)

A 18.17 Tue 17:00 C/Foyer

Towards the Fermi Quantum Microscope — •Katharina Kleinlein[1], Ahmed Omran[1], Martin Boll[1], Timon Hilker[1], Guillaume Salomon[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultracold atoms in optical lattices have proven to be a powerful tool for exploring a variety of phenomena in strongly correlated many-body systems. Its controllability and possibilities of probing its states allow for simulation of a wide range of phenomena occurring in solid-state systems. A new door for exploring those many-body states opened with the achievement of single-site resolved imaging of bosonic atoms in optical lattices. However, single-site resolution of fermionic atoms remains challenging. Here we report on the latest progress of our ^{6}Li machine aimed at achieving this goal. We load ultracold ^{6}Li into a far detuned (1064nm) 3D optical lattice with variable lattice geometry. The system is described by the Fermi-Hubbard Hamiltonian, yielding a rich phase diagram for investigation. A smaller scale, deep pinning lattice is superimposed onto the larger scale physics lattice, where Raman-sideband cooling is applied. The scattered photons of this process provide the detection signal, which will be collected using a high resolution microscope objective. We present insights and progress on this Raman-sideband cooling and detection technique, representing a possible key technology towards single-site resolved imaging of strongly-correlated fermionic many-body systems.

A 18.18 Tue 17:00 C/Foyer

Polaronic effects in one- and two-band quantum systems — •Tao Yin, Daniel Cocks, Karla Baumann, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt/Main, Germany

In this work we study the formation and dynamics of polarons in a system with a few latticed impurities immersed in a Bose-Einstein condensate (BEC). This system can be well described by a two-band model for the impurities, along with a Bogoliubov approximation for the BEC, with phonons coupled to impurities via both intra- and inter-band interaction. We decouple this Fröhlich-like coupling by an extended two-band Lang-Firsov polaron transformation using a variational method. The new effective Hamiltonian with two (polaron) bands differs from the original Hamiltonian by modified coherent transport, polaron energy shift and induced long-range interaction. Using Gutzwiller mean-field theory, we calculate the phase diagram and dynamics of this polaronic Hamiltonian in different dimension controlled by trapping lattice. An inhomogeneous system is also considered including BEC deformation from impurities, as well as a tilted optical lattice.

On the other hand, in order to focus on decoherence and relaxation effects, motivated by recent experiments, we specify our system as single impurity trapped in a quasi-1D system. Within a Lindblad master equation we take into account residual incoherent coupling between polaron and bath. Under this polaronic treatment, the inter-band relaxation process leads to a description of impurity dynamics beyond Fermi's Golden Rule.

A 18.19 Tue 17:00 C/Foyer

Experimental realization of the ionic Hubbard model on a honeycomb lattice with ultracold fermions — Michael Messer, •Rémi Desbuquois, Thomas Uehlinger, Gregor Jotzu, Frederik Görg, Daniel Greif, Sebastian Huber, and Tilman Esslinger — ETH Zurich, Zurich, Switzerland

Ultracold atoms in optical lattices constitute a tool of choice to realize the Fermi-Hubbard model. There, the on-site interaction energy opens a gap in the charge excitation spectrum, leading to a Mott insulating ground state. However, in the ionic Hubbard model, the addition of a staggered energy offset on each lattice site also leads to an insulating ground state with charge-density-wave ordering, even in the absence of inter-particle interactions. In our experiment we realize the Ionic Hubbard model on a honeycomb lattice by loading a two-component interacting Fermi gas into an optical lattice with a staggered energy offset on alternating sites. The underlying density order of the ground state is revealed through the correlations in the noise of the measured momentum distribution. For a large energy offset, we observe a charge-density-wave ordering, which is suppressed as the on-site interactions are increased. To further elucidate the nature of the ground state, we measure the double occupancy of lattice sites and the charge excitation spectrum for a wide range of parameters.

A 18.20 Tue 17:00 C/Foyer

Nonlinear tunneling in a Rydberg-dressed optical lattice — •Laura Gil and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Dresden

We study ultra-cold atoms in an optical lattice that are off-resonantly excited to a high-lying Rydberg state. This Rydberg dressing is known to lead to tunable effective interactions between ground state atoms. However, we find that the motional dynamics of virtually excited Rydberg pairs also gives rise to interaction-induced tunnelling terms. In contrast to the common one-body tunnelling, these terms are of nonlinear and highly nonlocal nature. We discuss conditions for the most interesting case in which nonlocal interactions and tunnelling effects become comparable and explore its consequences for the resulting extended Bose-Hubbard model.

A 18.21 Tue 17:00 C/Foyer

Trapping of Topological Defects in Coulomb Crystals — •Philip Kiefer[1], Jonathan Brox[1], Ulrich Warring[1], Daniel Suess[2], Haggai Landa[3], David Gross[2], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Quantum correlations, Physikalisches Institut, Universität Freiburg, Rheinstr. 10, 79104 Freiburg — [3]LPTMS, Université Paris Sud, Orsay, France

We study structural defects (kinks) which are formed during the transition from a laser cooled cloud of Mg-Ions to a Coulomb crystal, consisting of more than 50 ions in a linear radiofrequency trap [1]. Simulations reveal a strong anharmonicity of the kink's internal mode of vibration, further enhanced bye the controlled extension into three dimensions. As a consequence, the periodic Peierls-Nabarro potential experienced by a discrete kink becomes a globally confining potential, capable of trapping defects at the center of the crystal.

The formation of kink configurations and the transformation of kinks between different structures in dependence on the trapping parameters are investigated. We present configurations of pairs of interacting kinks stable for long times [2], as well as a concept for fast detection and conditional manipulation.

[1] M. Mielenz et al., Phys. Rev. Lett. **110**, 133004 (2013)
[2] H. Landa et al., New J. Phys. **15**, 093003 (2013)

A 18.22 Tue 17:00 C/Foyer

Towards Sub-Doppler Cooling of Discrete Solitons inside Coulomb Crystals — •Jonathan Brox[1], Philip Kiefer[1], Haggai Landa[2], Ulrich Warring[1], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]LPTMS, Université Paris Sud, Orsay, France

We study structural defects (kinks) which are formed during the transition from a laser cooled cloud of Mg-Ions to a Coulomb crystal [1]. Via tuning the ratio of the trapping frequencies we are able to shape the kink's structure [2]. Ion crystals with such structural defects feature a gapped mode in the spectrum of phonons. Since the gap separation of the latter is nearly independent of the crystal size, this approach could be particularly useful for producing entanglement and studying system-environment interactions in large, two- and possibly three-dimensional systems[3].

We discuss first concepts on the experimental realisation of subdoppler cooling based on two photon transitions in combination with topological defects.

[1] M. Mielenz et al., Phys. Rev. Lett. **110**, 133004 (2013)
[2] H. Landa et al., New J. Phys. **15**, 093003 (2013)
[3] H. Landa et al., Phys. Rev. Lett. **113**, 053001 (2014)

A 18.23 Tue 17:00 C/Foyer

Quantum Point Contacts for Strongly Interacting Fermions — •Sebastian Krinner, Dominik Husmann, Martin Lebrat, Charles Grenier, Jean-Philippe Brantut, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland

We extend the concepts of quantum simulation to device-like structures connected to atomic reservoirs. We use high-resolution microscopy to write tiny structures, such as a quantum point contact (QPC). The connected reservoirs allow us to measure transport in direct analogy to solid-state physics experiments, where transport measurements constitute an extremely sensitive tool to detect many-body effects. Here we study transport through a QPC in the normal, strongly interacting and superfluid regime. The system thereby goes smoothly from a regime exhibiting quantized conductance to a regime showing nonlinear I-V characteristics.

A 18.24 Tue 17:00 C/Foyer

Ba^+ and Rb laser system for ultracold chemistry experiments — •Georg Hoppe, Leon Karpa, Alexander Lambrecht, Julian Schmidt, and Tobias Schaetz — Albert-Ludwigs-Universität Freiburg

Our experimental setup is designed for the study of ultracold collisions [1] between Barium ions and Rubidium atoms in a BEC.

To reach the ultracold regime we first trap a Barium ion in a linear rf-Paul trap, where it's prepared and Doppler cooled to temperatures of millikelvin. We then transfer the ion into an optical trap [2] to avoid rf-induced heating effects [3]. As next step Rubidium atoms will be used to sympathetically cool the ion to reach the ultracold temperature regime.

I will present our laser systems for cooling and preparation of the ions and atoms. The most important among them are the lasers for Doppler cooling (493nm, 780nm), repumping (650nm) and photoionisation (413nm), which is stabilized with a cavity. Additionally, we designed a diode laser at 780nm [4] as a Rubidium imaging system.

[1] M. Krych et al., Phys. Rev. Lett. 83, 032723 (2011)
[2] T. Huber et al., Nat. Commun. 5 (2014)
[3] A.T. Grier et al., Phys. Rev. Lett. 102, 223201 (2009)
[4] L. Ricci et al., Optics Commun., 117 (1995)

A 18.25 Tue 17:00 C/Foyer

Unbalanced homodyne detection for interaction-free measurements — •Jan Peise[1], Bernd Lücke[1], Luca Pezzé[2], Frank Deuretzbacher[3], Wolfgang Ertmer[1], Jan Arlt[4], Augusto Smerzi[2], Luis Santos[3], and Carsten Klempt[1] — [1]Leibniz Universität Hannover, Welfengarten 1, 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, Appelstraße 2, 30167 Hannover, Germany — [4]QUANTOP, Institut for Fysik og Astronomi, Aarhus Universitet, 8000 Arhus C, Denmark

Interaction-free measurements (IFMs) permit the detection of an object without the need of any interaction with it. Existing proposals for IFMs demand a single-particle source. Here, we realize a new many-particle IFM concept based on an indirect quantum Zeno effect in an unstable spinor Bose-Einstein condensate. For IFMs, it is necessary to discriminate between zero and a finite number of particles. We overcome this considerable experimental challenge by implementing an unbalanced homodyne detection for ultracold atoms. This new technique achieves single-particle sensitivity and serves as an important tool for future experiments in the field of quantum atom optics.

A 18.26 Tue 17:00 C/Foyer

Towards Ultracold Chemistry - Scattering of Ba+ and Rb in an optical dipole trap — •Alexander Lambrecht, Julian Schmidt, Georg Hoppe, Leon Karpa, and Tobias Schaetz — Albert-Ludwigs-Universitaet Freiburg

Examining collisions of atoms and ions at extremely low velocities permits to gain information about the corresponding scattering potentials and therefore of quantum effects in chemical reactions. In the last years several experimental groups investigated cold collisions between atoms and ions, leading to better understanding of the atom-ion interaction in many different aspects[1-3]. Our approach to reach the regime of ultracold collisions is to precool a barium+ ion, trapped in a conventional Radio-Frequency (RF) trap, by Doppler cooling followed by sympathetic cooling via an ambient rubidium MOT. By spatially overlapping the ion and the atom ensemble within a bichromatic optical dipole trap we overcome the limitations set by heating due to the RF micromotion[4]. We describe the experimental apparatus in its recent stage and the first experiments towards the simultaneous optical trapping of ions and atoms.

[1]A.T.Grier et al., Phys.Rev.Lett. 102,223201(2009)
[2]C.Zipkes et al., Nature 464, 388 (2010)
[3]W.G.Rellergert et al. , Phys.Ref.Lett. 107,243201 (2011)
[4]T.Huber et al., Nat. Comm. 5, 5587 (2014)

A 18.27 Tue 17:00 C/Foyer

Single Atom Detection in Ultracold Quantum Gases — •Carola Rogulj, Tobias Menold, Malte Reinschmidt, Peter Federsel, Markus Stecker, Hannah Schefzyk, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

Investigating quantum gases beyond the mean field approach, has become one of the main research topics in quantum-atom optics. Therefore, single atom detection techniques have to be developed, which allow for measuring statistics and correlations in ultracold quantum gases.

Our approach uses a state- and energy-selective ionization scheme, to realize a time-resolved single atom detector. We demonstrate the performance of this detector, by measuring dynamical processes, like center-of mass oscillations or shape oscillations, in real-time with high detection efficiency. This way, we demonstrate force spectroscopy and measure the energy distribution of trapped quantum gases in-situ. Having access to temporal correlations, we realize noise-spectroscopy on ultracold quantum gases, which proof the detection scheme to be suitable for realizing quantum galvanometer [1].

To extend the single atom detection to the spatial regime, we develop a novel high resolution ion microscope, which allows for magnifications up to 1000 and spatial resolution below the optical diffraction limit. We present both, the simulations and the first experimental realization of such a time- and space-resolved single atom detector.

[1] Kalman et al., Nano Letters 12, 435-439 (2012)

A 18.28 Tue 17:00 C/Foyer

High efficiency demagnetization cooling by suppression of light-assisted collisions — •Jahn Rührig, Tobias Bäuerle, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, Stuttgart, 70569 , Germany

Demagnetization cooling [1] utilizes dipolar relaxations [2] that couple the internal degree of freedom (spin) to the external (angular momentum) in order to cool an atomic cloud efficiently [3,4]. Optical pumping into a dark state constantly recycles the atoms that were promoted to higher spin states. The net energy taken away by a single photon is very favorable since the lost energy per atom is the Zeeman energy rather than the recoil energy. As the density of the atomic sample rises the inherent involvement of the photons leads to limiting processes. In our previous publication [5] we have shown that light-assisted collisions are such an important limiting process. We present latest results on the suppression of light-assisted collisions in ^{52}Cr by detuning the optical pumping light such that the Condon point coincides with the first node of the ground state wave function of two colliding atoms [6]. This leads to an increased cooling efficiency $\chi \geq 17$ as well as to increased maximum densities of $n \approx 1 \cdot 10^{20} m^{-3}$.

[1]:A. Kastler, Le Journal de Physique et le Radium 11, 255 (1950).
[2]:S. Hensler et al. , Appl.Phys.B 77, 765 (2003).
[3]:S. Hensler et al. , Europhys. Lett. 71,918 (2005).
[4]:M. Fattori et al. , Nature Physics 2, 765 (2006).
[5]:V. Volchkov et al. , Phys. Rev. A 89, 043417 (2014).
[6]: K. Burnett et al. , Phys. Rev. Lett. 77, 1416-1419 (1996).

A 18.29 Tue 17:00 C/Foyer

Cold atoms near superconductors: Towards coherent coupling in a hybrid quantum system — •Helge Hattermann, Lörinc Sárkány, Patrizia Weiss, Daniel Bothner, Matthias Rudolph, Benedikt Ferdinand, Simon Bernon, Reinhold Kleiner, Dieter Koelle, and József Fortágh — CQ Center for Collective Quantum Phenomena and their Applications, Physikalisches Institut Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

We describe an experimental system combining Bose-Einstein condensates and superconducting atom chips at 4.2 K. We demonstrate the coherent state manipulation of atoms at the superconducting chip [1], the generation of noise protected clock states [2] and the design and implementation of superconducting coplanar waveguide cavities. In addition, we present experimental results on the mapping of the flux state in a superconducting ring onto an ensemble of cold atoms.

[1] S. Bernon *et. al.*, Nat. Commun. **4**, 2380 (2013)
[2] L. Sárkány *et. al.*, Phys. Rev. A **90**, 053416 (2014)

A 18.30 Tue 17:00 C/Foyer

Interference of ultracold Bose gases — •Holger Hauptmann, Sigmund Heller, and Walter T. Strunz — Technische Universität Dresden

We study equilibrium and dynamical aspects of ultracold quasi one-dimensional Bose gases with repulsive self interaction. To describe Bose gases in the canonical ensemble (fixed particle number) a non-linear stochastic matter-field equation will be presented. Applications of this equation to interference experiments from the Schmiedmayer group [1] will be shown. Moreover to study dynamical properties, it is necessary to create two correlated quasi one-dimensional cigar-shaped Bose gases. We present a stochastic splitting mechanism which simulates the tearing of one quasi one-dimensional cigar-shaped gas along the logitudinal axis into two Bose gases. Applications to dynamical interference experiments [1] exhibit good agreement.

A 18.31 Tue 17:00 C/Foyer

Toward cold atom mixture of lithium and caesium — •Pierre Jouve — University of Nottingham, United Kingdom

Ultracold mixtures hold the promise of understanding new phases of matter and collisions at very low energies. We are setting up an experiment for bose-fermi mixtures of lithium and caesium, which are especially well suited to study impurities, transport, solitons or mixtures in optical lattices. These species are appealing because they offer favourable interactions properties and can be manipulated independently of each other due to their different resonance frequencies. Here we present the current status of our experiment. We detail the cooling schemes for the two atomic species and include the development and optimal loading of an optical dipole trap. We have constructed a two-species Zeeman slower for subsequent loading of lithium and caesium. We are also investigating ways to couple cold and ultracold caesium atoms to photons delivered through a waveguide. In principle such a light-matter interface can act as a building block for photon storage, optical switching or quantum computational tasks [1]. This work is funded by an EU-FET- young explorers project and includes researchers from the University of Vienna, Dresden, Jena and Nottingham.

A 18.32 Tue 17:00 C/Foyer

Phase-Imprinting through Rydberg Dressing — Rick Mukherjee[1], Cenap Ates[2], Weibin Li[2], and •Sebastian Wüster[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, German — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

We show how the phase profile of Bose-Einstein condensates can be engineered through its interactions with suitably placed Rydberg excitations. The interaction is made controllable and long-range by off-resonantly coupling the condensate to another Rydberg state as in [1], which will dominate over direct interactions between condensate atoms and Rydberg electrons [2].

Our technique allows the mapping of entanglement generated in systems of few strongly interacting Rydberg atoms onto much larger atom clouds in hybrid setups. As an example we discuss the creation of a spatial mesoscopic superposition state from a bright soliton. Additionally, the phase imprinted onto the condensate using the Rydberg excitations can be used to infer the locations of the latter. We investigate the resulting link between condensate momentum distributions and different embedded Rydberg crystal patterns.

[1] N. Henkel *et al.* Phys. Rev. Lett. **104**, 195302 (2010).
[2] J. B. Balewski *et al.* Nature **502**, 664 (2013)

A 18.33 Tue 17:00 C/Foyer

Single shot realization and characterization of multiple quantum phase transitions — •Robert Heck, Romain Müller, Aske R. Thorsen, Mario Napolitano, Mark G. Bason, Jan Arlt, and Jacob F. Sherson — Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, 8000 Aarhus C, Denmark

Local manipulation of ultracold atomic clouds with optically induced micropotentials has in recent years become a versatile tool. Among others, they have been used for efficient BEC creation using the so-called dimple approach [1, 2], to form arbitrarily shaped traps [3], and recently to address single atoms in an optical lattice [4].

We present our setup for creating time-averaged potentials with a strongly focused laser beam. In analogy with previous work [2], we have demonstrated up to 30 consecutive, conservative crossings of the phase transition to a BEC. Here, however, we combine the approach with high-resolved QND imaging to enable the continuous characterization of the dynamics. This allows us to investigate online the evolution of the in-situ cloud across the transition. Next steps will be the single-shot detection of entire phase diagrams and investigations of the stochastic nature of condensation dynamics during the formation of a BEC.

Finally, our setup allows for the simultaneous loading of several micro traps. The coherence properties of these has been verified by the observation of interference in ballistic expansion.

[1] P. Pinkse et al., PRL **78**, 990 (1997); [2] D. Stamper-Kurn et al., PRL **81**, 2194 (1998); [3] K. Henderson et al., NJP **11**, 043030 (2009); [4] C. Weitenberg et al., Nature **471**, 319 (2011)

A 18.34 Tue 17:00 C/Foyer

Linear to zigzag transition in dipolar chains — •Florian Cartarius[1,2,3], Anna Minguzzi[2,3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Laboratoire de Physique et Modélisation des Milieux Condensés, Université Grenoble Alpes, F-38000 Grenoble, France — [3]Laboratoire de Physique et Modélisation des Milieux Condensés, CNRS, F-38000 Grenoble, France

In very anisotropic confinement cold dipolar particles can arrange in linear chains. By relaxing the transverse confinement these chains split into a zigzag structure. We consider a chain of dipolar bosons superimposed by an optical lattice, where the particles can tunnel from one site to the next. In deep optical lattices the coupling to the axial phonons can be neglected and it is possible to describe the behaviour of the system by two coupled extended Bose-Hubbard Hamiltonians close to the transition [1]. We present the solution of this model using a path integral Monte Carlo method.

[1] Pietro Silvi, Tommaso Calarco, Giovanna Morigi, Simone Montangero, Phys. Rev. B 89, 094103 (2014)

A 18.35 Tue 17:00 C/Foyer

Towards Nanofiber-Based Quantum Networks — •Jakob Hinney, Christoph Clausen, Adarsh Prasad, Philipp Schneeweiss, Jürgen Volz, and Arno Rauschenbeutel — VCQ, TU Wien, Atominstitut, Stadionallee 2, 1020 Wien, Austria

In a new project, we plan to establish nanofiber-based atom-light interfaces as quantum-enabled fiber-optical components for quantum in- formation processing and communication. The key ingredient is a nanofiber-based optical dipole trap which stores cold atoms in the evanescent field around the nanofiber [1,2]. In this evanescently coupled atom-waveguide-system, even a few hundred atoms are already optically dense for near-resonant photons propagating through the nanofiber. The first goal of this project is to realize efficient quantum memories which allow one to directly store and retrieve the quantum state of fiber-guided photons. Furthermore, nanofiber-coupled atoms can provide a strong optical non-linearity. The second goal of this project is to explore and to maximize this non-linearity until it prevails down to the single photon level. This would then enable optical quantum switches and photon-photon quantum gates which are essential for implementing deterministic optical quantum computation. The final goal is to interconnect these components in order to demonstrate different quantum network applications, such as highly efficient photon counting, heralded entanglement of two fiber-coupled quantum memories, and a non-linear interaction between two single-photon pulses. [1] E. Vetsch et al., Phys. Rev. Lett. 104, 203603 (2010). [2] D. Reitz et al., Phys. Rev. Lett. 110, 243603 (2013).

A 19: Precision Measurements and Metrology V (with Q)

Time: Wednesday 11:00–12:30 Location: C/HSO

A 19.1 Wed 11:00 C/HSO

Compact mode-locked diode laser system for high precision frequency comparison experiments in space — •Heike Christopher[1,2], Evgeny Kovalchuk[1,2], Andreas Wicht[1,2], Götz Erbert[2], Günther Tränkle[2], and Achim Peters[1,2] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik Berlin

We present a compact mode-locked diode laser system designed to generate an optical frequency comb in the wavelength range around 780 nm. It will be used for precision experiments in space which will test the universality of free fall (UFF) by employing light pulse atom interferometry for rubidium and potassium ultra-cold quantum gases.

The passively mode-locked extended-cavity diode laser contains an AlGaAs ridge-waveguide diode chip, collimation aspheric micro-optics, and an external nearly zero group velocity dispersion (GVD) dielectric mirror. Reverse biasing a short section of the two section laser diode enables the passive mode-locking process. Highly stable pulse performance is realized at a repetition rate of about 4 GHz where a free running full-width-at-half-maximum (FWHM) RF linewidth of about 100 Hz (resolution bandwidth 50 Hz) was achieved. We present the current status of our work and discuss options for further improvements, e.g. extending the wavelength range and active stabilization of the repetition rate.

This project is supported by the German Space Agency DLR, with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant numbers 50WM1237-1240.

A 19.2 Wed 11:15 C/HSO

Frequency stabilized laser systems for sounding rockets - towards precision measurements in space. — •Vladimir Schkolnik[1], Max Schiemangk[1,2], Aline Dinkelaker[1], Achim Peters[1,2], The LASUS Team[1,2,3,5], and The KALEXUS Team[1,2,4,5] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]FBH Berlin — [3]ILP Hamburg — [4]JGU Mainz — [5]IQO Hannover

Lasers with stable and accurate output frequencies are the key element in high precision experiments such as atom interferometers and atomic clocks. Moreover, future space missions, including quantum based tests of the equivalence principle or the detection of gravitational waves, require such robust and compact lasers with high mechanical and frequency stability.

We present two laser systems that fulfill these requirements. First, a micro-integrated distributed feedback laser (DFB) stabilized to a rubidium transition which will operate together with a frequency comb on the TEXUS 51 sounding rocket mission scheduled for April 2015. The second laser system contains two narrow linewidth extended cavity diode lasers (ECDLs) for potassium spectroscopy, including a redundancy architecture for reliable operation. The system will be integrated together with control and driver electronics within a pressurized payload module and operate autonomously on the TEXUS 53 mission.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant numbers DLR 50WM 1237 and 1345.

A 19.3 Wed 11:30 C/HSO

Utilizing weak pump depletion to stabilize squeezed vacuum states — •Timo Denker[1], Maximilian H. Wimmer[1], Dirk Schütte[1], Trevor A. Wheatley[2], Elanor Huntington[3], and Michèle Heurs[1] — [1]Albert-Einstein-Institut (Max-Planck-Institut für Gravitationsphysik), Hannover, Deutschland — [2]The University of New South Wales, Canberra, Australia — [3]The Australian National University, Canberra, Australia

We propose and demonstrate a pump-phase locking technique that makes use of weak pump depletion (WPD) – an unavoidable effect that is usually neglected – in a sub-threshold optical parametric oscillator (OPO). We show that the phase difference between seed and pump field is imprinted on pump and seed light by the non-linear interaction in the crystal and can be read out without disturbing the squeezed output. In our experimental setup the input of the OPO is 0.55 mW of 1064 nm and it is pumped with 67.8 mW of 532 nm laser light to observe squeezing levels of 1.96±0.0085 dB, with an antisqueezing level of 3.78 ± 0.0150 dB. Our new locking technique allows the first experimental realisation of a pump-phase lock by read-out of the phase information pre-existing in the pump field. There is no degradation of the detected squeezed states.

A 19.4 Wed 11:45 C/HSO

Line-shape manipulation for x-ray frequency-comb generation — •Stefano M. Cavaletto, Zuoye Liu, Zoltan Harman, Christian Ott, Christian Buth, Thomas Pfeifer, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Optical frequency combs had a revolutionary impact on precision spectroscopy and metrology. This was recently enabled at extreme-ultraviolet frequencies via methods based on high-harmonic generation (HHG). We put forward a three-level Λ-type scheme in which the absorption spectrum of a short pulse, tuned to an x-ray transition, is manipulated by an optical-frequency-comb laser which couples the excited state to a nearby level [S. M. Cavaletto *et al.*, *Nature Photonics* **8**, 520 (2014)]. The comb structure displayed by the x-ray absorption spectrum might eventually represent an alternative scheme for x-ray frequency-comb generation, overcoming the limitations of present HHG-based methods. We then present related line-shape-manipulation schemes in rubidium atoms, whose $5s\,^2S_{1/2} \rightarrow 5p\,^2P_{1/2}$ (794.76 nm) and $5s\,^2S_{1/2} \rightarrow 5p\,^2P_{3/2}$ (780.03 nm) transitions are simultaneously excited by pump/probe optical pulses centered at 780 nm. We model the atomic system via a three-level V-type scheme, in order to connect the absorption line shape of the two excited transitions for different time delays to the quantum evolution (in amplitude and phase) of the atomic state.

A 19.5 Wed 12:00 C/HSO

Frequency comb-based heterodyne many-wavelength interferometry — •Jutta Mildner, Karl Meiners-Hagen, and Florian Pollinger — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig

Up-to-date long distance metrology in engineering, geodesy and surveying ask for relative measurement uncertainties of better than 10^{-7}. A promising tool to push optical-based measurement techniques into this regime are broadband optical frequency combs. In this contribution we want to present a novel concept of a comb-based many-wavelength interferometer in which a direct heterodyne phase detection of individual comb lines is aimed at. To this end a single fiber-based optical frequency comb with CEO-stabilization is used as a seed laser. By cavity filtering two coherent combs of different mode spacing are generated and subsequently used as local oscillator and measurement beam. Based on this scheme, a complete chain of synthetic wavelengths from the optical to the microwave range can be realized in theory, making full phase unwrapping possible without additional high accuracy information. Development and demonstration of a prototype filtering unit with tunable spacing will be presented, including simulations and experiments on positioning sensitivity. Furthermore, we want to discuss the deployed stabilization schemes as well as current progress on optimization measures. This project is performed within the joint research project SIB60 'Surveying' of the European Metrology Research Programme (EMRP). The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

A 19.6 Wed 12:15 C/HSO

Dispersive Qubit Measurement by Interferometry with Parametric Amplifiers — •Shabir Barzanjeh, David DiVincenzo, and Barbara Terhal — Institute for Quantum Information, RWTH Aachen University, 52056 Aachen, Germany

We perform a detailed analysis of how an amplified interferometer can be used to enhance the quality of a dispersive qubit measurement, such as one performed on a superconducting transmon qubit, using homodyne detection on an amplified microwave signal. Our modeling makes a realistic assessment of what is possible in current circuit-QED experiments; in particular, we take into account the frequency-dependence of the qubit-induced phase shift for short microwaves pulses. We compare the possible signal-to-noise ratios obtainable with (single-mode) SU(1,1) interferometers with the current coherent measurement and find a considerable reduction in measurement error probability in an experimentally-accessible range of parameters.

A 20: Interaction with strong or short laser pulses II

Time: Wednesday 11:00–13:00 Location: C/HSW

Invited Talk A 20.1 Wed 11:00 C/HSW

Strong-field ionization of molecules in circularly polarized fields — Ingo Petersen, Jost Henkel, and •Manfred Lein — Institut für Theoretische Physik, Leibniz Universität Hannover, 30167 Hannover

The electron momentum distribution from strong-field ionization of molecules contains rich information about the molecular electronic structure. Circularly polarized light is particularly advantageous because (i) it delivers a 360 degree scan of the molecule, (ii) the absence of recollisions makes the ionization process easier to interpret, and (iii) enantiomers of chiral molecules can be distinguished by exploiting photoelectron circular dichroism. Our calculations for diatomic and polyatomic molecules show that the width of the momentum distribution in the direction perpendicular to the polarization plane is a robust observable that is useful for imaging of aligned molecules. In particular, a strong variation of the width as a function of emission angle indicates contributions of multiple orbitals to the total ionization. For chiral molecules, we implement an extension of the strong-field approximation where the plane-wave continuum states are replaced by the Born approximation. The calculated distributions from a gas of randomly oriented molecules (using the examples camphor and fenchone) exhibit a forward-backward asymmetry as expected due to the dichroism effect, but they are not in quantitative agreement with recent experiments.

A 20.2 Wed 11:30 C/HSW

Wavelength and intensity dependent fragmentation of H_2^+ in the mid-infrared — •Wustelt P.[1,2], Möller M.[1,2], Rathje T.[1,2], Sayler A.M.[1,2], and Paulus G.G.[1,2] — [1]Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena, Germany — [2]Helmholtz Institute Jena, Germany

The wavelength and intensity dependent ultra-short laser-induced ionization and dissociation of an H_2^+ molecular ion beam target is measured at mid-infrared wavelength between 0.8 and 2.2 μm and at intensities up to 10^{16} W/cm^2. A three-dimensional coincidence imaging system allows kinematically complete coincidence measurements of both fragmentation channels and enables an unprecedented look into laser-driven fragmentation dynamics of the simplest molecule in strong mid-infrared laser fields.

A 20.3 Wed 11:45 C/HSW

Differential spectra for dissociative ionization of H_2^+ — •Volker Mosert and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

We compute and analyze correlated spectra for the dissociative ionization (DI) of the H_2^+ molecular ion using the tSURFF method. A low dimensional model of H_2^+ allows us too treat both nuclear and electronic degree of freedom exactly. In our TDSE simulations the molecular ion interacts with intense short laser pulses in the near IR regime. We find a pronounced modulation in the DI yield with respect to the kinetic energy of the protons. This modulation is almost independent of the electronic energy and could - erroneously - be attributed to vibrational excitations. However, by comparison with calculations for fixed internuclear distances the modulation can be traced back to an electronic interference effect that depends on the ionization potential.

A 20.4 Wed 12:00 C/HSW

Quantum Optimal Control of Photoelectron Spectra. — Esteban Goetz[1], Antonia Karamatskou[2], Robin Santra[2], and •Christiane Koch[1] — [1]Theoretische Physik, Kassel Universität, Kassel, Deutschland — [2]Center for Free-Electron Laser Science, Hamburg, Deutschland

Photoelectron spectra obtained in photoionization reveal information on charge transfert or hole coherence in the parent ion. Optimal control can be used to enhance certain desired features in the photoelectron spectrum. To this end, we combine Krotov's optimal control algorithm[1], time-dependent configuration-interaction singles formalism and the time-splitting method [2] for the calculation and optimization of photoelectron spectra.

The optimization target can be formulated to include specific desired properties in the angle-resolved photoelectron spectrum (PES) alone, in the energy-resolved PES, or both. As an example, we demonstrate our algorithm to maximize the difference between the number of electrons emitted into the upper hemisphere and the number of electrons emitted into the lower hemisphere for Argon.

[1] D. Reich, M. Ndong, and C.P. Koch, J. Chem. Phys. 136, 104103 (2012). [2] A. Karamatskou, S.Pabst, Yi-Jen Chen, and R. Santra, Phys. Rev. A 89, 033415 (2014).

A 20.5 Wed 12:15 C/HSW

Electron-correlation effects in laser-intensity dependent ionization processes observed by transient-absorption spectroscopy of helium atoms — •Andreas Kaldun, Veit Stooss, Christian Ott, Alexander Blättermann, Thomas Ding, Andreas Fischer, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

In our transient-absorption spectroscopy setup we simultaneously observe the line shapes of the singly-excited states of helium (1snp) and the doubly exited states of helium (sp$_{2,n+}$). Both line series are coherently excited by an attosecond-pulsed extreme-ultraviolet(XUV)field. A strong near-visible (VIS) laser pulse is co-propagating with the XUV. Both pulses overlap spatially and temporally. Scanning the intensity of the VIS laser pulse we observe different ionization thresholds for the uncorrelated (1snp) and correlated (sp$_{2,n+}$) electronic wave function, respectively. Several different ionization channels (direct photo ionization, autoionization, tunneling, barrier-suppressed ionization) complicate the situation.

A 20.6 Wed 12:30 C/HSW

In situ characterization of few-cycle laser pulses in transient absorption spectroscopy — •Alexander Blättermann[1], Chrsitian Ott[1,2], Andreas Kaldun[1], Thomas Ding[1], Martin Laux[1], Veit Stooss[1], Marc Rebholz[1], Maximilian Hartmann[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg , Germany — [2]Chemistry Department, University of California, 94720 Berkeley CA, United States

We demonstrate a method that allows to extract the pulse duration and intensity of few-cycle laser pulses directly from a measured extreme ultraviolet transient-absorption spectrum. Since we analyze the signature of the laser pulse interacting with the spectroscopy target, the pulse is characterized in situ. By doing so, we combine laser pulse characterization and strong-field driven quantum dynamics measurement in a single experiment. The precise knowledge of the driving laser pulse is important to fully understand the highly nonlinear optical response of quantum systems to strong laser fields.

A 20.7 Wed 12:45 C/HSW

Description of the hydrogen molecular ion with time-dependent renormalized-natural-orbital theory — •Adrian Hanusch, Julius Rapp, Martins Brics, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Time-dependent natural-orbital theory is a promising approach to overcome the "exponential wall" in solving time-dependent many-body quantum problems numerically. Time-dependent renormalized-natural-orbital theory (TDRNOT) has already proven good performance using an exactly solvable 1D Helium model atom. Highly correlated phenomena — not accessible via practicable time-dependent density functional theory — have been successfully described with TDRNOT [1-3]. In this work, we extend TDRNOT to investigate the hydrogen molecular ion exactly, i.e., beyond the Born-Oppenheimer approximation, and in intense laser fields. The correlation between electron and nuclear degree of freedom is taken into account by considering electronic and nuclear natural orbitals, and their coupling.

[1] M. Brics, D. Bauer, Phys. Rev. A 88, 052514 (2013).
[2] J. Rapp, M. Brics, D. Bauer Phys. Rev. A 90, 012518 (2014).
[3] M. Brics, J. Rapp, D. Bauer, Phys. Rev. A 90, 053418 (2014).

A 21: Ultra-cold plasmas and Rydberg systems II (with Q)

Time: Wednesday 11:00–12:45 Location: C/kHS

A 21.1 Wed 11:00 C/kHS

Bistability in a dissipative Rydberg lattice model — •Dominik Linzner, Michael Höning, and Michael Fleischhauer — Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We study bistability in chains of atoms off-resonantly excited to strongly interacting Rydberg states. A novel approach enables simulation of system sizes substantially beyond previous investigations [1] by adapting established numeric methods based on matrix product states to dissipative systems. Whereas simulation of the dissipation free limit is infeasible using such methods, we show that the presence of dissipation renders the approach efficient.

The model gives unique insight into the emergence of bistability and the formation of aggregates in off-resonantly driven Rydberg systems. We quantitatively study the critical behavior of the size of aggregates and its relation to the overall time scale of relaxation. Based on this analysis we discuss the emergence of bimodal probability distributions for the number of excitations in extended systems and clarify the significance of earlier results obtained with a mean field ansatz.

[1] C. Ates et al., Phys. Rev. A, 85, 043620 (2012)

A 21.2 Wed 11:15 C/kHS

Imaging of Microwave Fields with sub-100 μm Resolution in Vapor Cells — •Andrew Horsley, Guan-Xiang Du, and Philipp Treutlein — University of Basel, Switzerland

Microwave devices form an essential part of modern technology, finding application, e.g., in telecommunications and scientific instrumentation. We have developed a technique for imaging microwave magnetic fields using alkali vapor cells, detecting microwaves through Rabi oscillations driven on atomic hyperfine transitions. This could prove transformative in the design, characterisation, and debugging of microwave devices, as there are currently no established microwave imaging techniques. We present results from a new imaging system which provides spatial resolutions of $40 - 100\,\mu$m, an order of magnitude improvement from our previous proof-of-principle setup. More importantly, our vapor cell allows imaging of fields as close as $150\,\mu$m above structures, through the use of extremely thin external cell walls. This is crucial in allowing us to take practical advantage of our high spatial resolution, as feature sizes in near-fields are on the order of the distance from their source. We demonstrate our system through the imaging of microwave fields above a selection of microwave devices.

Our spatial resolution and approach distance are now sufficient for characterising a range of real world devices at fixed frequencies. However, the development of a broadband imaging technique is essential for wider applications. We also present progress on a frequency-tunable setup, allowing us to image microwaves at any frequency, from sub-GHz to 10s of GHz.

A 21.3 Wed 11:30 C/kHS

Rydberg atoms in hollow-core photonic crystal fibres — •Georg Epple[1,2], Christian Veit[1], Kathrin Kleinbach[1], Tijmen Euser[2], Tilman Pfau[1], Philip Russell[2], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]Max Planck Institute for the Science of Light and Department of Physics, University of Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany

The exceptionally large polarizability of highly excited Rydberg atoms uniquely enables long-range interactions between atoms, giving rise to phenomena such as the Rydberg blockade. This makes them of great interest as sensitive electric field sensors or for creating optical nonlinearities at the single photon level. A promising route to technically feasible, miniaturized, room-temperature devices is the excitation of Rydberg atoms inside hollow-core photonic crystal fiber (HC-PCF). The confinement of both atoms and light in the hollow core results in perfect atom-light coupling. Recently we demonstrated coherent three-photon excitation to Rydberg states in a caesium vapour confined in both kagomé-style HC-PCFs and capillaries with various core diameters. Spectroscopic signals exhibiting sub-Doppler features were detected for principal quantum numbers up to n = 46. Our studies revealed that the frequencies of the absorption peaks measured in HC-PCF differed from those measured in a reference cell, suggesting interactions between the atoms and the core-walls. Our current goal is to better understand these line-shifts and to get insight into caesium diffusion in the fibres.

A 21.4 Wed 11:45 C/kHS

Effects of anisotropic dipole-dipole interactions on 3D flexible Rydberg aggegrates. — •Karsten Leonhardt, Sebastian Wüster, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems

Exciton pulses transport excitation and entanglement adiabatically through flexible Rydberg aggregates [1], assemblies of highly excited light atoms, which are set into directed motion by resonant dipole-dipole interaction [1-4]. In the systems studied so far, the dipole-dipole interaction among the Rydberg atoms was completely isotropic, either enforced by geometry [2-4] or by external fields [5]. Here, we present the dynamics of exciton pulses, taking into account the spatial dependence of the dipole-dipole interaction. We also include fine-structure splitting into our model, which is relevant for Rb experiments.

References

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[3] S. Möbius, S. Wüster, C. Ates, A. Eisfeld, J. M. Rost, *J. Phys. B.* **44**, 184011 (2011).
[4] S. Wüster, A. Eisfeld, J. M. Rost, *Phys. Rev. Lett.* **106**, 153002 (2011).
[5] K. Leonhardt, S. Wüster, J. M. Rost, *Phys. Rev. Lett.* **113**, 223001 (2014).

A 21.5 Wed 12:00 C/kHS

Probing mechanical oscillators with excited atoms — •Adrián Sanz Mora, Alexander Eisfeld, Sebastian Wüster, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, Germany

We investigate the use of electronically excited atoms to control the motion of nano-mechanical oscillators. A setup that exploits the optical response of a three-level ultracold atomic gas can serve as a means to drive the motion of a classically oscillating nano-mirror via electromagnetic radiation. The probe- and control beams that electromagnetically induce transparency (EIT) [1] in the gas, interact also with the vibrating mirror via radiation pressure forces. The control light field is phase-modulated by the mirror vibrations, thus altering the transparency of the atoms with respect to the probe light and leading to the generation of probe light sidebands. The frequency mismatch between the light fields and the atomic resonances can then be adjusted to either cool down or amplify the mirror motion. In another setup, by using highly excited Rydberg states of a beam of atoms one can realize protocols for quantum state reconstruction of mechanical motion [2] thanks to the extreme sensitivity of such atomic states to external perturbers.

[1] M. Fleischhauer, A. Imamoglu, J. P. Marangos, Rev. Mod. Phys. 77, 633 (2005).
[2] M. R. Vanner, I. Pikovski, M. S. Kim, http://arxiv.org/abs/1406.1013 (2014).

A 21.6 Wed 12:15 C/kHS

Modelling spin systems using arrays of single Rydberg atoms — •Henning Labuhn, Sylvain Ravets, Daniel Barredo, Thierry Lahaye, and Antoine Browaeys — Laboratoire Charles Fabry, UMR 8501, Institut d'Optique, CNRS, Univ Paris Sud 11, 2 avenue Augustin Fresnel, 91127 Palaiseau cedex, France

I will present the latest results of our experiment, where we trap single atoms in variable 2D arrays of optical tweezers [1]. By optically coupling the atoms to Rydberg states, i.e. electronic states with a high principle quantum number n, we can engineer strong interactions between the trapped atoms. We then use a microwave field to drive transitions in the Rydberg manifold. Applying such a transition locally on one atom allows us to investigate the coherent propagation of this excitation, which can be fully described by a XY spin Hamiltonian, in the atomic array [2]. The results suggest that arrays of Rydberg atoms are ideally suited to large scale, high-fidelity quantum simulation of spin dynamics.

[1] F. Nogrette, H. Labuhn, S. Ravets, D. Barredo, L. Béguin, A. Vernier, T. Lahaye and A. Browaeys, "Single-Atom Trapping in Holographic 2D Arrays of Microtraps with Arbitrary Geometries", Phys. Rev. **X** 4, 021034 (2014)
[2] D. Barredo, H. Labuhn, S. Ravets, T. Lahaye, A. Browaeys, C. S. Adams, "Coherent Excitation Transfer in a "Spin Chain" of Three Rydberg Atoms", arXiv:1408.1055

A 21.7 Wed 12:30 C/kHS

Photonic phase gates in multi-level Rydberg EIT media — •Callum Murray and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The interaction of Rydberg polaritons under conditions of electromagnetically induced transparency (EIT) represents a promising route towards realizing a photonic phase gate. The basic principle exploits the establishment of a locally refractive medium for a polariton in response to the conditional presence of another in its vicinity, allowing for the accumulation of a relative phase shift. However, previous studies have shown that high gate fidelities require such large atomic densities that ground state interactions would begin to manifest, bringing with it additional undesired decoherence effects. We report on recent progress in alleviating this issue by considering a modified EIT setting involving an auxiliary ground state. We show that this gives rise to a slowly propagating bright state polariton in response to Rydberg interactions that, in contrast to ladder excitation schemes, enables high fidelity phase gates at moderate densities.

A 22: Ultra-cold atoms, ions and BEC III (with Q)

Time: Wednesday 11:00–13:00 Location: M/HS1

A 22.1 Wed 11:00 M/HS1

Space charge dynamics and diffraction with ultracold electron and ion bunches — •Robert Scholten, Dene Murphy, Rory Speirs, Dan Thompson, Joshua Torrance, Richard Taylor, Andrew McCulloch, and Ben Sparkes — School of Physics, University of Melbourne, Australia

Cold electron and ion sources based on photoionisation of laser cooled atoms provide a unique system for investigating Coulomb interactions within complex charged particle bunches and for high coherence diffractive imaging. Space-charge driven expansion in charged particle beams is of critical importance for applications including electron and ion microscopy, mass spectrometry, synchrotrons and x-ray free electron lasers, and in electron diffraction where space-charge effects constrain the capacity to obtain diffraction information. Self-field effects are often difficult to observe because of thermal diffusion with traditional sources. Cold atom sources produce ions with temperatures of a few mK, such that subtle space-charge effects are apparent. We illustrate the capabilities through detailed investigation of a complex ion bunch shape, showing collective behaviour including high density caustics and shockwave structures arising from long-range interactions between small charge bunches. We also demonstrate ultra-fast diffraction with cold electrons.

A 22.2 Wed 11:15 M/HS1

Single particle dynamics in ultracold environments — •Paula Ostmann and Walter Strunz — Tu Dresden , Institut für Theoretische Physik, Deutschland

We investigate the quantum dynamics of a single ion which is immersed into a Bose-Einstein condensate. The ultracold environment acts as a refrigerator, and thus, the influence on the motion of the molecule or ion is dissipative. For a theoretical description, simple phenomenological master equation approaches are widely used to describe the ensuing damped quantum dynamics. Instead of calculating the particle dynamics itself, our focus lies on a more detailed description of the environment and the particle-environment interaction. We aim to describe the effective dynamics of the damped particle dynamics using the full bath correlation function instead of a simple damping rate. In this way we gain a more thorough theoretical understanding of properties of quantum matter, such as superfluidity, when acting as an environment.

A 22.3 Wed 11:30 M/HS1

Beyond Mean-Field Dynamics of Ultracold Bosonic Atoms in Lattices — •Axel U.J. Lode and Christoph Bruder — Department of Physics, University of Basel, Klingelbergstr. 82, CH-4056 Basel, Switzerland

The dynamics of ultracold bosons in optical lattices is a rich field with many fundamental physics questions and applications. Cold atoms in lattices represent a very versatile tool for the quantum simulation of various other states of matter. Theoretical methods for the treatment of the dynamics in one-dimensional lattices are available, but despite the large interest in the field, to date no reliable theoretical method to describe the dynamics of two- and three-dimensional systems has been formulated. An application of the multiconfigurational time-dependent Hartree method for bosons (MCTDHB, see http://ultracold.org) to describe the dynamics of the Bose-Hubbard Hamiltonian yields reliable predictions with a controlled error for the dynamics in one-, two-, and three-dimensional systems and therefore fills in this gap. The theory is introduced and example applications of beyond mean-field dynamics are discussed.

A 22.4 Wed 11:45 M/HS1

Optical trapping of Barium ions for ion-atom collision experiments — •Julian Schmidt[1], Alexander Lambrecht[1], Georg Hoppe[1], Leon Karpa[1,2], and Tobias Schaetz[1] — [1]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Strasse 3, 79104 Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS), Albertstrasse 19, 79104 Freiburg, Germany

Optical trapping of ions has been demonstrated recently [1,2]. In these experiments, the trapping beam is tuned close to the atomic resonance and off-resonant scattering resulted in severe recoil heating. We now present a recent experiment [3] in which we use a far-detuned optical dipole trap to trap a single Barium ion without any rf confinement, reducing recoil heating by four orders of magnitude.

We also describe a novel technique for micromotion compensation [3], in which the tightly focused optical trapping laser creates a position dependent ac-Stark shift. We can then measure the position of the ion with high resolution, allowing us to compensate stray fields to below 9mV/m.

In our improved setup, the optically trapped ion can be overlapped with a cloud of cold Rb atoms trapped inside in a magneto-optical and bichromatic optical dipole trap. This should allow us to avoid rf induced heating effects inherent to hybrid atom-ion traps [4].

[1] C. Schneider et al., Nat. Photon. 4, 772-775 (2010)
[2] M. Enderlein et al., Phys. Rev. Lett. 109, 233004 (2012)
[3] T. Huber et al., Nat. Comms 5, 5587 (2014)
[4] M. Cetina et al., Phys. Rev. Lett. 109, 253201 (2012)

A 22.5 Wed 12:00 M/HS1

Expansion of ultracold bosons in anisotropic two-dimensional optical lattices — •Konstantin Krutitsky[1], Friedemann Queisser[2], Patrick Navez[3], and Ralf Schützhold[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany — [2]Department of Physics, University of British Columbia, Vancouver, Canada — [3]Department of Physics, University of Crete, Greece

Motivated by experiments on the expansion of ultracold ^{39}K atoms in anisotropic two-dimensional optical lattices [1], we present a systematic theory of this phenomenon. Initially, the atoms are prepared in the Mott-insulator state with one atom per lattice site in a finite spatial region determined by a harmonic trap. The expansion is initiated by switching-off the harmonic potential and decreasing the amplitude of the optical lattice. The system is described by an anisotropic Bose-Hubbard Hamiltonian with local interaction and two in general different tunneling rates J_1 and J_2. We investigate the dependence of the expansion speed on the lattice anisotropy J_1/J_2 and the effects of multiple occupancy of the lattice sites. Our method is based on the truncated system of equations for the local and nonlocal reduced density matrices which allows efficient treatment of large lattice systems not only in one dimension but also in higher dimensions [2,3].

[1] J. P. Ronzheimer et al, Phys. Rev. Lett. **110**, 205301 (2013)
[2] F. Queisser, K. V. Krutitsky, P. Navez, and R. Schützhold, Phys. Rev. A **89**, 033616 (2014)
[3] K. V. Krutitsky, P. Navez, F. Queisser, and R. Schützhold, EPJ Quantum Technology **1**:12 (2014)

A 22.6 Wed 12:15 M/HS1

Fast Dynamics of a Fermi Impurity — Marko Cetina[1], •Michael Jag[1,2], Rianne Lous[1,2], Rudolf Grimm[1,2], Rasmus Sørensen[3], and Georg Bruun[3] — [1]IQOQI, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Inst. für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria — [3]Department of Physics and Astronomy, University of Aarhus, Aarhus, Denmark

We use Ramsey and spin-echo spectroscopy to probe the dynamics of a ^{40}K impurity in a degenerate Fermi sea of ^{6}Li atoms. At slow timescales (t>200 μs), the evolution of the impurity is dominated by elastic collisions with the background ^{6}Li atoms. The measured rate of elastic collisions as a function of the interaction strength and temperature is in very good agreement with the Fermi liquid picture. We employ a laser-induced resonance shift to rapidly vary the interaction strength and perform quenches of the impurity into the strongly interacting regime. At very short times after the quench (t<20 μs), we observe quantum dynamics of the impurity interacting with the Fermi sea. This investigation opens the possibility to observe the pairing dynamics in a Fermi gas and the formation of polaron states.

A 22.7 Wed 12:30 M/HS1

Reactive collisions of Ba^+ and Rb — •Joschka Wolf, Artjom Krükow, Amir Mohammadi, Amir Mahdian, and Johannes Hecker Denschlag — Universität Ulm, Institut für Quantenmaterie, Albert-Einstein-Allee 45, D-89069 Ulm, Deutschland

We investigate the reactive collisions of a laser-cooled trapped ^{138}Ba$^+$ ion, with an ultracold cloud of optically trapped ^{87}Rb atoms. At atom densities of $10^{11} - 10^{12}$ we observe a quadratic density dependence of the ion loss rate, indicating three body-recombination of the ion with two Rb atoms. We do not observe two-body charge transfer, in contrast to other measurements, see [1] or [2]. We have also studied the dependence of the reaction rates in terms of collision energies. The rate constant for three body recombination scales as $K_3 \propto E^{-(0.5\pm0.1)}$, which is in rough agreement with a prediction of the group of Chris Greene. Interestingly, we do not observe molecular ions as reaction products after three-body recombination. However, we have some evidence that secondary reactions occur, which might lead to molecular dissociation.

[1] Zipkes et al, PRL **105**, **133201 (2010)** [2] Haze et al, arxiv **1403.5091 (2014)**

A 22.8 Wed 12:45 M/HS1

Raman sideband cooling of quantum degenerate Li-6 — •Martin Boll[1], Timon Hilker[1], Katharina Kleinlein[1], Ahmed Omran[1], Guillaume Salomon[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

The ability of single-site resolved detection in optical lattice experiments had huge impact on the study of strongly correlated bosonic systems. In our experiment we plan to apply similar techniques to fermionic Li-6. However for strongly correlated fermions there does not yet exist an imaging technique which combines a sufficient ratio of signal to noise while keeping each atom trapped on its original lattice site.

In this talk we present our approach, employing degenerate Raman sideband cooling. We discuss our progress using a far detuned optical lattice to pin the atomic distribution while performing Raman sideband cooling and compare to our results of a near resonant lattice, only 85 GHz detuned with respect to the D1 transition of Li-6.

A 23: Ultra-cold atoms, ions and BEC IV (with Q)

Time: Wednesday 14:30–16:30 Location: C/HSW

A 23.1 Wed 14:30 C/HSW

A single Rydberg atom as a chemistry reaction center in a Bose-Einstein condensate — •Michael Schlagmüller, Huan Nguyen, Karl Magnus Westphal, Kathrin Kleinbach, Fabian Böttcher, Tara Cubel Liebisch, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

A single Rydberg atom can be excited in the center of a Bose-Einstein condensate (BEC), and act as a single impurity in a quantum gas. The high density and low temperature of BECs leads to a fascinating testbed of electron-neutral atom interactions and ion-neutral atom interactions. For a Rydberg state with a principal quantum number of 100, there are thousands of ground-state atoms with which the Rydberg electron interacts, leading to a shift of the Rydberg line which can be used e.g. to observe the BEC phase transition. In addition, collisions between the ionic core of the Rydberg atom with the neighboring ground-state atoms can be studied and can even lead to the formation of ionic molecules. We report on recent findings of ion-neutral-neutral ground-state recombination in this ultra-cold quantum chemistry regime.

A 23.2 Wed 14:45 C/HSW

Creation and Characterization of Quantum Synchronization in Trapped Ion Phonon-Lasers — Michael Hush, •Weibin Li, Sam Genway, Igor Lesanovsky, and Andrew Armour — School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom

We investigate quantum synchronization theoretically in a system consisting of two cold ions in microtraps. The ions' motion is damped by a standing-wave laser whilst also being driven by a blue-detuned laser which results in self-oscillation. Working in a non-classical regime, where these oscillations contain only a few phonons and have a sub-Poissonian number variance, we explore how synchronization occurs when the two ions are weakly coupled using a probability distribution for the relative phase. We show that strong correlations arise between the spin and vibrational degrees of freedom within each ion and find that when two ions synchronize their spin degrees of freedom in turn become correlated. This allows one to indirectly infer the presence of synchronization by measuring the ions' internal state.

A 23.3 Wed 15:00 C/HSW

Stability and Tunneling Dynamics of a Dark-Bright Soliton Pair in a Harmonic Trap — •Evangelos T. Karamatskos[1], Jan Stockhofe[1], Panayotis G. Kevrekidis[2,3], and Peter Schmelcher[1,4] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg — [2]University of Massachusetts, Amherst, USA — [3]Los Alamos National Laboratory, USA — [4]The Hamburg Centre for Ultrafast Imaging

We consider a binary repulsive Bose-Einstein condensate in a harmonic trap in one spatial dimension and investigate particular solutions consisting of two dark-bright solitons. There are two different stationary solutions characterized by the phase difference in the bright component, in-phase and out-of-phase states. We show that above a critical particle number in the bright component, a symmetry breaking bifurcation of the pitchfork type occurs that leads to a new asymmetric solution. These three different states support different small amplitude oscillations, characterized by an almost stationary density of the dark component and a tunneling of the bright component between the two dark solitons. Within a suitable effective double-well picture, these can be understood as the characteristic features of a Bosonic Josephson Junction (BJJ). For larger deviations from the stationary states, the simplifying double-well description breaks down due to the feedback of the bright component onto the dark one, causing the solitons to move. In this regime we observe intricate anharmonic and aperiodic dynamics, exhibiting remnants of the BJJ phase space.

E.T. Karamatskos et al., arXiv:1411.3957

A 23.4 Wed 15:15 C/HSW

Solution of the Fröhlich polaron problem at intermediate couplings — •Fabian Grusdt[1,2,3], Yulia E. Shchadilova[4,3], Alexey N. Rubtsov[5,4], and Eugene Demler[3] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany — [3]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [4]Russian Quantum Center, Skolkovo 143025, Russia — [5]Department of Physics, Moscow State University, 119991 Moscow, Russia

We develop a renormalization group approach for analyzing Fröhlich polarons and apply it to a problem of impurity atoms immersed in a Bose-Einstein condensate (BEC) of ultra cold atoms. Polaron energies obtained by our method are in excellent agreement with recent diagrammatic Monte Carlo calculations [Vlietinck et al., arXiv:1406.6506] for a wide range of interaction strengths. We show analytically that the energy of the Fröhlich polaron in a BEC is logarithmically UV divergent, and present a regularization scheme. This allows us to make predictions for the polaron energy, which can be tested in future experiments. Furthermore we calculate the effective mass of polarons and find a smooth crossover from weak to strong coupling regimes. Our method can be generalized to non-equilibrium polaron problems.

A 23.5 Wed 15:30 C/HSW

Vortices in a toroidal Bose-Einstein condensate with a rotating weak link — Aleksander Yakimenko[1], •Yuriy Bidasyuk[2,3], Michael Weyrauch[2], Yevgeniy Kuriatnikov[1], and Stanislav Vilchinskii[1] — [1]Department of Physics, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Bogoliubov Institute for Theoretical Physics, Kyiv, Ukraine

Recent series of experiments on atomic Bose-Einstein Condensates (BECs) in toroidal traps with a rotating weak link demonstrated possibilities to controllably generate and destroy persistent currents in such systems [K.C. Wright et. al. Phys. Rev. Lett. 110, 025302 (2013), S. Eckel et.al. Nature 506, 200 (2014)]. Motivated by these experiments, we investigate deterministic discontinuous jumps between quantized circulation states in a toroidal BEC. These phase slips are induced by vortex excitations created by a rotating weak link. We analyze influence of a localized condensate density depletion and atomic superflows, governed by the rotating barrier, on the energetic and dynamical stability of the vortices in the ring-shaped condensate. We simulate in a three-dimensional dissipative mean field model the dynamics of the condensate using parameters similar to the experimental conditions. We investigate in detail the vortex dynamics which leads to the observed phase slips and demonstrate the crucial role of moving vortex-antivortex dipoles in this process. Moreover, we consider the dynamics of the stirred condensate far beyond the experimentally explored region and reveal surprising manifestations of complex vortex dynamics.

A 23.6 Wed 15:45 C/HSW

Bose-Einstein Condensation of Dysprosium — •Matthias Schmitt, Thomas Maier, Holger Kadau, Matthias Wenzel, Clarissa Wink, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Strongly dipolar quantum gases enable the observation of many-body phenomena with anisotropic, long-range interaction. The element with the strongest magnetic dipole moment is dysprosium. It is a rare-earth element with a complex energy level structure with several possible cooling transitions. We have prepared samples of dysprosium atoms at 10 μK in a magneto-optical trap by laser cooling on a narrow transition at 626 nm. We load these cooled atoms into an optical dipole trap and transport them to a glass cell with high optical access. To finally reach quantum degeneracy we perform evaporative cooling in a crossed optical dipole trap. We create a BEC with up to N=20000 atoms at a critical temperature of 100 nK.

Additionally, we perform a trap-loss spectroscopy and observe Fano-Feshbach resonances within a magnetic field range of 70 G. We study quantum chaotic behaviour similar to investigations done with erbium atoms [1] and observe the onset of quantum chaos as a function of magnetic field.

[1] A. Frisch et al., Nature **507**, 475-479 (2014)

A 23.7 Wed 16:00 C/HSW

Two-channel model of Penning ionization of cold metastable neon atoms — •Christian Cop and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

At present, many experiments are geared towards Bose-Einstein-Condensation of other elements besides the alkalies; rare-earth-gases, composite molecules and metastable noble gases. At the Technical University of Darmstadt, the group of G. Birkl investigates experimentally the prospects to condense metastable neon atoms (Ne*) [1]. The high internal energy of Ne* (∼16eV) leads to loss rates through Penning ionization (PI). Spin-polarized samples are expected to have lower loss rates than unpolarized samples since PI is forbidden here. For Ne*, suppression of PI has been observed. Interestingly, the bosonic isotopes ^{20}Ne* and ^{22}Ne* behave very differently; suppression ratios deviate by one order of magnitude and scattering lengths differ in sign.

To explain these differences we set up a two-channel model. The colliding Ne* atoms are subject to quantum-statistical effects which we include by adapting already existing single-channel models [2]. We present our results and show that they are in good agreement with the measurements.

[1] G. Birkl et al., *Cold and trapped metastable noble gases*, Rev. Mod. Phys., **84**, 175-210 (2012).
[2] C. Orzel et al., *Spin polarization and quantum-statistical effects in ultracold ionizing collisions*, Phys. Rev. A, **59**, 1926 (1998).

A 23.8 Wed 16:15 C/HSW

Many-Body Simulations of Ultracold 1D Atom-Ion Quantum Systems — •Johannes Schurer[1,2], Peter Schmelcher[1,2], and Antonio Negretti[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We consider a trapped ensemble of interacting bosonic atoms in which a single strongly trapped ion is immersed. We focus on effects induced by the atom-ion interaction as the emergence of an additional length scale and the impact of bound states onto the properties of the system. Our study is carried out by means of the multilayer-multiconfiguration time-dependent Hartree method for bosons, a numerical exact method to calculate many-body quantum dynamics. As a first step, enabled through the development of a model interaction potential for the atom-ion interaction, we analyze the influence of the atom-atom interaction strength and the number of atoms on the ground state properties (see [1]). Further, we propose experimental viable strategies for the verification of our findings. Hereupon, we investigate the dynamics following a spontaneous creation of an ion in the atomic cloud. The additional length scale in the system becomes clearly apparent and we show the necessity of the description beyond a Gross-Pitaevskii type approach. These investigations serve as first building blocks for the understanding of hybrid atom-ion systems expected to exhibit intriguing phenomena as e.g. formation of molecular ions and ion induced density bubbles.

[1] Phys. Rev. A 90, 033601 (2014)

A 24: Attosecond physics

Time: Wednesday 14:30–16:30 Location: C/kHS

A 24.1 Wed 14:30 C/kHS

Phase space approach to propagating a quantum wavepacket — •Norio Takemoto[1,2], Asaf Shimshovitz[2], and David J. Tannor[2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Weizmann Institute of Science, Rehovot, Israel

We develop a new method to propagate a quantum wavepacket based on a phase space perspective. The method utilizes the periodic von Neumann basis with biorthogonal exchange (pvb basis) [A. Shimshovitz and D.J. Tannor, Phys. Rev. Lett. 109, 070402 (2012)] generated from a lattice of phase space Gaussians for accurate and efficient representation of the wavepacket. We choose a subset of the pvb basis in a time-dependent manner to adapt to the time evolution of the wavepacket in phase space. This subset can be selected with a guide of classical mechanical trajectories. We demonstrate the accuracy and efficiency of the method first in the propagation of an electronic wavepacket in a one-dimensional model of an atom driven by the combined field of an intense, few-cycle infrared laser pulse and an attosecond extreme-ultraviolet laser pulse [N. Takemoto, A. Shimshovitz, and D.J. Tannor, J. Chem. Phys. 137, 011102 (2012)]. As a first step for extension of the method to multi-dimensioanl systems, we show benchmarking results on the coherent state wavepacket on a two-dimensional harmonic potential.

A 24.2 Wed 14:45 C/kHS

Ultrafast Charge Redistribution in Small Halogenated Hydrocarbon Molecules — •Maximilian Hollstein and Daniela Pfannkuche — Jungiusstraße 9, 20355 Hamburg

We investigate theoretically the ultrafast charge redistribution in small halogenated hydrocarbon molecules following the inner-shell photoionization of a halogene site and the subsequent Auger decay of the induced core hole. By consideration of a truncated time-dependent multi-reference configuration interaction expansion of the dicationic valence wavefunction for a description of the valence electron dynamics, we not only determine final charge distributions but we are also able to estimate the timescale on which the charge redistribution process is completed. For iodomethane (CH3I), we found that charge can be redistributed between two atomic sites (the iodine atom and the carbon atom) within a few hundred attoseconds. However, for diiodomethane (CH2I2), where charge is transferred from one iodine atom to the other iodine atom through an additional atomic site, i.e. the central carbon atom, we found that a complete redistribution occurs on a considerable larger timescale (i.e. 10 - 15 fs). Our calculations suggest that this significant increase is related to a weak coupling of the carbon-iodine bonds within the carbon atom.

A 24.3 Wed 15:00 C/kHS

Sub-cycle resolved probe retardation in strong-field pumped dielectrics — •Adrian N Pfeiffer — Institute of Optics and Quantum Electronics, Abbe Center of Photonics, Friedrich Schiller University, Max Wien Platz 1, 07743 Jena, Germany

The ultrafast response of bulk solids to laser pulses in the strong-field regime is currently paving the way for novel applications of attosecond physics. According to theoretical studies, a possible underlying mechanism is that conduction band levels are transiently populated at the crests of the laser pulse, thereby switching the dielectric from an insulator into a conductor and back into an insulator within one optical cycle. Here, an experimental method is presented which delivers time-resolved information about strong-field processes that occur in dielectric solids during one laser cycle. The method is based on the well-known retardation of a probe pulse by a strong pump pulse. A close-to-collinear alignment of pump and probe beams facilitates the detection of sub-cycle dynamics with respect to an absolute time reference given by the interference signal of the pump and probe pulses. Comparing the sub-cycle resolved measurement of the probe delay to a calculation based on a two-band model reveals that the transient conduction band population affects the measurement in a characteristic way. Moreover, the measurement is sensitive to the interband dephasing time and hence delivers information about the coherence behavior of the strong-field induced conductivity.

A 24.4 Wed 15:15 C/kHS

Signatures of nonadiabatic, relativistic effects and tunneling time delay in the photoelectron momentum distributionof tunnel-ionization — •Enderalp Yakaboylu, Michael Klaiber, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg,Germany

We investigate the influence of the nonadiabatic and relativistic effects on the photoelectron momentum distribution in tunnel-ionization using relativistic strong field approximation. The asymptotic momentum distribution for the maximal tunneling probability in a laser field of elliptical polarization is derived. It is shown that the momentum distribution is shifted with respect to the nonrelativistic case along the laser propagation direction due to the relativistic effect, and the radius of the momentum distribution ellipse is increased due to the nonadiabatic effect. The modifications of the asymptotic momentum distribution arise due to the under-the-barrier dynamics [1,2]. Finally, we discuss the effect of tunneling time delay [2,3]. We define a quantum mechanical trajectory and map the time delay between the quasiclassical trajectory and a quantum mechanical one to a longitudinal momentum shift at the tunnel exit.

[1] M. Klaiber, E. Yakaboylu, H. Bauke, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Rev. Lett. 110, 153004 (2013). [2] E. Yakaboylu, M. Klaiber, H. Bauke, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Rev. A 88, 063421 (2013). [3] E. Yakaboylu, M. Klaiber, and K. Z. Hatsagortsyan, Phys. Rev. A 88, 063421 (2014).

A 24.5 Wed 15:30 C/kHS

Time delays in the ionization of atoms — •Hongcheng Ni, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

Time delays during the ionization process of atoms are studied.

A 24.6 Wed 15:45 C/kHS

Scaling attosecond sources in two complementary directions — •Christoph M. Heyl, Piotr Rudawski, Per Johnsson, Linnea Rading, Bastian Manschwetus, Anne Hardt, Chen Guo, Johan Mauritsson, Cord L. Arnold, and Anne L'Huillier — Lund University, Sweden

Extreme ultraviolet (XUV) light sources based on high-order harmonic generation are nowadays used in many laboratories. Based on the demands set by different applications, two complementary XUV source development directions can be identified: Towards high repetition rates as required by experiments involving electron or ion detection and towards high pulse energies, needed for example for nonlinear optics in the extreme ultraviolet as well as for coherent imaging.

In this talk, an overview about status and limitations for both directions is given and a general model allowing the scalability of pulse energy and repetition rate of attosecond sources over many orders of magnitude while maintaining the conversion efficiency into the XUV [1], is discussed. Examples of attosecond beam lines at both extremes are presented. This includes two beam lines at the Lund Laser Center, a 200 kHz OPCPA-based beam line approaching the single attosecond pulse regime [2] and an intense harmonic beam line [3] as well as an attosecond beam line for the European facility ELI-ALPS [4].

[1] C. M. Heyl *et al.*, Journal of Physics B **45**, 074020 (2012)
[2] P. Rudawski *et al.*, submitted for publication
[3] P. Rudawski *et al.*, Rev. of Sci. Instr. **84**, 073103 (2013)
[4] C. M. Heyl *et al.*, Conceptual design report ELI-ALPS (2012)

A 24.7 Wed 16:00 C/kHS

Carrier-envelope phase dependencies in photoelectron spectra of a metal nanotip and a noble gas in focused few-cycle laser pulses — •Dominik Hoff[1], Michael Krüger[2,3], Georg Wachter[4], Lothar Maisenbacher[3], Michael Förster[2], Sebastian Thomas[2], Joachim Burgdörfer[4], A. Max Sayler[1], Gerhard G. Paulus[1], and Peter Hommelhoff[2,3] — [1]Helmholtz Institute Jena and Institute for Optics and Quantum Electronics, Jena, Germany — [2]Department of Physics, University Erlangen-Nuremberg, Germany — [3]and Max Planck Institute of Quantum Optics, Garching, Germany — [4]Vienna University of Technology, Vienna, Austria

In the last years sensitive probes of the carrier-envelope-phase offset of few-cycle laser pulses have been discovered and developed into high accuracy phase meters. They are based on the re-scattering process of photo-electrons at noble gases like Xe [1] and at nanoscale metal tips [2]. We report on a comparison of the CEP dependence of these two systems which yields insight into the nano-optical response of the tip with attosecond resolution. Further, the nanotip allows for making a quantitative measurement of the behaviour of the carrier-envelope-phase of focused few-cycle laser pulses. These effects are of high interest in the field of nano-optics, plasmonics, attosecond-pulse generation and ultrafast science in general.

[1] T. Wittmann et al., *Nature Physics* **5**, 357 (2009).
[2] M. Krüger, M. Schenk, P. Hommelhoff, *Nature* **475**, 78 (2011).

A 24.8 Wed 16:15 C/kHS

Electronic pertubation during high-order harmonic generation from water droplets — •Heiko G. Kurz[1,2], Martin Kretschmar[1,2], Tamas Nagy[1], Detlev Ristau[1,2,3], Manfred Lein[2,4], Uwe Morgner[1,2,3], and Milutin Kovacev[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, Hannover — [2]QUEST, Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, Hannover — [3]Laser Zentrum Hannover e.V., Hollerithallee 8, Hannover — [4]Leibniz Universität Hannover, Institut für theoretische Physik, Appelstrasse 2, Hannover

We report on the spatial movement of the electron during high-order harmonic generation (HHG). In an in-situ pump-probe measurement with micrometer-sized liquid water droplets, the influence of high-density targets onto HHG is studied. By increasing the density of the target towards mean inter-particle distances matching the excursion distance of the electron, a decrease in the signal of the emitted harmonic radiation is observed. This decrease can be attributed to an increase in the probability of a perturbation of the electron on its trajectory in the continuum, which is induced by neighbouring molecules. This approach allows to follow the electronic movement with Ångstrom spatial resolution, and to probe electronic trajectories during HHG.

A 25: Clusters in Molecular Physics (with MO & MS)

Time: Wednesday 14:30–16:30 Location: PH/SR106

Invited Talk A 25.1 Wed 14:30 PH/SR106

Vibrational Spectroscopy of Cluster Complexes with Free Electron Lasers: Surface Science en Miniature — •André Fielicke — Institut für Optik und Atomare Physik, Technische Universität Berlin, Germany

Transition metal clusters are frequently used as model systems for low coordinated sites of extended surfaces and their study can provide valuable insights into the mechanisms of surface reactions. In many cases, however, there is still a lack of information on their structures and the relationship between structure and chemical behavior. Using vibrational spectroscopy of gas-phase clusters one can obtain information about the clusters' structure or the behavior of adsorbed species. The latter provides valuable insights into the binding geometry, the activation of bonds within the ligands or reactions occurring on the clusters' surface. Cluster size specific data can be obtained using infrared multiple photon dissociation spectroscopy. To cover the required spectral range from the far to the mid-IR our experiments make use of IR free electron lasers. The talk will discuss exemplary studies about reactions on platinum clusters [1] and the activation of molecular oxygen by small gold clusters [2].

[1] D.J. Harding, A. Fielicke, Chem. Eur. J. 20 (2014) 3258
[2] A.P. Woodham, A. Fielicke, Struct. Bond. 161 (2014) 243

A 25.2 Wed 15:00 PH/SR106

Vibrational spectra and structures of C, B, and N-doped silicon clusters — •Nguyen Xuan Truong, Bertram Jaeger, Philip Jäger, Marco Savoca, Andre Fielicke, and Otto Dopfer — IOAP, TU-Berlin, Germany

Doping Si clusters changes their physical and chemical properties in a way that might be promising for the miniaturization trend towards nanoelectronics. Here, we investigated Si clusters doped with C, B and N with resonant infrared-ultraviolet two-color ionization (IR-UV2CI) and global optimization coupled with electronic structure methods. Doped Si clusters are irradiated with tunable IR light from a Free Electron Laser before being ionized with UV photons from an F_2 laser. Resonant absorption of IR photons leads to an enhanced ionization efficiency for the neutral clusters and provides the size-specific IR-UV2CI spectra. Structural assignment of the clusters is achieved by comparing the experimental IR-UV2CI spectrum with the calculated linear absorption spectra of the most stable isomers. Low-energy isomers are found with the help of genetic and basin-hopping algorithms. For Si_mC_n (with $m + n = 6$), we observed the systematic transition from chain like geometries for C_6 to 3D structures for Si_6. We showed for the first row doped Si_6X (with X = Be, B, C, N, O) clusters that different structures, vibrational and electronic properties can be achieved depending on the nature of the dopant atom. All dopant atoms in Si_6X have a negative net charge suggesting that Si atoms act as electron donors within the clusters. Finally, vibrational spectra and structural assignments for B and N-doped Si clusters are discussed in detail.

A 25.3 Wed 15:15 PH/SR106

(N)IR spectroscopy on two- and three-centered isolated cationic cobalt-, nickel- and cobalt/nickel - ethanol clusters — •Markus Becherer[1], Daniel Bellaire[1], Wei Jin[2], Georgios Lefkidis[2], Wolfgang Hübner[2], and Markus Gerhards[1] — [1]TU Kaiserslautern, Fachbereich Chemie, Erwin-Schrödinger-Straße 52, 67663 Kaiserslautern — [2]TU Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Straße 47, 67663 Kaiserslautern

Clusters containing transition metals and aliphatic ligands provide model systems regarding e.g. catalytical properties, magnetism, reactivity and structure. Thus, the successive variation of size and composition of the metal clusters can give a fundamental insight on possible cooperative effects. The investigated two- and three-centered pure and combined cationic cobalt, nickel clusters are produced by applying laser ablation to a rotating metal rod and by attaching the ethanol ligand in a supersonic beam. The frequencies and frequency shifts of OH and CH stretching vibrations (between different clusters) are probed by means of IR-photofragmentation spectroscopy. A structural assignment is performed by comparing the experimental data with calculated frequencies obtained from DFT calculations. In case of the isolated cationic (cobalt)$_3$(ethanol)$_1$ and (cobalt)$_3$(ethanol)$_1$(water)$_1$ clusters both IR and electronic spectra (in the NIR region) are investigated through photodissociation spectroscopy. The experimentally observed spectra serve, among other aspects, as reference for theoretical calculations especially on the electronic transitions localized on the triangular Co trimer metal centre.

A 25.4 Wed 15:30 PH/SR106

First experiments with cooled clusters at the Cryogenic Trap for Fast ion beams — •Christian Meyer[1], Klaus Blaum[1], Christian Breitenfeld[1,2], Sebastian George[1], Juergen Goeck[1], Jonas Karthein[1], Thomas Kolling[3], Jennifer Mohrbach[3], Gereon Niedner-Schatteburg[3], Lutz Schweikhard[2], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt Universität, 17487 Greifswald, Germany — [3]Fachbereich Chemie, TU Kaiserslautern, Germany

The Cryogenic Trap for Fast ion beams (CTF) is an electrostatic ion beam trap for the investigation of charged particles in the gas phase located at the "Max-Planck-Institut für Kernphysik" in Heidelberg. It is suited to study thermionic and laser-induced electron emission of anions with complex multi-body structure such as clusters and molecules. They can be stored up to several minutes due to the low restgas pressure of 10^{-13} mbar [1] in an ambient temperature down to 15 K. The experiments were so far hampered by the ion production in a sputter source leading to excited particles with high rovibrational states. In order to be able to investigate the ground state properties of such systems a new supersonic expansion source [2] has been implemented. A laser-induced plasma is expanded into vacuum by short pulses (50 μs) of a helium carrier gas and thereby rovibrationally cooled. First tests with metal cluster will be presented and discussed.

[1] M. Lange et al., Rev. Sci. Instr., 81,055105 (2010)
[2] C. Berg et al., J. Chem. Phys. 102, 4870 (1995)

A 25.5 Wed 15:45 PH/SR106

Optical spectra and structures of C, N, and O-doped silicon clusters — •Bertram K.A. Jaeger, Janina Lebendig, Nguyen X. Truong, Andre Fielicke, and Otto Dopfer — IOAP, TU Berlin, Germany

Controlled changes in physical and chemical properties of doped Si clusters provide promising candidates of nanostructures for optoelectronics, sensors or medicine. We study Si clusters doped with C, N and O via their photodissociation spectra and compare them with theoretical quantum chemical calculations. Ionic clusters are produced in a laser vaporization source, then irradiated with tunable visible light from an OPO laser in the range from 410 to 580 nm and characterized by a reflectron time-of-flight mass spectrometer. Absorption of photons leads to dissociation of the clusters, which is detected in the mass spectrum. Calculated absorption spectra are compared to experimental data for assignment of geometries and electronic parameters of the observed clusters. The most stable and low-energy isomers are found with the help of genetic and basin-hopping algorithms. All results will be compared to existing studies about IR-UV two color ionization of neutral and doped Si clusters.

Pristine and tagged Au clusters show absorption bands in the visible range and are used as a test system to verify the experimental principle.

A 25.6 Wed 16:00 PH/SR106

Angular distribution of electron and photon emission from isolated SiO2 nanopartices excited by femtosecond laser pulses — •Egill Antonsson, Ina Halfpap, Christopher Raschpichler, Valerie Mondes, Jürgen Plenge, Burkhard Langer, and Eckart Rühl — Physical Chemistry, Freie Universität Berlin, Takustr. 3, 14195 Berlin

We excite isolated spherical SiO2 nanoparticles (diameter: 90 nm, size distribution: 8%) with intense femtosecond laser pulses (λ=800 nm, τ=80 fs, Intensity: 1-3$\cdot 10^{13}$ W/cm^2) and study the angular distribution of emitted electrons and UV photons (hν>8 eV). The nanoparticles are prepared in an aerodynamically focused beam which propagates into a high vacuum system where excitation and photoionization occurs. This ensures that fresh sample is available to each laser pulse and rules out effects due to particle-particle interactions, sample charging, and radiation damage. For electron emission, a distinct angular dependence with respect to the polarization vector of the laser pulses is observed, which varies for different photoelectron energies. High-energy photoelectrons are found to be emitted preferentially parallel to the polarization vector of the exciting laser photons, which is discussed in terms of an elastic scattering of continuum electrons at or near the surface of the nanoparticles. For low-energy photoelectrons, on the other hand, the angular dependence is quenched due to multiple inelastic scattering events of the photoelectrons in the nanoparticles which smears out angular effects.

A 25.7 Wed 16:15 PH/SR106

Vibrationally resolved UV fluorescence of diamondoids — •Torbjörn Rander[1], Robert Richter[1], Tobias Zimmermann[1], Andre Knecht[1], Andrea Merli[1], Christoph Heidrich[1], Ramon Rahner[1], Thomas Möller[1], Merle I. S. Röhr[2], Jens Petersen[2], Roland Mitric[2], Jeremy E. Dahl[3], and Robert M. K. Carlson[3] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Deutschland — [2]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Würzburg, Deutschland — [3]Stanford Institute of Materials and Energy Sciences, Stanford University

Diamondoids are a class of perfectly size- and shape selectable carbon nanoparticles, with a wide range of interesting properties. Due to the size-selectivity afforded by the diamondoids, they are ideal model systems for studying the photo-physics of hydrocarbon molecules of different sizes. We present a study of the size- and shape dependent energy resolved UV fluorescence of diamondoids, ranging from adamantane to pentamantane, using narrow band laser light as excitation source.

We conclude that previous, relatively straightforward interpretations of the fluorescence spectra recorded using synchrotron light are incomplete, and that the additional fine-structure observed in the laser excited spectra can only be properly assigned by performing computations, in our case DFT and TD-DFT was deemed sufficient to accurately describe and understand the spectral envelopes of the different sized diamondoids. The approach employed is thought to generally be applicable also for other hydrocarbon molecules.

A 26: Poster: Collisions, scattering and recombination

Time: Wednesday 17:00–19:00 Location: C/Foyer

A 26.1 Wed 17:00 C/Foyer

Energy-dependent electron impact induced fluorescence relative cross-sections of neon — •Catmarna Küstner-Wetekam, Philipp Schmidt, Andreas Hans, Christian Ozga, André Knie, and Arno Ehresmann — Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

Electron impact induced ionization cross-sections of rare gases are needed in astrophysics and as benchmarks for theoretical calculations. Electron impact induced fluorescence spectroscopy (EIFS) has been used to determine relative partial fluorescence emission cross-sections of neon within the fluorescence wavelength range between 190 nm and 210 nm. The excitation energy was varied between 0.3 keV and 3.5 keV. The used experimental EIFS-setup [1] is shown and explained. Observed lines are assigned to transitions within NeII and NeIII and the results of the energy-dependent measurements are compared with published cross-sections [2,3] .

[1] A. Knie et al., J. Elec. Spec. Relat. Phenom., 185, 492-497 (2012)

[2] D. P. Almeida et al., J. Phys. B., 28, 3335-3345 (1995)

[3] B. L. Schram et al., Physica, 32, 185-196 (1966)

A 26.2 Wed 17:00 C/Foyer

Linear polarization of x-ray transitions due to dielectronic recombination in highly charged ions — •Holger Jörg[1], Zhimin Hu[1], Hendrik Bekker[2], Michael Andreas Blessenohl[2], Daniel Hollain[2], Stephan Fritzsche[3,4], Andrey Surzhykov[3], José Ramón Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institut der Universität Heidelberg, 69120 Heidelberg, Germany — [2]Max-Plank-Institut für Kernphysik, Heidelberg, 69117 Heidelberg, Germany — [3]Helmholtz-Institut Jena, 07743 Jena, Germany — [4]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

Linear polarization of x-rays produced in the process of dielectronic recombination in highly charged xenon ions was studied at an electron beam ion trap by means of the Compton polarimetry technique. The experimental results are in all cases in good agreement with the theoretical predictions. In the specific case of the dielectronic recombination resonance exciting the [1s2s22p1/2]1 state, the Breit interaction between bound electrons strongly influences the polarization of the emitted x-rays. The results agree with the predictions which include the Breit interaction and by 5σ rule out the theory taking into account only the Coulomb electron-electron repulsion. Apart from the fundamental importance, the experimental results open numerous possibilities for polarization diagnostics of hot anisotropic plasmas. In particular the directions of the electrons in the plasmas, found e.g. in the accretion discs and jets of black holes, can be probed by measuring polarization of the satellite transitions in HCIs.

A 26.3 Wed 17:00 C/Foyer

PEGASUS: Building an intense spin-polarized electron gun - First test runs — Michael Lestinsky[1], •Daniel Schury[1,2], Siegbert Hagmann[1], Christophor Koshuharov[1], and Thomas Stoehlker[1,3] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt — [2]Institut für Atom- und Molekühlphysik, Universität Giessen, D-35392 Giessen — [3]Helmholtzinstitut Jena, Friedrich-Schiller-Universität Jena, D-07743 Jena

The PEGASUS project aims at building an intense and portable spin-polarized electron gun for experiments in crossed beams arrangements at various ion beam facilities. The electron beam will cover energies between 1 and 10 keV at electron currents up to 100 μA. As source material we will utilize laser-induced electron emission from GaAs photocathodes which will be prepared in a state of negative electron affinity. With a set of electrostatic lenses and benders, the electrons will be transported to the interaction zone and Wien-filters will be used for controlling the spin orientation.

Results from first test runs will be presented and foreseen experiments discussed.

A 26.4 Wed 17:00 C/Foyer

Diagnostics of the electron cyclotron motion in an electron beam ion trap — •Chintan Shah[1], Pedro Amaro[1], René Steinbrügge[2], Christian Beilmann[1,2], Sven Bernitt[2], Stephan Fritzsche[3,4], Andrey Surzhykov[3], José Ramón Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institut, Heidelberg, Germany — [2]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [3]Helmholtz-Institut Jena, Jena, Germany — [4]Theoretisch-Physikalisches Institut, Jena, Germany

The electron cyclotron motion within an electron beam propagating through a strong magnetic field was studied at the electron beam ion trap FLASH-EBIT at the Max Planck Institute for Nuclear Physics in Heidelberg. It was probed by measuring the angular distribution of the x rays produced by resonant electron recombination in highly charged iron and krypton ions. For this purpose two germanium detectors registered x rays emitted along and perpendicularly to the beam propagation direction. A comparison of the measured x-ray emission asymmetries with those predicted using the Flexible Atomic Code revealed a small systematic discrepancy which we attribute to a non-vanishing component of the electron momentum transverse to the beam propagation direction. This cyclotron motion is enhanced as the beam propagates from the cathode into the much stronger magnetic field at the trap region. From the data we have deduced the cyclotron motion energy component at the trap center. This experiment demonstrates the suitability of resonant recombination angular distribution measurements for accurate diagnostics of plasma anisotropies.

A 26.5 Wed 17:00 C/Foyer

X-ray emission asymmetries in resonant recombination into highly charged iron ions — •Chintan Shah[1], Pedro Amaro[1], René Steinbrügge[2], Christian Beilmann[1,2], Sven Bernitt[2], Stephan Fritzsche[3,4], Andrey Surzhykov[3], José Ramón Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institut, Heidelberg, Germany — [2]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [3]Helmholtz-Institut Jena, Jena, Germany — [4]Theoretisch-Physikalisches Institut, Jena, Germany

We report the first systematic measurement of the photon angular distribution in the inter-shell dielectronic, trielectronic and quadroelectronic recombination of free electrons into highly charged ions of iron. Ions in He-like through O-like charge states were produced in an electron beam ion trap, and the electron-ion collision energy was scanned over the recombination resonances exciting a K-shell electron. Two germanium detectors mounted head-on and side-on with respect to the electron beam propagation recorded X rays emitted in the decays of resonantly populated states. The measured x-ray emission asymmetries indicate the alignment of those states. The corresponding alignment parameters were extracted for 40 dominant KLL recombination resonances providing a comprehensive data for benchmarking advanced atomic codes, such as FAC and RATIP. This data can also be used for modelling and diagnostics of hot astrophysical plasmas.

A 26.6 Wed 17:00 C/Foyer

Strong correlation between the electron spin orientation and bremsstrahlung linear polarization observed in the relativistic regime — •Oleksiy Kovtun[1], Valeriy Tioukine[2], Andrey Surzhikov[3], Vladimir Yerokhin[4], Anton Khaplanov[5], Bo Cederwall[5], and Stanislav Tashenov[1] — [1]Physikalisches Institut der Universität Heidelberg, 69120 Heidelberg, Germany — [2]Institut für Kernphysik Johannes Gutenberg-Universität Mainz, Germany — [3]Helmholtz-Institut Jena, 07743 Jena, Germany — [4]Center for Advanced Studies, St. Petersburg State Polytechnical University, St. Petersburg 195251, Russia — [5]Royal Institute of Technology, SE-10691 Stockholm, Sweden

Polarization of bremsstrahlung produced in collisions of 2MeV electrons with a thin gold foil was studied using a polarized electron beam and the Compton polarimetry technique. A strong correlation between the spin orientation of the incoming electrons and the linear polarization of the emitted x-rays was observed at the high energy part of the x-ray spectrum. For longitudinally polarized electrons the plane of the x-ray linear polarization was tilted by several tens of degrees depending on the electron spin orientation. We attribute this effect to the precession of electron spin and orbital momentum in the magnetic field, which is induced in the rest frame of the electron by the moving nucleus. In comparison to an earlier experiment performed with

100 keV electrons, which observed a similar but much smaller effect, the significantly enhanced polarization correlation indicates a much stronger spin-orbit interaction at higher collision energies.

A 26.7 Wed 17:00 C/Foyer

Coincidence studies of K-LL dielectronic resonances and simultaneous vacuum ultraviolet transitions in highly charged iron — •Stepan Dobrodey[1], Sven Bernitt[2], Michael Blessenohl[1], and José Ramón Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität, Jena, Germany

We study dielectronic recombination (DR) in iron ions using an electron beam ion trap by observing the K_α X-ray photons and simultaneous transitions in the VUV range. The VUV spectra are obtained using a grating spectrometer equipped with a microchannel plate and a delay line anode. This allows for a time-resolved and wavelength-resolved detection of the VUV photons. The decay of the intermediate excited state to the ground state can occur by cascaded emission of a X-ray and a VUV photon. By recording the intensity of the spectral lines as a funtion of the electron beam energy, it becomes possible to distinguish different relaxation channels and to observe changes in the population of excited intermediate states. By simultaneously detecting a X-ray photon and a VUV photon we could separate decay channels resulting from different DR resonances which could not be resolved in previous measurements. This experimental setup will allow to study photonic relaxation after resonant recombination in more detail.

A 26.8 Wed 17:00 C/Foyer

Ionization cross sections of DNA constituents by light ions — •Mingjie Wang, Daniel Bennett, Ticia Buhr, Benedikt Rudek, Gerhard Hilgers, and Hans Rabus — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Within the framework of the EMRP Joint Research Project "BioQuaRT" [1], a multiscale track structure simulation program based on interaction cross sections of DNA constituents is being developed. To this end, ionization cross sections for model molecules representing DNA constituents are being determined.

In the present work, double differential cross sections for the ionization of tetrahydrofuran (THF) by protons and helium ions with energies in the respective Bragg peak regions were measured. The experiments were carried out using the accelerator facilities at the PTB at energies from 70 keV to 3.3 MeV. The electrons emitted at angles between 30° and 90° relative to the ion beam direction were detected with an electrostatic hemispherical electron spectrometer. The measured spectra are converted into absolute cross sections using the transmission and detection efficiency of the analyzer. The latter are determined from measured spectra for the collision of 100 eV electrons with THF using electron cross section data for elastic scattering and ionization of THF reported by Baek et al. [2].

[1] Project web site: http://www.ptb.de/emrp/bioquart.html. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

[2] W. Y. Baek et al., Phys. Rev. A 86, 032702 (2012)

A 26.9 Wed 17:00 C/Foyer

FAIR High Energy Storage Ring in the heavy-ion mode operation — •Oleksandr Kovalenko[1,2], Oleksiy Dolinskyy[2], Yuri A. Litvinov[2,3], Dieter Prasuhn[4], and Thomas Stöhlker[5] — [1]Heidelberg University — [2]GSI Helmholtz Centre for Heavy Ion Research — [3]Max Planck Institute for Nuclear Physics — [4]Jülich Research Centre — [5]Friedrich Schiller University and Helmholtz Institute Jena

The HESR (High Energy Storage Ring) is an essential part of the Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt. It will be used in antiproton as well as in heavy ion operation modes. The latter is the main topic of the current study. The storage ring employs electron and stochastic cooling methods which helps to significantly reduce beam size, divergence and momentum spread. The energy of about 5 GeV per nucleon is foreseen for bare uranium. This all results in unprecedented conditions for high-precision internal target experiments with heavy ion beams. The experimental program will be carried out in the framework of the SPARC (Stored Particle Atomic Physics Collaboration) project.

In this study an ion optical layout designed specifically for the HESR operating with heavy ions is presented. The nonlinear beam dynamics simulations are carried out and the results are discussed.

A 27: Poster: Attosecond physics

Time: Wednesday 17:00–19:00 Location: C/Foyer

A 27.1 Wed 17:00 C/Foyer

Tunneling time in Atto-Second Experiments and Time-Energy Uncertainty Relation — •Ossama Kullie — Institute für Physik, Universität Kassel

In this work [1] we suggest an analytical relation to calculate the tunneling time (TT) in attosecond and strong field experiments for the important case of the He-atom [2], precisely our TT was related to the time of passage similarly to the Einstein's *photon box Gedanken experiment*. This presents an important study case for the theory of time in quantum mechanics and is very promising for the search for a (general) time operator in quantum mechanics. The work can be seen as a fundamental step in dealing with the tunneling time in strong field and ultrafast science, and is appealing to more elaborate treatments, and especially for complex atom and molecules. [1] O. Kullie. Tunneling time in attosecond experiments and time-energy uncertainty relation, work in progress. [2] P. Eckle et al. Nat. Phys.**4** , 565 (2008).

A 27.2 Wed 17:00 C/Foyer

Classical analytical approach for Coulomb focusing of tunnelled electrons in intense laser fields. — •Jiří Daněk, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Recent high resolution experiments on the kinematically complete measurement of photoelectron spectra in the tunneling ionization in intense laser fields led to discovery of new low energy structures (LES), very low energy structures (VLES) and zero energy structures (ZES) in the spectra at energies of the order of electronvolts, lower than electronvolts and milielectronvolts, respectively. Although, investigations show that these structures are due to the role of the Coulomb field of the atomic core in the laser driven dynamics of the tunnelled electron, there is no clear unified picture for the dynamics.

In our poster, we present our classical analytic approach to this problem for a linearly polarized laser field, which allows us to determine the influence of the parent ion on the ionized electron due to Coulomb interaction. Restricting the Coulomb field effect to rescattering events of the freed electron with the atomic core, we derive analytical formulas for the longitudinal and transversal momentum changes for the electron due to the Coulomb field, with further aim to explain the final momentum distribution via the effect of multiple rescattering. We also discuss the possibility of trapping of the ionized electron in the Rydberg states and the role of the trapping on the final spectra.

A 27.3 Wed 17:00 C/Foyer

Core hole spectroscopy with XUV-initiated high harmonic generation — Doron Azoury, •Michael Krüger, Barry D. Bruner, and Nirit Dudovich — Weizmann Institute of Science, Rehovot 76100, Israel

High-harmonic spectroscopy is a powerful tool to image atomic and molecular structure on angstrom length and attosecond time scales (see, e.g., [1]). However, conventional high-harmonic generation (HHG) that employs tunneling ionization can only adress orbitals belonging to outer shell states. In XUV-initiated HHG, the tunneling ionization step is replaced by photoionization of electrons by an XUV attosecond pulse [2]. This enables the excitation of inner-shell electrons and core holes. The induced inner-shell dynamics can then be probed by the liberated electron which is brought to recollision by an infrared laser field at a well-defined time instant [3]. The technique should be applicable not only to atomic, but also to complex molecular targets such as hydrocarbons. Here we detail our setup for a proof-of-principle XUV-pump IR-probe experiment and report on its current status.

[1] O. Smirnova et al., Nature 460, 972 (2009).

[2] G. Gademann et al., NJP 13, 033002 (2011).

[3] J. Leeuwenburgh et al., PRL 111, 123002 (2013).

A 27.4 Wed 17:00 C/Foyer

Time Delays in Two-Photon Ionization — Jing Su[1], •Hongcheng Ni[2], Agnieszka Jaron-Becker[1], and Andreas Becker[1] — [1]JILA and Department of Physics, University of Colorado, Boulder, Colorado 80309-0440, USA — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

We study the time delays in two-photon ionization of the helium atom. We find that in the case of a nonresonant transition the absorption of the two photons occurs without time delay. In contrast, for a resonant transition a substantial absorption time delay is present, which scales linearly with the duration of the ionizing pulse. The two-photon absorption time delay can be related to the phase acquired during the transition of the electron from the initial ground state to the continuum.

A 28: Poster: Interaction with VUV and X-ray light II

Time: Wednesday 17:00–19:00 Location: C/Foyer

A 28.1 Wed 17:00 C/Foyer

Few-Photon Quantum Optics with Nuclei in Thin-Film Cavities — •Paolo Longo, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik (MPIK), 69117 Heidelberg

Recent activities in the field of X-ray quantum optics [1–4] address, for example, the problem of single-photon superradiance in an extended sample of ^{57}Fe nuclei embedded in a thin-film cavity [5]. In the near future, new light sources [6] will further boost the study of such collective phenomena and eventually go beyond the level of at most one photon. Based on first principles and our earlier work on collective emission [7], we develop a theoretical description for the study of X-ray few-photon quantum optics, revealing the collective atomic states' properties in conjunction with the resulting far-field signatures.

[1] Adams *et al.*, J. Mod. Opt. **60**, 2 (2013).
[2] Röhlsberger *et al.*, Nature **482**, 199 (2012).
[3] Heeg *et al.*, Phys. Rev. Lett. **111**, 073601 (2013).
[4] Heeg *et al.*, arXiv:1411.1545 (2014).
[5] Röhlsberger *et al.*, Science **328**, 1248 (2010).
[6] http://www.xfel.eu/
[7] Longo *et al.*, Phys. Rev. Lett. **112**, 193601 (2014); arXiv:1408.2961 (2014).

A 28.2 Wed 17:00 C/Foyer

Angle-resolved study of resonant Auger decay and fluorescence emission processes after core excitations of the terminal and central nitrogen atoms in N_2O — André Knie[1], Markus Ilchen[2,3], Philipp Schmidt[1], Philipp Reiss[1], •Christian Ozga[1], Andreas Hans[1], Nicolas David Müglich[1], Leif Glaser[2], Peter Walter[2], Jens Viefhaus[2], Arno Ehresmann[1], and Philipp V Demekhin[1] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett Straße 40, 34132 Kassel, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [3]European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany

The linear molecule N_2O is one of the easiest showcase examples for the investigation of electronic properties within completely different chemical surroundings. Here we present our results of the study on interference effects between direct and indirect ionization processes (ESI) as well as between the relaxation into a specific vibronic state from different vibrational states of a higher lying electronic state (LVI). Since these effects are more pronounced in angle resolved measurements due to the sensitivity on the phases of the outgoing partial photoelectron waves we investigated the behavior of the angular distribution parameters of photoelectrons and fluorescence photons under variation of the energy of the exciting photons in the vicinity of the resonant 1s core excitations of the central and terminal nitrogen atom.

A 28.3 Wed 17:00 C/Foyer

Dynamical Phase Control in Resonant Nuclear Scattering — •Patrick Reiser, Andreas Kaldun, Christoph H. Keitel, Thomas Pfeifer, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg

In spectroscopy, the observed signatures arise from interference between the incident probing light and the light scattered by the sample. By imprinting a relative phase between incident and scattered light, a modification of spectral line shapes can be achieved [1,2]. Motivated by this, our aim is to establish dynamical phase control at x-ray energies. We propose a setup using resonant nuclear forward scattering of synchrotron radiation on ^{57}Fe Mössbauer nuclei. The phase shifts are mechanically mediated via piezoelectric film elements. Our theoretical calculations suggest that this setup provides access to a number of promising applications in nuclear quantum optics. Additionally, first results from a Mössbauer test experiment will be shown.

[1] C. Ott et al., Science 340, 716 (2013)
[2] K. P. Heeg et al., arXiv:1411.1545 [quant-ph]

A 28.4 Wed 17:00 C/Foyer

X-ray lasing with highly charged ions — •Chunhai Lyu, Zoltán Harman, Stefano M. Cavaletto, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We theoretically propose an approach to create population inversion by K-shell ionization of highly charged ions with x-ray free electron laser pulses, which results in subsequent lasing in the X-ray regime. The time-dependent dynamics of the population of the ionic states and the gain of the x-ray laser pulses are simulated numerically in the framework of a density matrix approach. Due to the absence of Auger decay, in selected ions, the bandwidth of the x-ray laser is decreased and hence the coherence is improved. Furthermore, the frequency of the laser can be increased approximately quadratically with the charge number of the ions, and can be extended to the hard x-ray regime if heavy ions are used.

A 28.5 Wed 17:00 C/Foyer

Trapped highly charged ions at ultrabrilliant light sources — •Sven Bernitt[1,2], René Steinbrügge[1], Jan Rudolph[1,3], Sascha Epp[4], and José Ramón Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]IOQ, Friedrich-Schiller-Universität, Jena, Deutschland — [3]IAMP, Justus-Liebig-Universität, Gießen, Deutschland — [4]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Deutschland

The properties of many astrophysical objects are determined by the interaction of highly charged ions with VUV and X-ray radiation. The newest generation of ultrabrilliant light sources – synchrotrons and free-electron lasers – in combination with high-resolution monochromators, allows to directly study those interactions.

In the experiments presented, the transportable electron beam ion trap FLASH-EBIT was used to provide targets of trapped highly charged ions for the synchrotrons BESSY II and PETRA III, as well as the free-electron lasers FLASH and LCLS.

By observing resonantly excited fluorescence and ion charge state changes, induced by resonant photoionization, we were able to measure precise wavelengths, line widths, and branching ratios. This provides valuable data for the interpretation of spectra from astrophysical and laboratory plasmas. Furthermore, by studying high-Z few-electron systems, we can benchmark atomic theory on the level of QED contributions.

A 28.6 Wed 17:00 C/Foyer

X-ray and gamma-ray polarimetry and imaging — •Stanislav Tashenov — Physikalisches Institut der Universität Heidelberg

To study fundamental atomic processes in the x-ray and gamma-ray regimes and to perform polarization diagnostics of laboratory fusion and astrophysical plasmas we develop a broad range of polarization sensitive and imaging x-ray and gamma-ray detectors. Two detectors are based on Silicon PIN diodes and Silicon Drift Detectors and dedicated to the energy range of 10–30 keV. This is the lowest energy range that was accessed by the Compton polarimetry. For the energy range of 30 keV – 2 MeV we use a segmented planar germanium detector. It employs a novel technique of Pulse Shape Analysis of the detector signals for a 3D sensitivity to the positions of the x-ray interactions.

With this detector we for the first time employed the techniques of Compton Imaging and background reduction in a laboratory physics experiment. It also achieved the polarization resolution of 0.3 deg which is the record for Compton polarimetry. To improve this further we develop a high resolution polarimeter that is based on a rotationally symmetric annular planar segmented germanium detector.

A 28.7 Wed 17:00 C/Foyer

Diffraction effects in the Recoil-Frame Photoelectron Angular Distributions of Halomethanes. — •Cédric Bomme[1], Denis Anielski[1,2], Evgeny Saveleyv[1], Rebecca Boll[1], Benjamin Erk[1], Sadia Bari[3], Jens Kienitz[1,2], Nele Mueller[1], Thomas Kierspiel[1,4], Sebastian Trippel[1], Jens Viefhaus[1], Jochen Kuepper[1,4], Mauro Stener[5], Piero Decleva[5], and Daniel Rolles[1,6] — [1]Deutsches Electronen-Synchrotron(DESY), Hamburg, Germany. — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany. — [3]European XFEL GmbH, Hamburg, Germany. — [4]Hamburg Center for Ultrafast Imaging, University of Hamburg, Germany. — [5]Universita' di Trieste, Trieste, Italy. — [6]Kansas State University, Manhattan, KS, USA.

We have measured the recoil frame photoelectron angular distributions (RF-PADs) for inner-shell photoionization of the halomethanes CH3F, CH3I, ClCH2I and CF3I in the gas-phase. Using our new double-sided velocity map imaging (VMI) spectrometer optimized for electron-ion coincidence measurements of high-kinetic energy electrons, we are able to determined RF-PADs for photoelectrons up to 300 eV. For these high kinetic energies, the RF-PADs are dominated by diffraction effects that encode information on the molecular geometry in the RF-PADs.

A 28.8 Wed 17:00 C/Foyer

Measuring Molecular (Recoil) Frame-Photoelectron Angular Distribution of Halogenated Carbon Compounds. — •Evgeny Savelyev[1,2], Cédric Bomme[1], Rajesh Kushuwaha[3], Timur Osipov[4], Hui Xiong[5], Nora Berrah[5], and Daniel Rolles[1,3] — [1]Deutsches Elektronen-Synchrotron — [2]Georg-August-Universität Göttingen — [3]Kansas State University — [4]SLAC National Accelerator Laboratory — [5]University of Connecticut

We investigated Recoil Frame - Photoelectron Angular Distribution(RF-PADs) of halogenated hydrocarbons such as CH3I, CF3I, and 2,6-Difluoroiodobenzene molecules using a double-sided Velocity Map Imaging Spectrometer at beamline 10.0.1 of the Advanced Light Source (ALS) and at the FLASH Free Electron Laser. At the ALS, the RF-PADs were measured using a photoelectron-ion coincidence technique, while adiabatic laser alignment was used at FLASH in order to fix the molecular axis in the laboratory frame. Both experiments were performed approximately 50eV above the iodine 4d photoionization threshold (i.e. at 107 eV photon energy). The results as well as a comparison and discussion of these two measurements are presented on this poster.

A 28.9 Wed 17:00 C/Foyer

CAMP at BL1 - a Permanent User Endstation for X-Ray Imaging and Pump-Probe Experiments at FLASH — Daniel Rolles[1], Benjamin Erk[1], •Cédric Bomme[1], Rebecca Boll[1], Evgeny Saveleyv[1], Elke Ploenjes-Palm[1], Barbara Keitel[1], Kai Tiedtke[1], Andrey Sorokin[1], Guenter Brenner[1], Siarhei Dziarzhytski1[1], Rolf Treusch[1], Robert Moshammer[2], Jan P. Müller[3], Thomas Möller[3], and CAMP collaboration[1,2,3] — [1]Deutsches Electronen-Synchrotron(DESY), Hamburg, Germany. — [2]Max-Planck-Institut f. Kernphysik, Heidelberg, Germany. — [3]Technische Universität Berlin, Berlin, Germany

CAMP is a multi-purpose instrument optimized for imaging and pump-probe experiments with Free-Electron Lasers (FELs) that was developed in the Max Planck Advanced Study Group at the Center for Free-Electron Laser Science (CFEL) in Hamburg [1] and that was employed at the LCLS, FLASH, and SACLA FELs for the last four years. It offers a choice of large-area, single-photon counting X-ray pnCCD imaging detectors as well as various charged particle spectrometers for electron and ion imaging and coincidence experiments. CAMP is now installed at FLASH BL1, which was equipped with new micro-focusing KB optics, as a permanent endstation available to all users. Here we present an overview of the endstation layout and the results of the commissioning beamtimes including focus imprints, wave front sensor measurements, and ion TOF spectra of rares gases. [1] L. Strüder et al., Nucl. Instr. Meth. Phys. Res. A. 614, 483 (2010).

A 28.10 Wed 17:00 C/Foyer

Multiphoton Ionization of Krypton Explored by Electron-Ion Coincidence Studies — •Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Georg Schmid[1], Sven Augustin[1], Yifan Liu[1], Artem Rudenko[2], Tatiana Marchenko[3], Marc Simon[3], Rolf Treusch[4], Joachim Ullrich[5], Thomas Pfeifer[1], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]J.R. Macdonald Laboratory, Kansas State University — [3]UPMC and CNRS, Paris — [4]Deutsches Elektronen-Synchrotron, Hamburg — [5]Physikalisch-Technische Bundesanstalt, Braunschweig

Understanding the mechanisms of multiphoton absorption and secondary relaxation processes in the XUV and X-ray regime is a prerequisite for all applications of short-wavelength free-electron lasers (FELs), e.g. for single-molecule imaging. Here, we present an electron-ion coincidence study on multiphoton ionization of krypton at 210 eV performed with a reaction microscope at the FEL facility FLASH. The production mechanisms for all observed charge states are analyzed by evaluating intensity-dependent Kr^{n+} ion spectra and the corresponding electron spectra. Even the highest charge state, Kr^{11+}, is found to be produced by sequential multiphoton ionization, which is in line with theoretical predictions (Rudek *et al.*, Nat. Phot. 6, 858-865 (2012)).

A 28.11 Wed 17:00 C/Foyer

Electron Rearrangement Dynamics in Dissociating I_2^{n+} Molecules Accessed by XUV Pump-Probe Experiments — •Kirsten Schnorr[1], Arne Senftleben[1], Moritz Kurka[1], Georg Schmid[1], Sven Augustin[1], Yifan Liu[1], Thomas Pfeifer[1], Artem Rudenko[2], Kristina Meyer[1], Matthias Kübel[3], Matthias Kling[3], Björn Siemer[4], Michael Wöstmann[4], Helmut Zacharias[4], Stefan Düsterer[5], Rolf Treusch[5], Joachim Ullrich[6], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]J.R. Macdonald Laboratory, Kansas State University — [3]Max-Planck-Institut für Quantenoptik, Garching — [4]Westfälische Wilhelms-Universität, Münster — [5]Deutsches Elektronen-Synchrotron, Hamburg — [6]Physikalisch-Technische Bundesanstalt, Braunschweig

The dynamics of dissociating multiply charged iodine molecules, I_2^{n+}, is induced and probed by intense XUV pulses delivered by the free-electron laser in Hamburg (FLASH). A first pulse multiply ionizes I_2 and thereby triggers the fragmentation of the molecule. During the dissociation a probe pulse further ionizes the fragments after an adjustable time-delay. Depending on the internuclear distance the probe pulse may or may not initiate electron transfer between the ions. By detecting the charge states of coincident ion pairs as a function of the pump-probe delay, we determine the critical separation and time scales up to which electron transfer along the internuclear axis takes place. These scales are important for understanding the radiation damage occurring in X-ray single-molecule imaging.

A 28.12 Wed 17:00 C/Foyer

Coulomb-THz-Field-Coupling Induced Time Shifts in Atomic Photoemission — •Georg Schmid[1], Kirsten Schnorr[1], Sven Augustin[1], Jakob Kunz[1], Arne Senftleben[1,9], Shaofeng Zhang[1], Artem Rudenko[3], Matthias Kübel[4], Lutz Foucar[8], Michael Gensch[5], Yuhai H. Jiang[6], Joachim Ullrich[7], Alaa Al-Shemmary[2], Torsten Golz[2], Nikola Stojanovic[2], Claus-Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]MPI für Kernphysik, Heidelberg — [2]DESY, Hamburg — [3]Kansas State University, Manhattan, KS — [4]MPI für Quantenoptik, Garching — [5]HZDR, Dresden — [6]SARI, Shanghai — [7]PTB, Braunschweig — [8]MPI für medizinische Forschung, Heidelberg — [9]Universität Kassel

XUV pump - THz probe experiments were carried out at the free-electron laser in Hamburg. At a photon energy of 59.4 eV, neon 2p, 2s and valence shake-up photoelectrons (PEs) were emitted into a THz probe field of 152 um. Using a reaction microscope, the 3-dim PE momentum vectors were measured as a function of the pump-probe delay. By tracing the delay-dependent streaking spectrograms, a relative time shift in the emission of valence shake-up PEs and direct 2p PEs was observed. In the framework of attosecond streaking, it was shown that so-called Coulomb-laser-coupling leads to measurement-induced time shifts in addtion to the quantum mechanical EWS time shift. It is predicted that low-energetic PEs are strongly effected by the combined action of Coulomb and long-wave THz field. By selecting shake-up PEs with energies < 1 eV, we experimentally confirm Coulomb-laser-coupling time shifts in the range of low PE energies.

A 28.13 Wed 17:00 C/Foyer

Time Resolved Electron- and Ion-Spectroscopy of Iodine Containing Molecules — •Karolin Mertens[1], Nils Gerken[1], Stephan Klumpp[1], Ivan Baev[1], Tommaso Mazza[2], Alberto De Fanis[2], Michael Meyer[2], and Michael Martins[1] — [1]Physik Department, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]European XFEL, Notkestrasse 85, 22607 Hamburg

Using the intense soft x-ray laser pulses from FLASH, we have studied the photofragmentation and ionization behavior of small iodine containing molecules with the goal to investigate charge redistribution processes as well as the time scales of the involved dissociation processes. The molecules CH3I and CH2I2 have been chosen as model systems, as a strong local core hole excitation can easily be generated at one or two different iodine sites of the molecules by tuning the photon energy to the strong 4d-4f shape resonance. The photoionization- and dissociation process is studied by ion time-of-flight spectroscopy. We present first results of measurements with a XUV-pump-XUV-probe setup. By using a Mach-Zehnder type split- and delay setup it is possible to track the development of the different ionic charge states of the molecule fragments depending on the time delay between two XUV pulses. Delay-dependent intensity changes in the iodine ion charge states are a clear indication of charge migration processes within the molecule. We also present preliminary photoelectron spectra of these systems measured with a magnetic-bottle type of spectrometer. This work is supported by the collaborative research center SFB 925 "Light induced dynamics and control of correlated quantum systems".

A 28.14 Wed 17:00 C/Foyer

An Experimental Setup for Multidimensional Soft X-Ray Spectroscopy — •Thomas Ding, Marc Rebholz, Faiq Bakar, Paul Birk, Kristina Meyer, Andreas Kaldun, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Information on both the structure and the dynamics of quantum systems is encoded in their optical-response spectra. In recent years multidimensional visible and ultraviolet spectroscopy has shed light on electronic/exciton dynamics in large molecular systems. However, due to the failure of standard optical elements for higher frequencies, the extension to the extreme ultraviolet or x-ray range to observe electronic core-level dynamics has not yet been realized. Here, we present an experimental design and first proof-of-principle results of a multidimensional soft x-ray spectroscopy scheme applicable for both attosecond high-harmonic sources and ultra-intense free-electron lasers. The heart of the setup is a dynamical soft x-ray-compatible four-segment split mirror to generate temporarily well-controlled multi-pulse sequences in a noncollinear box geometry for four-wave mixing. In the near future, one key application will be the time-resolved and site-specific spectroscopy of core- and valence-electron dynamics and the correlated electronic motion inside molecules.

A 28.15 Wed 17:00 C/Foyer

XUV-pump/IR-probe studies of photoionization and dissociation of N_2O — •Michael Schönwald[1], Philipp Cörlin[1], Andreas Fischer[1], Tomoya Mizuno[1], Alexander Sperl[1], Arne Senftleben[2], Joachim Ullrich[3], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck Institut für Kernphysik, Heidelberg, Deutschland — [2]Institut für Physik, Universität Kassel, Deutschland — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

We present the results of kinematically complete XUV-pump/IR-probe experiments on nitrous oxide (N_2O) using a reaction microscope. A train of attosecond XUV pulses, produced via high harmonic generation in an Ar-filled gas cell, covers the energy range from 20 to 50 eV, in which the molecule can either be singly ionized or directly doubly ionized. In addition, the excited cation N_2O^{+*} in a state near the double ionization threshold can either dissociate into a charged and a neutral fragment or it autoionizes into N_2O^{2+}, which subsequently leads to a Coulomb explosion into two charged fragments that are detected in coincidence ($N_2O^{2+} \rightarrow N^+ + NO^+$ or $N_2O^{2+} \rightarrow N_2^+ + O^+$). We investigated the influence of the additional IR-field on the double ionization yield. Both decay channels are enhanced but respond differently [1]. In addition we present the corresponding photoelectron energy spectra, which show indications for the autoionization process and its dependence on the delay and the kinetic energy release of the respective ions.

[1] X.Zhou et al., Nature Physics Vol.8, March 2012

A 29: Interaction with VUV and X-ray light I

Time: Thursday 11:00–13:15 Location: C/HSW

Invited Talk A 29.1 Thu 11:00 C/HSW

Electronic structure in high-intensity x-ray fields — •Robin Santra — Center for Free-Electron Laser Science, DESY, Hamburg, Germany — Department of Physics, University of Hamburg, Hamburg, Germany

Generally, the probability that a given atom in a material absorbs an x-ray photon in a single x-ray pulse is much less than unity for storage-ring-based x-ray sources, even for third-generation synchrotron radiation sources. This situation has changed dramatically with the arrival of x-ray free-electron lasers: In the micro-focus of an x-ray free-electron laser, saturation of x-ray photoabsorption is routinely achieved. The immediate consequence is that the overall behavior of matter under such extreme conditions is characterized by efficient multiphoton absorption via a sequence of single-photon absorption events combined with inner-shell decay cascades and collisional ionization processes. In this way, unusual, highly excited states of matter are formed, whose properties and dynamics are challenging to describe theoretically. In this talk, I will discuss progress that has been made towards developing suitable electronic structure tools. The performance of currently available electronic structure tools will be assessed by direct comparison with experimental data.

A 29.2 Thu 11:30 C/HSW

Theoretical characterization of the collective resonance states underlying the xenon giant dipole resonance — •Yi-Jen Chen[1,2], Stefan Pabst[1], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany

We present a detailed theoretical characterization of the two fundamental collective resonances underlying the xenon giant dipole resonance (GDR). This is achieved consistently by two complementary methods implemented within the framework of the configuration-interaction singles (CIS) theory. The first method accesses the resonance states by diagonalizing the many-electron Hamiltonian using the smooth exterior complex scaling technique. The second method involves a new application of the Gabor analysis to wave-packet dynamics. We identify one resonance at an excitation energy of 74 eV with a lifetime of 27 as, and the second at 107 eV with a lifetime of 11 as. Our work provides a deeper understanding of the nature of the resonances associated with the GDR: a group of close-lying intrachannel resonances splits into two far-separated resonances through interchannel couplings involving the $4d$ electrons. The CIS approach allows a transparent interpretation of the two resonances as new collective modes. Due to the strong entanglement between the excited electron and the ionic core, the resonance wave functions are not dominated by any single particle-hole state. This gives rise to plasma-like collective oscillations of the $4d$ shell as a whole.

A 29.3 Thu 11:45 C/HSW

Theoretical calculation of above-threshold ionization of xenon involving the giant dipole resonance — •Antonia Karamatskou[1,2], Robin Santra[1,2], Tommaso Mazza[3], and Michael Meyer[3] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Universität Hamburg, Hamburg, Germany — [3]European XFEL GmbH, Hamburg, Germany

We present a theoretical study on above-threshold ionization (ATI) of xenon in the photon energy range between 100 and 150 eV. Our numerical method relies on the exact solution of the Schrödinger equation within the time-dependent configuration interaction singles scheme (TDCIS). Within TDCIS it is possible to include and distinguish certain electronic correlation effects that are mediated by Coulomb interaction. In this way, the influence of collectiveness on the process studied can be quantified. Analyzing the 2-photon ATI cross section we find that, in contrast to the 1-photon ionization case, in the nonlinear regime two distinct resonance states underlying the giant dipole resonance can be resolved. The existence of two energy poles was predicted already in the 70's by Wendin [J.Phys. B At. Mol. Opt. Phys. 6, 42 (1973)]. We compare our theoretical results to recent measurements performed at the free-electron laser FLASH in Hamburg, which provided nonlinear electron-spectroscopy data on xenon in the XUV energy range.

This work was supported by the Deutsche Forschungsgemeinschaft under Grant No. SFB 925/A5.

A 29.4 Thu 12:00 C/HSW

Time-resolved relaxation dynamics in resonantly excited He nanodroplets — •Aaron LaForge[1], Alessandra Ciavardini[2], Mike Ziemkiewicz[3], Yevheniy Ovcharenko[4], Oksana Plekan[5], Paola Finetti[5], Robert Richter[5], Kevin Prince[5], Paolo Piseri[6], Michele Di Friaia[7], Arik Mika[8], Marcel Drabbels[8], Carlo Callegari[5], Thomas Moeller[4], Frank Stienkemeier[1], Patrick O'Keeffe[2], and Marcel Mudrich[1] — [1]Universität Freiburg, 79104 Freiburg, Germany — [2]CNR_IMP, 00016 Monterotondo Scalo, Italy — [3]University of California, Berkeley, California 94720, USA — [4]TU Berlin, 10623 Berlin, Germany — [5]Elettra, Basovizza, 34149 Trieste, Italy — [6]Università degli Studi di Milano, 20133 Milano, Italy — [7]University of Trieste, 34128 Trieste, Italy — [8]EPFL, CH-1015 Lausanne, Switzerland

The relaxation dynamics of resonantly excited helium droplets by XUV radiation has been investigated. Using an XUV-UV pump-probe setup, we initially resonantly excite the droplet and observe the various relaxation pathways prior to UV ionization. From the results we can clearly see an initial droplet band relaxation followed by the electron relaxing to an atomic state. Here, we will present the time resolved results for various resonant excitations and droplet sizes.

A 29.5 Thu 12:15 C/HSW

Two-color X-ray pump X-ray probe study of core-hole decay dynamics — Carl Stefan Lehmann[1], Antonio Picón[1], Steve Southworth[1], Gilles Doumy[1], Anne Marie March[1], Dooshaye Moonshiram[1], Bertold Krässig[1], Elliot Kanter[1], Linda Young[1], Benjamin Erk[2], Cedric Bomme[2], Daniel Rolles[2,3], Artem Rudenko[3], •Steve Pratt[4], Dipanwita Ray[5], Timur Osipov[6], Nora Berrah[6], and Christoph Bostedt[7] — [1]X-ray Science Division, Argonne National Laboratory — [2]Max-Planck-Advanced Study Group at CFEL, DESY — [3]Department of Physics, Kansas State University — [4]Chemical Sciences & Engineering Division, Argonne National Laboratory — [5]Chemical Science Division, Lawrence Berkeley National Laboratory — [6]Department of Physics, UCONN — [7]LCLS, SLAC National Accelerator Laboratory

To resolve the femtosecond inner-shell dynamics and the subsequent induced electron transfer in a molecule, the core-hole decay dynamics in XeF2 have been directly studied using femtosecond time-resolved x-ray pump x-ray probe coincidence imaging.

The recently developed capability at LCLS was used to generate two-color x-ray pulses with variable delay. A time and position sensitive detector has been used to record the ion fragments in coincidence.

XeF2 is a very interesting molecule, as it allows us to compare the molecular core-hole decay with the atomic case, Xe atom. Hence, we used a specific photon energy for the pump pulse to induce a core-hole in the Xe site, and with the probe pulse we ionize again for different time delays and photon energies, both for Xe atom and XeF2 molecule.

A 29.6 Thu 12:30 C/HSW

Testing calculated potential energy curves of molecular oxygen by measuring vibrational wave-packets with an XUV–IR experiment — •Philipp Cörlin, Andreas Fischer, Michael Schönwald, Tomoya Mizuno, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Heidelberg

In our experiment XUV photons (18 eV to 40 eV) created from 10 fs IR laser pulses by high-harmonic generation are used to ionize molecular oxygen. The ionic state is probed by a delayed IR pulse with an effective intensity of 3e12 W/cm^2. Charged fragments are detected with a reaction microscope and a pronounced oscillation in the count rate of very low energetic O^+ ions is measured. The low KER and the oscillation period of 40.0 fs point towards a wave-packet oscillation within the binding ionic $a^4\Pi_u$ potential which is probed via the weakly repulsive $f^4\Pi_g$ state by resonant absorption of an IR photon [1, 2]. By comparison of experimental spectra with the results of a coupled channel simulation, we are able to test different sets of calculated potential curves. While the agreement between experiment and theory is on a level not observed for O_2^+ wave-packets before, some properties of the experimental spectra cannot be reproduced in a satisfying manner by our simulation, if calculated binding potentials are used. In order to demonstrate the sensitivity on the shape of the binding potential curve, we perform a simulation with a Morse potential fitted to the experimental data which reproduces the experimental spectra very well.

[1] S. De *et al.*, Phys. Rev. A 84, 043410 (2011)
[2] M. Magrakvelidze *et al.*, Phys. Rev. A 86, 023402 (2012).

A 29.7 Thu 12:45 C/HSW

Single-shot autocorrelation in the vacuum ultraviolet spectral range — •Dimitrios Rompotis[1,2,3], Thomas Gebert[1,2,3], Marek Wieland[1,2,3], Theophilos Maltezopoulos[1,2,3], and Markus Drescher[1,2,3] — [1]Institut fuer Experimentalphysik Universitaet Hamburg, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging (CUI), Hamburg, Germany — [3]Centre for Free-Electron-Laser Science, Hamburg, Germany

We introduce a method for single-shot time metrology in the VUV based on a non-linear autocorrelation scheme. In an all-reflective design, the technique is applicable to a wide spectral range, from the infrared to the extreme ultraviolet.

Single-shot autocorrelation is demonstrated for the first time, to our knowledge, in the VUV spectral range. Non-resonant two-photon ionization of Krypton is used to obtain a second-order autocorrelation measurement of an intense, Ti:Sa fifth-harmonic pulse at 161.8 nm.

In addition to ultrashort pulse characterization, the experimental scheme is being utilized in a single-shot, VUV pump-VUV probe configuration, for the investigation of ultrafast dynamics. We present results, demonstrating the feasibility of non-linear, time-resolved molecular spectroscopy in the vacuum ultraviolet.

A 29.8 Thu 13:00 C/HSW

Time-Dependent Multiphoton Ionization of Xenon in the Soft-X-Ray Regime — Nils Gerken[1], Stephan Klumpp[1], Andrey Sorokin[2,3], Kai Tiedtke[2], •Mathias Richter[4], Vera Bürk[1], Karolin Mertens[1], Pavle Juranić[2], and Michael Martins[1] — [1]Universität Hamburg, Institut für Experimentalphysik, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron, DESY, Notkestraße 85, 22603 Hamburg, Germany — [3]Ioffe Physico-Technical Institute, Polytekhnicheskaya 26, 194021 St. Petersburg, Russia — [4]Physikalisch-Technische Bundesanstalt, PTB, Abbestraße 2-12, 10587 Berlin, Germany

The time-dependent multiphoton ionization of xenon atoms was studied with femtosecond pulses in the excitation range of the 4d giant resonance at the photon energy of 93 eV [1]. Benefiting from a special operation mode of the free electron laser FLASH, the measurements were performed with varying pulse durations. A strong dependence of the ion charge distribution on the pulse duration allowed the different multiphoton mechanisms behind the multiple photoionization of xenon to be disentangled up to a charge state of 10+. The results up to 8+ are well explained by sequences of single photon, multiphoton, and Auger processes, but higher charge state generation suggests the need for collective electron multiphoton excitations.

[1] N. Gerken, S. Klumpp, A. A. Sorokin, K. Tiedtke, M. Richter, V. Bürk, K. Mertens, P. Juranić, M. Martins, Phys. Rev. Lett. 112, 213002 (2014)

A 30: Precision spectroscopy of atoms and ions III (with Q)

Time: Thursday 11:00–13:00 Location: M/HS1

A 30.1 Thu 11:00 M/HS1

Untersuchung von Lanthanoiden mittels Laserresonanzionisation an der Mainzer Atomic Beam Unit — •Patrick Dyrauf, Michael Franzmann, Tina Gottwald, Tom Kieck, Tobias Kron, Pascal Naubereit, Fabian Schneider, Dominik Studer und Klaus Wendt — Institut für Physik, Universität Mainz

Die Spektren einiger Lanthanoiden sind bis heute im Bereich hochliegender Resonanzen in der Nähe des ersten Ionisationspotentials noch wenig bzw. gar nicht erforscht. Dies liegt primär an ihrer komplexen atomaren Struktur, die sowohl Messungen als auch besonders deren Auswertung und Interpretation erschwert. Die Anwendung des Verfahrens der mehrstufigen Resonanzionisations-Massenspektrometrie zur elementselektiven Ionisation an Isotopenproduktionsanlagen bzw. zur Isobarenabtrennung wird dadurch behindert. Gleichzeitig bietet dies aber auch gute Möglichkeiten um hier nützliches atomphysikalisches Datenmaterial zu generieren und damit Ionisationsprozesse und deren Effizienz zu optimieren bzw. ein tieferes Verständnis der reichen Niveauschemata zu erlangen. Hierzu wird an der Universität Mainz ein hoch-repetierendes Titan-Saphir-Lasersystem an der Atomstrahlapparatur MABU verwendet, die ein kompaktes Quadrupol-Massenspektrometer zur Isotopenselektion enthält. Erste Untersuchungen betrafen Anregungsschemata im Spektrum des Dysprosiums, zusätzlich sind Messungen an Holmium und Erbium vorgesehen. Der Einsatz eines weit abstimmbaren Lasers mit reduzierter Linienbreite ist vorgesehen, um die Signifikanz bereits erzielter Daten zu erhöhen und einen möglichst großen Energiebereich abzudecken.

A 30.2 Thu 11:15 M/HS1

Ba^+ Atomic Properties from Single Ion Experiments — •Elwin A. Dijck, Amita Mohanty, Mayerlin Nunez-Portela, Nivedya Valappol, Andrew T. Grier, Oliver Boell, Steven Hoekstra, Lorenz Willmann, and Klaus Jungmann — Van Swinderen Institute, University of Groningen, The Netherlands

Single trapped, laser cooled Ba^+ and Ra^+ ions are ideally suited for high precision measurements of the weak mixing angle at low energy; in addition, the same experimental setup can be used to build an atomic clock with a fractional frequency uncertainty of 10^{-18}. Both applications require powerful diagnostics of trap dynamics and percent level accuracy in atomic theory. Here the lifetime of the metastable $5d^2D_{5/2}$ level of Ba^+ provides a sensitive diagnostic for perturbations of the ion. Using quantum jump spectroscopy of a single trapped ion, a lifetime of 26(2) s was determined, correcting for collisions with residual gas. Furthermore, we have determined the $6s^2S_{1/2}$–$6d^2P_{1/2}$ and $6s^2P_{1/2}$–$5d^2D_{3/2}$ transition frequencies to MHz accuracy using Raman spectroscopy referenced to an optical frequency comb. This constitutes an improvement in the absolute accuracy of some 2 orders of magnitude.

A 30.3 Thu 11:30 M/HS1

Light Shifts: Measuring Atomic Parity Violation in Single Trapped Ions — •Amita Mohanty, Elwin A. Dijck, Mayerlin Nunez Portela, Nivedya Valappol, Andrew T. Grier, Steven Hoekstra, Klaus Jungmann, and Lorenz Willmann — Van Swinderen Institute, University of Groningen, The Netherlands

Light shifts permit the mapping of weak interaction effects onto the energy splitting of the magnetic sub-levels in Ra^+. A precise measurement of atomic parity violation (APV) provides for the determination of the weak mixing angle ($\sin^2\Theta_W$), the Standard Model parameter which describes the connection between the electromagnetic and weak interactions. APV is also sensitive to light dark matter bosons, e.g dark Z bosons with masses below a few 100 MeV. For the experiment, localization of a single ion within a fraction of an optical wavelength in two orthogonal light fields of known polarization is required in order to disentangle the electromagnetic and weak contributions to the light shift. The heavy alkaline earth ion Ra^+ is very well suited for such experiments because the APV signal scales significantly stronger than with Z^3. Ba^+ serves as a precursor and the precise determination of the light shift in the $5d^2D_{3/2}$–$6s^2S_{1/2}$ transition is the next step towards the Ra^+ ion APV experiment.

A 30.4 Thu 11:45 M/HS1

Search for optical excitation of the low-energy nuclear isomer of ^{229}Th — •David-Marcel Meier, Maksim V. Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Direct optical excitation of the nuclear transition between ground state and the 7.8 eV isomer in ^{229}Th is the missing link towards a study of this system as a precise nuclear clock. We plan to use two-photon laser excitation via electronic bridge processes in Th^+ [1]. The high density of states within the energy range from 7.3 to 8.3 eV [2,3] in Th^+ promises a strongly enhanced nuclear excitation rate. Using laser ablation loading of the ion trap and photodissociation of molecular ions that are formed in reactions of Th^+ with impurities in the buffer gas, we efficiently load and stably store ions of the radioactive ^{229}Th isotope. We have measured the hyperfine structure and isotope shifts of two resonance lines where one of these lines shows an untypical negative isotope shift compared to all previously known lines in ^{229}Th which show a positive shift. Both lines are suitable as first excitation stages of the electronic bridge.

[1] S. G. Porsev et al., Phys. Rev. Lett. 105, 182501 (2010)
[2] O. A. Herrera-Sancho et al., Phys. Rev. A 85, 033402 (2012)
[3] O. A. Herrera-Sancho et al., Phys. Rev. A 88, 012512 (2013)

A 30.5 Thu 12:00 M/HS1

Astrophysical line diagnosis requires non-linear dynamical atomic modeling — •Natalia S. Oreshkina, Stefano M. Cavaletto, Christoph H. Keitel, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Line intensities and oscillator strengths for the controversial 3C and 3D astrophysically relevant lines in neonlike Fe^{16+} ions are calculated [1]. First, a large-scale configuration-interaction calculation of oscillator strengths is performed with the inclusion of higher-order electron-correlation effects. Also, QED effects to the transition energies are calculated. Further considered dynamical effects give a possible resolution of the discrepancy of theory and experiment found by recent x-ray free electron laser measurements [2]. We find that, for strong x-ray sources, the modeling of the spectral lines by a peak with an area proportional to the oscillator strength is not sufficient and non-linear dynamical effects have to be taken into account. Thus we advocate the use of light-matter interaction models also valid for strong light fields in the analysis and interpretation of astrophysical and laboratory x-ray spectra.

[1] N. S. Oreshkina, S. M. Cavaletto, C. H. Keitel and Z. Harman, Phys. Rev. Lett. **113**, 143001 (2014).
[2] S. Bernitt, G. V. Brown, J. K. Rudolph, R. Steinbrügge *et al.*, Nature **492**, 225 (2012).

A 30.6 Thu 12:15 M/HS1

Life times of the HFS transitions in H-like and Li-like bismuth — •Jonas Vollbrecht for the LIBELLE-Collaboration — Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, Germany

In 2011 the LIBELLE collaboration succeeded to measure the hyperfine splitting in highly charged $^{209}Bi^{82+}$ and for the first time in a laser spectroscopy experiment, in $^{209}Bi^{80+}$. For this purpose the ions were accelerated to 400 MeV/u by the GSI accelerator infrastructure and stored in the experimental storage ring (ESR) in the form of two bunches at a velocity of $\beta \approx 0.71$. One of the bunches was excited by a laser and the emitted fluorescence photons were detected by specialized detector systems. Besides the transition wavelengths some data for the life time of the lithium like bismuth were recorded. The precision of the measurement was limited by the calibration of the electron cooler voltage that determines the ion velocity which is needed to transform the results from co-moving coordinates to the rest frame. Therefore a second beam time was scheduled for march 2014 with an improved voltage calibration via a high precision voltage divider provided by Physikalisch-Technische Bundesanstalt Braunschweig (PTB) and an updated DAQ system. Besides a much higher accuracy of the transition energies, the new setup also allowed to gather high statistics data on the life times of both HFS transitions in $^{209}Bi^{82+}$ an $^{209}Bi^{80+}$. The analysis of the life times will be presented in this talk.

This work is supported by BMBF under contract number 05P12PMFAE and 05P12RDFA4.

A 30.7 Thu 12:30 M/HS1

Search for the $^{1}P_1$ level in ^{254}No in a buffer-gas cell — •Felix Lautenschläger[1], Hartmut Backe[2], Michael Block[3,4], Bradley Cheal[5], Premaditya Chhetri[1], Peter Kunz[6], Fritz-Peter Hessberger[3,4], Mustapha Laatiaoui[3,4], Werner Lauth[2], Sebastian Raeder[7], Thomas Walther[1], and Calvin Wraith[5] — [1]Technische Universität Darmstadt, Deutschland — [2]Johannes Gutenberg-Universität Mainz, Deutschland — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Deutschland — [4]Helmholtzinstitut Mainz, Deutschland — [5]University of Liverpool, Großbritannien — [6]TRIUMF, Kanada — [7]Katholieke Universiteit Leuven, Belgien

The atomic structure of the heaviest elements (Z>100) is strongly affected by relativistic effects. Their description in modern Relativistic-Coupled-Clusters and Multi-Configuration-Dirac-Fock theories can be benchmarked by laser spectroscopy of the atomic levels in ^{254}No, which has a simple atomic structure allowing precise predictions of the atomic transitions. At present, no experimental information is available for the atomic levels of ^{254}No. It can be produced using the nuclear fusion reaction ^{208}Pb(^{48}Ca,2n)^{254}No. In our experiment, we employ the Radioation Detected Resonance Ionization Spectroscopy in a buffer-gas cell behind the velocity-filter SHIP at GSI. In a recent experiment the search for the predicted 5f^{14}7s7p $^{1}P_1$ level in ^{254}No has been continued. First results of this measurement campaign will be presented.

A 30.8 Thu 12:45 M/HS1

The ALPHATRAP Experiment — •Robert Wolf[1], Stefan Erlewein[1,2], Henrik Hirzler[1,2], Sandro Kraemer[1,2], Tim Sailer[1,2], Andreas Weigel[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik, Universität Heidelberg

The ALPHATRAP experiment aims for the ultra-high precision determination of the g-factor of the bound electron in highly charged hydrogen-, lithium- and boron-like heavy ions as ^{208}Pb^{81+}, ^{208}Pb^{79+} and ^{208}Pb^{77+}. In these systems the electron is exposed to extremely strong fields of up to 10^{16} V/cm. Simultaneously, bound-state quantum electrodynamic (BS-QED) effects scale with the nuclear charge number, making these measurements a very stringent test of the underlying theory under extreme conditions. In combination with currently conducted BS-QED calculations, the measurement will provide an independent determination of the fine-structure constant α with high precision. To achieve this, the prospective ALPHATRAP experiment, consisting of a cryogenic double Penning-trap setup, is coupled via an ultra-high vacuum beamline to the Electron-Beam Ion Trap at the Max-Planck Institut für Kernphysik, which provides the highly charged ions. The status of the project as well as the measurement program will be presented.

A 31: Ultracold Atoms: Trapping and Cooling I (with Q)

Time: Thursday 11:00–12:30 Location: P/H2

Group Report A 31.1 Thu 11:00 P/H2

Isospaced ion crystals and fault-tolerant Hahn-Ramsey interferometry — •Michael Johanning[1], Timm F. Gloger[1], Peter Kaufmann[1], Delia Kaufmann[1], Thomas Collath[1], M. Tanveer Baig[1], Nikolay V. Vitanov[2], and Christof Wunderlich[1] — [1]Faculty of Science and Technology, Department of Physics, University of Siegen, Walter Flex Str. 3, 57072 Siegen, Germany — [2]Department of Physics, St Kliment Ohridski University of Sofia, 5 James Bourchier blvd, 1164 Sofia, Bulgaria

We describe the static and dynamic properties of strings of ions stored in segmented electrodynamical Paul traps with a uniform ion separation achieved by an anharmonic effective potential generated by suitable voltages applied to segmented dc electrodes or by appropriate electrode shaping. We find expressions for the desired potential and calculate normal modes and the effective spin coupling when the ion string is exposed to a magnetic gradient. The effect on the radial confinement and the transition of the equidistant linear chain to an almost equidistant zigzag are investigated.

In the second part, a scheme for efficient correction of driving field frequency drifts in Ramsey interferometry is presented. The two near-resonant $\pi/2$ pulses of duration T used in the traditional Ramsey setup are supplemented with an additional refocussing pulse of duration $2T$ and opposite detuning. We demonstrate the validity of the concept by comparing experimental results from plain Ramsey and Hahn-Ramsey measurements, obtained from microwave spectroscopy on ^{171}Yb^{+} ions in a segmented linear Paul trap.

A 31.2 Thu 11:30 P/H2

"Second-order magic" radio-frequency dressing for magnetically trapped 87Rb atoms. — •Georgy Kazakov and Thorsten Schumm — Institute of Atomic and Subatomic Physics, Vienna University of Technology, Stadionallee 2, 1020 Vienna, Austria

We consider the modification of magnetic trap potential what allow to decrease the position-dependent decoherence in trapped atomic ensembles. To mitigate the perturbing effects of the magnetic trap, "near-magic field" configurations are usually employed, where the involved clock transition becomes independent of the atoms potential energy to first order. Still, higher order effects are a dominating source for dephasing, limiting the perfomance of this approach.

Here we propose a simple method to cancel the energy dependence to both, first and second order, using weak radio-frequency dressing. We give corresponding values of dressing frequencies, amplitudes, and trapping fields for 87Rb atoms, and investigate quantitatively the robustness of these "second-order magic" conditions to variations of the trapping field and dressing field amplitude and polarization. We conclude that such radio-frequency dressing can suppress field-induced dephasing by at least one order of magnitude in comparison with "ordinary" magic trap without dressing.

A 31.3 Thu 11:45 P/H2

Prethermalization of atoms due to photon-mediated long-range interactions — •Stefan Schütz and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

Atoms can spontaneously form spatially ordered structures in optical resonators when they are transversally driven by lasers. This occurs when the laser intensity exceeds a threshold value and results from the mechanical forces on the atoms associated with superradiant scattering into the cavity mode. We treat the atomic motion semiclassically [1] and show that, while the onset of spatial ordering depends on the intracavity-photon number, the stationary momentum distribution is a Gaussian function whose width is determined by the rate of photon losses. Above threshold, the dynamics is characterized by two time scales: after a violent relaxation, the system slowly reaches the stationary state over time scales exceeding the cavity lifetime by several orders of magnitude. In this transient regime the atomic momenta form non-Gaussian metastable distributions, which emerge from the interplay between the long-range dispersive and dissipative mechanical forces of light [2]. We argue that the dynamics of self-organization of atoms in cavities offers a test bed for studying the statistical mechanics of long-range interacting systems.

[1] S. Schütz, H. Habibian, and G. Morigi, Phys. Rev. A **88**, 033427 (2013)

[2] S. Schütz and G. Morigi, Phys. Rev. Lett. **113**, 203002 (2014)

A 31.4 Thu 12:00 P/H2

Mean-Field Analysis of Selforganization of Atoms in Cavities — •Simon Jäger, Stefan Schütz, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

Atoms can spontaneously form spatially ordered structures in optical resonators when they are transversally driven by lasers. This occurs by means of photon-mediated long-range forces, which establish correlations when the intracavity photon number exceeds a threshold value. The selforganization transition is an out-of-equilibrium phenomenon, where losses are an essential element determining the threshold behaviour [1]. In this contribution, we analyse the nature of the transition by means of a mean-field Fokker-Planck equation (FPE), which has been systematically derived from the master equation of atoms and cavity field and describes the dynamics of the one-particle density matrix. This FPE has the form of a Vlaslov equation when retardation effects, giving rise to noise, are neglected [2]. We analyse the dynamics of the order parameter, which quantifies the localization of the atoms in ordered patterns, and show that close to the selforganization threshold its dynamics is determined by a potential of Landau form in an appropriately defined thermodynamic limit. We then perform a stability analysis which permits us to identify the spectral properties of the intracavity field.

[1] S.Schütz and G. Morigi, Phys. Rev. Lett. **113**, 203002 (2014)
[2] A. Campa, T. Dauxois, and S. Ruffo, Phys. Rep. **480**, 57 (2009)

A 31.5 Thu 12:15 P/H2

Redistributional laser cooling and thermalization in dense gaseous ensembles — •Benedikt Gerwers, Stavros Christopoulos, Roberto Cota, Katharina Knicker, Anne Sass, Lars Weller, Peter Moroshkin, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Deutschland

Redistributional laser cooling is a novel cooling technique applicable to ultradense gaseous ensembles. Optically active atoms undergo frequent collisions with noble buffer gas at high pressure, thus shifting the atomic resonances. This enables the absorption of far red-detuned laser excitation, while subsequent spontaneous decay occurs closer to the unperturbed resonances. During such a cooling cycle, kinetic energy of the order of kT is extracted from the ensemble. Thermal deflection spectroscopy indicates temperature changes as high as 500K. Temperature determination is also possible through Kennard-Stepanov analysis of the pressure-broadened absorption and fluorescence spectra of thermalized atomic and molecular transitions. Alkali and noble dimers are also investigated for molecular redistribution cooling.

A 32: Interaction with strong or short laser pulses III

Time: Thursday 14:30–16:30 Location: C/HSW

Invited Talk A 32.1 Thu 14:30 C/HSW

Time-Resolved Measurement of Interatomic Coulombic Decay in Ne_2 — •Kirsten Schnorr — Max-Planck-Institut für Kernphysik, Heidelberg

Interatomic Coulombic Decay (ICD) is a radiationless relaxation mechanism where deexcitation of one atom is achieved via energy transfer to a weakly bound neighbouring atom, which then emits an electron. The process has been theoretically predicted by Cederbaum *et al.* in 1997 and experimentally confirmed in clusters and molecules a few years later. Although the decay time of ICD is a crucial parameter for understanding the underlying mechanism, no time-resolved investigation was performed so far.

In our measurement we determine the ICD lifetime in Ne_2: A 58 eV pump pulse of approximately 60 fs creates a $2s$ hole at one of the Ne atoms, thereby initiating the decay process, which is then probed after an adjustable time delay by an exact copy of the first pulse. Only if the decay has happened by the time the probe pulse arrives, a certain energy level may be populated. This leads to a characteristic fragmentation channel that can be separated by using a Reaction Micrsoscope, which allows us to study charged particles in coincidence.

A 32.2 Thu 15:00 C/HSW

Inversion symmetry breaking of atomic bound states in strong laser fields — •Veit Stooss[1], Andreas Kaldun[1], Alexander Blättermann[1], Thomas Ding[1], Christian Ott[2], and Thomas Pfeifer[1] — [1]Max Planck Institut für Kernphysik, Heidelberg, Deutschland — [2]University of California, Berkeley, USA

Light induced states represent one of the most prominent features appearing in transient-absorption spectroscopy and contain a lot of information about dynamic processes. Disentangling and understanding the various contributions to these features is essential in order to gain information about the induced couplings and electronic dynamics of atomic and molecular systems in strong external fields. We present an explanation for the physical origin of spectral features arising at one photon energy around dipole-forbidden states in transient-absorption spectra. The results are based on experiments in singly-excited Helium and a few-level model calculation. The features appear due to instantaneous polarization and breaking of the symmetry of the atom following the infrared-fs pulse used in the transient-absorption scheme. Using this effect the onset of symmetry-breaking for low-lying states in Helium by tuning from a weak to a strong electric field was directly observed.

A 32.3 Thu 15:15 C/HSW

Quantum oscillations between close-by states mediated by the electronic continuum in intense high-frequency pulses — •Philipp V Demekhin[1] and Lorenz S Cederbaum[2] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett-Strasse 40, D-34132 Kassel, Germany — [2]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 229, D-69120 Heidelberg, Germany

The dynamics of neighboring states exposed to short intense laser pulses of carrier frequencies well above the ionization threshold of the system is investigated from first principles. It is shown that the pulse induces a time-dependent non-hermitian coupling between these states determined by the AC Stark effect in the electronic continuum and the direct ionization probability. This coupling induces quantum oscillations between the neighboring states while the strong pulse is on. The phenomenon opens the possibility to achieve a coherent control over the populations of neighboring states by strongly off-resonant ionizing pulses. Numerical exemplifications of the present analytical results suggest exciting applications for experiments.

A 32.4 Thu 15:30 C/HSW

Explosion dynamics of single clusters resolved for particle size and laser power density — •D. Rupp[1], L. Flückiger[1], M. Adolph[1], T. Gorkhover[1,2], M. Krikunova[1], M. Müller[1], J. Müller[1], T. Oelze[1], Y. Ovcharenko[1], M. Sauppe[1], B. Röben[1], S. Schorb[1,2], D. Wolter[1], R. Treusch[3], C. Bostedt[1,2], and T. Möller[1] — [1]TU Berlin — [2]LCLS@SLAC — [3]FLASH@DESY

Direct imaging and simultaneous ion spectroscopy of single clusters with x-ray free-electron lasers such as FLASH in Hamburg allows for analyzing ion spectra of a single cluster of *known size irradiated with defined laser intensity* [1]. The averaging over focal intensity profile and cluster size distribution - experimental reality in almost all previous studies of lasers with gas-phase targets - typically leads to wash-out of the key signatures. From the x-ray scattering patterns of single clusters the initial state of the cluster can be deduced, its size and shape, as well as the FEL power density the cluster has been exposed to. Our results give strong evidence that the ions from XUV-irradiated large xenon clusters expand only from the surface of a super-dense, almost neutral nanoplasma, while recombination within the fully screened core competes with the expansion process, ultimately bringing it to halt. The dominant recombination strongly shapes the measured ion kinetic energies, resulting in narrow distributions of only fast ions with about a factor of 25 higher ion than electron energies. The size and laser intensity resolved ion spectra allow for detailed studying of the acceleration mechanism and disentangling hydrodynamic and Coulombic contributions. [1] T. Gorkhover *et al.*, PRL **108**, 245005 (2012)

A 32.5 Thu 15:45 C/HSW

XUV spectroscopy on argon micro droplets in intense NIR laser fields — •Robert Irsig, Lev Kazak, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock, Germany

We investigate the emission of soft x-ray radiation from liquid microsized argon droplets. The droplets are irradiated by ultra-short intense laser pulses with a center wavelength at 810nm. Due to efficient heating, highly charged ions with a characteristic plasma emission pattern are produced. With the use of a home-build flat-field XUV spectrometer, various atomic transitions can be identified allowing to study the nanoplasma properties. We present first results of the influence of the laser pulse parameters such as pulse length and pulse energy on the XUV emission.

A 32.6 Thu 16:00 C/HSW

Robust signatures of quantum radiation reaction in focused ultrashort laser pulses — •jian-xing li, karen z. hatsagortsyan, and christoph h. keitel — Max-Planck-Institut für Kern-

physik, Saupfercheckweg 1, 69029 Heidelberg, Germany

Radiation reaction effects in the interaction of an electron bunch with a superstrong focused ultrashort laser pulse are investigated in the quantum radiation dominated regime. In dependence of the laser pulse duration we find signatures of quantum radiation reaction in the radiation spectra, which are characteristic for the focused laser beam and visible in the qualitative behaviour of both the angular spread and the spectral bandwidth of the radiation spectra. The signatures are robust with respect to the variation of the electron and laser beam parameters in a large range. They fully differ qualitatively from those in the classical radiation reaction regime and are measurable with presently available laser technology [1].

[1] Jian-Xing Li, Karen Z. Hatsagortsyan, Christoph H. Keitel. Phys. Rev. Lett., **113, 044801 (2014).**

A 32.7 Thu 16:15 C/HSW

The tunneling picture of electron-positron pair creation — •Anton Wöllert, Michael Klaiber, Heiko Bauke, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The common tunneling picture of electron-positron pair creation in a strong electric field is generalized to pair creation in combined crossed electric and magnetic fields [1]. This new picture is formulated in a gauge invariant and Lorentz invariant manner for quasistatic fields. It may be used to infer qualitative features of the pair creation process. In particular, it allows for an intuitive interpretation of how the presence of a magnetic field modifies and in particular cases even enhances pair creation. The enhanced picture makes it easy to understand how an energetic photon, which may assist the creation of electrons and positrons from the vacuum, modifies pair creation by lowering the potential barrier but also increasing the relativistic mass of the created particles.

[1] A. Wöllert, M. Klaiber, H. Bauke, C. H. Keitel, "The tunneling picture of electron-positron pair creation", arXiv:1410.2401

A 33: Collisions, scattering and recombination

Time: Thursday 14:30–16:30 Location: C/kHS

A 33.1 Thu 14:30 C/kHS

Singularimetry of light with electron vortex beams — •Armen Hayrapetyan and Jörg Götte — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden

We study the interaction of electron vortex beams (EVBs) with the standing wave of laser light, where electrons impinge perpendicularly on two counter propagating light beams. For such a crossed-beam scenario, we derive analytical expression for the wave function of the transmitted EVB by employing the Hamiltonian Analogy between electron optics and quantum mechanics. By analyzing the phase of the EVB after passing through the field, we show the splitting of a single electron vortex into a constellation of unit vortices, similar to the analogous splitting of optical vortices from dielectric interfaces, predicted recently by Dennis and Götte. Thereupon, by interchanging the roles of light and matter and considering the light as a refractive medium for electrons, we demonstrate that the concept of singularimetry, that is the probing of a scatterer by means of the singularities in the probe beam, can be extended to EVBs transmitted through light.

References: M.R. Dennis and J.B. Götte, Phys. Rev. Lett. 109, 183903 (2012).

A 33.2 Thu 14:45 C/kHS

Linear polarization of x-ray transitions due to dielectronic recombination in highly charged ions — •Holger Jörg[1], Zhimin Hu[1], Hendrik Bekker[2], Michael Andres Blessenohl[2], Daniel Hollain[2], Stephan Fritzsche[3,4], Andrey Surzhykov[3], José Ramón Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institut der Universität Heidelberg, 69120 Heidelberg, Germany — [2]Max-Plank-Institut für Kernphysik, Heidelberg, 69117 Heidelberg, Germany — [3]Helmholtz-Institut Jena, 07743 Jena, Germany — [4]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

Linear polarization of x-rays produced in the process of dielectronic recombination in highly charged xenon ions was studied at an electron beam ion trap by means of the Compton polarimetry technique. The experimental results are in all cases in good agreement with the theoretical predictions. In the specific case of the dielectronic recombination resonance exciting the [1s2s22p1/2]1 state, the Breit interaction between bound electrons strongly influences the polarization of the emitted x-rays. The results agree with the predictions which include the Breit interaction and by 5σ rule out the theory taking into account only the Coulomb electron-electron repulsion. Apart from the fundamental importance, the experimental results open numerous possibilities for polarization diagnostics of hot anisotropic plasmas. In particular the directions of the electrons in the plasmas, found e.g. in the accretion discs and jets of black holes, can be probed by measuring polarization of the satellite transitions in HCIs.

A 33.3 Thu 15:00 C/kHS

Influence of the laser field's turn-on duration and frequency detuning on Kapitza-Dirac scattering — •Matthias M. Dellweg and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

Diffractive scattering of an electron beam from a standing wave of light (Kapitza-Dirac effect) is studied theoretically. The corresponding Schrödinger equation is solved by combined analytical and numerical means. We examine the roles played by the nature of the field's turning-on phase and by a detuning of the light frequency. We demonstrate that the characteristic Rabi oscillations between the initial and scattered electron states are strongly suppressed when the turn-on of the field takes too long [1] or when the field frequency is largely detuned from the resonance (Bragg) condition. A mutual interplay between the detrimental effects of detuning and turn-on duration is revealed [2]. Also the case of very fast turn-on is considered where we show that the electron dynamics follow a scaling law with respect to an action variable.

[1] M. V. Fedorov, Opt. Commun. 12, 205 (1974)
[2] M. M. Dellweg and C. Müller, in preparation

A 33.4 Thu 15:15 C/kHS

Angle-resolved properties of characteristic x-rays as a tool for determining small level splittings in highly charged ions — •Zhongwen Wu[1,2], Nikolay Kabachnik[3,4], Andrey Surzhykov[1], Chenzhong Dong[2], and Stephan Fritzsche[1,5] — [1]Helmholtz Institute Jena, Germany — [2]Northwest Normal University, China — [3]European XFEL, Germany — [4]Lomonosov Moscow State University, Russia — [5]University of Jena, Germany

The angular distribution and the photon-photon angular correlation of x-ray emissions have been studied for two-step radiative cascades that proceed via overlapping intermediate resonances. Special attention was placed especially upon the questions of how the level splitting of the intermediate resonances affects the x-ray emissions and whether angle-resolved measurements can help determine small splittings in the level structure of highly charged ions. As an example, detailed computations within the multiconfiguration Dirac-Fock method were performed for the two-step cascade $1s2p^2\ J_i = 1/2, 3/2 \rightarrow 1s2s2p\ J = 1/2, 3/2 + \gamma_1 \rightarrow 1s^2 2s\ J_f = 1/2 + \gamma_1 + \gamma_2$ of lithium-like ions, for which a level crossing of the two $1s2s2p\ J = 1/2, 3/2$ intermediate resonances occurs in the range $74 \leq Z \leq 79$. A remarkably strong effect associated with finite lifetime and level splitting of these intermediate resonances was found for the angular distribution and the photon-photon angular correlation. We therefore suggest that accurate angle-resolved measurements of x-ray emissions may serve as a tool for determining small level splittings [1].

[1] Z. W. Wu *et al.*, Phys. Rev. A 90, 052515 (2014).

A 33.5 Thu 15:30 C/kHS

Observation of coherence in the time-reversed relativistic photoelectric effect — •Stanislav Tashenov[1], Holger Jörg[1], Darius Banas[2], Heinrich Beier[3], Carsten Brandau[3], Alexandre Gumberidze[3], Siegbert Hagmann[3], Pierre-Michel Hillenbrand[3], Ivan Kojouharov[3], Christophor Kozhuharov[3], Michael Lestinsky[3], Yury Litvinov[3], Anna Maiorova[4], Hen-

ning Schaffner[3], Uwe Spillmann[3], Thomas Stöhlker[5,6], Andrey Surzhykov[6], Stephan Fritzsche[5], Sergiy Trotsenko[3], and Vladimir Shabaev[4] — [1]Heidelberg University, Germany — [2]Jan Kochanowski University, Kielce, Poland — [3]GSI Helmholtzzentrum, Darmstadt, Germany — [4]St. Petersburg State University, Russia — [5]Friedrich-Schiller-Universität Jena, Germany — [6]Helmholtz-Institut Jena, Germany

The photoelectric effect has been studied in the regime of hard x-rays and strong Coulomb fields via its time-reversed process of radiative recombination (RR). In the experiment the relativistic electrons recombined into the $2p_{3/2}$ excited state of hydrogenlike uranium ions and both, the RR x-rays as well as the subsequently emitted characteristic x-rays were detected in coincidence. This allowed to observe and manipulate the coherence between the magnetic substates in a highly charged ion and to identify the contribution of the spin-orbit interaction to the RR process.

A 33.6 Thu 15:45 C/kHS

Atomic-scale imaging of molecular bonds with laser-induced electron diffraction — •Benjamin Wolter[1], Michael G. Pullen[1], Anh-Thu Le[2], Matthias Baudisch[1], Michele Sclafani[1], Hugo Pires[1], Arne Senftleben[3], Claus Dieter Schröter[4], Joachim Ullrich[4,5], Robert Moshammer[4], Chii-Dong Lin[2], and Jens Biegert[1,6] — [1]ICFO - Institut de Ciències Fotòniques, Mediterranean Technology Park, Castelldefels (Barcelona), Spain — [2]J. R. Macdonald Laboratory, Physics Department, Kansas State University, Manhattan, Kansas, USA — [3]Universität Kassel, Institut für Physik and CINSaT, Kassel, Germany — [4]Max - Planck - Institut für Kernphysik, Heidelberg, Germany — [5]Physikalisch - Technische Bundesanstalt, Braunschweig, Germany — [6]ICREA - Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

Dynamic imaging of molecular dynamics is one of the grand challenges of science as it requires sub-Ångström spatial and few femtosecond temporal resolutions. These demands are fulfilled by laser-induced electron diffraction (LIED), where a molecule is structurally probed with its own returning electron after tunnel ionization induced by a strong mid-IR laser field. Here, we present the retrieval of multiple bond lengths from polyatomic molecules by simultaneously measuring the C-C and C-H bond lengths of aligned acetylene. Our approach is based on the combination of an ultrafast 160 kHz mid-IR source with full 3D electron-ion coincidence detection towards investigating ultrafast processes like e.g. dissociation or proton migration.

A 33.7 Thu 16:00 C/kHS

Pair creation with channeling ions — •Nikolay Belov and Zoltán Harman — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69126 Heidelberg

The creation of particle-antiparticle pairs plays a role in several physical enviroments. We suggest an alternative way to investigate this phenomenon by the channeling of accelerated heavy ions through a crystal. In the framework of the ion, the energy of virtual photons arising from the periodic crystal potential may exceed the thresold $2mc^2$. This scheme increases the pair production rate coherently and allows to provide a more precise investigation of nuclear pair conversion [1]. It also allows to depopulate nuclei in metastable states, and convert the nuclear energy stored to electron-positron pairs. Pair creation by channeling ions can be also regarded as an extension of the resonance coherent excitation of highly charged ions to higher frequencies and higher ion velocities, which has been investigated at the GSI before [2]. Therefore, this novel channel of pair creation can be examined at the upcoming FAIR facility in the nearest future.

[1] N. A. Belov, Z. Harman, arXiv:1411.5711(2014).
[2] Y. Nakano, Y. Takano, T. Ikeda, et al., Phys. Rev. A 87, 060501 (2013).

A 33.8 Thu 16:15 C/kHS

Dominante Korrelationseffekte in Atomspektren — •Hubert Klar — Duale Hochschule BW, FB Maschinenbau, Hangstr.46-50, 79539 Lörrach

Das Spektrum von Zwei-Elektronen-Atomen wird in hypersphärischen Koordinaten studiert. Wir finden eine Rydbergserie von instabilen Cooper-Paaren unterhalb der Schwelle für Doppelionisation. Die Bindung wird vermittelt durch eine neuartige Kraft resultierend aus der Beugung einer Welle an einem Potentialrücken. Infolge spontaner Symmetriebrechung gehorchen diese Paare nicht dem Pauliprinzip. Die Wannier'sche Schwellenionisation wird als Zerfall eines Cooper-Paars identifiziert.

A 34: Ultracold Atoms: Trapping and Cooling II (with Q)

Time: Thursday 14:30–16:15 Location: P/H2

A 34.1 Thu 14:30 P/H2

Trapping atoms with laser written waveguides — Dario Jukić, Thomas Pohl, and •Jörg Götte — Max-Planck-Insitut für Physik komplexer Systeme, Dresden

We show how simple waveguide structures written into fused silica with femtosecond lasers, can be operated to trap Caesium atoms in the evanescent field in close proximity to the fused silica to air interface. The use of the fundamental mode of red detuned light and two spatial modes of blue detuned light allows us to balance the attractive surface forces and to create a stable potential minimum a few hundred nanometers from the surface of the waveguide. The process is very flexible, cost effective and allows for the realisation of a variety of complex trapping geometries. Using counter propagating waves we can realise optical conveyor belts with this design which is why our setup lends itself ideally for integration in optical atom chips.

A 34.2 Thu 14:45 P/H2

Loading atoms into hollow-core fibers — •Lachezar Simeonov[1], Micha Ober[2], Thorsten Peters[1], and Reinhold Walser[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstrasse 6, 64289 Darmstadt, Germany — [2]Institut für Angewandte Physik Technische Universität Darmstadt Geb. S2/09, 2. Stock, Zimmer 104 Hochschulstrasse 4A D-64289 Darmstadt, Germany

Loading cold Rb atoms at temperature 120 μK out of a magneto-optical trap (MOT) into a hollow-core photonic crystal fiber (7 μm core diameter) [1] promises interesting scenarios for strong light-atom coupling. To simulate the loading procedure and to optimize the coupling efficiency, we use a 3-dimensional Quantum-Monte-Carlo wave function simulation [2]. In this contribution, we discuss basic aspects of this simulation, modelling Rb atoms as a two-level system. We describe the non-equilibrium relaxation of a thermal ensemble subject to laser cooling in phase space and present results.

[1] F. Blatt, T. Halfmann, and T. Peters, Opt. Lett., Vol.39, No. 3 (2014).
[2] C. W. Gardiner, P. Zoller, Quantum Noise, a handbook of Markovian and non-Markovian quantum stochastic methods with applications to quantum optics, 2. enl. ed.- Springer, 2000

A 34.3 Thu 15:00 P/H2

Double-EIT Cooling: A Quicker Route to the Ground State — Jannes Wübbena[1], Nils Scharnhorst[1], Stephan Hannig[1], •Ian D. Leroux[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig — [2]Leibniz Universität Hannover, 30167 Hannover

Laser cooling using the Lorentzian scattering resonances of (effective) two-level atoms suffers from a fundamental conflict between low equilibrium temperatures, which require narrow cooling resonances, and fast cooling, which requires frequent scattering to remove entropy from the atom's motion and broad resonances to address multiple motional modes at once. In multi-level atoms, coherences between levels can be used to design non-Lorentzian scattering spectra that selectively suppress heating processes. This allows laser cooling with a speed and bandwidth typical of Doppler cooling to equilibrium temperatures normally only reached through slow sideband cooling on narrow transitions. We demonstrate that so-called double-EIT cooling, based on a tripod level scheme, can be used to cool a $^{40}Ca^+$ ion to the motional ground state several times faster than optimised sideband cooling. Such fast cooling has important applications in state-of-the-art optical frequency standards, which we briefly discuss.

A 34.4 Thu 15:15 P/H2

Mechanical and electronic energy eigenstates of neutral Rb atoms in deep optical lattices — •Andreas Neuzner, Matthias Körber, Olivier Morin, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Optical lattices allow for tight three-dimensional confinement of neutral atoms in quasi-harmonic potentials and have become a standard tool in experimental quantum optics. Applications range from fundamental topics like metrology to applications in quantum communication and quantum information processing. In this talk we present an experimental characterization of the motional and internal energy eigenstates of optically trapped ^{87}Rb atoms. We implement different spectroscopy techniques based on non-destructive hyperfine state detection using an optical cavity. Applying this technique, we observe and explain a series of effects like the decoupling of the hyperfine spin due to a tensor lightshift and mechanical effects associated with a small non-orthogonality of the lattice axes. The observed effects are generally of high experimental relevance. Furthermore, we succeed to exploit the latter for optical cooling of a single atom into the two-dimensional mechanical groundstate in an environment with restricted optical access.

A 34.5 Thu 15:30 P/H2

Measuring heating rate of ions in a planar ion trap with variable ion-surface separation — •Ivan Boldin, Alexander Kraft, and Christof Wunderlich — University of Siegen, 57068 Siegen, Germany

Planar electrode ion traps are considered to have great potential for quantum information science as: a) they are relatively easy to scale up and allow for complex electrode structures that might be needed for future quantum processors; b) ions can be trapped tens of micrometers above the surface, therefore strong static and oscillating field gradients can be imposed on ions and utilized in the realization of microwave qubit processing.

While reducing the ion-surface separation is advantageous for stronger field gradients and hence faster quantum gates, it also increases undesired interactions with the electrode surface. This heating is one of the major sources of decoherence and its mechanism is not well understood so far. In order to better understand this mechanism it is of interest to know how it depends on the ion-surface separation. Here we present the results of such heating rate measurements.

We have built a planar electrode ion trap in which the ion-surface distance can be varied in the range of 45 - 155 um by applying additional RF voltage to the central electrode. We measure the heating rates by recooling method i.e. allowing ion to heat up for a certain time and suddenly switching on the laser cooling and measuring the photon scattering rate over time. Fitting this curve with the theoretical allows estimation of the heating rate.

A 34.6 Thu 15:45 P/H2

Atomfalle zum isotopenselektiven Einfang von optisch angeregten Kryptonatomen — •Carsten Sieveke[1], Markus Kohler[1], Peter Sahling[1], Simon Hebel[1], Friderike Göring[1], Ergin Simsek[1], Christoph Becker[2] und Klaus Sengstock[2] — [1]ZNF, Universität Hamburg — [2]ILP, Universität Hamburg

Das nahezu ausschließlich in Kernspaltungsprozessen entstehende Isotop Kr-85 ist aufgrund seiner chemischen Trägheit hervorragend geeignet, als Indikator für die Entdeckung nuklearer Wiederaufbereitungsaktivitäten eingesetzt zu werden. Die äußerst geringen Konzentrationen dieses Spurengases nach seiner Freisetzung in die Atmosphäre erfordern eine hochsensitive Nachweismethode.

1999 wurde am Argonne National Laboratory eine neue Möglichkeit (Atom Trap Trace Analysis, ATTA) entwickelt, die Konzentration dieses Isotops in Luftproben der Größenordnung 10 Liter zu bestimmen. Das Mindestprobenvolumen und der Probendurchsatz wurde technisch durch die Notwendigkeit einer Elektronenstoßanregung vorgegeben.

Vorgestellt wird eine Weiterentwicklung dieser Methode, bei der die Elektronenstoßanregung durch eine optische Anregung ersetzt wird, um die Limitierung von Probengröße und -durchsatz zu überwinden. Diese basiert auf einer Kombination von 2D- und 3D-MOT, deren Funktionsweise und physikalische Eigenschaften demonstriert werden.

A 34.7 Thu 16:00 P/H2

Implementation of Λ-enhanced gray-molasses cooling for ^{40}K — •Matthias Tarnowski, Nick Fläschner, Dominik Vogel, Benno Rem, Christof Weitenberg, and Klaus Sengstock — Institut für Laserphysik, Uni Hamburg

Sub-Doppler cooling is an important step to reach quantum degeneracy in atomic gases. It has recently been demonstrated that the Λ-enhanced gray-molasses scheme leads to much lower temperatures than expected for alkali atoms. Here, we present a detailed study of a blue-detuned gray-molasses cooling scheme for fermionic ^{40}K on the D_1 transition. We find that the Raman resonance condition between the cooling and repumping frequency in a Λ-type system has indeed to be fulfilled to observe the anticipated narrow feature of very low temperatures around the resonance. With optimal parameters we achieve a temperature of 6 μK. In combination with repumping and optical pumping on the D_1 transition we realize efficient loading of a K-Rb mixture into a magnetic trap and fast subsequent evaporation. We significantly reduce the cycle time of our experimental sequence compared to cooling on the D_2 transition. Our results demonstrate ideal starting conditions for all-optical production of potassium degenerate gases.

A 35: Poster: Precision spectroscopy of atoms and ions (with Q)

Time: Thursday 17:00–19:00 Location: C/Foyer

A 35.1 Thu 17:00 C/Foyer

Rydberg spectroscopy using optical and electrical read out in thermal vapor cells — •Johannes Schmidt[1,2], Renate Daschner[1], Patrick Schalberger[2], Harald Kübler[1], Norbert Frühauf[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut — [2]Institut für großflächige Mikroelektronik, Universität Stuttgart, Germany

Rydberg atoms in a thermal vapor are discussed as promising candidates for the realization of quantum devices such as single photon sources or single photon subtractors. We present a very sensitive and scalable method to measure the population of highly excited Rydberg states in a thermal vapor cell of rubidium atoms. For this application a cell with structured electrodes and a sealing method based on anodic bonding was invented [1]. The large DC Stark shift of Rydberg atoms provides a possibility to induce transmission or absorption in the medium. Rydberg spectroscopy can be done either by measuring the optical transmission [2] or the Rydberg ionization current [3]. This technique is compatible with state of the art fabrication methods of thin film electronics offering both scalability and miniaturization. Future prospects are arrays of individually addressable sites with integrated electronics, e.g. for signal amplification.

[1] Daschner, R., et al., Appl. Phys. Lett. 105, 041107 (2014)
[2] Daschner, R., et al., Opt. Lett. 37, 2271 (2012)
[3] Barredo, D.,et al., Phys. Rev. Lett. 110, 123002 (2013)

A 35.2 Thu 17:00 C/Foyer

An ultra-stable cryogenic Paul Trap for Quantum Logic Spectroscopy of Highly Charged Ions — •Maria Schwarz[1,2], Lisa Schmöger[1,2], Peter Micke[1,2], Tobias Leopold[1], Joachim Ullrich[1], José Ramon Crespo López-Urrutia[2], and Piet Oliver Schmidt[1,3] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [3]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover

For the purpose of high precision frequency measurements on highly charged ions (HCI) an ultra-stable cryogenic Paul trap is currently being designed at the MPIK in collaboration with the PTB. The design of this trap is based on the cryogenic Paul trap experiment (CryPTEx), which in combination with the ion injection capability from an electron beam ion trap has been successfully used for the storage and sympathetic cooling of HCIs in a Coulomb crystal. Furthermore, the extremely low background pressure provides a long storage time for HCIs which is essential for precision. The next generation design focuses on the decoupling of the vibrations in order to obtain more stable trapping conditions. Two vibration damping stages are implemented between the cryostat and the trap chamber. A horizontal design of the cryogenic supply parts beneath the laser table guarantees an optimized access to the trap. Our final goal is the application of quantum logic spectroscopy, where a singly charged ion species is responsible for sympathetic cooling and state detection of the HCI.

A 35.3 Thu 17:00 C/Foyer

Single-shot 3D-imaging of mixed-species coulomb crystals with a plenoptic camera — •Baptist Piest[1], Lisa Schmöger[1,2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

It has recently been demonstrated in [1], that it is possible to combine light field microscopy techniques [2] with three-dimensional (3D) deconvolution to obtain the 3D-structure of dilute atomic gas clouds. A similar setup is currently being setup at the Cryogenic Paul Trap Experiment (CryPTEx) [3]. It is of particular interest for understanding the spatial structure of 3D Be^+-coulomb crystals with individually implanted highly charged ions and as input for molecular-dynamics simulations. For this purpose, the construction is optimized for imaging the fluorescent light of the $^2S_{1/2}$ - $^2P_{3/2}$ transition in $^9Be^+$ driven by a cooling-laser at 313 nm. The spatial structure can be obtained in two steps: The first one is the digital refocussing of the light field to a stack of different focal planes. The second step requires the numerical deconvolution of the refocused images with the 3D point spread function (PSF). The measurement of the PSF is thus an essential step for a successful application of this technique.

[1] K. Sakmann and M. Kasevich, arXiv:1405.3598 [physics.atom-ph] (2014).
[2] M. Levoy et al., ACM Transactions on Graphics 25(3), Proc. SIGGRAPH (2006).
[3] M. Schwarz et al. Rev. Sci. Instr. 83, 083115 (2012).

A 35.4 Thu 17:00 C/Foyer

Towards investigations of highly charged rare and unstable isotopes — •Hendrik Bekker[1], Michael Blessenohl[1], Sergey Eliseev[1], Klaus Werner[2], Klaus Blaum[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Eberhard Karls University, Tübingen

Highly charged ions of unstable isotopes are required for two new projects at the Heidelberg electron beam ion trap (HD-EBIT): (i) Within the framework of the ECHo collaboration the Penning-trap experiment PENTATRAP aims to measure the masses of ^{163}Ho and ^{163}Dy to high precision [1,2]. The Q-value of the electron capture process in ^{163}Ho obtained in this way is an important input for the determinations of the electron neutrino mass. (ii) The lightest unstable element, technetium, was observed in S-type stars in 1952 already and was an important piece of evidence for nucleosynthesis [3]. Presently, spectroscopic data of highly charged technetium is required to further improve our understanding of stellar evolution and dynamics.

For the production of the required ions, the unstable isotopes need to be efficiently injected into HD-EBIT. To this end a wire probe injector [4] is currently under development, first results will be presented.

[1] L. Gastaldo et al., J. Low Temp. Physics., 876-884, 176 (2014)
[2] J. Repp et al., Appl. Phys. B 107 983 (2012)
[3] P.W. Merrill, The Astrophysical Journal 116 21 (1952)
[4] S.R. Elliot and R.E. Marrs, Nucl. Instrum. Methods B 100 529 (1995)

A 35.5 Thu 17:00 C/Foyer

Dating with Atom Trap Trace Analysis of ^{39}Ar — •Sven Ebser[1], Florian Ritterbusch[1,2], Zhongyi Feng[1], Anke Heilmann[1], Arne Kersting[2], Werner Aeschbach-Hertig[2], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institute for Physics, Heidelberg, Germany — [2]Institute of Environmental Physics, Heidelberg, Germany

Atom Trap Trace Analysis (ATTA) is an ultra-sensitive counting method for rare isotopes. It is based on the high selectivity of resonant photon scattering during laser cooling and trapping in order to distinguish the rare isotope from the abundant ones. The special strength of this method lies in small sample sizes required for dating with long-lived isotopes.

We have developed an ATTA-setup for the rare argon isotope ^{39}Ar. As an inert noble gas and with a half-life of 269 years it is the perfect tracer for dating ice and water samples in the time range between 50 and 1000 years before present. In this range no other reliable tracer exists. The experimental challenge lies in the low atmospheric abundance of ^{39}Ar (^{39}Ar/Ar $= 8.23\times10^{-16}$) and in the required stable and reproducible performance of all components of the apparatus leading to a robust ^{39}Ar detection efficiency. We achieved a stable atmospheric count rate of 3.58 ± 0.10 atoms/h with which we dated groundwater samples with ^{39}Ar-ATTA for the first time.

A 35.6 Thu 17:00 C/Foyer

Approaching 10^{-19} relative frequency uncertainty with an optical clock based on ion Coulomb crystals — •Tobias Burgermeister[1], Jonas Keller[1], Dimitri Kalincev[1], Miroslav Doležal[2], Petr Balling[2], and Tanja E. Mehlstäubler[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Czech Metrology Institute, Prague, Czech Republic

Single ion optical clocks are fundamentally limited in stability by quantum projection noise and require days or weeks of averaging to resolve frequencies with 10^{-18} uncertainty. We want to show that it is possible to increase the stability by building a clock based on ion Coulomb crystals with $^{115}In^+$ ions sympathetically cooled by $^{172}Yb^+$ ions.

Therefore we developed a chip-based linear Paul trap design, which is optimized for minimum axial micromotion [1,2]. Using a prototype trap made out of Rogers4350 we compare different techniques for micromotion minimization and show that we can measure micromotion amplitudes corresponding to fractional frequency shifts of below 10^{-19} for $^{115}In^+$. In the prototype trap a heating rate of less than 2 phonons/s at a trap frequency of 500 kHz was observed.

With an advanced next generation ion trap based on gold coated AlN wafers experiments and simulations of the trap temperature rise due to the applied high RF voltage have been carried out at CMI, Prague. From first results we expect a fractional frequency uncertainty due to black-body radiation of the trap on the level of a few 10^{-19}.

[1] Herschbach *et al.*, *Appl. Phys. B* **107**, 891 (2012)
[2] Pyka *et al.*, *Appl. Phys. B* **114**, 231 (2013)

A 35.7 Thu 17:00 C/Foyer

Towards Precision Spectroscopy of Argon XIV in the SpecTrap Penning Trap — •Tobias Murböck[1], Stefan Schmidt[2,3], Zoran Andelkovic[4], Gerhard Birkl[1], Volker Hannen[5], Kristian König[2], Alexander Martin[1], Wilfried Nörtershäuser[2], Manuel Vogel[1,4], Jonas Vollbrecht[5], Danny Segal[6], and Richard Thompson[6] — [1]IAP, TU Darmstadt — [2]IKP, TU Darmstadt — [3]Institut für Kernchemie, Universität Mainz — [4]GSI Darmstadt — [5]IAP, Universität Münster — [6]Department of Physics, Imperial College London

In few-electron ions, the strong electric and magnetic fields in the vicinity of the ionic nucleus significantly influence the remaining electronic system. By means of laser spectroscopy, the transition energies and lifetimes of fine structure and hyperfine structure transitions in highly charged ions (HCI) can be determined with an accuracy that reveals the contributions of bound-state QED in strong fields. We present the SpecTrap experiment located at the HITRAP facility at GSI and the associated low-energy beamline, which is currently being operated with an EBIS to produce mid-Z HCI such as Ar13+ and a second ion source for Mg+. Laser cooling on Mg+ ions to the mK regime and other functionalities of the trap have already been demonstrated. By use of resistive and sympathetic cooling with Mg+, the HCI can be cooled to cryogenic temperatures to prolong the storage time of the HCI and reduce Doppler broadening to some 10 MHz. Here, we discuss the scientific outline, the experimental apparatus and first results of the detection and manipulation of ions inside the Penning trap.

A 35.8 Thu 17:00 C/Foyer

A power stabilized UV laser system for cooling trapped Be^+ ions — •Stefanie Feuchtenbeiner[1], Lisa Schmöger[1,2], Oscar O. Versolato[1,2], Alexander Windberger[1], Matthias Kohnen[2], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]MPI für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]PTB, Bundesallee 100, 38116 Braunschweig — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Cold, precisely localized highly charged ions (HCIs) are of particular interest for metrology and investigations of fundamental physics. Cold HCIs are prepared by means of sympathetic motional cooling, since direct laser cooling is not possible due to a lack of suitable laser transitions. $^9Be^+$ is the cooling ion of choice here, since it can be co-trapped with HCIs in a cryogenic linear Paul trap. The Doppler cooling laser drives the $^2S_{1/2}$ - $^2P_{3/2}$ transition in $^9Be^+$ at 313 nm. Its design is based on [1], generating the sum frequency of 1051 nm and 1550 nm from two fiber lasers in a PPLN crystal with quasi-phase matching followed by cavity-enhanced second harmonic generation in a BBO crystal stabilized by a Hänsch-Couillaud lock. Time-dependent measurements of fluorescence intensities and efficient laser cooling require a stable output power at 313 nm. For this purpose, two setups working on different time scales have been implemented. The first one compensates slow power drifts at 626 nm using a motorized $\lambda/2$-waveplate and a Glen-α-polarizer, and the second one suppresses fast power fluctuations at 313 nm with an acousto-optic modulator as key element.

[1] A. C. Wilson et al., Appl. Phys. B 105 (2011)

A 35.9 Thu 17:00 C/Foyer

Auflösung radiativer Rekombinationsprozesse durch Absorptionskanten — •Daniel Hollain[1], Hendrik Bekker[1], José Ramón Crespo López-Urrutia[1], Sven Bernitt[1,2] und Michael Blessenohl[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]Friedrich-Schiller-Universität, Jena, Deutschland

Die Energieauflösung von Röntgen-Photonendetektoren im Bereich von 50 keV ist typischerweise etwa 500 eV FWHM. Für die Untersuchung der Rekombination freier Elektronen mit hochgeladenen Ionen von schweren Elementen ist es nötig, einen etwa zehnmal besseren Wert zu erreichen, weil dadurch der Einfang von Elektronen in verschiedenen Ladungszuständen unterschieden werden kann. Zu diesem Zweck wurden Metallfolien mit charakteristischen Absorptionskanten vor einem Röntgendetektor positioniert. Die Energieschwelle der Absorptionskante ließ sich diskret variieren, indem diverse Materialien, wie Wolfram und Tantal, gewählt wurden. Die Folien absorbieren Photonen oberhalb ihrer Absorptionskante. Dazu wurde die Energie der rekombinierenden Elektronen kontinuierlich variiert, und der inverse Photoeffekt (genannt radiative Rekombination) beobachtet. Die Photonenenergie hängt dabei linear von der Elektronenenergie ab, mit dem Ionisationspotential als konstanter additiver Parameter. Mit Hilfe dieses Effekts wurde in einem Ensemble von Iridiumionen helium- bis fluorartige Ladungszustände untersucht, und die jeweiligen Ionisationspotentiale wurden daraus mit Unsicherheiten in Größenordnungen von 20 eV bestimmt. Theoretischen Vorhersagen aus MCDF-Rechnungen stehen in guter Übereinstimmung mit diesen erstmals gemessenen Werten.

A 35.10 Thu 17:00 C/Foyer

High-resolution spectroscopy with multi-photon transitions in Highly Charged Ions — •Andrii Borodin, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max Planck Institute for Nuclear Physics, Heidelberg

Highly charged ions (HCI), being atomic systems with tightly bound electrons, allow performing accurate tests of quantum electrodynamics, and determination of high-precision values of fundamental constants. Nowadays, HCI are routinely produced using electron beam ion traps. HCI are abundant in hot plasmas in stars, and thus are also of interest for astrophysics. Their advantages for studies of time variations of fundamental constants have been recently emphasized. So far, most observations in HCI are made with ions at temperatures of more than 10^2 eV. Recent progress in trapping HCI in a cryogenic linear quadrupole trap [Schwarz *et al*, Rev. Sci. Inst. **83**, pp. 1-10 (2012)], and sympathetic cooling with Be^+ ions, opens up the possibility for high-precision laser spectroscopy. A very large number of transitions have energies of few ten eV. So far, excitation of these transitions required the use of free-electron lasers. The aim of this project is to perform high-resolution spectroscopy of extreme ultraviolet transitions by multi-photon transitions, induced by femtosecond laser pulses and amplified by an enhancement cavity. An experimental scheme for realizing this approach will be presented.

A 35.11 Thu 17:00 C/Foyer

Parity violation effects in the Josephson junction of a *p*-wave superconductor — •Nikolay Belov and Zoltán Harman — Max Planck Institute for Nuclear Physics

The electroweak theory, combining two fundamental interactions – electromagnetic and weak, was introduced by Salam, Glashow and Weinberg in 1970s. It explains the nuclear beta-decay and weak effects in particle physics. One of the most interesting properties of the electroweak theory is the spatial parity violation (PV). Firstly PV was experimentally detected in the beta decay. PV terms of the electroweak interaction can also influence the interaction of electrons with the crystal lattice of nuclei in the solid state. Possible solid state systems, where one may detect PV contribution are superconductors (SC). The main advantage of the PV detection in SC is the small size and relatively small price of the possible experimental setup. The idea that parity violation effects can appear in superconductors was supposed by A. I. Vainstein and I. B. Khriplovich in 1974. They have showed that this electroweak contribution is negligible small in conventional *s*-wave superconductors. In our work we present an estimate for this effect to be observed in unconventional *p*-wave ferromagnetic superconductors. This estimation gives values several orders of magnitude larger than for the *s*-wave case and shows that the PV effect may be observed in future.

A 35.12 Thu 17:00 C/Foyer

A superconducting resonator-driven linear radio-frequency trap for strong confinement of highly charged ions — •Julian Stark[1], Lisa Schmoeger[1,2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Cold, strongly localized highly charged ions (HCI) are interesting candidates for both novel frequency standards at a potential 10^{-19} level accuracy and quantum information protocols. For sympathetic cooling of the HCI, they are simultaneously trapped with laser-cooled Be^+ ions in a cryogenic linear radio-frequency (RF) Paul trap [1]. Its pseudopotential is strongly dependent on the RF amplitude, phase and frequency. Stable localization requires a high voltage RF drive with low noise, since instabilities in the RF drive cause excess micromotion and thus heating of the trapped ions. Employing a RF resonator with high quality factor Q inside the trap enables high amplitudes and drastically reduces the RF noise. In order to be able to trap and sympathetically cool HCI efficiently, we are currently designing a superconducting RF resonator which includes the quadrupole trapping electrodes. Integrating them into the RF cavity will suppress coupling losses and maintain a very high Q value, as well as improve the overall stability of the trapping conditions.

[1] M. Schwarz et al., Rev. Sci. Instrum. 83, 083115 (2012)

A 35.13 Thu 17:00 C/Foyer

Identification of EUV $5s$–$5p$ transitions in Re, Os, Ir, and Pt — •Hendrik Bekker[1], Oscar O. Versolato[1], Alexander Windberger[1], Natalia S. Oreshkina[1], Ruben Schupp[1], Zoltán Harman[1], Christoph H. Keitel[1], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Institut für Quantumoptik, Leibniz Universität Hannover

Despite recent theoretical and experimental investigations of $5s$–$5p$ resonance lines in promethium-like highly charged ions near the $4f$–$5s$ level crossing, the transitions were never unambiguously identified yet [1,2]. To resolve this issue we studied the Pm-like and neighboring isoelectronic sequences spanning Re, Os, Ir, and Pt (Z=75–78) produced in the Heidelberg electron beam ion trap. The spectra obtained in the extreme ultra-violet (EUV) region around 20 nm were compared to collisional radiative model calculations which allowed us to identify the $5s$–$5p$ transitions and additional $5s^2$-$5s5p$ transitions. Independent configuration interaction calculations support our identifications. Understanding the $4f$–$5s$ level crossing is of particular importance for future searches for a possible fine structure constant variation, and future optical clocks.

[1] U. I. Safronova, A. S. Safronova, and P. Beiersdorfer, Phys. Rev. A 88, 032512 (2013)
[2] Y. Kobayashi et al., Phys. Rev. A 89, 010501 (2014)

A 35.14 Thu 17:00 C/Foyer

Theory of the bound-muon *g*-factor — •Bastian Sikora, Zoltán Harman, Jacek Zatorski, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The theory of the *g*-factor of the muon bound in a nuclear potential is presented. We include one-loop quantum electrodynamic corrections with the interaction with the nuclear potential taken into account to all orders, and finite nuclear size effects. Similarly to the recent high-precision determination of the electron mass [1], the theory of the bound-muon *g*-factor, combined with possible future experiments with muons bound in a nuclear potential, can be used in principle to determine physical constants with high precision. Furthermore, since nuclear effects are larger in systems with bound muons, nuclear pa-

rameters such as nuclear radii can be extracted to high precision from a comparison of the theoretical and experimental bound-muon g-factor.
[1] S. Sturm *et al.*, *Nature* **506**, 467-470 (2014)

A 35.15 Thu 17:00 C/Foyer

Efficient Quantum Algorithm for Readout in Multi-Ion Clocks — •Marius Schulte — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

New generations of atomic clocks are planned to rely on stable optical transitions. An important criterion for good frequency standards are extremely narrow bandwiths in the considered clock ions, but this choice comes with some problems. Due to very small scattering rates and inaccessible laser frequencies the states of the clock ions can not be measured directly. The techniques of quantum logic spectroscopy and quantum logic readouts were developed to solve these difficulties by using a second ion (logic-Ion) to perform the readout of the internal states. Up to now optical frequency standards were used with just a single clock-Ion and a sigle logic-Ion. Experiments with such configurations were able to find record breaking accuracies in the frequency measurement but suffered from poor stabilities since only one Ion was used. Therefore the next step is to scale this process up by using multiple Ions. The dominant problem there is to find an efficient readout strategy that determines the internal states of the clock-Ions via the logic-Ions. On my poster i present a possible solution to this, using an efficient quantum algorithm. The number of logic ions and gates in this method scales only logarithmically with the number of clock Ions and can therefore provide a good strategy already for small Ion numbers.

A 35.16 Thu 17:00 C/Foyer

Narrowband Light Sources for optical Clocks of Ba^+ and Ra^+ — •Nivedya Valappol, Elwin A. Dijck, Andrew Grier, Klaus Jungmann, Amita Mohanty, Mayerlin Nuñez Portela, and Lorenz Willmann — Van Swinderen Institute, University of Groningen, The Netherlands

Narrow transitions in single ions such as Al^+, Mg^+, Sr^+ and Hg^+ are the basis for optical clocks. The ultra-narrow electric quadrupole transitions ns $^2S_{1/2}$ * (n-1)d $^2D_{5/2}$ in some isotopes of Ra+ (n=7) and Ba+ (n=6) are less sensitive to some of the major clock systematics. Narrowband lasers for the clock transitions (728nm in Ra^+ and 1761.7nm in Ba^+) and cooling transitions for state manipulation are required. These ion clocks will be compared via a 2x300km long fiber link between Groningen and the University of Amsterdam [1] with other stable frequency references. For the cooling transition at 650nm in Ba^+ a diode laser is stabilized to a high finesse optical cavity in order to observe narrow Raman resonances and manipulate the internal state. The design is applicable to light sources for other transitions where laser diodes are available. In addition, the lasers provide for measurements of atomic parity violation in Ba^+ and Ra^+.

[1] T.J. Pinkert et al., arXiv:1410.4600 (2014)

A 35.17 Thu 17:00 C/Foyer

Nonlinear optics with atomic mercury vapor inside a hollow-core photonic crystal fiber — •Ulrich Vogl, Christian Peuntinger, Nicolas Y. Joly, Philip St. J. Russell, Christoph Marquardt, and Gerd Leuchs — Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1/Bldg. 24, 91058 Erlangen, Germany

We demonstrate high atomic mercury vapor pressure in a kagomé-style hollow-core photonic crystal fiber at room temperature. After a few days of exposure to mercury vapor the fiber is homogeneously filled and the optical depth achieved remains constant. With incoherent optical pumping from the ground state we achieve an optical depth of 114 at the 6^3P_2 - 6^3D_3 transition, corresponding to an atomic mercury number density of 6 $\times 10^{10}$ cm^{-3} [1]. We present Autler-Townes spectroscopy at low light levels and first results demonstrating all-optical delay of pulses in the system. Currently we investigate soliton dynamics and self-induced transparency phenomena in the mercury-filled fiber system.

[1] U. Vogl, C. Peuntinger, N. Joly, P. Russell, C. Marquardt, and G. Leuchs, "Atomic mercury vapor inside a hollow-core photonic crystal fiber," Opt. Express 22, 29375-29381 (2014).

A 35.18 Thu 17:00 C/Foyer

Quantum Logic Spectroscopy of Highly Charged Ions — •Peter Micke[1,2], Tobias Leopold[1], Maria Schwarz[1,2], Lisa Schmöger[1,2], Oscar O. Versolato[1,2], Joachim H. Ullrich[1,2], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Leibniz Universität Hannover, Germany

Highly charged ions (HCIs) offer forbidden optical transitions near level crossings due to reordering of the electronic levels as the charge state grows. Some of these transitions have an enhanced sensitivity to a possible variation of the fine-structure constant. Furthermore, HCIs are insensitive to external fields because of their strong internal Coulomb field. This can be exploited for building optical clocks with small systematic shifts. We are currently setting up an experiment for the Physikalisch–Technische Bundesanstalt aiming at quantum logic spectroscopy of HCIs. A novel compact EBIT based on permanent magnets breeds HCIs. Next, they are extracted, decelerated and injected into an ultra-stable cryogenic Paul trap. Generally, HCIs do not have transitions appropriate for direct laser cooling. However, they can be sympathetically cooled with another ion species – in our case Be^+. Spectroscopic measurements can be carried out by using quantum logic: A single HCI is co-trapped together with a Be^+ logic ion, which provides not only cooling, but also both state preparation and readout.

A 35.19 Thu 17:00 C/Foyer

Neutrino Oscillation Observations using 400 MeV/u Highly Ionized 142Pm60+ Ions — •Fatma Cagla Ozturk[1,2] and Yuri Litvinov[1] — [1]GSI, Darmstadt, Germany — [2]Istanbul University, Istanbul, Turkey

GSI accelerator facility leads the scientific innovations on highly charged, heavy ions and search for the structure of atomic nucleaus and the universe. Experimental Storage Ring (ESR) gives a great opportunity to study the periodic time modulations, found recently in the two-body orbital electron capture (EC) decay of 142Pm60+ ion, with period near to 6 seconds by using a 245 MHz resonator cavity with a high sensitivity and time resolution. This study presents the results obtained from the latest experiment on EC decays of Pm ions which are produced in FRS in ESR ring.

A 35.20 Thu 17:00 C/Foyer

Bound-electron g-factor correction due to coupling of global and internal dynamics of ions — •Niklas Michel and Jacek Zatorski — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

Penning-trap precision measurements of the bound electron g-factor in hydrogen-like ions have proved to be very useful for the determination of certain physical constants and parameters, i.e. the electron mass. They have also provided one of the most stringent tests of quantum electrodynamics in a strong external electric field.

With the prospect of further improvement of experimental precision, we calculated the dominant correction to the experimental value of the g-factor due to coupling of the ion's global movement to the ion's internal dynamics. Also, we estimated the influence of an analogous effect on measurements in a Paul trap.

A 35.21 Thu 17:00 C/Foyer

Towards Doppler Laser Cooling of Negative Ions — •Elena Jordan, Giovanni Cerchiari, and Alban Kellerbauer — Max-Planck-Institut für Kernphysik, Heidelberg

We want to demonstrate the first direct laser cooling of negative ions in a Penning trap. For the cooling the hyperfine structure and the Zeeman splitting in the magnetic field of the trap need to be known. We carried out collinear ion beam spectroscopy and determined the transition frequencies in negative lanthanum ions with unprecedented precision. The transition cross sections of bound-bound transitions were measured. The transition studied in this work had been found potentially suitable for Doppler laser cooling both from theory and experiment [1,2,3]. Presently, lanthanum is the most promising candidate among the atomic negative ions.
Once one species of negative ions is cooled, any other species can be cooled sympathetically [4].

[1] C.W. Walter et al. *Physical Review Letters* 113, 063001 (2014)
[2] S.M. O'Malley and D.R.Beck, *Physical Review A* 81, 032503 (2010)
[3] L.Pan and D.R.Beck, *Physical Review A* 82, 014501 (2010)
[4] A.Kellerbauer and J.Walz, *New Journal of Physics* 8, 45 (2006)

A 35.22 Thu 17:00 C/Foyer

The Muonic Helium Lamb Shift experiment — •Marc Diepold and The CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

This poster gives a detailed overview about the working principle and setup of the Muonic Helium Lamb shift experiment at the Paul-Scherrer-Institute in Switzerland.

Newly implemented features in the ongoing data analysis are emphasised and preliminary results for different $2S \rightarrow 2P$ transitions measured in both the μ^4He^+ and μ^3He^+ exotic ions are provided.

These results shed new light on the Proton Radius Puzzle created by the 7 sigma discrepancy between different determinations of the rms charge radius of the proton.

A 35.23 Thu 17:00 C/Foyer

A way to detect the isomeric state I= $(3/2)^+$ in ^{229}Th with the use of LIF method — •Jerzy Dembczyński[1], Magdalena Elantkowska[2], and Jarosław Ruczkowski[1] — [1]Institute of Control and Information Engineering, Poznań University of Technology, Poznań, Poland — [2]Laboratory of Quantum Engineering and Metrology, Poznań University of Technology, Poznań, Poland

The existence of a low-lying isomeric state at an energy of 7.6 ± 0.5 eV was inferred from high-resolution gamma-ray spectroscopy [1]. Inamura and Haba [2] search for this state at a region 3.5 eV using a hollow-cathode electric discharge. Sakharow [3] questioned existing of this state at whole. Peik et al. [4] show that is possible to reach high lying electronic levels using a laser beam for the ^{232}Th$^+$. If the metastable state $I = 3/2$ exist we should observe the effects of mixing of the nuclear wave functions of the ground state $I = 5/2$ and the isomeric $I = 3/2$ state via electronic shells. It will be revealed at the differences between the A- and B constants measured by means of the LIF methods and those predicted by semi-empirical calculations. Therefore, we consider advisable a systematic study of the hyperfine structure of the electronic levels of the ^{229}Th atom or ions.

This work was supported by the Poznan University of Technology within the frame of the project 04/45/DSPB/0121

[1] E. Peik et al., arXiv:0812.3458 (2009)
[2] T.T. Inamura, H. Haba, Phys. Rev. C 79, 034313 (2009)
[3] S. L. Sakharov, Physics of at. Nuclei 73, 1-8 (2010)
[4] O. A. Herrera-Sancho et al.,Phys. Rev. A 85, 033402 (2012)

A 35.24 Thu 17:00 C/Foyer

The Multipass Cavity of the μHe$^+$ Lamb Shift Experiment — •Julian J. Krauth, Beatrice Franke, and the CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

A multipass laser cavity is presented which can be used to illuminate an elongated volume from a transverse direction. The illuminated volume can have a several cm^2 large transverse cross section. Convenient access to the illuminated volume for other experimental components is granted at a large solid angle. The multipass cavity is very robust against misalignment, and no active stabilization is needed. The scheme is suitable e.g. for beam experiments, where the beam path must not be blocked by a laser mirror, or if the illuminated volume has to be very large. Measurements of the intensity distribution inside the multipass cavity are found to be in good agreement with the simulation.

On this poster, the technical developments used to operate the cavity are presented, and an overview on possible applications is given: It was used for the muonic-hydrogen experiment in which 6 μm laser light illuminated a volume of $7 \times 25 \times 176$ mm^3, consisting of mirrors that are only 12 mm in height. Furthermore it may be suited for transverse cooling of a beam of atoms/molecules (using two of such cavities) or the creation of a "light curtain" illuminating a region of about $20{\times}10$ cm^2 over a distance of 1 cm or more along the beam axis.

A 35.25 Thu 17:00 C/Foyer

Towards future kilo-pixel x-ray detector arrays: SQUIDs and SQUID multiplexers for the readout of high-resolution x-ray detectors — •Mathias Wegner, Anna Ferring, Andreas Fleischmann, Loredana Gastaldo, Sebastian Kempf, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University.

Calorimetric low-temperature particle detectors such as superconducting transition edge sensors, metallic magnetic calorimeters and magnetic penetration thermometers have proven to be suitable devices for performing high-resolution x-ray spectroscopy. They are therefore very frequently used for precision experiments in atomic and nuclear physics. To read out these kind of detectors, superconducting quantum interference devices (SQUIDs) are the devices of choice since they provide very low noise, a large system bandwidth and are compatible with sub-Kelvin operation temperatures. Driven by the need for devices that allow for the readout of future kilo-pixel x-ray detector arrays as well as of single-channel detectors with sub-eV energy resolution, we have recently started the development of low-T_c current-sensing SQUIDs. In particular, we are developing cryogenic frequency-domain multiplexers based on non-hysteretic rf-SQUIDs for array readout as well as dc-SQUIDs for single channel detector readout. We discuss our SQUID designs and the performance of prototype SQUIDs that are based on Nb/Al-AlO$_x$/Nb Josephson junctions. We also outline that our SQUIDs might be very useful for other applications such as penning-trap mass spectroscopy due to their excellent noise performance.

A 35.26 Thu 17:00 C/Foyer

Metallic Magnetic Calorimeters for High-Resolution X-ray Spectroscopy with Highly Charged Ions — •C. Schötz[1], D. Hengstler[1], M. Keller[1], M. Krantz[1], J. Geist[1], T. Gassner[2,3], K.H. Blumenhagen[2,3], R. Märtin[2,3], G. Weber[2,3], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], Th. Stöhlker[2,3,4], and C. Enss[1] — [1]KIP, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Darmstadt — [4]IOQ, Jena University

Metallic magnetic calorimeters (MMCs) are energy dispersive particle detectors which have a high energy resolution over a wide energy range. They operate at milli-Kelvin temperatures and convert the energy of a single absorbed photon into a temperature rise, which lead to a magnetization change in an attached paramagnetic sensor. The magnetization change in the temperature sensor is inductively read out by a SQUID-magnetometer. We show our developed maXs-200 detector, a 1x8 array with 200 μm thick absorber and an active area of 8 mm^2 that is optimized to measure X-rays up to 200 keV. The performance under ideal condition showed an energy resolution of 45 eV for 60 keV γ-photons of an ^{241}Am calibration source. We discuss two different sucessfully performed measurements at the Experimental Storage Ring (ESR) at GSI with the maXs-200. The detector was mounted on the cold finger of a pulse tube cooled ^{3}He/^{4}He-dilution refrigerator. The achieved energy resolution in an energy range from 0 keV up to 60 keV was below 60 eV. In addition we show the simulation results of different designs of a compton polarimeter including the efficiency of the 90° scattered photons, wherein the maXs-200 is also involved.

A 35.27 Thu 17:00 C/Foyer

Investigations of the hyperfine interaction in Ti-like bismuth — •Michael A. Blessenohl, Hendrik Bekker, Alexander Windberger, and José R. Crespo López-Urrutia — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

The ground state configuration [Ar]$3d^4$ of titanium-like ions split into 34 different levels that feature a $J = 2 \rightarrow 3$ magnetic dipole transition in the optical regime for a broad range of atomic numbers Z. This allows for very accurate measurements of the quantum electrodynamical (QED) corrections of the electron potential in atoms. Predictions made with the Flexible Atomic Code (FAC) place the transition at 340.6 nm for the Bi^{61+} ion. We plan to present first results of high-resolution measurements of this transition at the Heidelberg electron beam ion trap (HD-EBIT) using a Czerny-Turner type spectrometer equipped with a cooled CCD camera. Due to the large magnetic moment of the bismuth nucleus a prominent hyperfine splitting is expected to appear, enabling us to probe nuclear size effects in a regime where the hyperfine structure (HFS) splitting is of a magnitude similar to the strong magnetic field of an EBIT, and the QED relative contributions to the transition energy are extremely large.

A 35.28 Thu 17:00 C/Foyer

Description of the Ho-163 electron capture spectrum — •Loredana Gastaldo for the ECHo-Collaboration — Kirchhoff Institute for Physics, Heidelberg University

The sensitivity to the neutrino mass achievable with the analysis of calorimetrically measured Ho-163 electron capture spectrum is strongly dependent on the precise understanding of the expected spectral shape. The high energy resolution calorimetric measurements of the Ho-163 spectrum performed by the ECHo collaboration pointed out that several parameters for the description of the spectral shape need to be defined with higher accuracy. Two aspects are of particular importance: the determination of Q-value, that is the value of the energy available to the decay, and the determination of the contribution to the atomic de-excitation of the daughter atom, dysprosium, of higher order processes. We compare the parameters obtained by the analysis of the calorimetrically measured Ho-163 spectrum with the ones available in literature and discuss the discrepancies with present models and available data. We present new experimental methods and improved theoretical models to achieve a better accuracy in the determination of the parameters describing the Ho-163 spectrum.

A 35.29 Thu 17:00 C/Foyer

Angular Distribution of DR-Induced X-ray Transitions in Be-like Uranium — •Sergiy Trotsenko[1,2], Alexandre Gumberidze[2], Yong Gao[3], Christophor Kozhuharov[2], Stephan Fritzsche[1,4], Andrey Surzhykov[1,4], Heinrich Beyer[2], Siegbert Hagmann[2,5], Pierre-Michel Hillenbrand[2], Nikolaos Petridis[2], Uwe Spillmann[2], Daniel Thorn[2,6,7], Günter Weber[1], and Thomas Stöhlker[1,2,4] — [1]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany — [3]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China — [4]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [5]Institut für Kernphysik, Universität Frankfurt, 60486 Frankfurt am Main, Germany — [6]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany — [7]FIAS Frankfurt Institute for Advanced Studies, Ruth-Moufang-Straße 1, 60438 Frankfurt am Main, Germany

X-rays following 116.15 MeV/u collisions of Li-like uranium with hydrogen target were measured at different observation angles with regard to the ion beam direction. From the measured experimental spectra combined with radiative electron capture calculations, we obtain angular distribution of characteristic x-rays following the resonance transfer and excitation. Our result shows a good qualitative agreement with theoretical predictions.

A 36: Poster: Ultra-cold plasmas and Rydberg systems (with Q)

Time: Thursday 17:00–19:00 Location: C/Foyer

A 36.1 Thu 17:00 C/Foyer

Entangled Motion Using Rydberg Blockade - From Single Atoms to Atom Clouds — Sebastian Möbius, •Michael Genkin, Sebastian Wüster, Alexander Eisfeld, and Jan Michael Rost — MPI for the Physics of Complex Systems, Dresden

When excited to Rydberg states, atoms are subject to strong long range interactions, e.g. van-der-Waals or resonant dipole-dipole interactions. They give rise to strong correlations and state-dependent atomic motion. These two effects occur jointly when one considers resonant dipole-dipole interactions between atom clouds which are in the van-der-Waals blockade regime. We study the Rydberg excitation exchange and atomic motion for such a setup and distinguish between two possibilities to introduce the Rydberg excitation into the clouds: A resonant two-photon transition, which leads to a coherent collective state, or an off-resonant coupling which yields a small admixture of Rydberg state properties to the atoms. This determines whether a single atom pair or the entire cloud is set in motion by the dipole-dipole forces. Both scenarios are interesting for potential applications in entanglement protocols. We present two examples: A source of pairwise entangled atoms which can be ejected on-demand, and a mesoscopic Schrödinger cat, where the entanglement is encoded in the motion. It prevails for several microseconds and is maintained over a distance of several micrometers.

A 36.2 Thu 17:00 C/Foyer

State-selective all-optical population detection of Rydberg atoms — •Florian Karlewski[1], Markus Mack[1], Jens Grimmel[1], Nóra Sándor[2,3], and József Fortágh[1] — [1]Physikalisches Institut der Universität Tübingen — [2]Laboratoire de Physique Quantique, Strasbourg, France — [3]Department for Quantumoptics and Quantuminformatics, Wigner Research Center for Physics, Budapest

We present an all-optical protocol for detecting population in a selected Rydberg state of alkali atoms. The detection scheme is based on the interaction of the atoms with two laser pulses: one weak probe pulse which is resonant with the transition between the ground state and first excited state, and a relatively strong pulse which couples the first excited state to the selected Rydberg state. We show that by monitoring the absorption signal of the probe laser over time, we can imply the initial population of the Rydberg state. We also present the results of a proof-of-principle measurement performed on a cold gas of ^{87}Rb atoms, as well as applications in studies of the lifetimes of Rydberg states under various environment conditions.

A 36.3 Thu 17:00 C/Foyer

Characteristics of Rydberg aggregation in vapor cells — •Alban Urvoy[1], Fabian Ripka[1], Igor Lesanovsky[2], Donald W. Booth[3], James P. Shaffer[3], Tilman Pfau[1], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK — [3]Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, 440 West Brooks Street, Norman, Oklahoma 73019, USA

Vapor cells present the advantage of offering compact and flexible experimental arrangements, as well as parameter regimes that are complementary to cold atom experiments. Several important results have already been obtained with van-der-Waals interacting Rydberg atoms in vapor cells [1,2], in spite of the strong effects due to thermal motion of the atoms.
Here we present our results at higher densities on the excitation dynamics of Rydberg aggregates in a vapor cell [3]. In particular, we will focus on the specifics of the aggregation in our configuration. We will examine the influence of complex Rydberg interactions at these high densities, such as the symmetry-breaking dipole-quadrupole interaction. We will also discuss the definition of aggregates when thermal motion is non-negligible and the influence of having predominantly motional dephasing rather than laser dephasing.

[1] T. Baluktsian, B. Huber, et al., PRL **110**, 123001 (2013)
[2] C. Carr et al., PRL **111**, 113901 (2013)
[3] A. Urvoy et al., arXiv:1408.0039 [physics.atom-ph] (2014)

A 36.4 Thu 17:00 C/Foyer

Measurements and numerical calculations of ^{87}Rb Rydberg Stark Maps — •Jens Grimmel[1], Markus Mack[1], Florian Karlewski[1], Florian Jessen[1], Malte Reinschmidt[1], Ahmad Rizehbandy[1], Nóra Sándor[2,3], and József Fortágh[1] — [1]Physikalisches Institut der Universität Tübingen — [2]Department of Quantumoptics and Quantuminformatics, Wigner Research Center for Physics, Budapest, Hungary — [3]Laboratoire de Physique Quantique, ISIS, Strasbourg, France

Rydberg atoms are extremely sensitive to electric fields and consequently have a rich Stark spectrum. We present measurements and numerical calculations of Stark shifts for Rydberg states of 87Rb. We extended the numerical method of [M. Zimmerman et al., Phys. Rev. A 20, 2251-2275 (1979)] to allow for a calculation of the transition strength from low lying states to Stark shifted Rydberg states. The results from these calculations are compared to high precision measurements of Stark Maps for Rubidium Rydberg atoms with principal quantum numbers up to 70 and electric fields ranging beyond the classical ionization threshold. An electromagnetically induced transparency measurement scheme is used to detect Rydberg states inbetween two electrodes of a capacitor in a glass vapor cell.

A 36.5 Thu 17:00 C/Foyer

Patterned Rydberg excitation and ionisation with a spatial light modulator — •Rick van Bijnen[1,2], Cornee Ravensbergen[1], Servaas Kokkelmans[1], and Edgar Vredenbregt[1] — [1]Eindhoven University of Technology, Eindhoven, Netherlands — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We demonstrate the ability to excite atoms at well-defined, programmable locations in a magneto-optical trap, either to the continuum (ionisation), or to a Rydberg state [1]. To this end, excitation laser light is shaped into arbitrary intensity patterns with a spatial light modulator. These optical patterns are sensitive to aberrations of the phase of the light field, occuring while traversing the optical beamline. These aberrations are characterised and corrected without observing the actual light field in the vacuum chamber. In addition, our detection system allows for spatially resolved single ion detection, which we use to directly measure correlation functions.

[1] arXiv:1407.6856

A 36.6 Thu 17:00 C/Foyer

Enhanced relaxation rate of atom counting statistics in weakly interacting Rydberg lattices — •Wildan Abdussalam[1], Laura Gil[1], Igor Lesanovsky[2], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics and Complex Systems — [2]School of Physics and Astronomy, The University of Nottingham

We study the dynamics of spin lattices with power-law interactions driven by coherence laser-coupling under decoherence processes. We determine and analyse the atom counting statistics induced by dephasing, due to both homogeneous and inhomogeneous laser phase noises, via master equation and quantum stochastic methods. We find that the relaxation rate of atom counting statistics for the homogeneous laser noise increases when the weakly Rydberg-Rydberg interaction is applied. Meanwhile, the relaxation rate remains the same in the case of inhomogeneous laser noise.

A 36.7 Thu 17:00 C/Foyer

Long-range Rydberg molecules – Rydberg-Rydberg and Rydberg–ground-state interactions — •Johannes Deiglmayr, Heiner Sassmannshausen, and Frédéric Merkt — Laboratory of Physical Chemistry, ETH Zürich, Switzerland

We report on two recent observations in our experiments with ultracold Cs atoms [1]. First, we discuss the observation of dipole-quadrupole interactions between two Rydberg atoms. Because the dipole-quadrupole interaction does not conserve the electronic parity, the conservation of total parity requires that the excitation of dipole-quadrupole-coupled pair states in our experiments [2] is accompanied by an entanglement of electronic and rotational motions of the atom pair, which is facilitated by the near-degeneracy of even- and odd-L partial waves.

Second, we report on the experimental characterization of singlet-scattering channels in long-range Rydberg molecules composed of a Rydberg and a ground-state atom. We observe the formation of such molecules by photoassociation spectroscopy near $n\mathrm{p}_{3/2}$ resonances (n=26-34). The spectra reveal two types of molecular states recently predicted by Anderson *et al.* [PRL **112**, 163201 (2014)]: Deeply bound pure triplet states and more weakly bound states with mixed singlet and triplet character. The experimental observations are well described by a model including s-wave scattering, the hyperfine interaction of the ground-state atom and the fine-structure of the Rydberg atom.

[1] H. Saßmannshausen, F. Merkt, J. Deiglmayr, PRA **87**, 032519 (2013); [2] J. Deiglmayr, H. Saßmannshausen, P. Pillet, and F. Merkt, PRL **113**, 193001 (2014)

A 36.8 Thu 17:00 C/Foyer

Limits for Light Modulation by Stark Shifting Rydberg EIT and Superradiance in Thermal Vapor Cells — •Harald Kübler, Margarita Reschke, Mohamad Abdo, Alban Urvoy, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

Over the past few years, the usage of atomic vapors has become more and more relevant in technological applications. The demonstration of coherent dynamics on the nanosecond scale [1] opened the field for high frequency applications.

We demonstrate our progress towards a light modulator based on Rydberg EIT, where the Rydberg state can be shifted by an external RF field. We investigate the limitations on the modulation frequency as well as the limitations on the modulation depth.

One limiting factor in systems with high Rydberg densities is Superradiance. The wavelength of Rydberg to Rydberg transitions can be on the order of 1cm, meaning that a lot of Rydberg excitations are within the volume of one wavelength. These excitations can decay collectively and this can become the dominant decay process. We study the decay dynamics of this process in a thermal vapor cell and compare the experimental results to a rate equation model.

[1] Huber et al., *PRL* **107**, 243001 (2011)

A 36.9 Thu 17:00 C/Foyer

Constrained diffusion in noisy lattice gases of polar molecules — •Benjamin Everest — University of Nottingham, Nottingham, UK

Strongly correlated many body states in cold molecular gases are at present in the focus of intense research. Motivated by this we investigate the dynamics of a lattice system in one and two dimensions in which particles tunnel between lattice sites and interact via a van-der-Waals potential. We are particularly interested in the limit of strong dephasing in which the dynamics can be described by a classical master equation with constrained diffusion[1]. While the steady state features a uniform distribution of the particle density, the dynamics is rather intricate showing a variety of different timescales. We focus our investigations mainly on the case in which there is initially a dense particle cluster which is dissolved with time. We will present a simple classical model which captures the main features of this dissolution and compare the interacting and non-interacting cases.

[1] I. Lesanovsky, and J. P. Garrahan, Phys. Rev. Lett. **111**, 215305 (2013)

A 37: Poster: Twisted light and particles (SYTL)

Time: Thursday 17:00–19:00 Location: C/Foyer

A 37.1 Thu 17:00 C/Foyer

Photoionization of the hydrogen molecular ion by twisted light — •Anton Peshkov[1], Stephan Fritzsche[1,2], and Andrey Surzhykov[1] — [1]Helmholtz-Institut Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Germany

During the last decades the photoionization of diatomic molecules has been studied intensively in both experiment and theory. In these studies special attention has been paid to the interference between electrons emitted from either of two atomic centers of molecule. This interference leads to the oscillatory behavior of the angular-differential cross section similar to what was observed in the Young's double-slit experiment. Up to the present the Young-type ionization studies have been performed mainly with a plane wave incident radiation. However, owing to the recent developments in optics the photoionization of diatomic molecules can be explored also by using the twisted light beams. These beams are designed to carry a non-zero projection of the orbital angular momentum (OAM) onto to their propagation direction and can be produced with energies up to 100 eV. In this contribution we have investigated the interaction of aligned molecules with twisted Bessel light. Analysis is performed within the nonrelativistic framework and the first Born approximation. Detailed calculations have been performed for the hydrogen molecular ion H_2^+, whose electronic wave function was constructed as a linear combination of atomic orbitals. Results of these calculations indicate that the angular-differential cross section is sensitive to the position of the molecule within the wave-front as well as to the OAM and polarization of incident radiation.

A 37.2 Thu 17:00 C/Foyer

Photoabsorption and ionization of twisted light by many-electron atoms and ions — •Stephan Fritzsche[1,2], Daniel Seipt[1], Valery Serbo[3], and Andrey Surzhykov[1] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Universität Jena, 07743 Jena, Germany — [3]Novosibirsk State University, 630090 Novosibirsk, Russia

The excitation of many-electron atoms and ions by twisted light has been investigated within the framework of the density matrix theory and Dirac's relativistic equation. In particular, general expressions were derived for the alignment of the excited states if the incident photons are prepared in a coherent superposition of two twisted Bessel beams. It is shown that both, the population of the excited atoms as well as the angular distribution of the photoelectrons, are sensitive to the transverse momentum and the (projection of the) total angular momentum of the incident radiation [1].

[1] A. Surzhykov *et al.*, submitted (2014).

A 37.3 Thu 17:00 C/Foyer

A basis of states for vortex beams — •Koen van Kruining — Max Planck Institut für Physik komplexer Systeme, Dresden

Quantum mechanics requires one to decompose a physical system in a complete orthonormal basis of eigenstates. For twisted light, a basis of transverse electric and transverse magnetic beams is presented. This basis is then applied for identifying the spin eigenstates and describing the interaction of a vortex beam with a birefringent medium.

A 37.4 Thu 17:00 C/Foyer

Relativistic electron beams carrying orbital angular momentum — •Teuntje Tijssen and Mark Dennis — H. H. Wills Physics Laboratory, Bristol, United Kingdom

A simple analytic form of a relativistic electron beam carrying orbital angular momentum is the so-called Bessel beam solution of the Dirac equation, whose components are eigenfunctions of the angular momentum operator around the beam axis with different integer azimuthal labels. Close to the axis of the beam, the different angular momentum labels of different components give rise to an angular interference effect, somewhat similar to the quantum cores studied for optical vortices. our analytic investigation includes careful regularisation of the relativistic electron Bessel beams to have finite energy and self-consistency with the induced electromagnetic field along the core.

A 38: Interaction with VUV and X-ray light II

Time: Friday 11:00–13:15 Location: C/HSW

Invited Talk A 38.1 Fri 11:00 C/HSW

X-ray quantum optics: From Mössbauer to Fano — Kilian P. Heeg[1], Christian Ott[1], Daniel Schumacher[2], Hans-Christian Wille[2], Ralf Röhlsberger[2], Thomas Pfeifer[1], and •Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg

Modern x-ray light sources promise access to structure and dynamics of matter in largely unexplored spectral regions. However, the desired information is encoded in the light intensity and phase, whereas detectors register only the intensity. This phase problem is ubiquitous in crystallography and imaging, and impedes the exploration of quantum effects at x-ray energies. Here, we demonstrate phase-sensitive measurements characterizing the quantum state of a nuclear two-level system at hard x-ray energies [1]. This system comprises a large ensemble of nuclei in a x-ray cavity. The nuclei are initially prepared in a superposition state via a short x-ray pulse. Subsequently, the relative phase of this superposition is interferometrically reconstructed from the emitted x-rays via the cavity. Next to phase-sensitive measurements, also control of spectroscopic line shapes at hard x-ray energies is enabled via the tunable Fano interference [2].

[1] K. P. Heeg et al., arXiv:1411.1545 [quant-ph]
[2] C. Ott et al., Science 340, 716 (2013)

A 38.2 Fri 11:30 C/HSW

Nonlinear effects with Mössbauer nuclei — •Kilian P. Heeg, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Probing Mössbauer nuclei in a cavity environment has recently facilitated the observation of many quantum optical effects in the hard x-ray regime [1-5]. However, due to the limitations of current 3rd generation synchrotron sources only the weak excitation regime could be accessed so far. In contrast, free electron laser sources enable the step to nonlinear quantum optics with Mössbauer nuclei. Based on our recent theoretical model [6] we explore this new parameter regime and give an overview of the arising effects and possible applications.

[1] R. Röhlsberger *et al.*, Science **328**, 1248–1251 (2010)
[2] R. Röhlsberger *et al.*, Nature **482**, 199–203 (2012)
[3] K. P. Heeg *et al.*, Phys. Rev. Lett. **111**, 073601 (2013)
[4] K. P. Heeg *et al.*, arXiv:1409.0365
[5] K. P. Heeg *et al.*, arXiv:1411.1545
[6] K. P. Heeg and J. Evers, Phys. Rev. A **88**, 043828 (2013)

A 38.3 Fri 11:45 C/HSW

X-ray polarization control using nuclear transitions — •Jonas Gunst, Adriana Pálffy, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg

Due to the recent progress of x-ray light sources, a number of quantum optical schemes could be transferred to the realm of nuclear physics [1]. In addition, the highly brilliant photon beams provided by x–ray free electron lasers (XFEL) are expected to render the resonant driving of nuclei embedded in solid–state targets efficient via direct or secondary electron-mediated processes [2]. For applications in the fields of photonics or quantum information, x-ray photon energies (10-100 keV) would drastically decrease the limitation on nanoscale photonic circuits determined by the diffraction limit ($\sim 1\ \mu$m for optical photons). Here, we investigate theoretically how to coherently control the polarization properties of x-rays in the course of nuclear forward scattering (NFS) on ensembles of Mössbauer ^{57}Fe nuclei. We show that it is possible to manipulate the polarization response of a nuclear 2-level system by employing NFS in external magnetic fields. Several control schemes are then applied to x-ray qubits in order to read, store and manipulate their polarization coding.

[1] F. Vagizov *et al.*, Nature **508**, 80 (2014)
[2] J. Gunst *et al.*, Phys. Rev. Lett. **112**, 082501 (2014)

A 38.4 Fri 12:00 C/HSW

Polaritons in a nuclear optical lattice — •Johann Haber[1], Kai Schlage[1], Kai Sven Schulze[2,3], Tatyana Guryeva[1], Robert Lötzsch[2,3], Lars Bocklage[1], Daniel Schumacher[1], Hans-Christian Wille[1], Ingo Uschmann[2,3], Rudolf Rüffer[4], and Ralf Röhlsberger[1] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg, Germany — [2]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [3]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena, Germany — [4]European Synchrotron Radiation Facility, B.P. 220, 38043 Grenoble Cedex, France

We fabricate a nuclear optical lattice by sputtering alternating layers of nuclear resonant ^{57}Fe and non-resonant ^{56}Fe. The multilayer has no variation in the background refractive index, but the polaritonic interaction of x-ray radiation and the ^{57}Fe- nuclei leads to a variation of the index of refraction at the 14.41 keV resonance of ^{57}Fe. We perform reflectivity measurements and Mössbauer spectroscopy of the multilayer around the Bragg angle and explain our results in terms of the dispersion relation of the system which we derive by a transfer matrix algorithm as well as a simple quantum optical model.

A 38.5 Fri 12:15 C/HSW

Resonant scattering from single He nanodroplets in intense XUV laser pulses — •B. Langbehn[1], Y. Ovcharenko[1], D. Rupp[1], M. Coreno[2], R. Cucini[3], M. Devetta[4], P. Finetti[3], A. Garz[1], C. Grazioli[3], T. Mazza[5], O. Plekan[3], P. Piseri[4], K. C. Prince[2,6], S. Stranges[6,7], C. Callegari[3], F. Stienkemeier[8], and T. Möller[1] — [1]TU Berlin — [2]CNR Istituto di Metodologie Inorganiche e dei Plasmi, Monterotondo Scalo — [3]Elletra-Sincrotrone Trieste — [4]Università di Milano — [5]European XFEL, Hamburg — [6]CNR Istituto Officina dei Materiali, Trieste — [7]Università Sapienza, Roma — [8]Universität Freiburg

With the advent of tunable XUV light sources such as the free electron laser FERMI studying resonant light scattering by small particles has become possible. In particular, He nanodroplets can serve as model systems to investigate plasma formation as well as plasma dynamics by extracting the complex refractive index from scattering patterns obtained in a single-shot single-particle experiment.

Recently, such kind of experiment has been started at the FERMI free electron laser's low density matter beamline [1]. In order to measure single-cluster scattering patterns, a cluster source was set up using an Even-Lavie-valve to generate a stable pulsed He cluster beam. Scattering patterns of large He nanodroplets ($\langle N \rangle = 10^9$ atoms) have been recorded at photon energies ranging from 19 eV to 37 eV giving an insight into the droplets' optical properties.

[1] Lyamayev, V. et al., *J. Phys. B* **46** (2013)

A 38.6 Fri 12:30 C/HSW

Electron dynamics in He nanodroplets resonantly induced by intense XUV pulses — •Y. Ovcharenko[1], A. LaForge[2], M. Mudrich[2], P. O'Keeffe[3], A. Ciavardini[3], O. Plekan[4], P.

Finetti[4], M. Devetta[5], P. Piseri[5], A. Mika[6], R. Richter[4], K.C. Prince[4,7], M. Drabbels[6], C. Callegari[4], F. Stienkemeier[2], and T. Möller[1] — [1]TU Berlin, Germany — [2]Universität Freiburg, Germany — [3]CNR Istituto di Metodologie Inorganiche e dei Plasmi, Monterotondo Scalo, Italy — [4]Elettra-Sincrotrone Trieste, Trieste, Italy — [5]Universita di Milano, Milano, Italy — [6]EPFL, Lausanne, Switzerland — [7]7IOM-CNR TASC Laboratory, Trieste, Italy

Since the first seeded Free Electron Laser FERMI became available for users, it offers unique possibility to perform detailed investigations in complex atomic and molecular systems due to the narrow bandwidth, fine energy tunability and high intensity in XUV energy range. By using this new source the ionization dynamics in He nanodroplets has been explored with electron spectroscopy in a wide energy range above first ionization potential (IP) as well as below it, going through the surface as well as bulk excitations. In addition to the conventional sequential multi-step ionization (MSI) with a photon energy well above IP a novel collective ionization process [1] following resonant bulk excitation is observed. It is due to autoionization of two or more electronically excited cluster atoms as predicted recently. The process is very efficient and can exceed the rate of direct photoionization above IP.

[1] Y. Ovcharenko et al., Phys. Rev. Lett. 112, 073401 (2014)

A 38.7 Fri 12:45 C/HSW

Excitation energy resolved photon-induced fluorescence spectrum of hydrogen molecules in the regime of singly excited molecular states — •Philipp Schmidt[1], Christian Ozga[1], Philipp Reiss[1], Andreas Hans[1], Ltaief Ben Ltaief[1], André Knie[1], Arno Ehresmann[1], Kouichi Hosaka[2], Masashi Kitajima[2], and Noriyuki Kouchi[2] — [1]Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Department of Chemistry, Tokyo Institute of Technology, Meguro-ku, Tokyo 152, Japan

The potential energy landscape of molecules is a fundamental concept to explain and characterize a multitude of molecular processes. The hydrogen molecule is the most abundant molecule in the universe and has been a prototype for calculations of such energy landscapes for a long time. Here we present results for the photon-induced fluorescence spectrum of hydrogen molecules in the far ultraviolet regime after photoexcitation with synchrotron radiation in the energy range between 10 eV and 18 eV. The high resolution of both the excitation source and the fluorescence spectrum in this experiment allows the direct probing of the potential energy diagram. These regimes for the hydrogen molecule in particular cover the excitation into the B and C electronic states as well as the dissociation into neutral and excited hydrogen atoms leading to molecular and atomic fluorescence features showcasing various effects and processes that are not visible in common potential energy calculations.

A 38.8 Fri 13:00 C/HSW

Excitation energy transfer processes in Ar dimers below the Interatomic Coulombic decay (ICD) threshold probed with XUV-pump IR-probe experiments — •Tomoya Mizuno, Philipp Cörlin, Andreas Fischer, Michael Schönwald, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphsik, Heidelberg, Germany

We investigated the mechanism of transferring excitation energy to a neighbouring atom in Ar dimers below the ICD threshold by using XUV-pump IR-probe experiments. The first XUV pulse, which is generated from 10 fs IR laser pulse via HHG in Ar gas, creates two different types of excited states in one of two Ar atoms, such as a $3s$ inner-shell vacancy and $3d$ excitation state (Ar $3p^{-2}(3P)3d\ ^2P$ and ^2D) following $3p$ valence ionization by shake-up process. And then, the delayed IR probe pulse further ionizes into a repulsive Ar+$(3p^{-1})$ and $Ar^+(3p^{-1})$ state after a variable time delay. Finally, all charged reaction products emerging from the Ar dimer were detected by a reaction microscope. The apparatus enables us to record the kinetic energy release (KER) of a $Ar^+ + Ar^+$ ion-pair as a function of the pump-probe delay, in order to discuss the internuclear distance R at a given time. We found that the delay-dependent KER spectra exhibit clearly two dissociation pathways, corresponding to decay of 3s inner-shell ionization channel and shake-up channel, respectively. Moreover it was also found that the excitation energy is transferred to a neighbouring atom at the crossing points due to nonadiabatic transition.

A 39: Precision spectroscopy of atoms and ions IV (with Q)

Time: Friday 11:00–13:00 Location: C/kHS

A 39.1 Fri 11:00 C/kHS

The BASE catching trap: A reservoir for antiprotons — •Christian Smorra for the BASE-Collaboration — CERN, CH-1211 Geneva 23, Switzerland

The Baryon-Antibaryon Symmetry Experiment BASE has commissioned a four-Penning trap system for the high-precision measurement of the antiproton magnetic moment at the Antiproton Decelerator (AD) of CERN. To inject, capture and cool antiprotons of 5.3 MeV kinetic energy from the AD to below 100 meV, a catching trap forms the interface between the decelerator and the precision trap system. It features a mesh degrader system of variable thickness with broad energy acceptance, high-voltage electrodes to apply catching pulses, and a five-pole Penning trap with a high-quality image current detection system for measurements of the motional frequencies and resistive cooling.

An extraction scheme for single particles from an antiproton cloud has been developed, which allows to separate and merge fractions of the antiproton cloud without particle loss. Using this scheme BASE will be able to perform precision experiments with antiprotons even in long accelerator shutdown periods.

Results of the commissioning of the catching trap and the BASE apparatus with protons and antiprotons will be presented.

A 39.2 Fri 11:15 C/kHS

BASE: Topics in Data Analysis — •Kurt Franke for the BASE-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany — Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

BASE (Baryon-Antibaryon Symmetry Experiment) is a new experiment at CERN with the purpose of making high-precision comparison measurements of the properties of protons and antiprotons. As such, BASE functions as a sensitive test of CPT invariance in the baryon sector. This talk will cover several important data analysis aspects relevant to BASE and similar Penning-trap experiments. A single trapped particle in thermal equilibrium with a detection system creates a narrow notch or "dip" in the thermal noise of the detector at the eigenfrequency of the particle. First, these so-called "dip" measurement will be analyzed, and an expression for the expected accuracy and optimal FFT-window function for this measurement technique will be given. Next, a Bayesian recursive algorithm for calculating probabilities for spin states will be presented. Finally, the parameter selection algorithm for analyzing Larmor resonances will be presented. These analysis techniques have been applied in the most precise measurement of the proton's magnetic moment [Nature **509**, 596–599 (2014)].

A 39.3 Fri 11:30 C/kHS

Identification of optical transitions in Ir^{17+} ions with high sensitivity to a variation of the fine-structure constant — •Alexander Windberger[1], Oscar O. Versolato[2,3], Hendrik Bekker[1], Natalia S. Oreshkina[1], Julian C. Berengut[4], Anastasia Borschevsky[5], Victor Bock[1], Zoltán Harman[1], Sebastian Kaul[1], Ulyana I. Safronova[6], Victor V. Flambaum[4], Christoph H. Keitel[1], Piet O. Schmidt[2,7], Joachim Ullrich[1,2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik — [2]Physikalisch-Technische Bundesanstalt — [3]Advanced Research for Nanolithography — [4]University of New South Wales — [5]GSI Helmholtzzentrum für Schwerionenforschung, — [6]University of Nevada — [7]Leibniz Universität Hannover

The unique electronic structure of the Nd-like Ir^{17+} ion allows for optical transitions of interest for metrology and the investigation of a possible variation of the fine-structure constant α. We performed spectroscopy in the optical range on Ir^{17+} ions produced and trapped in an electron beam ion trap (EBIT). Complex electron correlations in Ir^{17+} impede accurate theoretical predictions making a direct identification of transitions impossible. In a different approach, we investigated the characteristic energy scaling of fine-structure transitions with the atomic number Z. In the obtained spectra of the isoelectronic Nd-like W^{14+}, Re^{15+}, Os^{16+}, and Pt^{18+}, we identified 45 transitions contributing to these energy scalings. To confirm this method, the established transitions in Ir^{17+} were independently identified via their Zeeman-structures in the magnetic field of the EBIT.

A 39.4 Fri 11:45 C/kHS

Current status of the Proton Radius Puzzle — •Julian J. Krauth and the CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

This talk gives an overview on the current status of the Proton Radius Puzzle.

In 2009 the CREMA Collaboration provided a measurement of the rms charge radius of the proton via the 2S-2P Lamb shift in muonic hydrogen. It is particularly remarcable that the proton radius is found to be 4% smaller than indicated by previous experiments using electronic hydrogen or electron scattering. The radius measured by the CREMA Collaboration has a 7σ discrepancy with respect to the 2010 CODATA value which is composed by the mentioned previous experiments. The so-called Proton Radius Puzzle has caused a huge debate in the scientific community but remains unsolved up to this date. In order to shed light on the puzzle we recently performed 2S-2P Lamb shift measurements with muonic helium.

A 39.5 Fri 12:00 C/kHS

The Experimental Apparatus of the Muonic Helium Lamb Shift Measurement — •Beatrice Franke and the CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

Muonic atoms have an increased sensitivity on finite size effects of the nucleus due to the approximately 200-fold mass of the muon compared to the electron. The Lamb shift experiment of the CREMA collaboration in muonic hydrogen [1] and deuterium allowed to determine the proton radius and other nuclear properties with an improved precision compared to previously conducted measurements. As a successor experiment, the determination of the Lamb shift in the muonic helium ions mu3He+ and mu4He+ [2] will be a contribution to solving the proton radius puzzle [3] as well as the discrepancy in electronic isotope-shift measurements. In this talk, an overview of the components of the experimental apparatus is given: Details on the muon beam line, the laser scheme and the different detector systems as well as other specifics necessary to perform this high sensitivity measurement.

[1] R. Pohl et al. (CREMA coll.), Nature 466, 213 (2010)

[2] A. Antognini et al. (CREMA coll.), Can. J. Phys. 89, 47-57 (2011)

[3] R. Pohl et al., Annu. Rev. Nucl. Part. Sci. 63, 175-204 (2013)

A 39.6 Fri 12:15 C/kHS

Towards solving the proton radius puzzle: Results from the Muonic Helium Lamb Shift experiment — •Marc Diepold and the CREMA Collaboration — Max-Planck-Institute of Quantum Optics, Garching

The recently completed muonic helium Lamb shift experiment located at Paul-Scherrer-Institute (Switzerland) measured different $2S \rightarrow 2P$ Lamb-shift transition frequencies in the μ^4He^+ and μ^3He^+ exotic ions by means of laser spectroscopy.

In these hydrogen-like systems all of the atom's electrons are replaced by a single muon upon creation when negative muons are stopped in ordinary matter. The muon's Bohr radius is 200 times smaller than the corresponding electronic Bohr radius in ordinary H-like ions due to the 200 times larger mass of the muon. This results in a large increase in sensitivity to the finite charge and magnetic radius of the nucleus.

Preliminary results are presented that will use this to determine the nuclear rms charge radii of the smallest helium isotopes ten times more accurately in the future, serving as important input parameters in both nuclear models and atomic theory.

Furthermore these findings shed new light on the so-called Proton Radius Puzzle that was created by the 7 sigma discrepancy between measurements of the proton rms charge radius in muonic hydrogen and normal hydrogen spectroscopy or electron scattering experiments.

A 39.7 Fri 12:30 C/kHS

First measurements of Metallic Magnetic Calorimeters for High-Resolution X-ray Spectroscopy at GSI — •D. Hengstler[1], M. Keller[1], C. Schötz[1], M. Krantz[1], J. Geist[1], T. Gassner[2,3], K.H. Blumenhagen[2,3], R. Märtin[2,3], G. Weber[2,3], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], Th. Stöhlker[2,3,4], and C. Enss[1] — [1]KIP, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Darmstadt — [4]IOQ, Jena University

Metallic magnetic calorimeters are particle detectors that provide a high energy resolution over a large energy range as well as an excellent linearity. They convert the energy of a single incoming photon into a temperature rise, leading to a change of magnetization in a paramagnetic Au:Er temperature sensor that is inductively read out by a SQUID magnetometer. Three different detector arrays, optimized for x-rays with energies up to 20, 30 and 200 keV respectively are presently developed as well as a compton polarimeter. With a detector optimized for 200 keV photons we performed two successful measurements at the Experimental Storage Ring at GSI. The detector was operated at $T = 20$mK and was attached to the tip of a 400 mm long and 80 mm wide cold finger of a cryogen free $^3He/^4He$-dilution refrigerator. During the two beamtimes we achieved an energy resolution below 60 eV for photon energies up to 60 keV and investigated projectile beams of Au^{76+} and Xe^{54+} colliding with a Xe gas target, respectively. We were able to identify the Lyman series of Xe^{53+} up to Ly-η as well as spectral lines from He-like Xe and show that metallic magnetic Calorimeters will be a promising tool for future precision experiments at FAIR.

A 39.8 Fri 12:45 C/kHS

Comparative study of the nuclear-polarization corrections in highly charged ions — •Andrey Volotka and Günter Plunien — Institut für Theoretische Physik, TU Dresden

A systematic investigation of the nuclear-polarization effects in one- and few-electron heavy ions is presented. The nuclear-polarization corrections in the zeroth and first orders in 1/Z have been evaluated to the binding energies, the hyperfine splitting, and the bound-electron g factor. The effect of the nuclear polarization has been investigated for the specific differences constructed in a way to cancel the nuclear size corrections. In all cases considered, it has been demonstarted, that the nuclear-polarization contributions can be substantially canceled simultaneously with the rigid nuclear corrections [1]. Therefore, the rigorous investigations of the specific differences provide a unique opportunity to test the strong-field QED with a much higher accuracy than expected before.

[1] A. V. Volotka and G. Plunien, Phys. Rev. Lett. 113, 023002 (2014).

A 40: Ultracold Atoms and Molecules (with Q)

Time: Friday 11:00–13:00 Location: B/SR

A 40.1 Fri 11:00 B/SR

Quadrupole-quadrupole interactions in ultracold atom systems — •Martin Lahrz[1], Mikhail Lemeshko[2], Klaus Sengstock[1], Christoph Becker[1], and Ludwig Mathey[1] — [1]University of Hamburg, Hamburg, Germany — [2]Harvard University, Cambridge, Massachusetts, USA

We investigate quadrupole-quadrupole interactions of ultracold atom systems. These interactions have a long-range and anisotropic character, which goes beyond the properties of contact potentials. In this talk, we will report briefly about our proposal [1] to detect quadrupolar interactions in ultracold Fermi gases by measuring the induced mean-field shift. We consider a quasi-2D system of quadrupoles aligned by an external magnetic field and tilted with respect to the system geometry. This results in a characteristic angular dependence constituting the "smoking gun" feature of this interaction. The magnitude of the shift is of the order of tens of Hertz for Yb($^3P_2$) and similarly for Sr($^3P_2$) making this experimentally conceivable with current technologies. Further, we discuss many-body effects that can be created with quadrupole-quadrupole interactions.

[1] M. Lahrz, M. Lemeshko, K. Sengstock, C. Becker, and L. Mathey, Phys. Rev. A **89**, 043616 (2014).

A 40.2 Fri 11:15 B/SR

Detecting Floquet resonances with directed transport of ultracold atoms — •Christopher Grossert[1], Martin Leder[1], Sergey Denisov[2], Peter Hänggi[2], and Martin Weitz[1] — [1]Institut für Angewandte Physik,Universität Bonn, Germany — [2]Institut für Physik, Universität Augsburg, Germany

The breaking of spatiotemporal symmetry can lead to directed motion in periodically driven systems without any gradients or net forces. To break the relevant symmetries, a biharmonic driving is sufficient in the classical case as well as in the quantum case. For a dissipative system, this so called rocking ratchet system has been studied in previous work. In this talk, we investigate directed transport of ultracold rubidium atoms in a optical realization of a quantum rocking ratchet. By changing parameters of the underlying periodic modulations we resolve transport resonances in the mean momentum of an atomic Bose-Einstein condensate [1]. These resonances are attributed to the avoided crossings between Floquet eigenstates which are widely separated on the energy scale. We observe a bifurcation of a single-peak resonance into a doublet by increasing the amplitude of the drive. Our results prove the feasibility of the fine experimental control over coherent quantum transport in ac-driven optical lattices.

References: [1] Grossert et al., arXiv:1407.0605 (2014)

A 40.3 Fri 11:30 B/SR

Dicke super-radiance as non-destructive probe for super-fluidity in optical lattices — •Nicolai ten Brinke and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, D-47057 Duisburg, Germany

We study Dicke super-radiance as collective and coherent absorption and emission of photons from an ensemble of ultra-cold atoms in an optical lattice. Since this process depends on the coherence properties of the atoms (e.g., super-fluidity), it can be used as a probe for their quantum state. This detection method is less invasive than time-of-flight experiments or direct (projective) measurements of the atom number (or parity) per lattice site, which both destroy properties of the quantum state such as phase coherence.

With our method, we are able to distinguish a partially excited (e.g., thermal) gas of atoms from a fully condensed (super-fluid) state. Regarding a phase transition from the Mott state to the super-fluid phase, it is possible to discriminate an adiabatic passage from a sudden transition. In this talk, we also discuss options for an experimental realization.

A 40.4 Fri 11:45 B/SR

Role of excitation spectrum during a quantum phase transition: Semiclassical approach — •Manuel Gessner[1], Victor Manuel Bastidas[2], Tobias Brandes[2], and Andreas Buchleitner[1,3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [3]Freiburg Institute for Advanced Studies, Albert-Ludwig-Universität, Albertstr. 19, 79104 Freiburg

We develop a semiclassical method to reproduce spectral features of a family of spin chain models with variable range in a transverse magnetic field, which interpolates between the Lipkin-Meshkov-Glick and the Ising model. The semiclassical spectrum is exact in the limit of very strong or vanishing external magnetic fields. Each of the semiclassical energy landscapes shows a bifurcation when the external magnetic field drops below a threshold value. This reflects the quantum phase transition from the symmetric paramagnetic phase to the symmetry-breaking (anti-)ferromagnetic phase in the entire excitation spectrum - and not just in the ground state.

A 40.5 Fri 12:00 B/SR

Improved ground-state scattering length of ^{40}Ca by two-colour photoassociation — •Veit P. Dahlke[1], Evgenij Pachomow[1], Eberhard Tiemann[2], Fritz Riehle[1], and Uwe Sterr[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig — [2]Institut für Quantenoptik, Leibniz-Universität Hannover, Welfengarten 1, 30167 Hannover

We have measured the second to last weakly bound ground state vibrational level $J = 0$ in the $^1S_0 + {}^1S_0$ potential of $^{40}Ca_2$. We used two-colour photoassociation with the intermediate level $v' = -1$, $\Omega' = 1$, $J' = 1$ in the $^1S_0 + {}^3P_1$ potential on a cold ensemble of about 10^5 calcium atoms trapped in a crossed dipole trap at a temperature of approximately 1 μK. The photoassociation light is applied via two offset locked precisely tunable lasers. The vibrational level is located 1387.439(9) MHz below the asymptote and corresponds to the $v = 39$, $J = 0$ state.

With the exact determination of this level it becomes possible to derive a more accurate description of the ground state potential which will result in a more precise value for the ground state scattering length. By detecting more bound levels it will be possible to further improve on the accuracy and also enable us to predict the tunability of the scattering length by low-loss optical Feshbach resonances in the case of ^{40}Ca.

A 40.6 Fri 12:15 B/SR

Photoassociation spectroscopy of an ultra cold 23Na-40K mixture: En route to many-body physics with polar molecules — •Zhenkai Lu[1], Nikolaus Buchheim[1], Frauke Seesselberg[1], Tobias Schneider[1], Immanuel Bloch[1,2], and Christoph Gohle[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultra cold quantum gases with long-range dipolar interaction promise exciting new possibilities for quantum simulation of strongly interacting many-body systems. One way of realizing this is to create an ultra cold sample of ground state polar molecules.

A crucial step is the stimulated Raman adiabatic passage (STIRAP), a two-photon process involving a resonant intermediate state. We identified promising candidates for this intermediate level in the molecular potentials of the sodium D-line asymptote. We observe a series of deeply bound vibrational levels, resolving fine and hyperfine structure, by photoassociation spectroscopy on a nearly degenerate mixture of ^{23}Na and ^{40}K. By applying external fields, we observe Zeeman and Stark sub structure.

A 40.7 Fri 12:30 B/SR

Quantum Logic Spectroscopy of Molecular Ions — •Fabian Wolf[1], Jan C. Heip[1], Yong Wan[1], Florian Gebert[1], and Piet O. Schmidt[1,2] — [1]QUEST Institut, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

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

We propose to prepare a translationally cold molecular ion in a specific ro-vibrational state by employing 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 is achieved via a quantum-non-demolition measurement (QNDM).

By analyzing the signal obtained from QNDM we can extract spectroscopic information about the $X^1\Sigma^+ \rightarrow A^1\Sigma^+$ transition.

References

[1] Schmidt et al., Science 309, 749 (2005)

A 40.8 Fri 12:45 B/SR

Towards ultracold LiK ground-state molecules — •Markus Debatin, Sambit B. Pal, Mark Lam, and Kai Dieckmann — Center for Quantum Technologies, National University of Singapore Block S15, 3 Science Drive 2,Singapore 117543

Ultracold heteronuclear molecules have seen increasing interest in the scientific community over the last few years [1]. Due to their large electric dipole moment of 3.6 Debye LiK ground-state molecules are particularly suited to investigate the physics of strongly-interacting dipolar quantum gases.

In our experiment [2] we perform spectroscopy on ultracold ^{6}Li^{40}K Feshbach molecules with the aim to create ground-state molecules. Starting with samples of about $3 \cdot 10^4$ ultracold Feshbach molecules we currently investigate transitions mainly to levels close to the asymptote of the $B^1\Pi$ electronic potential. For these levels a good coupling efficiency to the ground state of the $X^1\Sigma^+$ potential is predicted. This will be investigated in the next steps in order to develope a scheme to transfer the Feshbach molecules to the absolute ground state via a simulated Raman adiabatic passage (STIRAP). In the talk our spectroscopy results as well as an update on the current experimental status will be presented.

[1] M. A. Baranov et al. Chem. Rev. 112, 5012-5061, 2012
[2] A.-C. Voigt et al. Phys. Rev. Lett. 102, 020405, 2009

A 41: Ultra-cold atoms, ions and BEC V (with Q)

Time: Friday 11:00–13:15 Location: M/HS1

A 41.1 Fri 11:00 M/HS1

Probing superfluidity of Bose-Einstein condensates via stirring — •Vijay Pal Singh[1,2], Wolf Weimer[2], Kai Morgener[2], Jonas Siegl[2], Klaus Hueck[2], Niclas Luick[2], Henning Moritz[2], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We investigate the superfluid behavior of a Bose-Einstein condensate of ^{6}Li molecules. In the experiment the condensate is stirred by a small attractive potential along a circular path. The moving potential produces almost no heating when its velocity is below the critical velocity v_c. The rate of induced heating increases steeply above v_c. The observed critical velocity, however, is smaller than the Bogoliubov speed of sound. To understand this, we perform numerical simulations and identify the factors that reduce v_c. The critical velocity is influenced by the finite temperature, the inhomogeneous density along the strongly confined direction, the circular instead of linear motion of the stirring potential, and the finite depth of the potential. The simulated critical velocities with experimental parameters are in excellent agreement with the experimentally measured ones.

A 41.2 Fri 11:15 M/HS1

Cavity-Optomechanics with cold atoms: Quantum mechanical oscillators coupled by a cavity-mediated optical spring — •Nicolas Spethmann[1,2], Jonathan Kohler[1], Sydney Schreppler[1], Lukas Buchmann[1], and Dan Stamper-Kurn[1] — [1]University of California, Berkeley — [2]Universität Kaiserslautern

A complex quantum system can be constructed by coupling simple quantum elements to one another. Oscillators comprised of the collective motion of ultracold, neutral atoms are excellent model systems in the quantum regime. However, neutral atoms inherently exhibit only weak interactions, so that it is a challenge to create tuneable, long-range coupling. Such interactions can be induced employing photons in a cavity containing the ultracold atoms. Because of the decay of cavity photons, such a coupling necessarily leads to measurement back-action noise being imparted onto the oscillators.

We demonstrate cavity-mediated coupling between two near-groundstate oscillators composed of ultracold Rb atoms trapped inside a high-finesse cavity. We observe phase-coherent transfer of excitation between the oscillators. At the same time, we detect the motional noise of the oscillators to monotonically increase with coupling time due to back-action. We show that this back-action noise exhibits two-oscillator correlations, reflecting the properties of the coupled mode system during cavity-mediated interaction. Our results point to the potential, and also the challenge, of coupling quantum oscillators with light.

A 41.3 Fri 11:30 M/HS1

Loschmidt Echo in Fock Space — •Thomas Engl[1], Julien Dujardin[2], Peter Schlagheck[2], Juan Diego Urbina[1], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Département de Physique, Université de Liège, 4000 Liège, Belgium

The Loschmidt echo is a measure of stability of a quantum system with respect to an external perturbation. While for single particle systems the Loschmidt echo has been extensively studied [1], for the fundamental issue of quantum stability in interacting many-body systems only few, mainly numerical, results are available [2]. However, the recent development of methods to describe many-body quantum systems in the semiclassical regime [3], allows to attack analytically this difficult problem.

Here, we consider bosonic atoms in an optical lattice well described by a Bose-Hubbard model, where the perturbation is given by a small difference of the on-site energies. In the disordered case, we compute both the amplitude and the modulus square of the Loschmidt echo using the new semiclassical methods. Our analytical results show excellent agreement when compared to numerical calculations.

[1]A. Goussev, R. A. Jalabert, H. M. Pastawski and D. A. Wisniacki, Loschmidt echo. Scholarpedia **7**, 11687 (2012)
[2]J. D. Bodyfelt, M. Hiller, and T. Kottos, Europhys. Lett. **78**, 50003 (2007)
[3]T. Engl, J. Dujardin, A. Argüelles, P. Schlagheck, K. Richter and J. D. Urbina, Phys. Rev. Lett. **112**, 140403 (2014)

A 41.4 Fri 11:45 M/HS1

Sympathetic cooling of ions in radio frequency traps beyond the critical mass ratio — •Pascal Weckesser, Bastian Höltkemeier, Henry Lopez, and Matthias Weidemüller — Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg

Sympathetic cooling has become a powerful and universal method for preparing ultracold ions confined in radio frequency traps. We theoretically investigate the possibility of using laser-cooled atoms as a buffer gas. Recent theories indicate that cooling of ions in radio frequency traps is limited by the mass ratio of the coolant and the ion.

We present an approach to overcome the this mass ratio limitation. By performing Monte-Carlo simulations we find universal solutions for the ion's steady state at all mass ratios. A detailed description of these solutions and the corresponding cooling limit for experimental applications will be presented.

A 41.5 Fri 12:00 M/HS1

Two-photon ionization of a Bose-Einstein condensate — •Bernhard Ruff[1,2], Alexander Grote[3], Harald Blazy[3], Harry Krüger[3], Hannes Duncker[3], Jasper Krauser[3], Juliette Simonet[3], Philipp Wessels[1,3], Klaus Sengstock[1,3], and Markus Drescher[1,2] — [1]Centre for Ultrafast Imaging, Hamburg, Germany — [2]Institut für Experimentalphysik, Hamburg, Germany — [3]Zentrum für optische Quantentechnologien, Hamburg, Germany

Hybrid quantum systems involving ultracold atoms and ions have undergone a spectacular development in the past years. Many approaches have been pursued to prepare such systems amoung which the combination of atom and ion traps, photoionization schemes or electron impact ionization.

We report on the investigation of a ^{87}Rb condensate interacting with femtosecond laser pulses at 515 nm wavelength. The light pulses ionize atoms of the condensate within the focus region (7 μm waist) of the beam via two-photon absorption. The number of produced ions can be controlled by tuning the intensity or the wavelength of the laser pulses. We work in a regime where several thousands of ions are created in the quantum gas. The remaining atoms are detected by resonant absorption imaging, either in situ or after time-of-flight, which allows extracting the number of atoms and their temperature. First results on the relaxation of the condensate after interacting with one femtosecond laser pulse will be discussed.

A 41.6 Fri 12:15 M/HS1

Critical quasienergy states in driven many-body systems — Victor Manuel Bastidas[1], •Georg Engelhardt[1], Pedro Pérez-Fernández[2], Malte Vogl[3], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Departamento de Física Aplicada III, Escuela Superior de Ingeniería, Universidad de Sevilla, Camino de los Descubrimientos s/n, ES-41092 Sevilla, Spain — [3]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

We discuss singularities in the spectrum of driven many-body spin systems. In contrast to undriven models, the driving allows us to control the geometry of the quasienergy landscape. As a consequence, one can engineer singularities in the density of quasienergy states by tuning an external control. We show that the density of levels exhibits logarithmic divergences at the saddle points, while jumps are due to local minima of the quasienergy landscape. We discuss the characteristic signatures of these divergences in observables like the magnetization, which should be measurable with current technology [1].

[1] V.M. Bastidas, G. Engelhardt, P. Pérez-Fernández, M. Vogl, and T. Brandes. arXiv:1410.5281 (To appear in Phys. Rev. A)

A 41.7 Fri 12:30 M/HS1

Critical temperatures in a gas of Sodium spin-1 atoms — •Tilman Zibold, Vincent Corre, Camille Frapolli, Andrea Invernizzi, Jean Dalibard, and Fabrice Gerbier — Collège de France, 11 place Marcelin Berthelot, 75005 Paris, France

We investigate the Bose-Einstein condensation of a gas of Sodium atoms with spin degree of freedom. The phase transition of the different Zeeman components to the condensed phase occurs in general at different critical temperatures, depending on the (conserved) total magnetization of the sample and quadratic Zeeman energy. The higher critical temperature simply corresponds to the condensation of the majority component. The two lower ones correspond to the appearance of magnetic ordering and generally depend more strongly on direct and exchange interactions. We measure this effect for different magnetizations and in different magnetic fields with good agreement with simple theoretical models.

A 41.8 Fri 12:45 M/HS1

Interaction-free measurements with ultracold atoms — Jan Peise[1], •Bernd Lücke[1], Luca Pezzé[2], Frank Deuretzbacher[3], Wolfgang Ertmer[1], Jan Arlt[4], Augusto Smerzi[2], Luis Santos[3], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 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, Appelstraße 2, 30167 Hannover, Germany — [4]QUANTOP, Institut for Fysik og Astronomi, Aarhus Universitet, 8000 Arhus C, Denmark

In contrast to our intuition, possible events can influence our physical reality even if they do not occur. This is particularly well illustrated by the idea of interaction-free measurement (IFM), which permits the detection of an object without the need of any interaction with it. We use the quantum Zeno effect in a spinor Bose-Einstein condensate to demonstrate a new scheme for interaction-free measurements. Highly efficient single-atom detection - a major requirement for IFM - is reached via the unprecedented realization of an unbalanced homodyne detection with ultracold atoms. Our experiments provide the first realization of the long-sought indirect quantum Zeno effect and demonstrate IFM efficiencies surpassing all previous realizations, since our many-particle scheme is inherently robust against losses and decoherence that strongly plague the single-particle variants.

A 41.9 Fri 13:00 M/HS1

Bose-Einstein condensation in classically frustrated optical lattices — •Peter Janzen[1,2], Wen-Min Huang[1,2,3], and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany

We investigate Bose-Einstein condensation in a classically frustrated triangular lattice geometry, as realized recently in experiment [1]. In this system, the single particle dispersion has two distinct minima in the Brillouin zone. Therefore, in addition to a continuous $U(1)$ symmetry, a discrete $\mathbb{Z}_2$ symmetry can be broken upon condensation. We derive a general effective action for systems with these symmetries. Using a renormalization group approach, we investigate the critical behavior of this effective action. We find that for the triangular lattice geometry, the condensed state breaks the $\mathbb{Z}_2$ symmetry. Also, we find that the transition is of first order, unlike Bose-Einstein condensation in free space, which is a continuous phase transition.

[1] J. Struck, M. Weinberg, C. Ölschläger, P. Windpassinger, J. Simonet, K. Sengstock, R. Höppner, P. Hauke, A. Eckardt, M. Lewenstein, and L. Mathey, Nature Physics **9**, 738 (2013).

A 42: Ultracold Plasmas and Rydberg Systems III (with Q)

Time: Friday 11:00–12:45 Location: P/H2

A 42.1 Fri 11:00 P/H2

Coherent manipulation of a superatom — •Johannes Zeiher[1], Peter Schauss[1], Sebastian Hild[1], Jae-yoon Choi[1], Tommaso Macri[1,2], Immanuel Bloch[1,3], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]QSTAR, Largo Enrico Fermi 2, 50125 Firenze, Italy — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Rydberg atoms offer the possibility to engineer long range interacting systems of ultracold atoms due to their strong van der Waals interactions. This can be harnessed to generate entangled states of many particles, which are of interest for metrology and quantum information applications. In our experiment, we start from a 2d Mott insulator of ground state atoms of rubidium-87. Using our recently developed single site addressing technique, we spatially control their shape and prepare samples with sub-shot noise atom number fluctuations. We optically excite Rydberg atoms and detect them in our optical lattice with submicron resolution. When the interaction energy becomes larger than the optical coupling bandwidth, the system is fully Rydberg blockaded and described as an effective two-level system, frequently called "superatom". We confirm the predicted collective $\sqrt{N}$ scaling of the optical coupling with the number of atoms from a single up to 180 particles. Furthermore, we demonstrate coherent manipulation of the superatom by performing Ramsey spectroscopy. We explore physics beyond the superatom description by detecting doubly excited states when the system size is on the order of the blockade radius.

A 42.2 Fri 11:15 P/H2

Mesoscopic Rydberg-blockaded ensembles in the superatom regime and beyond — Tobias M. Weber, Michael Höning, Thomas Niederprüm, Torsten Manthey, •Oliver Thomas, Vera Guarrera, Michael Fleischhauer, Giovanni Barontini, and Herwig Ott — TU Kaiserslautern, Kaiserslautern, Germany

In recent years great progress has been made in understanding the collective behaviour introduced by Rydberg excitations in ultra cold gases. Because of their strong van der Waals interaction it is not possible to excite two Rydberg atoms resonantly within a blockade volume defined by the interaction strength and the excitation bandwidth. In dense atomic clouds hundreds of ground state atoms can be found within this volume, forming a so-called superatom. These strongly correlated ensembles show an increased excitation probability, described by an effective two-level system. Here we report on the controlled creation and characterization of an isolated mesoscopic superatom by means of accurate density engineering and excitation to Rydberg p-states [1]. Its variable size allows us to investigate the transition from a strongly confined effective two-level to an extended many-body system. By monitoring continuous laser-induced ionization we are able to determine the $g^2(\tau)$ correlation function and observe the expected anti bunching effect for resonant excitation, as well as bunching for off resonant coupling. The observed amplitudes and timescales can be described with an effective rate-equation model.

[1]: T. M. Weber et al, Creation, excitation and ionization of a mesoscopic superatom. arXiv:1407.3611

A 42.3 Fri 11:30 P/H2

Excitation Energy Transfer in Ultra-Cold Rydberg Gase — •Torsten Scholak[1,2], Thomas Wellens[2], and Andreas Buchleitner[2,3] — [1]Department of Chemistry, University of Toronto, Toronto, Canada M5S 3H6 — [2]Physikalisches Institut der Albert-Ludwigs-Universität, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany — [3]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität, Albertstr. 19, D-79104 Freiburg, Germany

Ultra-cold gases of Rydberg atoms are one of the few many-body systems with tunable long-range interactions. This feature, along with their exceptional static and dynamic properties, as well as their versatility, has propelled them into the limelight. Now, with the advent of novel imaging methods capable of non-destructive monitoring of

Rydberg excitations, Rydberg gases become an ideal testbed and a proving ground for theories of energy transport in complex systems, in particular, frustrated spin glasses, nitrogen-vacancy centers, and photosynthetic light-harvesting complexes. In this talk, we reveal how the nature of excitation energy transfer (EET) in the gas can be controlled via the dipole blockade effect [1]. For weak blockade, we predict transient localization of EET on small clusters of two or more atoms. For stronger blockade, EET will be significantly faster, because the excitations are efficiently migrated by delocalized states. We present our analysis of the ensemble-averaged mean-square displacement $\langle[\boldsymbol{r}(t)-\boldsymbol{r}(0)]^2\rangle$ and a thorough study of the spatial distribution of the system's eigenstates.

[1] T. Scholak, T. Wellens, and A. Buchleitner, Phys. Rev. A , in press (2014), arXiv:1409.5625.

A 42.4 Fri 11:45 P/H2

Resonant Rydberg dressing of two-electron atoms — •Christopher Gaul and Thomas Pohl — Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzer Str. 38, D-01187 Dresden

We study the emergence of effective atomic interactions from resonant laser excitation to high-lying, strongly interacting Rydberg states. Specifically, we consider two-electron atoms which permit two-photon coupling via a long-lived intermediate triplet state. Exploiting the formation of a dark state on resonance, we demonstrate that losses due to spontaneous decay can be greatly suppressed in this system. At the same time, the correlated Rydberg-excitation dynamics gives rise to significant effective interactions between two driven atoms.

Studying the resulting correlated steady state, we identify a two-body resonance, where induced light shifts balance with the Rydberg interaction and the laser detuning. Under strong driving, this resonance is shown to enable greatly enhanced effective interactions while keeping the corresponding decoherence rates at a very low level.

Compared to previous two-level schemes this new approach is found to yield much stronger interactions and shown to permit flexible tunability of the magnitude as well as the shape of the effective interaction potential. Potential applications will also be discussed.

A 42.5 Fri 12:00 P/H2

Rydberg-Electron Assisted Molecule Formation in Ultracold Atomic Clouds — •Thomas Niederprüm, Torsten Manthey, Oliver Thomas, Tobias Weber, and Herwig Ott — Technische Universität, Kaiserslautern

The continuously improving level of experimental control allows for the realization of excitations to increasingly high principle quantum numbers inside of cold atomic clouds. As the size of a Rydberg atom as well as it's lifetime increases with the principal quantum number, it eventually enters a regime where it is likely to interact with the thermal ground state atoms surrounding it. At large distances this interaction is dominated by the scattering of the Rydberg electron with the ground state atom. At small internuclear separations however the 1/r4 - interaction between the ionic core of the Rydberg atom and the ground state atom is the leading contribution. The combined potential efficiently transports ground state atoms entering the Rydberg electrons wavefunction towards the ionic core. Approaching each other the ionic core and the ground state atom can undergo resonant dipole energy exchange and form an ionic Rb_2^+ molecule while the Rydberg electron gains the binding energy of the molecule and escapes. We report on the creation of such molecular ions in dense thermal clouds of ^{87}Rb under excitation to Rydberg p-States. Furthermore a systematic study on the density dependence of the molecule production for various principal quantum numbers enables us to obtain the effective cross section for the molecule formation process as well as it's scaling behavior.

A 42.6 Fri 12:15 P/H2

Towards deterministic single-photon source via four-wave mixing in a thermal microcell — •Yi-Hsin Chen, Fabian Ripka, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

Single-photon sources are the keys for photonic-based quantum security communication and information processing. One promising candidate to realize the deterministic single-photon source is based on the combination of four-wave-mixing (FWM) and Rydberg blockade effect. We propose that a single-photon source can be generated in a thermal vapor confined in a cell with micrometer scale, which is so-called microcell [1]. Similar to the studies of coherent Rydberg dynamics on nanosecond timescales [2] and van-der Waals interatomic interaction [3] in three-level system, we implement a pulsed FWM scheme to observe both coherent dynamics and effects of dephasing due to Rydberg-Rydberg interaction [4]. Furthermore, we investigate the effects of the excitation volume by reducing the volume to below the Rydberg interaction range (few micrometers). We discuss prospects for the generation of non-classical light.

[1] M. M. Müller et al., PRA 87, 053412 (2013)
[2] Huber et al., PRL 107, 243001 (2011)
[3] Baluktsian et al., PRL 110, 123001 (2013)
[4] Huber et al., PRA 90, 053806 (2014)

A 42.7 Fri 12:30 P/H2

Taking trapped strontium ions to a higher level — •Gerard Higgins[1], Fabian Pokorny[1], Christine Maier[2], Johannes Haag[1], Florian Kress[1], Yves Colombe[1], and Markus Hennrich[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

Trapped Rydberg ions are a novel approach to quantum information processing [1]. By combining the high degree of control of trapped ion systems with long-range dipolar interactions of Rydberg ions [2], fast entanglement gates $\sim 1\mu$s may be realised in large ion crystals [3].

We are working towards exciting strontium ions, trapped in a linear Paul trap, to Rydberg states 26<n<60 using a two-photon excitation scheme with 243nm and 304-309nm laser light.

We report on excitation using the UV lasers into higher levels, such as the intermediate state ($6P_{1/2}$) with 243nm laser light. We also present the overlapping of both Rydberg-excitation laser beams using a hydrogen-loaded photonic crystal fiber [4] and the focussing of both beams down to $\sim 10\mu$m onto trapped ions.

[1] M. Müller, et al., New J. Phys. **10**, 093009 (2008)
[2] D. Jaksch, et al., Phys. Rev. Lett. **85**, 2208 (2000)
[3] F. Schmidt-Kaler, et al., New J. Phys. **13**, 075014 (2011)
[4] Y. Colombe, et al., Opt. Express, **22**, 19783 (2014)

A 43: Ultracold Plasmas and Rydberg Systems IV (with Q)

Time: Friday 14:30–16:00 Location: P/H2

A 43.1 Fri 14:30 P/H2

Controlled interactions between optical photons stored as Rydberg polaritons — •Hannes Busche, Simon W. Ball, Teodora Ilieva, Paul Huillery, Daniel Maxwell, David Paredes-Barato, David J. Szwer, Matthew P. A. Jones, and Charles S. Adams — Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, South Road, Durham, DH1 3LE, United Kingdom

We are using electromagnetically induced transparency to store photons as Rydberg excitations in a cold atom cloud in order to map their strong and long-ranged dipolar interactions onto the optical field and introduce effective interactions at the single photon level. The application of an external microwave field [1] allows control of the interaction strength, manifesting itself in a modification of the retrieved photon statistics [2].

Recently, we completed a new experimental apparatus that will give us the ability to store single photons in individually addressable sites. In this setup, we aim to study interactions between stored photons in spatially separated channels and explore applications such as the implementation of a universal quantum gate for photonic qubits [3].

[1] D. Maxwell et al., Phys. Rev. Lett. 110, 103001 (2013).
[2] D. Maxwell et al., Phys. Rev. A 89, 043782 (2014).
[3] D. Paredes Barato and C. S. Adams, Phys. Rev. Lett. 112, 040501 (2014).

A 43.2 Fri 14:45 P/H2

Two-photon bound states of Rydberg polaritons — •Matthias

Moos, Razmik Unanyan, and Michael Fleischhauer — Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We consider the propagation of photons in a medium of Rydberg atoms. Under conditions of electromagnetically induced transparency the photons form strongly interacting massive particles, termed Rydberg polaritons. Recent experiments have realized strong interactions between Rydberg polaritons and shown photon blockade as well as bunching phenomena [1],[2]. We consider an off-resonant coupling of the Rydberg polaritons to the medium. We derive a one-dimensional effective Hamiltonian and find parameter regimes where bound states can be excited near the threshold of the scattering continuum. Using numerical wave-function simulations we show that bound states can be created in a pulsed experiment and analyze their properties and time-evolution inside the medium.

[1] Peyronel et al. Nature 488, 57 (2012)
[2] Firstenberg et al. Nature 502, 71 (2013)

A 43.3 Fri 15:00 P/H2

Dipolar Dephasing of Rydberg D-state Polaritons — •Christoph Tresp[1], Przemyslaw Bienias[2], Sebastian Weber[2], Hannes Gorniaczyk[1], Ivan Mirgorodskiy[1], and Sebastian Hofferberth[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]3. Institut für theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We report on our current experiments investigating photon propagation through a cold Rubidium sample, by coupling the ground state to a long lived Rydberg D-state via electromagnetically-induced transparency (EIT). In addition to the strong nonlinearities known from similar experiments carried out with Rydberg S-states, we observe a decay of transmission over time. The rate of this decay strongly depends on the number of photons send into the medium. We attribute this effect to induced dipolar dephasing of Rydberg polaritons, which occurs for nonzero interaction angles of Rydberg pair-states and leads to stationary Rydberg excitations. For further understanding, we model our system by numerically solving the polariton propagation through our system, taking the full interaction problem into account.

A 43.4 Fri 15:15 P/H2

Photon interactions in a laser-driven Rydberg gas — •Dario Jukić, Fabian Maucher, and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

Electromagnetically induced transparency (EIT) in a system of interacting Rydberg atoms provides a unique platform to explore strong and nonlocal optical nonlinearities, both in the classical and quantum regime. We present our recent progress in understanding the nature of effective photon interactions in such a medium. In the limit of large photon numbers and moderate nonlinearities we discuss the applicability of a mean-field approach for the light field, which is shown to permit an analytical treatment of its propagation dynamics. In the opposite limit, strong correlation effects start to play a dominant role and are explored within few-body quantum calculations. Experimental signatures for the found interaction effects will also be discussed.

A 43.5 Fri 15:30 P/H2

Single-Photon Transistor Based on Rydberg Blockade — •Daniel Tiarks, Simon Baur, Katharina Schneider, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Garching, Deutschland

An all-optical transistor is a device in which a gate light pulse switches the transmission of a target light pulse with a gain above unity. The gain quantifies the change of the transmitted target photon number per incoming gate photon. In Refs. [1,2], we study the quantum limit of one incoming gate photon and observe a gain of 20. The gate pulse is stored as a Rydberg excitation in an ultracold gas. The transmission of the subsequent target pulse is suppressed by Rydberg blockade which is enhanced by a Förster resonance. The detected target photons reveal in a single shot with a fidelity above 0.86 whether a Rydberg excitation was created during the gate pulse. The gain offers the possibility to distribute the transistor output to the inputs of many transistors, thus making complex computational tasks possible.

[1] D. Tiarks et al. PRL 113, 053602 (2014); see also H. Gorniaczyk et al. PRL 113, 053601 (2014).
[2] S. Baur et al. PRL 112, 073901 (2014).

A 43.6 Fri 15:45 P/H2

Single-Photon Transistor Mediated by Interstate Rydberg Interactions — •Hannes Gorniaczyk[1], Christoph Tresp[1], Ivan Mirgorodskiy[1], Johannes Schmidt[1], Helmut Fedder[2], and Sebastian Hofferberth[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]3. Physikalisches Institut, Universität Stuttgart, Germany

We present the realization of an all-optical transistor by mapping gate and source photons into strongly interacting Rydberg excitations with different principal quantum numbers in an ultracold atomic ensemble. A switch contrast of 40% is obtained for a coherent gate input with mean photon number one. We show that over 60 source photons can be attenuated with a single gate photon demonstrating a high-gain optical transistor. We use this optical transistor for the nondestructive detection of a single Rydberg atom with a fidelity of 79%. The read-out of gate photons marks a crucial step for the implementation of quantum information protocols. For this reason, we study the coherence of gate photon spin waves in the context of source-gate interaction.