Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture rooms f107, f142, f303, and f428; Poster Empore Lichthof)

Invited Talks

A 3.1	Mon	11:00–11:30	f303	**Interaction of atoms and ions with twisted light** — •Stephan Fritzsche, Daniel Seipt, Andrey Surzhykov
A 7.1	Mon	14:30–15:00	f107	**Probing QED in strong fields via the magnetic moment of highly charged ions** — •Sven Sturm
A 7.4	Mon	15:30–16:00	f107	**X–ray emission from highly charged ions** — •Andrey Surzhykov, Stephan Fritzsche, Andrey Volotka, Vladimir Yerokhin, Thomas Stöhlker
A 16.1	Tue	14:30–15:00	f142	**Observation of the Efimov state of the helium trimer** — •Maksim Kunitski, Stefan Zeller, Jörg Voigtsberger, Anton Kalinin, Lothar Ph. H. Schmidt, Markus Schöffler, Achim Czasch, Wieland Schöllkopf, Robert E. Grisenti, Till Jahnke, Dörte Blume, Reinhard Dörner
A 25.1	Wed	14:30–15:00	f107	**Describing the correlated electron dynamics in atoms and molecules** — •Sebastian Bauch
A 27.1	Wed	14:30–15:00	f428	**Atomic level scheme of neutral actinium** — •Sebastian Raeder, Randolf Beerwerth, Rafael Ferrer, Camilo Granados, Amin Hakimi, Mustapha Laataoui, Volker Sonnenschein, Norbert Trautmann, Klaus Wendt
A 33.1	Thu	11:00–11:30	f303	**Imaging single nanoparticles with intense XUV pulses from a high-order harmonic generation source** — •D. Rupp, B. Langbehn, M. Sauppe, N. Monserud, A. Ulmer, J. Zimmermann, T. Möller, F. Frassetto, A. Trabattoni, F. Calegari, M. Vrakking, A. Rouzee
A 34.1	Thu	11:00–11:30	f428	**The magnetic moment of the antiproton** — •Stefan Sellner, Klaus Blaum, Matthias Borchert, Takashi Higuchi, Nathan Leefer, Yasuyuki Matsuda, Andreas Mooser, Hiroki Nagahama, Christian Ospelkaus, Wolfgang Quint, Georg Schneider, Christian Smorra, Toya Tanaka, Jochen Walz, Yasunori Yamazaki, Stefan Ulmer
A 35.1	Thu	14:30–15:00	f107	**History and current status of the Keldysh theory** — •Sergey Popruzhenko
A 35.2	Thu	15:00–15:30	f107	**Multidimensional control of XUV-initiated high harmonic generation** — Doron Azoury, •Michael Krüger, Henrik R. Larsson, Sebastian Bauch, David J. Tannor, Barry D. Bruner, Nirit Dudovich
A 39.1	Fri	11:00–11:30	f303	**Enhanced ionization of embedded clusters by electron transfer mediated decay in helium nanodroplets** — •A. C. LaForge, V. Stumpf, K. Gokhberg, J. von Vangerow, N. V. Kryzhevoi, P. O'Keeffe, A. Ciavardini, S. Krishnan, K. C. Prince, R. Richter, R. Moshammer, T. Pfeifer, L. S. Cederbaum, F. Stienkemeier, M. Mudrich

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	11:00–11:30	e415	**Artificial gauge fields and topology with ultracold atoms in optical lattices** — •Monika Aidelsburger
SYAD 1.2	Tue	11:30–12:00	e415	**Many-body physics with impurities in ultracold quantum gases** — •Fabian Grusdt

SYAD 1.3	Tue	12:00–12:30	e415	**How to determine the handedness of single molecules** — •Martin Pitzer
SYAD 1.4	Tue	12:30–13:00	e415	**Quantum systems under gravitational time dilation** — •Magdalena Zych

Invited talks of the joint symposium SYUL

See SYUL for the full program of the symposium.

SYUL 1.1	Fri	11:00–11:50	e415	**Exawatt laser concepts for extreme field science** — •Chris Barty
SYUL 1.2	Fri	11:50–12:20	e415	**Generation of short pulses with ultra-high temporal contrast at the PHELIX petawatt facility** — •Vincent Bagnoud
SYUL 1.3	Fri	12:20–12:50	e415	**Petawatt lasers for particle acceleration at HZDR Dresden** — •Ulrich Schramm
SYUL 1.4	Fri	12:50–13:20	e415	**High-intensity few-cycle pulses with ultrahigh temporal contrast** — •Stefan Karsch, Alexander Kessel, Christoph Skrobol, Mathias Krüger, Christoph Wandt, Sandro Klingebiel, Olga Lysov, Izhar Ahmad, Sergei Trushin, Vyacheslav Leshchenko, Zsuzsanna Major, Ferenc Krausz
SYUL 2.1	Fri	14:00–14:30	e415	**Coherent Combination of Ultrafast Fiber Lasers** — •Jens Limpert
SYUL 2.2	Fri	14:30–15:00	e415	**Cryogenic multipass amplifiers for high peak and average power ultrafast lasers** — •Luis E. Zapata
SYUL 2.3	Fri	15:00–15:30	e415	**Multi-TW infrared laser using Frequency domain Optical Parametric Amplification** — •Bruno E. Schmidt, Philippe Lassonde, Guilmot Ernotte, Mathieu Giguere, Nicolas Thire, Antoine Laramee, Heide Ibrahim, Francois Legare

Sessions

A 1.1–1.7	Mon	11:00–12:45	a310	**Precision Measurements and Metrology I (with Q)**
A 2.1–2.8	Mon	11:00–13:00	e001	**Ultracold Atoms, Ions and Molecules I (with Q)**
A 3.1–3.7	Mon	11:00–13:00	f303	**Atomic systems in external fields I**
A 4.1–4.5	Mon	11:00–12:15	f107	**Collisions, scattering and correlation phenomena I**
A 5.1–5.7	Mon	14:30–16:15	a310	**Precision Measurements and Metrology II (with Q)**
A 6.1–6.8	Mon	14:30–16:30	e001	**Ultracold Atoms, Ions and Molecules II (with Q)**
A 7.1–7.6	Mon	14:30–16:30	f107	**Highly charged ions and their applications**
A 8.1–8.7	Mon	14:30–16:15	f303	**Atomic systems in external fields II**
A 9.1–9.51	Mon	16:30–19:00	Empore Lichthof	**Ultra-cold atoms, ions and BEC (with Q)**
A 10.1–10.5	Mon	17:00–18:15	a310	**Precision Measurements and Metrology III (with Q)**
A 11.1–11.7	Mon	17:00–18:45	f107	**Atomic clusters I (with MO)**
A 12.1–12.7	Mon	17:00–18:45	f303	**Ultracold plasmas and Rydberg systems I (with Q)**
A 13.1–13.8	Tue	11:00–13:00	a310	**Precision Measurements and Metrology IV (with Q)**
A 14.1–14.9	Tue	11:00–13:15	f342	**Ultracold Atoms, Ions and Molecules III (with Q)**
A 15.1–15.8	Tue	14:30–16:30	f107	**Atomic clusters II (with MO)**
A 16.1–16.7	Tue	14:30–16:30	f142	**Collisions, scattering and correlation phenomena II**
A 17.1–17.8	Tue	14:30–16:30	f303	**Ultracold plasmas and Rydberg systems II (with Q)**
A 18.1–18.5	Tue	16:30–19:00	Empore Lichthof	**Highly charged ions and their applications**
A 19.1–19.5	Tue	16:30–19:00	Empore Lichthof	**Collisions, scattering and correlation phenomena**
A 20.1–20.9	Tue	16:30–19:00	Empore Lichthof	**Atomic systems in external fields**
A 21.1–21.15	Tue	16:30–19:00	Empore Lichthof	**Interaction with strong or short laser pulses**
A 22.1–22.19	Tue	16:30–19:00	Empore Lichthof	**Interaction with VUV and X-ray light**
A 23.1–23.8	Wed	11:00–13:00	f107	**Ultra-cold atoms, ions and BEC I (with Q)**
A 24.1–24.8	Wed	11:00–13:00	f303	**Interaction with strong or short laser pulses I**
A 25.1–25.7	Wed	14:30–16:30	f107	**Interaction with strong or short laser pulses II**
A 26.1–26.8	Wed	14:30–16:30	f303	**Ultra-cold atoms, ions and BEC II (with Q)**
A 27.1–27.7	Wed	14:30–16:30	f428	**Precision spectroscopy of atoms and ions I (with Q)**
A 28.1–28.10	Wed	16:30–19:00	Empore Lichthof	**Ultracold plasmas and Rydberg systems (with Q)**
A 29.1–29.6	Wed	16:30–19:00	Empore Lichthof	**Atomic clusters (with MO)**
A 30.1–30.24	Wed	16:30–19:00	Empore Lichthof	**Precision spectroscopy of atoms and ions (with Q)**
A 31.1–31.3	Wed	16:30–19:00	Empore Lichthof	**Attosecond physics**

A 32.1–32.8	Thu	11:00–13:00	f107	**Ultra-cold atoms, ions and BEC III (with Q)**
A 33.1–33.6	Thu	11:00–12:45	f303	**Interaction with strong or short laser pulses III**
A 34.1–34.7	Thu	11:00–13:00	f428	**Precision spectroscopy of atoms and ions II (with Q)**
A 35.1–35.6	Thu	14:30–16:30	f107	**Attosecond physics**
A 36.1–36.8	Thu	14:30–16:30	f303	**Ultra-cold atoms, ions and BEC IV (with Q)**
A 37.1–37.4	Fri	11:00–13:20	e415	**Advanced Concepts for High Peak Power Ultrafast Lasers I**
A 38.1–38.8	Fri	11:00–13:00	f107	**Ultra-cold atoms, ions and BEC V (with Q)**
A 39.1–39.8	Fri	11:00–13:15	f303	**Interaction with VUV and X-ray light**
A 40.1–40.7	Fri	11:00–12:45	f428	**Precision spectroscopy of atoms and ions III (with Q)**
A 41.1–41.3	Fri	14:00–15:30	e415	**Advanced Concepts for High Peak Power Ultrafast Lasers II**

Annual General Meeting of the Atomic Physics Division

Thursday 13:15–14:00 f107

A 1: Precision Measurements and Metrology I (with Q)

Time: Monday 11:00–12:45 Location: a310

A 1.1 Mon 11:00 a310

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

Direct traceability to the SI definition of the meter and the capability to generate synthetic wavelengths from the optical to the microwave regime make broadband optical frequency combs highly promising sources for future length metrology with high precision as required in engineering, geodesy and surveying.

In this contribution we want to present the development of a novel 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 and 250 MHz repetition rate is used as a seed laser. By cavity filtering two coherent combs of different mode spacings in the GHz band are generated and subsequently used as local oscillator and measurement beam. The deployed filtering duplet with tunable spacing and Pound-Drever-Hall stabilization scheme will be presented as well as the electronic filtering unit for phase detection. Furthermore, we want to discuss the current progress on the interferometer head setup and show preliminary results of first length measurements.

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 1.2 Mon 11:15 a310

Squeezed light and self-induced transparency in mercury-filled hollow core photonic crystal fibers — •Ulrich Vogl[1,2], Nicolas Y. Joly[1,2], Philip St.J. Russell[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [2]University Erlangen-Nuremberg, Erlangen, Germany

We recently demonstrated that the use of atomic mercury vapour allows greatly improved loading of an atomic gas into hollow core photonic crystal fibres (PCFs), leading to high and constant vapour pressure in the fibre core [1]. The kagomé-PCFs used guide light not by the photonic band gap effect, but by a two-dimensional version of anti-resonant reflection, and offer much broader windows of transmission, typically over 1000 nm. The generation of squeezed states of light, using pulses that fulfil the self-induced transparency (SIT) condition, was proposed in 1989 [2]. We successfully demonstrate SIT of optical pulses in the mercury-filled PCF system and its use in the generation of squeezed states of light. In the first experiments we observed squeezing below the shot noise limit upon launching short nanosecond pulses into the fibre and using a measurement in direct difference detection. Future prospects include phase-sensitive detection of SIT solitons with temporally shaped local oscillator forms to investigate the phase and number uncertainty of the generated states.

[1] U. Vogl, Ch. Peuntinger, N. Y. Joly, P. St.J. Russell, Ch. Marquardt, and G. Leuchs. Optics Express **22**, 29375 (2014).
[2] K. Watanabe, et. al. Phys. Rev. Lett. **62**, 2257 (1989).

A 1.3 Mon 11:30 a310

Dilatometer Setup to Characterize Dimensionally Stable Materials by the Coefficient of Thermal Expansion at a Temperature Range from 100 K to 325 K — •Ines Hamann[1], Ruven Spannagel[1], Thilo Schuldt[1], Jose Sanjuan[1], Martin Gohlke[1], Ulrich Johann[2], Dennis Weise[2], and Claus Braxmaier[1,3] — [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

Space missions with the aim of high precision optical measurements are often limited by the dimensional stability of the instrument which can be exposed to high temperature fluctuations, due to the environment of the space probe. To minimize the change of the geometric dimension due to temperature changes, highly dimensionally stable materials are needed at the specific environmental temperatures. Materials like glass ceramics offer a minimal coefficient of thermal expansion (CTE) but they are also very heavy. Composite materials like CFRP or SiC offer also a very low CTE but with a lower weight and are more and more used for such applications. To characterize such low expansion materials we use a laser dilatometer with a heterodyne interferometer to measure length variations of the sample caused by an applied temperature variation. Using a cryocooler in combination with a heating system, we are able to determine CTEs at the 10 ppb/K level within a temperature range from 100 K to 325 K. In this talk, we present improvements of our setup and recent sample measurements.

A 1.4 Mon 11:45 a310

Precision rubidium spectroscopy in space — •Vladimir Schkolnik[1], Markus Krutzik[1], Achim Peters[1,2], and The FOKUS Team[1,2,3,4,5] — [1]Institut für Physik, Humboldt- Universität zu Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [3]ILP, Universität Hamburg — [4]Institut für Physik, JGU Mainz — [5]Menlo Systems, Martinsried

Frequency stabilized lasers are one of the key elements in high precision instruments such as atom interferometers and atomic clocks. Accordingly, future space missions for tests of the equivalence principle require robust and compact lasers with high mechanical and frequency stability.

In this talk, we present the first Doppler free spectroscopy on rubidium in space, performed during the flight of the sounding rocket mission TEXUS 51. We present the spectroscopy payload, the autonomous stabilization scheme and the experimental results of the flight. The frequency of the stabilized laser was compared to a microwave reference using a fiber based frequency comb during launch and microgravity phase. This frequency measurement can be interpreted as a test of the local position invariance and paves the way for future high precision experiments in space.

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 1237-1240, and 1345.

A 1.5 Mon 12:00 a310

Coating Thermal Noise Interferometer — •Janis Wöhler for the AEI 10m Prototype Team — MPG for Gravitational Physics Hannover

Thermal noise in the coatings of highly reflective mirrors is becoming a limiting noise source in interferometers used for the detection of gravitational waves. It is caused by mechanical losses of the thin films used in the coatings. A way to reduce the noise is to use crystalline coatings due to their inherently lower mechanical losses. Crystalline AlGaAs-coatings are a promising candidate and their noise properties will be measured before using them in a quantum limited Michelson interferometer. For the measurement, all other noise sources, especially seismic noise and acoustic disturbances, have to be reduced below the thermal noise level. The AEI 10 m Prototype facility is probably the best suited environment for this kind of experiment.

In this talk the setup of the Thermal Noise Interferometer will be presented, which can measure thermal noise in a frequency band from 10Hz to 50kHz, limited from below by seismic noise and from above by photon shot noise. Furthermore prospects of using crystalline coatings in large scale gravitational wave detectors will be discussed.

A 1.6 Mon 12:15 a310

Enhancing quantum sensing sensitvity and spectral resolution by a quantum memory — •Sebastian Zaiser, Torsten Rendler, Ingmar Jakobi, Samuel Wagner, Philipp Neumann, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Deutschland

Measurement of the phase accumulation of a quantum state is central to quantum sensing. Typically, the sensor coherence time (here $400\mu s$) limits the timescale for this phase accumulation and hence the energy resolution. Processes occuring on larger timescales can indeed be observed[1]. We employ a small nuclear spin quantum register to store quantum information on timescales of the sensors longitudinal relaxation time (here $5ms$). This allows us an increase in frequency resolution by more than one order of magnitude while keeping the full measurement signal. We show that the measurement signal is strongly correlated to the amount of quantum information on the memory qubit by gradually disentangling sensing and memory qubit before the sensing step. We further apply our quantum sensor-memory couple for high resolution NMR spectroscopy of single ^{13}C nuclear spins.

[1] A. Laraoui et al., Nature Communica- tions 4, 1651 (2013), arXiv: 1305.1536

A 1.7 Mon 12:30 a310

Spectroscopic tests of Lorentz and CPT invariance — •Ralf Lehnert — Indiana University Center for Spacetime Symmetries, Bloomington, USA — Leibniz Universität Hannover, Hannover, Germany

Various approaches to new physics allow for the possibility of small departures from Lorentz and CPT symmetry. This talk provides a brief discussion of the identification of suitable experimental tests for these ideas. Emphasis is placed on low-energy high-precision spectroscopic measurements.

A 2: Ultracold Atoms, Ions and Molecules I (with Q)

Time: Monday 11:00–13:00 Location: e001

A 2.1 Mon 11:00 e001

3D Printed Atom Traps — •Reece Saint[1], Will Evans[1], Yijia Zhou[1], Mark Fromhold[1], Ehab Saleh[2], Christopher Tuck[2], Ricky Wildmann[2], Mark Hardy[2], Ian Maskery[2], Fedjia Oručević[1], and Peter Krüger[1] — [1]School of Physics and Astronomy, University of Nottingham, United Kingdom — [2]Additive Manufacturing,University of Nottingham, United Kingdom

Atom chip technologies have shown excellent promise as a base in order to probe the physics of quantum gases, but also for the implementation of quantum based sensors in gravitometry [e.g. EU-funded iSense project], nanoTesla sensitive magnetic devices with micrometer resolution and optical cloud based microscopy. Such chips are inherently ultra-high vacuum (UHV) compatible, necessary for long lifetime atom traps. Further these traps rely on highly power consuming and planar "under-structures", required to form and cool the magneto-optical traps (MOT) on which atom-chip based experiments depend; not to mention often cumbersome experimental baggage.

We introduce a different approach, addressing the challenges started above: additive manufacturing (3D Printing). Using an additive process where successive layers of material are laid down allows for almost arbitrary structures to be created; coupling this with modern optimization algorithms to optimize magnetic trapping in terms of power consumption, heat generation, structure robustness and size would substantially improve overall device performance. 3D Printing offers the possibility of integrating electronic, optical or vacuum components, potentially allowing the formation of a fully integrated atom chip device.

A 2.2 Mon 11:15 e001

A 3d micro-structured trap with low axial micromotion and high field gradients — •Delia Kaufmann, Timm F. Gloger, Peter Kaufmann, Michael Johanning, and Christof Wunderlich — Department Physik, Universität Siegen, 57068 Siegen, Germany

We present the status of a second generation 3d micro-structured segmented ion trap with built in solenoids for the creation of inhomogeneous magnetic fields. The new design is based on a trap, which, among other things, was used to demonstrate rf single ion addressing [1] and fault tolerant Hahn-Ramsey-spectroscopy [2]. To overcome the present limitations in terms of finite gradient size and axial micromotion and make it better suitable for the application of MAgnetic Gradient Induced Coupling (MAGIC) [3], and the formation of tailored entangled states [4], the new trap features a redesigned middle layer for lower axial micromotion and improved connectivity for higher solenoid current damage threshold. We discuss the design, simulations and the status of the experimental setup.

[1] D. Kaufmann et al., Appl. Phys. B 107, 935 (2012); D. Kaufmann, PhD thesis, Siegen, 2011.

[2] N. Vitanov et al., Phys. Rev. A 91, 033406 (2015)

[3] Ch. Piltz et al., arXiv:1509.01478 (2015)

[4] S. Zipilli et al., Phys. Rev. A 89, 042308 (2014)

A 2.3 Mon 11:30 e001

Investigation of hyperfine qubit dephasing in trapped ions — •Theeraphot Sriarunothai, Christian Piltz, Gouri Giri, and Christof Wunderlich — Department Physik, Universität Siegen, 57068 Siegen, Germany

Magnetic sensitive hyperfine states of trapped ions that serve as qubits can be protected against decoherence by use of continuous or pulsed dynamical decoupling (e.g., [1]). Nevertheless it is desirable to experimentally identify noise sources and characterize them to enhance the basic stability of experiments in quantum information science. We report on investigations into the dephasing of hyperfine qubits exposed to a magnetic gradient using trapped $^{171}Yb^{+}$ ions confined in a macroscopic linear Paul trap. Effective magnetic field noise caused by the ions' motion in varying electric fields is reduced by minimizing the ions' micromotion and by passively filtering the DC potentials applied to trap electrodes. An active magnetic field compensation system counteracts ambient magnetic noise. The dependence of the fidelity of conditional quantum gates (e.g., CNOT) is investigated as a function of the thermal excitation of the ions' motion in the range between the Doppler cooling limit and close to the motional ground state employing microwave sideband cooling [2-4].

[1] N. Timoney *et al.*, Nature **476**, 185 (2011).

[2] C. Ospelkaus *et al.*, Nature **476**, 181 (2011).

[3] A. Khromova *et al.*, Phys. Rev. Lett. **108**, 220502 (2012).

[4] S. Weidt *et al.*, Phys. Rev. Lett. **115**, 013002 (2015.)

A 2.4 Mon 11:45 e001

Feedback-based position stabilisation of microparticles — •Saravanan Sengottuvel, Michael Johanning, and Christoph Wunderlich — University of Siegen, Germany

We report on the status of an experiment utilizing feedback for the three-dimensional position stabilization of a charged micro particle. Laser light scattered by the particle illuminates position sensitive detectors and generates an error signal upon displacement of the particle. This error signal is then used to generate a compensating field using correction electrodes. For a particle that is initially trapped in a linear segmented Paul trap, this allows to ramp down and finally switch off the trap and end up with a well localized quasi-free particle. We discuss the approach, potential applications and limitations for sensitivity, position confinement and particle size.

A 2.5 Mon 12:00 e001

All-optical Atom Trap Trace Analysis for Rare Krypton Isotopes — •Pablo Woelk[1], Markus Kohler[1], Carsten Sieveke[1], Simon Hebel[1], Peter Sahling[1], Christoph Becker[2], and Klaus Sengstock[2] — [1]Carl Friedrich von Weizsäcker Centre for Science and Peace Research, University of Hamburg, Beim Schlump 83, 20144 Hamburg — [2]Institut für Laser-Physik, University of Hamburg, 22761 Hamburg

The isotope Krypton-85 is an excellent indicator for the detection of nuclear reprocessing activities. However, for the analysis of atmospheric air samples, sensitive measuring methods down to the single atom level are required because of the small concentrations. Furthermore, for a practical and effective detection of clandestine reprocessing, small sample sizes and a high sample throughput rate are desirable.

Established methods using Atom Trap Trace Analysis (ATTA) allow high sensitivity but have a limited throughput of about 200 samples per year, since the vacuum chambers have to be flushed for several hours after each measurement to avoid cross contamination due to the RF-driven excitation of metastable states.

Here we present an enhanced ATTA apparatus, which in contrast to the established methods, produces metastable Kr all-optically. This avoids cross contamination, therefore allowing a much higher throughput rate. The apparatus is based on a self-made VUV-lamp and a 2D-3D magneto-optical trap setup. In the 2D trap metastable krypton is produced and a beam of atoms is formed by Doppler-cooling simultaneously.

A 2.6 Mon 12:15 e001

Quantum simulation of the dynamical Casimir effect with trapped ions — •Nils Trautmann[1] and Philipp Hauke[2,3] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt — [2]Institut für Quantenoptik und Quanteninformation, Österreichis-

che Akademie der Wissenschaften — [3]Institut für Theoretische Physik, Universität Innsbruck

Quantum vacuum fluctuations are a direct manifestation of Heisenberg's uncertainty principle. The dynamical Casimir effect allows for the observation of these vacuum fluctuations by turning them into real, observable photons. However, the observation of this effect in a cavity QED experiment would require the rapid variation of the length of a cavity with relativistic velocities, a daunting challenge. Here, we propose a quantum simulation of the dynamical Casimir effect using an ion chain confined in a segmented ion trap. We derive a discrete model that enables us to map the dynamics of the multimode radiation field inside a variable-length cavity to radial phonons of the ion crystal. We perform a numerical study comparing the ion-chain quantum simulation under realistic experimental parameters to an ideal Fabry–Perot cavity, demonstrating the viability of the mapping. The proposed quantum simulator, therefore, allows for probing the photon (respectively phonon) production caused by the dynamical Casimir effect on the single photon level.

A 2.7 Mon 12:30 e001

Experimental realization of a single-ion heat eninge — •Kilian Singer[1,2], Johannes Rossnagel[1,2], Samuel Thomas Dawkins[1,2], Ferdinand Schmidt-Kaler[1], Georg Jacob[1], and Dawid Criwelli[1,2] — [1]Quantum, Institut für Physik, Universität Mainz, D-55128 Mainz, Germany — [2]Experimentalphysik I, Universität Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Thermodynamic machines can be reduced to the ultimate atomic limit [1], using a single ion as a working agent. The confinement in a linear Paul trap with tapered geometry allows for coupling axial and radial modes of oscillation.

The heat-engine is driven thermally by coupling it alternately to hot and cold reservoirs, using the output power of the engine to drive a harmonic oscillation [2].

From direct measurements of the ion dynamics, the thermodynamic cycles for various temperature differences of the reservoirs can be determined [3] and the efficiency compared with analytical estimates.

[1] J. Rossnagel et al., "A single-atom heat engine", arXiv:1510.03681
[2] O. Abah et al., Phys. Rev. Lett. 109, 203006 (2012).
[3] J. Rossnagel et al., New J. Phys. 17, 045004 (2015)

A 2.8 Mon 12:45 e001

Single-ion heat pump — •Dawid Crivelli[1,2], Johannes Rossnagel[1,2], Samuel Thomas Dawkins[1,2], Ferdinand Schmidt-Kaler[1], Georg Jacob[1,2], and Kilian Singer[1,2] — [1]Quantum, Institut für Physik, Universität Mainz, D-55128 Mainz, Germany — [2]Experimentalphysik I, Universität Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

We will present new concepts of implementing a heat pump with a single atom. Analytical and numerical predictions employing realistic experimental conditions are reviewed together with a new trap design for the implementation. We include a detailed description of the experimental procedure. We build on the results of our previous implementation of a single ion heat engine [1,2,3], inverting the mechanism to realize a heat-pump, transferring heat from the cold to the hot reservoir, induced by an external electric field.

[1] J. Rossnagel et al., "A single-atom heat engine", arXiv: 1510.03681.
[2] O. Abah et al., Phys. Rev. Lett. 109, 203006 (2012).
[3] J. Rossnagel et al., New J. Phys. 17, 045004 (2015).

A 3: Atomic systems in external fields I

Time: Monday 11:00–13:00 Location: f303

Invited Talk A 3.1 Mon 11:00 f303

Interaction of atoms and ions with twisted light — •Stephan Fritzsche[1,2], Daniel Seipt[1,2], and Andrey Surzhykov[1] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Universität Jena, 07743 Jena, Germany

Research on optical vortices, popularly known also as *twisted* light, has attracted much interest during the past two decades. However, while the spin and orbital angular momentum distributions of such light beams have been explored in good detail, little is known so far about their interaction with (clouds of) atoms and how the angular momentum of the light affects the subsequent fluorescence or photoelectron emission. Here, we summarize recent results on the photoexcitation and photoionization of (multi-electron) atoms as obtained within the framework of the density matrix theory. It is shown that the population of the excited atoms, their photon emission as well as the angular distribution of the photoelectrons become sensitive to the transverse momentum and the (projection of the) total angular momentum of the incident radiation, especially if the atoms are localized with regard to the beam (axis).

[1] M. Scholz-Marggraf *et al.*, Phys. Rev. A**90** 013425.
[2] A. Surzhykov *et al.*, Phys. Rev. A**91** 013403.

A 3.2 Mon 11:30 f303

Ab initio 2D computations for quantum reflection from metallic surfaces — •Emanuele Galiffi[1,3], Maarten DeKieviet[2], and Sandro Wimberger[1,4,5] — [1]Institut für Theoretische Physik, Philosophenweg 16, D-69120, Heidelberg, Germany — [2]Physikalisches Institut - Im Neuenheimer Feld 226 69120, Heidelberg, Germany — [3]Department of Physics - Imperial College London, South Kensington Campus London SW7 2AZ, UK — [4]Dipartimento di Fisica e Scienze della Terra - Università degli Studi di Parma, Via G. P. Usberti 7/a, 43124, Italy — [5]INFN, Istituto Nazionale di Fisica Nucleare - Sezione di Milano Bicocca, Gruppo Collegato di Parma, Italy

The numerical study of scattering problems finds a wide range of applications in surface science, and in particular quantum reflection (QR). We present a highly optimised, norm-preserving method to compute QR of slow atoms from metallic surfaces by solving numerically the Time-Dependent Schrödinger Equation in 2D. The aim of our study is to provide a proof of principle that QR from 2D uni-axially periodic potential structures can be investigated in a time-dependent fashion. To this end, the numerical procedures used are presented, as well as comparisons with 1D results for QR from static and oscillating 1D potentials and preliminary results for QR from a truly 2D non-separable potential. This enables the first systematic investigation of atom-surface potentials, where Casimir interactions are relevant, as well as numerical tests on quantum diffraction.

A 3.3 Mon 11:45 f303

Excitonic spectra in high external fields — •Frank Schweiner, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, 70550 Stuttgart, Germany

To understand and interpret excitonic absorption spectra of real semiconductors it is indispensable to incorporate the complete valence-band structure into a quantitative theory. Very recently the zero field splitting of states with different angular momentum quantum number has been investigated for cuprous oxide and successfully explained by effects due to the complexity of the valence band structure [1]. Solving the Schrödinger equation in a complete basis and determining the eigenvalues for high principal quantum numbers, we now want to investigate the spectra in external fields quantitatively.

In a recent preprint [2] quantum chaos and GUE statistics were observed for excitons in high magnetic fields. The GUE statistics has been attributed to the interaction of excitons and phonons. Neglecting the effect of the band structure but considering the movement of the center of mass of the exciton, we also want to solve the corresponding hydrogen-like Schrödinger equation and investigate the effect of phonons on the spectra qualitatively to find out whether GUE statistics appears.

[1] J. Thewes et al, Phys. Rev. Lett. 115, 027402, 2015
[2] M. Aßmann et al, Quantum Chaos of Rydberg excitons, to be published

A 3.4 Mon 12:00 f303

Frequency tunable microwave field imaging with sub-100 μm

resolution using atomic vapor cells — •Andrew Horsley, Guan-Xiang Du, and Philipp Treutlein — University of Basel, Switzerland

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 (e.g. atom chips or ion traps), as there are currently no established microwave imaging techniques. Our technique may also find applications in medical imaging. We have built a high resolution imaging system, whose $50 \times 50 \times 140\,\mu m^3$ spatial resolution, $1\,\mu T/Hz^{1/2}$ sensitivity, and $150\,\mu m$ approach distance are now sufficient for characterising a range of real world devices at fixed microwave frequencies [1].

Frequency tunability is essential for wider applications, however we can only detect microwaves that are resonant with an atomic transition. Our solution is to use a large dc magnetic field to Zeeman shift the hyperfine ground state transitions to any desired frequency. In addition to high resolution images of 6.8 GHz microwave fields, we present results from a proof-of-principle setup, where we have used a 0.8 T solenoid to detect microwaves from 2.3 to 26.4 GHz.

[1] A. Horsley, G.-X. Du and P. Treutlein, *Imaging of Electromagnetic Fields in Alkali Vapor Cells with sub-100 μm Resolution,* New Journal of Physics, 17(11), 112002, (2015)

A 3.5 Mon 12:15 f303

Orbital magnetic flux quantization in hydrogen based on non-relativistic quantum theory with and without external magnetic field — •Wolf-Dieter R. Stein — Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, D-14109 Berlin, Germany

An investigation of the quantization of magnetic flux through atomic orbits of the hydrogen atom in non-relativstic quantum theory is presented. In contrast to earlier investigations only an l-dependence of the magnetic flux quantization in units of $h/2e$ is found for the Gordon current contribution in case of vanishing external fields. The spin magnetization current for the ground-state and for the excited-states of hydrogen is considered together with the quantization of their corresponding orbital magnetic fluxes. Application of external magnetic field results in an additional current and hence in an additional magnetic flux, which is taken as the origin of an energy shift. Taking these results, the Zeeman effect is discussed closer on the bases of orbital magnetic flux quantization. For strong magnetic fields the obtained correction behaves differently compared to other models.

A 3.6 Mon 12:30 f303

Progress toward a Global Network of Optical Magnetometers for Exotic research (GNOME) — •Hector Masia-Roig, Arne Wickenbrock, and Samer Afach — Johannes Gutenberg-Universität Mainz

GNOME is a novel experimental scheme which enables the investigation of exotic spin couplings between nuclei and exotic fields generated by astrophysical sources by measuring spin precession. It consist of a network of geographically separated (>100 km), time synchronized and ultrasensitive ($\sim fT/\sqrt{Hz}$) optical magnetometers, each placed in a magnetically shielded environment. This network and similar configurations enables the study of exotic global transient effects.

A specific example of such exotic fields are certain models of axion-like particles which form a network of light pseudoscalar fields permeating the universe.

Here we present an estimation of the experimentally accessible parameter space of such pseudoscalar fields that can be detected within GNOME along with first correlated measurements of long-time run signals will be discussed.

A 3.7 Mon 12:45 f303

Absorption of Laguerre-Gaussian light beam by hydrogen atoms — •Anton Peshkov[1], Andrey Surzhykov[1], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Theoretisch-Physikalisches Institut, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany

The family of twisted (or vortex) light beams was actively explored in experiment and theory during the last three decades. These beams possess a well-defined projection of the angular momentum onto their propagation direction. Special attention was paid to the paraxial Laguerre-Gaussian (LG) and nonparaxial Bessel beams. An interaction of atoms with such types of light beams, for instance a photoabsorption process, is thought to be of interest. There was the recent study [1] which have concerned an absorption of Bessel beam by hydrogen atoms. In this contribution we discuss the absorption of LG beam by the hydrogen atoms. The analysis is performed within non-relativistic first-order perturbation theory. It is shown that the well-known selection rules for atomic magnetic quantum numbers are not valid anymore when atoms absorb a high-order LG mode. In addition, we compare a population of atomic magnetic substates for the transition $1s \to 2p$ with results for an incident Bessel beam obtained in the previous work [1].

[1] H. M. Scholz-Marggraf, S. Fritzsche, V. G. Serbo, A. Afanasev, and A. Surzhykov, Phys. Rev. A 90, 013425 (2014).

A 4: Collisions, scattering and correlation phenomena I

Time: Monday 11:00–12:15 Location: f107

A 4.1 Mon 11:00 f107

Electron-impact ionization of beryllium-like carbon ions — •Benjamin Ebinger[1,2], Alexander Borovik Jr.[1,2], Stefan Schippers[1,2], and Alfred Müller[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

Reliable atomic input data are of crucial importance for the modelling of ionized-matter environments. Cross sections for electron-impact ionization of atoms and ions are particularly important. Besides the fairly well understood direct-ionization process, indirect ionization mechanisms such as excitation-autoionization (EA) and resonant-excitation double autoionization (REDA) may significantly contribute to net single-ionization [1]. Benchmark experiments uncovering fine structures that arise from indirect ionization in few-electron systems provide guidance for theoretical efforts to adequately describe total single ionization by electron collisions. Here, we present measurements of electron-impact single-ionization cross sections of the C^{2+} ion, i. e., of a fairly simple four-electron system. Complications arise, however, from the presence of both $1s^2 2s^2\,{}^1S_0$ ground-level and $1s^2 2s2p\,{}^3P_{0,1,2}$ metastable-level ions in the experiment. Employing the well-established fine-step energy-scan technique [2], contributions of indirect-ionization processes invoked by excitation of the K-shell were uncovered with a statistical uncertainty of less than 0.03% thus helping to disentangle the various cross-section contributions.

[1] Liu et al., Phys. Rev. A 92 (2015) 012701
[2] A. Müller et al., Phys. Rev. Lett. 61 (1988) 70

A 4.2 Mon 11:15 f107

Correlated reduced density operators of quantum lattice models — •Konstantin Krutitsky, Andreas Osterloh, and Ralf Schützhold — Fakultät für Physik der Universität Duisburg-Essen, Campus Duisburg, 47048 Duisburg

We present a systematic study of nonlocal correlations in quantum lattice models. With this purpose in mind we introduce correlated reduced density operators for arbitrary number of lattice sites q located at arbitrary distances from each other. Quantitative estimates of the nonlocal correlations are obtained calculating the Schatten p-norms of the correlated reduced density operators. For the Bose-Hubbard model in the case of unit filling, the Schatten norms with $p = 1$ (trace norm) decrease with the number of sites q in the Mott-insulator phase and increase in the superfluid phase, while the norms with $p = 2$ (Frobenius norm) decrease in both phases. For the transverse Ising model, the $p = 1$ and $p = 2$ norms decrease with the number of sites q in the disordered phase below the critical point. However, near and above the critical point the norms display a nonmonotonic behavior with respect to q. These results can be useful for the development of controlled approximations for the solution of quantum lattice models.

A 4.3 Mon 11:30 f107

New ficticious force in electron-atom/ion scattering — •Hubert Klar — DHBW Lörrach

We treat two-elctron atoms (like He) in the nonrelativistic frame. We derive for the e-e interaction a momentum-dependent ficticious force in addition to the electrostatic interactions. In contrast to other ficticious forces in mechanics our force constitutes an entirely new quantum effect. The diffraction of an electron wave from the three-body Coulomb potential surface induces an e-e force. This effect has only little influence onto the lower part of the spectrum, and was therefore overlooked sofar. High double excitation, however, changes dramatically.

A 4.4 Mon 11:45 f107

Setup of a high-resolution Seya-Namioka-type fluorescence spectrometer for the spectral range between 35 nm and 180 nm for experiments at ion storage rings — •Philipp Reiss, Philipp Schmidt, Christian Ozga, André Knie, and Arno Ehresmann — University of Kassel, Institute of Physics and CINSaT, Heinrich-Plett-Str. 40, 34132 Kassel

A Seya-Namioka type spectrometer for the detection of highly resolved dispersed fluorescence in the wavelength range between 35 nm and 180 nm for experiments at gas- and electron targets and electron coolers at the FAIR facility will be set up. Depending on the experimental requirements, optical reflection gratings with a short focus (f = 1 m) for a higher solid angle coverage of the emitted fluorescence and a resolution of $\Delta\lambda = 0.3$ nm or a grating with a long focus (f = 3 m) for high resolution ($\Delta\lambda = 0.1$ nm) will be used. The pursued high resolution will enable the determination of the degree of ionization as well as the radiative states of excited ions via their emitted fluorescence wavelengths and thus help answering a variety of scientific questions. A characterization of the gas target or the longitudinal ion bunch profiles is also possible.

A 4.5 Mon 12:00 f107

Pikosekunden Masteroszillator-Faserverstärker-System zur Ionenstrahlkühlung — •Daniel Kiefer, Tobias Beck und Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schlossgartenstr. 7, 64289 Darmstadt

Laserkühlung von relativistischen Ionenstrahlen wurde bereits mehrfach erfolgreich erprobt. Hierbei wurde entweder die Energiedifferenz des Kühlübergangs manipuliert [1] oder, als neuere Methode, der Laser periodisch in seiner Frequenz verstimmt [2]. Bei beiden Techniken gehen Ionen durch Coulombstöße untereinander (intra-beam-scattering) für den Kühlvorgang verloren. Um diese Verluste zu verringern, wurde Kühlen mit Hilfe von spektral verbreitertem Laserlicht vorgeschlagen (white-light-cooling) [3]. Hierzu präsentieren wir ein gepulstes Masteroszillator-Faserverstärker-System, das sich im Aufbau befindet. Die erforderliche spektrale Breite wird über Fourier-transform limitierte Pulse und entsprechend gewählte Pulslängen eingestellt. Als Masteroszillator dient ein ECDL bei 1028 nm dessen Licht zunächst in einer Ytterbium-dotierten Faser verstärkt wird. Mit Hilfe akustooptischer und elektrooptischer Modulation in Mach-Zehnder Konfiguration werden Pulse mit einer Länge zwischen 70 ps und 700 ps bei einer Wiederholrate von 0,5 bis zu 1,5 MHz erzeugt. Der Pulserzeugung schließen sich zwei weitere Ytterbium-basierte Faserverstärker an. Im Vortrag wird der Status des Aufbaus diskutiert. [1] S. Schröder et al, Phys. Rev. Lett. 64 (1990), 2901-2904. [2] T.Beck, Dissertation, TU-Darmstadt, (2014). [3] J. Hoffnagle, Opt. Lett. 13(2) (1988):102.

A 5: Precision Measurements and Metrology II (with Q)

Time: Monday 14:30–16:15 Location: a310

A 5.1 Mon 14:30 a310

Atom-chip fountain gravimeter — •Sven Abend[1], Martina Gebbe[2], Matthias Gersemann[1], Hauke Müntinga[2], Holger Ahlers[1], Claus Lämmerzahl[2], Wolfgang Ertmer[1], Ernst M. Rasel[1], and QUANTUS Team[1,2,3,4,5,6,7] — [1]Institut für Quantenoptik, LU Hannover — [2]Zarm, U Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Hamburg — [5]Institut für Quantenphysik, U Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]Institut für Physik, JGU Mainz

We developed a simple but effective method to coherently relaunch atoms by a combination of double Bragg diffraction and Bloch oscillations in a single retro-reflected light field. This method provides a novel tool for atomic quantum sensors extending the free fall time without increasing their complexity. We demonstrate an atom-chip fountain gravimeter utilizing ultracold atoms, where all necessary atom-optics operations are realized by the atom-chip, including condensation, magnetic transfer and delta-kick cooling. The atom-chip itself even acts as a retro-reflector in vacuum for the beam splitter as inertial reference for gravity. This implementation allows for high contrast interferometry over tens of milliseconds in a volume as little as a one centimeter cube, paving the way for measurements with sub-μGal accuracies in miniaturized devices.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under grant numbers DLR 50WM1552-1557 (QUANTUS-IV-Fallturm).

A 5.2 Mon 14:45 a310

Atom interferometry with Bose-Einstein condensates on sounding rockets — •Dennis Becker, Maike Lachmann, Stephan Seidel, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

The universality of free fall is one of the fundamental postulates of our description of nature. The comparison of the free fall of two ultra-cold clouds of different atomic species via atom interferometry comprises a method to precisely test this assumption. By performing the experiments in a microgravity environment the sensitivity of such an atom interferometric measurement can be increased. In order to fully utilize the potential of these experiments the usage of a Bose-Einstein condensate as the initial state of the atom interferometer is necessary.

As a step towards the transfer of such a system in space an atom optical experiment is currently being prepared as the scientific payload for a sounding rocket mission. This mission is aiming at the first demonstration of a Bose-Einstein condensate in space and using this quantum degenerate matter as a source for atom interferometry. The launch of the rocket is planned for 2016 from ESRANGE. This first mission will be followed by two more that extend the scientific goals to 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 universality of free fall with a space-born atom interferometer.

A 5.3 Mon 15:00 a310

Advances towards a T^3-interferometer — •Matthias Zimmermann[1], Maxim A. Efremov[1], Wolfgang P. Schleich[1], Sara A. DeSavage[2], Jon P. Davis[2], Frank A. Narducci[2], and Ernst M. Rasel[3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, 89081 Ulm, Germany — [2]EO Sensors Division, Naval Air Systems Command, Patuxent River, MD 20670, USA — [3]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

We present the theoretical background for and the progress on a novel atom interferometer with a phase shift scaling as T^3 in contrast to conventional atom interferometers with a scaling of T^2 [1]. Here T denotes the travelling time of the atoms in-between two Raman pulses. These pulses prepare a superposition of two magnetic sublevels while an external magnetic field is applied to imprint two different effective accelerations g_1 and g_2 for these two states [2]. A sequence consisting of four Raman pulses is used to close the interferometer and to obtain the T^3-scaling. Due to the position-dependent Zeeman shift the atomic resonance frequency changes throughout the experiment and the laser frequency has to be chirped in order to stay in resonance.

[1] W.P. Schleich, D.M. Greenberger, and E.M. Rasel, *New J. Phys.* **15**, 013007 (2013)

[2] J.P. Davis and F. A. Narducci, *J. Mod. Opt.*, **55**, 3173 (2008)

A 5.4 Mon 15:15 a310

Quantum Test of the Universality of Free Fall with a Dual Species Atom Interferometer — •Logan Richardson, Henning Albers, Dipankar Nath, Dennis Schlippert, Christian Schu-

bert, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik and
Centre for Quantum Engineering and Space-Time Research - QUEST, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

To understand gravity's role within the standard model, we can test for violations of the universality of free fall with dual-species atom interferometers [1]. To constrain possible violations we require accurate local gravitational acceleration measurements of both test masses. Vibrations can however corrupt these measurements by inducing phase shifts, masking any possible violation signal and fundamentally limiting the sensitivity of the experiment. Correlation of atomic interferometers with a classical sensor can provide a phase shift correction for vibrationally induced noise[2]. We discuss the experimental results of the application of this method into our dual species ^{87}Rb – ^{39}K interferometer, as well as the strategy for the upcoming large scale ^{87}Rb – ^{170}Yb interferometer[3]

[1] D. Schlippert et al., Phys. Rev. Lett. 112, 203002 (2014)
[2] B. Barrett et al., New Journal of Physics, 17, 085010 (2015)
[3] J. Hartwig et al., New J. Phys. 17, 035011 (2015)

A 5.5 Mon 15:30 a310

Quantum Test of the Universality of Free Fall in small and large scale devices — •Henning Albers, Christian Meiners, Dipankar Nath, Logan L. Richardson, Dennis Schlippert, Christian Schubert, Etienne Wodey, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

The foundation of general relativity is constituted by Einstein's equivalence principle, which is based on three postulates. One of them is the Universality of Free Fall (UFF), which can be tested by observing the free fall motion of a pair of test masses. Those tests have reached high precision with macroscopic objects [1].

The development of atom optics gives access to new types of inertial sensors to test fundamental physics. By comparing the differential acceleration measured by a simultaneous dual species Mach-Zehnder type atom interferometer we perform a quantum test of the UFF employing the two chemical elements, ^{39}K and ^{87}Rb [2]. We show the latest results as well as the improvements of the experiment aiming towards a test at a ppb uncertainty. To reach this level we will increase the stability and accuracy of the apparatus by using a dipole trap. Another step towards higher sensitivity will be the upscaling towards the 10 m Very Long Baseline Atom Interferometer (VLBAI) apparatus working with Rb and Yb[3].

[1] J. Müller et al., Class. Quantum Grav. 29 184006 (2012)
[2] D. Schlippert et al., Phys. Rev. Lett. 112, 203002 (2014)
[3] J. Hartwig et al., New J. Phys. 17, 035011 (2015)

A 5.6 Mon 15:45 a310

Towards a new generation of high-performance operational quantum sensors — •Jean Lautier-Gaud, Vincent Ménoret, Pierre Vermeulen, Jean-François Schaff, Guillaume Stern, Cédric Majek, Mathieu Guéridon, and Bruno Desruelle — Muquans, SAS, rue François Mitterrand 33400 Talence France

After 30 years of academic research in cold atom sciences, intensive developments are being conducted to improve the compactness and the reliability of experimental set-ups. One of the main objectives is to transfer such high-sensitivity experiments from laboratory-based research to an operational utilization outside of the laboratory. This will allow non-specialists and other areas of research to benefit from the outstanding advantages and the measurement capabilities that cold atoms offer. We will present the long-lasting developments that we have been carrying to provide the first industrial cold-atom absolute gravimeter and the first industrial cold-atom atomic clock. We will present the principles of operation and the main features of our instruments. Their performances in terms of sensitivity, stability, and accuracy, as well as the latest results they achieved will be reviewed. High-performance frequency-stabilized laser systems are one of the key technological elements to manipulate cold atoms, and they set the quality of the measurements. Muquans now turned these into benchtop reliable turnkey solutions dedicated to scientists eager to reach faster their scientific objectives. Such laser systems have been qualified on our own cold atom instruments, and a specific focus on our latest developments in this area in terms of performances will be proposed.

A 5.7 Mon 16:00 a310

Dark energy search using atom interferometry — •Philipp Haslinger[1], Matt Jaffe[1], Paul Hamilton[2], Justin Khoury[3], and Holger Müller[1] — [1]University of California, Berkeley, CA 94720, USA — [2]University of California, Los Angeles, CA 90095, USA — [3]University of Pennsylvania, Philadelphia, PA 19104, USA

If dark energy, which drives the accelerated expansion of the universe, consists of a light scalar field it might be detectable as a "fifth force" between normal-matter objects. In order to be consistent with cosmological observation and laboratory experiments, some leading theories use a screening mechanism to suppress this interaction. However, atom-interferometry presents a tool to reduce this screening [1] and has allowed us to place tight constraints on a certain class of these theories, the so-called chameleon models [2]. Recent modifications to our cavity-enhanced atom interferometer have improved the sensitivity by a hundredfold and we expect new results soon.

[1] C. Burrage, E. J. Copeland, E. A. Hinds, Probing dark energy with atom interferometry. J. Cosmol. Astropart. Phys. 2015, 042 (2015). [2] P. Hamilton, M. Jaffe, P. Haslinger, Q. Simmons, H. Müller, and J. Khoury, Atom-interferometry constraints on dark energy. Science 349, 849 (2015).

A 6: Ultracold Atoms, Ions and Molecules II (with Q)

Time: Monday 14:30–16:30 Location: e001

A 6.1 Mon 14:30 e001

Non-Equilibrium Thermodynamics of Harmonically Trapped Bosons — •Thomas Fogarty[1,4], Miguel Angel Garcia-March[2], Steve Campbell[3], Thomas Busch[4], and Mauro Paternostro[3] — [1]Theoretische Physik, Universitat des Saarlandes, Saarbrucken, Germany — [2]ICFO Institut de Ciencies Fotoniques, Spain — [3]CTAMOP, School of Mathematics and Physics, Queen's University Belfast, United Kingdom — [4]Quantum Systems Unit, Okinawa Institute of Science and Technology Graduate University, Okinawa, Japan

Trapped ensembles of bosonic atoms represent an ideal candidate to simulate some of the most interesting aspects in the phenomenology of out-of-equilibrium quantum systems. In this talk I will focus on harmonically trapped bosons and use the framework of non-equilibrium thermodynamics to the study the role quantum features play in setting the dynamic and static properties of the systems when the Hamiltonian parameters are suddenly quenched. Through a combination of analytical and numerical approaches I explore the non-trivial dynamics that arise from the interplay between the quenched trap frequency and an induced quench of the inter-particle interactions. Interesting quantum phenomena such as Anderson's Orthogonality catastrophe will be explored in this framework. I will further show some qualitative evidence for the relationship between the creation of entanglement and the (irreversible) work performed on the system. This highlights interesting connections between the degree of inter-particle entanglement and their non-equilibrium thermodynamics.

A 6.2 Mon 14:45 e001

Probing reflectionless potentials via atomic dynamics — •Martin Lahrz and Ludwig Mathey — University of Hamburg, Hamburg, Germany

We explore how reflectionless potentials can be probed via atomic dynamics. If a quantum mechanical wave package passes through a potential, ordinarily, a finite fraction of it gets reflected. However, in special cases, e.g. for specific Pöschl-Teller potentials, the reflection is zero and the full object is transmitted. We investigate the influence of the reflectionless potential on the outgoing wave function and compare it with the propagation of the free particle. This scenario might be realized in an ultra-cold atom system where the potential is represented by an optical trap.

A 6.3 Mon 15:00 e001

Two-dimensional Quantum Walks of Neutral Atoms in Spin-dependent Optical Lattices — •Geol Moon, Stefan Brakhane, Volker Schilling, Carsten Robens, Wolfgang Alt, Dieter Meschede, and Andrea Alberti — IAP institute - Wegelerstr. 8 - D-53115 Bonn

We report on the experimental realization of a two-dimensional spin-dependent optical lattice, which we will use to implement discrete-time quantum walks of Cs atoms in a two-dimensional geometry. We demonstrate high-resolution images of single atoms, which we detect through an objective lens with very high numerical aperture (NA∼0.92), which we designed and installed inside the home-built ultra-low-birefringence dodecagonal vacuum glass cell [1]. Our system provides an ideal platform to study the topological features of 2D quantum walk as the simulator of topological phases [2], which can be realized by suitable choice of the coin operation. We expect to observe exotic matter wave flow at the boundary between different topological domains. Furthermore, controlling the phase accumulated when atoms move from site to site on the 2D lattice permits to realize artificial gauge fields and to study the effect of magnetic fields on the 2D quantum walk [3].

[1] S. Brakhane, et al., *Ultra-low birefringence dodecagonal vacuum glass cell*, Submitted to Rev. Sci. Instrum. (2015)
[2] T. Kitagawa, et al., *Exploring topological phases with quantum walks*, Phys. Rev. A **82**, 033429 (2010)
[3] P. Arnault and F. Debbasch, *Quantum Walks and discrete Gauge Theories*, arXiv:1508.00038 (2015)

A 6.4 Mon 15:15 e001

Quantum Walks with Neutral Atoms: A look into the motion of a quantum particle — Carsten Robens, Stefan Brakhane, Wolfgang Alt, Dieter Meschede, and •Andrea Alberti — Institut für Angewandte Physik, Universität Bonn – Wegelerstr. 8, 53115 Bonn

I will present quantum walk experiments performed with neutral atoms in spin-dependent optical lattices. A cesium atom with two long-lived internal states behaves like a pseudo spin-1/2 particle. Depending on its spin state, the atom moves at regular time steps either one site to the left or to the right, delocalizing over multiple quantum paths. In the limit of vanishing lattice constant, its quantum behavior is described by the one-dimensional Dirac equation. We have recently developed a new spin-dependent transport system, which allows us to spin-selectively shift only one spin species at a time by an arbitrary number of lattice sites. The new atom transport system allows us to carry out interaction-free measurements of the atom's position, which we used to exclude (i.e., falsify) any explanation of quantum transport based on classical, well-defined trajectories [1]. To put it into perspective, our experiment represents the most massive test of quantum superposition states that has been hitherto performed based on the stringent, objective criteria provided by the Leggett-Garg inequality.

[1] C. Robens et al. *Ideal Negative Measurements in Quantum Walks Disprove Theories Based on Classical Trajectories*, Phys. Rev. X **5**, 011003 (2015).

A 6.5 Mon 15:30 e001

Half-life times of topological modes of a Bose-Einstein condensate in a gravito optical surface trap — •Zelimir Marojevic, Ertan Göklü, and Claus Lämmerzahl — ZARM, Am Fallturm, 28359 Bremen

We have numerically estimated the half-life times of six topological modes in an axially symmetric gravito optical surface trap $V(\rho, z) = \nu^2\rho^2 + \beta z$. The topological modes are solutions to the stationary Gross–Pitaevskii equation, which correspond to min-max saddle points of the functional, and these solutions are dynamically unstable. Due to the non linear nature of the problem the time evolution of a small perturbation is very complicated and shows different phases.

A 6.6 Mon 15:45 e001

News from the Garching ^{23}Na^{40}K mixture experiment — •Frauke Seeselberg[1], Nikolaus Buchheim[1], Zhenkai Lu[1], Roman Bause[1], Tobias Schneider[1], Immanuel Bloch[1,2], and Christoph Gohle[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultracold quantum gases with long-range dipolar interactions promise exciting new possibilities for quantum simulation of strongly interacting many-body systems. Our experimental apparatus is capable of creating ultracold sodium and potassium mixtures aiming towards ultracold groundstate ^{23}Na^{40}K molecules.
To obtain molecules in their absolute vibrational, rotational and hyperfine ground state, stimulated Raman adiabatic passage (STIRAP) has to be implemented. This is a two photon process capable of transferring weakly bound Feshbach molecules via an intermediate, excited molecular state to the molecular ground state with high efficiency.
With our apparatus we are also capable of analyzing the properties of a small number of potassium atoms immersed into a degenerate Bose gas of sodium atoms. Under these conditions signatures of the Bose polaron can be observed.

A 6.7 Mon 16:00 e001

Inelastic collisions of strongly confined triplet Rb_2 molecules — •Markus Deiss[1], Björn Drews[1], Krzysztof Jachymski[2,3], Zbigniew Idziaszek[2], and Johannes Hecker Denschlag[1] — [1]Institut für Quantenmaterie, Universität Ulm, 89069 Ulm, Germany — [2]Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland — [3]Institut für Theoretische Physik III, Universität Stuttgart, 70550 Stuttgart, Germany

We present experimental studies of inelastic collisions of metastable ultracold triplet molecules in the vibrational ground state. The measurements are performed with nonpolar Rb_2 dimers which are trapped in an array of quasi-1D potentials and prepared in precisely-defined quantum states. Using a simple model we can understand the molecular decay dynamics and extract reaction rate coefficients. We will show results both for nonrotating molecules that are prepared in the energetically absolutely lowest triplet hyperfine level and molecules with two quanta of rotational angular momentum. These results are compared to those obtained for vibrationally highly excited Feshbach molecules.

A 6.8 Mon 16:15 e001

Non-destructive rotational state detection for molecular ions — •Fabian Wolf[1], Yong Wan[1], Jan C. Heip[1], Florian Gebert[1], Chunyan Shi[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Leibniz Universität Hannover, Germany

High precision spectroscopy of molecular ions is a promising tool for the investigation of fundamental physics, e.g. the search for variation of fundamental constants, an electron electric dipole moment or parity violation in chiral molecules. However, the practical implementation has remained illusive due to the lack of efficient state preparation and detection schemes. Here, we present the first demonstration of a non-destructive rotational state detection for a single molecular ion trapped in a linear Paul trap [1]. For this purpose, we implement a quantum logic operation between the molecular $^{24}MgH^+$ ion and a co-trapped atomic $^{25}Mg^+$ logic ion.

The experimental sequence consists of sympathetic ground state cooling with the logic ion [2] and a state dependent optical dipole force that transfers the molecule's internal state to the shared state of motion. Afterwards, the motional state is mapped onto the atomic qubit state, that can be detected efficiently by state dependent fluorescence. We use this technique to perform a variant of quantum logic spectroscopy on a molecular transition.

[1] Wolf et al. arXiv:1507.07511 (2015)
[2] Wan et al. Phys. Rev. A **91**, 043425 (2015)

A 7: Highly charged ions and their applications

Time: Monday 14:30–16:30 Location: f107

Invited Talk A 7.1 Mon 14:30 f107

Probing QED in strong fields via the magnetic moment of highly charged ions — •Sven Sturm — Max-Planck-Institut für Kernphysik Heidelberg

The validity of the Standard Model, particularly Quantum Electrodynamics (QED), has been exquisitely tested by precision experiments in the low-field regime. However, in the presence of strong fields higher-order contributions beyond the Standard Model might become significant. The ultra-precise measurement of the g-factor of highly-charged ions provides a unique possibility to probe the validity of the Standard Model in extreme electric fields up to 10^{16} V/cm. By measuring the Larmor- and cyclotron frequencies of single highly charged ions in a cryogenic Penning trap with previously unprecedented precision, we have been able to perform the most stringent test of QED in strong fields. Recently, we were able to explicitly probe the effect of the nucleus on the g-factor of the electron and thus open a novel access to nuclear structure information. Currently, a new setup, ALPHATRAP, is being commissioned at the Max-PIanck-Institut für Kernphysik in Heidelberg, which will push these experiments towards the heaviest elements up to hydrogenlike $^{208}Pb^{81+}$. This will not only enable the most sensitive tests of QED, but also open a unique access to fundamental constants as the atomic mass of the electron and the finestructure constant α.

A 7.2 Mon 15:00 f107

The g-factor of light hydrogen- and lithiumlike ions for an improved extraction of the fine-structure constant — •Zoltán Harman[1], Vladimir A. Yerokhin[1,2], Ekaterina Berseneva[1,3], Ilya I. Tupitsyn[3], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia — [3]St. Petersburg State University, 198504 St. Petersburg, Russia

A specific weighted difference of the g-factors of the H- and Li-like ions of the same element is studied and optimized in order to maximize the cancelation of finite nuclear size effects between the two charge states [1]. It is shown that this weighted difference, or its combination for two different elements, can be used to extract the fine-structure constant from future bound-electron g-factor experiments with an accuracy improvement compared to its present value.

[1] V. A. Yerokhin, E. Berseneva, Z. Harman, I. I. Tupitsyn, C. H. Keitel, submitted (2015); arXiv:1509.08260

A 7.3 Mon 15:15 f107

A compact 0.74 T room-temperature electron beam ion trap — •Peter Micke[1,2], Sven Bernitt[1,3], James Harries[4], Ioanna Arapoglou[1,5], Klaus Blaum[1], Lisa F. Buchauer[1], Thore M. Bücking[1], Alexander Egl[1,5], Sandro Kraemer[1,5], Steffen Kühn[1,5], Thomas Pfeifer[1], Thomas Stöhlker[3], Sven Sturm[1], Robert Wolf[1], Piet O. Schmidt[2,6], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, QUEST, Braunschweig — [3]Friedrich-Schiller-Universität Jena — [4]SPring-8, Hyogo, Japan — [5]Ruprecht-Karls-Universität Heidelberg — [6]Leibniz Universität Hannover

Research on highly charged ions (HCI) is of great interest for atomic physics, and electron beam ion traps (EBIT) have proven to be indispensable tools for their production and study. In an EBIT, an electron beam, compressed by a strong, inhomogeneous magnetic field, is used to breed and trap HCIs. We have built a room-temperature EBIT based on permanent magnets, allowing low-maintenance operation. It can provide a continuous beam of Xe ions up to charge state 29+, and a total ion current of 100 pA, with a 4 mA 2 keV electron beam. Pulsed extraction of Ar ions up to charge state 16+ was demonstrated. The protoype currently serves as a HCI source for ALPHATRAP, a device dedicated to high-precision g-factor determinations. Three more EBITs are under construction to provide HCIs for quantum logic spectroscopy, XUV spectroscopy as well as X-ray laser spectroscopy at synchrotrons.

Invited Talk A 7.4 Mon 15:30 f107

X–ray emission from highly charged ions — •Andrey Surzhykov[1], Stephan Fritzsche[1,2], Andrey Volotka[1], Vladimir Yerokhin[3], and Thomas Stöhlker[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Universität Jena, Germany — [3]St. Petersburg Polytechnical University, Russia

With the recent advents of coherent light sources and ion traps, new possibilities arise to study the electronic structure of simple atomic systems in strong nuclear fields. The information about this electronic structure is usually obtained from the analysis of photon emission from highly charged ions. During the last decade, a large number of experiments have been performed to observe x–rays emitted in the course of characteristic bound–state transitions and elastic light scattering. To understand the outcome of these measurements, detailed theoretical investigations of the structure of highly charged ions and of their coupling to the electromagnetic field are needed. In our contribution, therefore, we present an overview of recent theoretical advances in the treatment of interaction of few–electron ions with light. We will pay special attention to the second–order QED processes such as two–photon transitions and elastic (Rayleigh) x–ray scattering. The analysis of these processes requires the knowledge about the complete Dirac spectrum of many–electron ions as represented either by Green's function or by B–spline basis sets. After a short discussion of both theoretical approaches, we will present and discuss calculations for the two–photon decay of beryllium–like ions as well as of elastic x–ray scattering by closed–shell medium– and high–Z systems.

A 7.5 Mon 16:00 f107

Performance and readout of state-of-the-art MMC detector arrays — •D. Hengstler, M. Wegner, J. Geist, M. Keller, M. Krantz, C. Schötz, S. Kempf, L. Gastaldo, A. Fleischmann, and C. Enss — Kirchhoff-Institute for Physics, Heidelberg University

Metallic magnetic calorimeters (MMCs) are energy dispersive X-ray detectors which have a very good energy resolution, a large dynamic range as well as an excellent linearity. An MMC operates at millikelvin temperatures and converts the energy of an incoming particle into a rise of temperature of an absorber and an attached paramagnetic temperature sensor. The resulting change of sensor magnetization is read out by a SQUID and serves as a measure for the energy input.

One of our goals is the development of large detector arrays to provide a large detection area for low-rate applications, to cope with a significantly increased count rate or to provide imaging capabilities. For this, we have developed several medium-scale detector arrays which are optimized for x-rays up to 20, 30 and 200 keV, respectively. They have a resolving power $E/\Delta E$ above 1500 and are read out using individual dc-SQUIDs. To account for the readout of very large arrays with up to 1000 detectors, we develop a cryogenic frequency domain multiplexer which enables the readout of such large arrays using only one HEMT amplifier and two coaxial cables.

In this contribution we present our micro fabricated detector arrays and discuss their performance in the field of high resolution X-ray spectroscopy. In addition we show for the very first time a simultaneous readout of MMCs using our cryogenic multiplexer.

A 7.6 Mon 16:15 f107

Laser cooling of relativistic highly charged ions — •Danyal Winters[1], Tobias Beck[2], Gerhard Birkl[2], Oliver Boine-Frankenheim[1,2], Christina Dimopoulou[1], Lewin Eidam[1,2], Volker Hannen[3], Thomas Kühl[1,4,5], Matthias Lochmann[1,4], Markus Löser[6,7], Xinwen Ma[8], Fritz Nolden[1], Wilfried Nörtershäuser[1,2,4], Benjamin Rein[2], Rodolfo Sanchez[1], Ulrich Schramm[6,7], Mathias Siebold[6], Peter Spiller[1], Markus Steck[1], Thomas Stöhlker[1,5,9], Johannes Ullmann[2,5], Thomas Walther[2], Weiqiang Wen[6,8], Jie Yang[8], Dacheng Zhang[8], and Michael Bussmann[6] — [1]GSI Helmholtzzentrum Darmstadt — [2]Technische Universität Darmstadt — [3]Universität Münster — [4]Universität Mainz — [5]Helmholtz Institut Jena — [6]Helmholtz-Zentrum Dresden-Rossendorf — [7]Technische Universität Dresden — [8]Institute of Modern Physics, Lanzhou, China — [9]Universität Jena

An overview of recent laser cooling activities with relativistic heavy ion beams at the ESR (GSI, Darmstadt, Germany) and the CSRe (IMP, Lanzhou, China) storage rings will be presented. Some of the latest results will be shown and new developments concerning xuv-detector systems and cw and pulsed laser systems will be addressed. Finally, plans for laser cooling at the future facility FAIR in Darmstadt will be described.

A 8: Atomic systems in external fields II

Time: Monday 14:30–16:15 Location: f303

A 8.1 Mon 14:30 f303

Strong-field photoionization of H2+ at mid-infrared wavelength — •Max Möller[1,2], Philipp Wustelt[1,2], A. Max Sayler[1,2], Stefanie Gräfe[3], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantum Electronics and Abbe Center of Photonics, Friedrich Schiller University, Max-Wien-Platz 1, D-07743 Jena, Germany — [2]Helmholtz Institute Jena, Fröbelstieg 3, D-07743 Jena — [3]Institute of Physical Chemistry and Abbe Center of Photonics, Friedrich-Schiller-University Jena, Helmholtzweg 4, D-07743 Jena, Germany

Increasing the driving laser wavelength into a region above 1 μm has lead to a number of interesting phenomena and applications in the field strong-field interactions of atoms. Examples are the discovery of low-energy structures or the generation or high harmonics with photon energies above 1 keV. Due to the nuclear degree of freedom, strong-field photoionization of small molecules induces more complex dynamics such as charge-resonant enhanced ionization, or laser-induced electron diffraction. Here, the fragmentation of an ion beam by a strong mid-infrared laser field is studied experimentally as a function of intensity. Three-dimensional coincidence imaging in combination with a well collimated ion beam and high pondermotive potential of the laser allows to perform a kinematically complete experiment. The experimental results are compared to solutions of the time-dependent Schrödinger equation in one and two dimensions.

A 8.2 Mon 14:45 f303

Few-cycle effect in dissociative ionization of H_2^+ — •Volker Mosert and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

We investigate the dissociative ionization of H_2^+ for few-cycle infrared laser pulses by solving the TDSE for a low dimensional model Hamiltonian including the nuclear degree of freedom. For laser intensities $I \approx 10^{14}$ W cm^{-2} the joint electron-proton spectrum exhibits intensity modulations with respect to the kinetic energy of the protons but almost independent of the electron's kinetic energy. This modulation of ionization probability is reproduced in the frozen core approximation and in other binding potentials with variable ionization potential. Furthermore the modulation of ionization yield goes hand in hand with the occupation of the first excited state of the system at the end of the pulse, and the existence of an excited bound state turns out to be a necessary condition for the effect. By employing a two state model we can reproduce the modulation of excited state occupation and ionization yield qualitatively. We provide an analytical solution for the occupation of the two states in this model, which is valid when ionization and occupation of excited states is small. This model predicts a similar modulation of the ionization yield when the wavelength is varied (ionization potentials fixed) which is confirmed by TDSE simulations. Finally we discuss the carrier envelope phase dependence of the effect.

[1] V. Mosert, D. Bauer, Phys. Rev. A 92, 043414 (2015)

A 8.3 Mon 15:00 f303

Multielectron dynamics in the tunneling ionization of a correlated quantum system — •Maximilian Hollstein and Daniela Pfannkuche — Universität Hamburg, I. Institut für Theoretische Physik, Jungiusstraße 9, 20355 Hamburg

The multielectron dynamics during the tunneling ionization of a correlated quantum system is investigated by comparison of the solution of the time-dependent Schrödinger equation (TDSE) with the time-dependent configuration interaction singles approach (TDCIS). Here, we point out the relevance of a multielectron description of the tunnel ionization process especially for weakly confined quantum systems i.e. for instance poly-atomic molecules or semiconductor quantum dots. Within this context, we observe that adiabatic driving by an intense light field can enhance the correlations between the electrons that are still trapped.

A 8.4 Mon 15:15 f303

TDRNOT applied to the laser-driven hydrogen molecular ion — •Adrian Hanusch, Julius Rapp, Martins Brics, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

The recently introduced time-dependent renormalized-natural-orbital theory (TDRNOT) has already proven good performance in benchmarks using an exactly solvable 1D Helium model atom [1-3].

TDRNOT is now extended towards a multi-component approach in order to describe a one-dimensional H_2^+ model system beyond the Born-Oppenheimer approximation. Different kinds of natural orbitals are introduced in order to describe the electronic and nuclear degree of freedom, and exact equations of motion for them are derived.

The theory is then benchmarked by calculating ground state properties and linear response spectra and comparing them to the exact results obtained from solving the time-dependent Schrödinger equation. Furthermore, we test the ability of TDRNOT to describe the fragmentation of H_2^+ in intense laser fields and high-order harmonic generation.

[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 8.5 Mon 15:30 f303

An improved method for finding exceptional points and application to Rydberg systems in external fields — •Matthias Feldmaier, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, 70550 Stuttgart, Germany

Exceptional points are special places in the spectrum of open quantum systems, where resonances degenerate and the associated eigenvectors coalesce. An example for such a system is the hydrogen atom in parallel electric and magnetic fields, for which we solve the Schrödinger equation in a complete basis to calculate the resonances and eigenvectors. Starting from an avoided crossing within the term scheme and using a two-dimensional matrix model, we develop an iterative algorithm to calculate both the position and energy of exceptional points, and to verify their basic properties. Additionally, we are able to visualize the wavefunctions of the degenerated states. We report the existence of various exceptional points. For the hydrogen atom these points are in an experimentally inaccessible regime of field strengths. However, excitons in cuprous oxide in parallel electric and magnetic fields as the corresponding hydrogen analog in a solid state provide a suitable system where the high-field regime can be reached at much smaller external fields and for which we propose an experiment to detect exceptional points.

A 8.6 Mon 15:45 f303

A semi-analitycal description of high-harmonic generation in inhomogeneous fields — •Carlos Zagoya Montiel, Matt Bonner, Emma Slade, and Carla Figueira de Morisson Faria — University College London

In this work, we perform a semi-analytical study of the high-order harmonic generation phenomenon in inhomogeneous media. In particular, we analyse how the inhomogeinity influences the spectrum and give an explanation for the harmonics appearing beyond the usual cutoff for homogeneous media. This is managed by employing windowed Fourier transforms and ensembles of classical trajectories. Furthermore, by neglecting the atomic core and considering the inhomogeinity parameter to be small, an analytical expression for the classical returning times can found which result to be in a good agreement with the numerical results.

A 8.7 Mon 16:00 f303

From the classical to the quantum Kibble-Zurek scaling — •Pietro Silvi[1], Giovanna Morigi[2], Tommaso Calarco[1], and Simone Montangero[1] — [1]Institute for complex quantum systems, Universitaet Ulm, D-89069 Ulm — [2]Theoretische Physik, Universitaet des Saarlandes, D-66123 Saarbruecken

The Kibble-Zurek (KZ) hypothesis identifies the relevant time scales in out-of-equilibrium dynamics of critical systems employing concepts valid at equilibrium: It predicts the scaling of the defect formation immediately after quenches across classical and quantum phase transitions as a function of the quench speed. Here we study the crossover between the scaling dictated by a slow quench, which is ruled by the critical properties of the quantum phase transition, and the excitations due to a faster quench, where the dynamics is often well described by the classical model. We estimate the value of the quench rate that separates the two regimes and support our argument using numerical simulations of the out-of-equilibrium many-body dynamics. For the specific case of a ϕ^4 model we demonstrate that the two regimes exhibit two different power-law scalings, which are in agreement with the KZ theory when applied to the quantum and to the classical case. This result contributes to extending the prediction power of the Kibble-Zurek mechanism and to provide insight into recent experimental observations in systems of cold atoms and ions.

A 9: Ultra-cold atoms, ions and BEC (with Q)

Time: Monday 16:30–19:00 Location: Empore Lichthof

A 9.1 Mon 16:30 Empore Lichthof

Heating and decoherence effects in a hybird atom-ion system — •Tao Yin, Tao Qin, and Walter Hofstetter — Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt/Main, Germany

In this work we study heating and decoherence effects in a hybrid atom-ion system, in which the atom and ion are trapped by a harmonic trap and Paul trap, respectively. We consider the entangled state of one ion strongly coupled to one atom. As a consequence of the time-dependent trapping potential and short-range atom-ion collisions, the ionic micromotion plays an important role in such systems. We investigate the dynamic properties in this system by the Floquet formalism and calculate the effects of heating and decoherence arising from the ionic micromotion. We also study the validity of the secular approximation for different atom-ion mass ratios and trapping geometries. Our results can be used to explain and design experiments on hybrid atom-ion simulators of this type. In addition, we consider adding a second ion to this system, and preliminarily study its possible effects on the atom-ion entangled state due to the long-range coulomb interaction between these two ions.

A 9.2 Mon 16:30 Empore Lichthof

Towards Ultracold Interaction - Optical trapping of Barium Ions and Rubidium Atoms — •Pascal Weckesser, Alexander Lambrecht, Julian Schmidt, Leon Karpa, and Tobias Schaetz — Albert-Ludwigs-Universität Freiburg

In the last years several experimental groups investigated collisions between laser-cooled atoms and ions, leading to a better understanding of the atom-ion interaction in many aspects [1-4]. Due to the RF-confinement of the ions these systems have been dominated by an intrinsic heating effect [5], limiting collision dynamics on the order of a few milli-Kelvin. A purely optical and electrostatic potential for both ions and atoms should overcome this effect [6] allowing to investigate ultracold interactions, such as cluster formation of an ion binding atoms wihtin the common $1/r^4$-potential [7].
Here we present our experimental setup combining simultaneously trapped Ba^+ ions and Rb atoms in a far detunded bichromatic dipole trap. We discuss the properties of this novel trap, methods for extending the ion lifetime as well as prospective experiments within reach with the presented setup.

[1] A.T.Grier et al., Phys.Rev.Lett. 102,223201(2009)
[2] C.Zipkes et al., Nature 464,388(2010)
[3] S.Schmid et al. Phys.Rev.Lett. 105.133202 (2010)
[4] W.G.Rellergert et al., Phys.Rev.Lett. 107,243201 (2011)
[5] M.Cetina et al., Phys.Rev.Lett. 109,253201 (2012)
[6] T.Huber et al., Nat. Comm. 5,5587 (2014)
[7] R.Cote et al. Phys.Rev.Lett. 89.093001 (2002)

A 9.3 Mon 16:30 Empore Lichthof

Orbital magnetism of ultracold fermionic gases in a lattice: Dynamical Mean-Field Approach — •Agnieszka Cichy[1], Anna Golubeva[1], Andrii Sotnikov[2], and Walter Hofstetter[1] — [1]Goethe Universität, Frankfurt a. M., Germany — [2]Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine

The impressive development of experimental techniques in ultracold quantum degenerate gases of alkaline-earth-like atoms in the last years has allowed investigation of strongly correlated systems. Long-lived metastable electronic states in combination with decoupled nuclear spin give the opportunity to study the Hamiltonians beyond the possibilities of current alkali-based experiments. Ytterbium is particularly convenient due to its large number of bosonic and fermionic (e.g. ^{173}Yb) isotopes with a wide range of interaction strengths.

We study finite-temperature properties of the two-band Hubbard model on a simple cubic lattice. Our main goal is to investigate the role of exchange interaction in finite temperature magnetic phases, for the whole range of fillings. We use the Dynamical Mean-Field Theory approach and its extension in real space to obtain finite-temperature phase diagrams including transitions to magnetically-ordered phases. We determine which parameter regimes are most favourable for ferromagnetism, in terms of experimental observation in ultracold atomic gases in a lattice. We also calculate the entropy in the vicinity of magnetically-ordered phases that allows to make important predictions for on-going and future experiments aiming at approaching and studying long-range ordered states in ultracold atomic mixtures.

A 9.4 Mon 16:30 Empore Lichthof

Dynamical Mean-Field Theory of the SU(4)-symmetric Fermi-Hubbard model and its extensions — •Anna Golubeva[1], Agnieszka Cichy[1], Andrii Sotnikov[2], and Walter Hofstetter[1] — [1]Goethe Universität, Frankfurt am Main, Germany — [2]Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine

Alkaline-earth-like atoms have emerged in the field of ultracold quantum gases as a promising alternative to alkali atoms. Their internal structure includes low-lying metastable electronic states offering the possibility to simulate many-body models with orbital phenomena. Furthermore, certain isotopes (specifically ^{87}Sr, ^{173}Yb) exhibit a high SU(N) symmetry of interactions which is a result of the decoupling between the nuclear spin and electronic degrees of freedom. Recent experimental advances in this field [1–3] have triggered theoretical interest.

We investigate the SU(4)-symmetric Fermi-Hubbard model in a simple cubic optical lattice at finite temperatures. By means of Dynamical Mean-Field Theory [4] and its real-space extension we study the magnetic phases and entropy characteristics of the system at half- and quarter-filling. We also analyze the influence of different interspecies interactions on possible magnetic orderings.

[1] Taie et al., Nature Phys. 8, 825–830 (2012)
[2] Taie et al., Phys. Rev. Lett. 105, 190401 (2010)
[3] Fukuhara et al., Phys. Rev. A 79, 021601 (2009)
[4] Georges et al., Rev. Mod. Phys. 68, 13 (1996)

A 9.5 Mon 16:30 Empore Lichthof

Manipulation of a dipolar Bose-Einstein condensate using an electro-optical deflector system — •Matthias Schmitt, Holger Kadau, Matthias Wenzel, Igor Ferrier-Barbut, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Strongly dipolar quantum gases enable the observation of many-body phenomena with anisotropic, long-range interactions. Observing these effects can be enhanced by an initial preparation of the atomic density distribution in multi-well [1] or ring-shaped potentials [2] as well as in-situ imaging.
We present the first results on tailored potentials imprinted on a Bose-Einstein condensate of dysprosium atoms. The potentials are created with a 532 nm laser modulated with an electro-optical deflector system and a Pockels cell. The light is focused on the atomic cloud using a diffraction-limited custom objective with high numerical aperture.

[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 9.6 Mon 16:30 Empore Lichthof

Controlling Rydberg atoms in dense gases — •Karl Magnus Westphal, Kathrin Sophie Kleinbach, Felix Engel, Fabian Böttcher, Michael Schlagmüller, Robert Löw, Tara Cubel

Liebisch, Sebastian Hofferberth, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

When a Rydberg atom is excited in a dense gas, there can be tens of thousands of neutral atoms within the Rydberg electron orbit, resulting in a density-dependent frequency shift, as discovered by Amaldi and Segrè in 1934. However, Rydberg excitations in a BEC lead not only to a density shift, but a line shape that changes with the principal quantum number n. The line broadening depends precisely on the interaction potential energy curves of the Rydberg electron with the neutral atom perturbers. In particular, we show the relevance of the triplet p-wave shape resonance in the e^--Rb($5S$) scattering, which significantly modifies the interaction potential [1]. We discuss a variety of results of experiments with a single charged impurity in quantum gases as well as wavefunction imaging. Spatial control of the excitations allows us to study the density-dependent quantum chemistry between a Rydberg atom and neutral atoms.

1 M. Schlagmüller et al., **arXiv:1510.07003**, (2015)

A 9.7 Mon 16:30 Empore Lichthof

Towards the production of RbCs ground-state molecules from degenerate gases in an optical lattice — •Beatrix Mayr[1], Lukas Reichsöllner[2], Andreas Schindewolf[1], Silva Mezinska[1], Rudolf Grimm[1,2], and Hanns-Christoph Nägerl[1] — [1]Institut für Experimentalphysik, Universität Innsbruck — [2]Institut für Quantenoptik und Quanteninformation IQOQI, Innsbruck

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 a low entropy sample of dipolar RbCs molecules in the rovibronic and hyperfine ground-state. To be able to mix degenerate samples of Rb and Cs, the inter-species scattering length a_{RbCs} has to be tuned close to zero by means of a magnetic Feshbach resonance. Since Cs three-body losses would cause a breakdown of a Cs BEC in the magnetic-field region, in which RbCs Feshbach resonances are available, we initially prepare a Cs Mott insulator with unity filling spatially separated from the Rb sample. The optical lattice wavelength and depth are chosen in a way that Rb is still superfluid and can be overlapped with Cs after switching the magnetic field to achieve $a_{\mathrm{RbCs}} = 0$. Precise control over the relative position of the two degenerate samples and high magnetic field stability will enable the formation of RbCs Feshbach molecules with a high filling factor of the optical lattice followed by the application of the STIRAP transfer to the absolute molecular ground-state, as demonstrated in Ref. [1].

[1] T. Takekoshi et al., Phys. Rev. Lett. **113**, 205301 (2014)

A 9.8 Mon 16:30 Empore Lichthof

Expansion dynamics of an ultracold gas from realistic trap potentials for atom interferometry — •Srihari Srinivasan and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt, Hochschulstraße 4a, 64289 Darmstadt

The versatility of Bose-Einstein Condensates (BEC) for use in experiments has enabled an entire genre of topics ranging from quantum optics and condensed matter physics to quantum simulators and sensors. The QUANTUS collaboration [1] aims to use atom interferometry with an ultracold ^{87}Rb gas in the vacuum drop tower at ZARM in Bremen [2]. The experiment module can either be catapulted or dropped inside the vacuum drop tower to perform atom interferometry in microgravity under free fall to test Einstein's Equivalence Principle.

Expansion dynamics of a BEC is well understood analytically [3]. Interferometric fringe contrast of an expanding BEC released from the trap is strongly influenced trap anharmonicity and thermal component of the gas. We aim to simulate the expansion of a BEC and a thermal cloud from a realistic, anisotropic magnetic trap of the QUANTUS II atom chip. This is done as a part of a comprehensive simulation of a realistic atom interferometer to be used for comparison with experimental data.

[1] QUANTUS Collaboration:www.iqo.uni-hannover.de/quantus.html

[2] T. van Zoest et al., Science, **328**, 1540 (2010) and H. Mütinga et al., Phys. Rev. Lett., **110**, 093602 (2013).

[3] Yu Kagan et al., Phys. Rev. A, **54**(3), R1753 (1996) and Y Castin et al., Phys. Rev. Lett., **77**(27), 5315 (1996).

A 9.9 Mon 16:30 Empore Lichthof

Regions of tunneling dynamics for few bosons in an optical lattice subjected to a quench of the imposed harmonic trap — •Georgios Koutentakis[1,2], Simeon Mistakidis[1], 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, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany

Recent advancements in ultracold atom experiments have introduced an interplay in the trapping length scales of lattice and harmonic confinement. This fact motivates the investigation, whether it is possible to prepare atomic gases at certain quantum states by utilizing a composite atomic trap consisting of a lattice potential that is embedded inside an overlying harmonic trap. In the present work, we examine how frequency modulations of the harmonic trap stimulate the dynamics of an 1D few-boson gas. The gas is initially prepared at a highly confined state, and the subsequent dynamics induced by a quench of the harmonic trap frequency to a lower value is examined. It is shown that a non-interacting gas always diffuses to the outer sites, whereas the response of the interacting system is more involved and is dominated by a resonance, which is induced by the bifurcation of the low-lying eigenstates. Our study reveals that the position of the resonance depends both on the atom number and the interaction coupling, manifesting its many body nature. A corresponding mean field treatment as well as a single-band approximation have been found to be inadequate for the description of the tunneling dynamics in the interacting case.

A 9.10 Mon 16:30 Empore Lichthof

Cradle-like processes and mode-coupling of interaction quenched ultracold bosons in periodically driven lattices — •Simeon Mistakidis[1] and Peter Schmelcher[1,2] — [1]Zentrum fuer Optische Quantentechnologien, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The out-of-equilibrium dynamics of ultracold bosons in one-dimensional lattices following an interaction quench upon a periodically driven optical latttice is investigated. It is shown that an interaction quench triggers the inter-well tunneling dynamics, while for the intra-well dynamics breathing and cradle-like processes can be generated. In particular, the occurence of a resonance between the cradle and tunneling modes is revealed. On the other hand, the employed periodic driving (vibration) enforces the bosons in the mirror wells to oscillate out-of-phase and to exhibit a dipole mode, while in the central well the cloud experiences a breathing mode. The dynamical behaviour of the system is investigated with respect to the driving frequency revealing a resonant-like behaviour of the intrawell dynamics. To drive the system in a highly non-equilibrium situation an interaction quench upon the driving is performed giving rise to admixing of excitations in the mirror wells, an enhanced breathing in the center and an amplification of the tunneling dynamics. As a result of the quench the system experiences multiple resonances between the inter- and intra-well dynamics at different quench amplitudes.

A 9.11 Mon 16:30 Empore Lichthof

A new apparatus of Bose-Fermi mixture — •Haoze Chen — University of Science and Technology of China Shanghai Branch, Shanghai, China

We will introduce a new apparatus for investigation of lithum6 and potassium41 Bose-Fermi mixture. The whole system contains several novel developed technics. Lithum6 and potassium41 are precooled by a spin-flipped Zeeman slower and 2D plus MOT respectly and captured by 3D-MOT simultaneously. Lithum6 cloud is further cooled by UV-MOT, while potassium41 is further cooled by gray molasses, which enhance the phase-space density from 1e-7 to 1e-4. We then apply D1 optical pumping for both atoms to increase the loading efficiency and purify the spin state. Then both species are loaded in a magnetic trap, and transport from our MOT chamber to science cell, which has a much better vacuum and optical access. We start evaporate cooling of potassium41 in a plugged magnetic trap, while lithum6 is sympathetic cooled by potassium41. After 15s of evaporation, we have generated double degenerate gas with more than 2e5 pure BEC of K41 and 5e5 degenerate fermi gas with 10% Fermi temperature of Li.

A 9.12 Mon 16:30 Empore Lichthof

Energy and mass transfer between zig-zag chains trapped in a double well potential — •Andrea Klumpp[1], Alexandrea Zampetaki[1], and Peter Schmelcher[1,2] — [1]ZOQ Universität Hamburg — [2]ILP Universität Hamburg

Ion traps are versatile tools for experiments in various fields, such as spectroscopy, quantum computing, molecular physics and biophysics [1]. The development of micro-fabricated segmented Paul traps opens up new fields for research relating, among others, to the transport of ions [2], the splitting [3] and also the coupling of ion crystals [4].

In our work we investigate the dynamics of two trapped ion crystals in a three dimensional double well potential with a strong confinement perpendicular to the x-z plane as in the case of a planar trap. The initial state of the ions in our setup is given by well separated zig-zag configurations in both wells. The crystals are built of 13 in the first well and 20 in the second. After lowering the barrier between the wells, we observe mass and energy transfer between the crystals as a result of the asymmetry in the initial crystal sizes. In addition, we detect oscillations propagating into the big crystal like a shock wave, while the small ion crystal melts completely.

[1] Major et al., Charged particle traps I+II Springer,(2005 + 2009)
[2] Huber et al., NJP 10, 013004 (2008)
[3] Ruster et al., Phys. Rev. A 90, 033410 (2014)
[4] Klumpp et al., arXiv:1508.07979

A 9.13 Mon 16:30 Empore Lichthof

Magnesium Ion Crystals at SpecTrap — •Manuel Vogel[1], Zoran Andelkovic[1], Gerhard Birkl[2], Tobias Murböck[2], Wilfried Nörtershäuser[3], and Stefan Schmidt[3] — [1]GSI, 64291 Darmstadt — [2]Institut für Angewandte Physik, TU Darmstadt, 64289 Darmstadt — [3]Institut für Kernphysik, TU Darmstadt, 64289 Darmstadt

We have investigated laser-cooled magnesium ions stored in a Penning trap. The ions are produced externally and are dynamically captured in the trap. We have combined buffer-gas cooling and laser cooling, thus reducing the ion temperatures from Mega-Kelvin to milli-Kelvin on the timescale of seconds. At this temperature, the ions adopt crystalline structures. For ion numbers of the order of a few thousand, these so-called 'mesoscopic' ion crystals display shell structures depending on experimental parameters, which we have visualized by use of a CCD camera. We have investigated the fluorescence signal depending on laser parameters and characterized the crystal structures. This is part of the sympathetic cooling of highly-charged ions as a next step in the framework of the SpecTrap experiment at the HITRAP facility at GSI/FAIR.

A 9.14 Mon 16:30 Empore Lichthof

Optimized atomic transport with an atom chip — •Robin Corgier[1,2], Eric Charron[2], Ernst Maria Rasel[1], and Naceur Gaaloul[1] — [1]Leibniz University of Hanover, Germany — [2]Université Paris-Sud, France

Recent proposals for testing performing a quantum test of Einsteins principle of equivalence assume Bose-Einstein condensates (BEC) as sources of atom interferometry sensors. Atom chip devices have allowed to build transportable BEC machines with high repetition rates as demonstrated in the QUANTUS project [J. Rudolph et al. New J. Phys. 17, 079601 (2015)]. The proximity of the atoms to the chip surface is, however, limiting their optical access and the times the atoms spend in the interferometer necessary for precision measurements. In this context, a fast and perturbation-free transport of the atoms is required. Shortcuts to adiabaticity protocols were proposed and allow in principle to implement such sequences with well defined boundary conditions. In this theoretical study, we engineer suitable protocols to move atomic ensembles trapped at the vicinity of an atom chip by tuning the realistic chip currents and external magnetic fields. We find a realistic protocole for moving the atomic trap optimizing the transport time and reducing detrimental effects due to the offset of atoms positions from the trap center. Further developments generelizing our method to anharmonic traps and spatially extended atomic wave packets are also discussed.

A 9.15 Mon 16:30 Empore Lichthof

Species and regime trade-off of atomic sources for extended-time atom interferometry — •Sina Loriani, Dennis Schlippert, Christian Schubert, Ernst Maria Rasel, and Naceur Gaaloul — Leibniz University of Hanover, Germany

Recent proposals for space-borne atomic sensors designed to detect gravitational waves or testing the universality of free fall predict unprecedented sensitivity for long interrogation times. These extremely long drift times of several seconds are possible thanks to the collimation technique of delta-kick cooling (DKC) [Müntinga, et al. Phys. Rev. Lett. **110**, 093602 (2013), T. Kovachy et al., Phys. Rev. Lett. **114**, 143004 (2015)]. These atomic lenses are, however, subject to aberrations depending on the extent of the collimated wave packets and the potentials used. In this theoretical study, we trade-off the performance of the DKC for commonly used alkaline and alkaline-earth-like ensembles of atoms (Rb, Sr, Yb, etc.) in the metrology context. The efficiency of the DKC is evaluated and contrasted for these isotopes in the three possible density regimes (thermal, hydrodynamic and degenerate). The expansion dynamics is followed by solving different scaling law approaches depending on the temperature and density of the considered atomic cloud. The results show a clear advantage when using condensed or hydrodynamic ensembles.

A 9.16 Mon 16:30 Empore Lichthof

Impurity in a Bose-Einstein condensate using quantum Monte Carlo methods — •Luis Ardila[1] and Stefano Giorgini[2] — [1]Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany — [2]INO-CNR BEC Center and Department of Physics, University of Trento - via Sommarive 14 38123 Povo

We investigate the properties of an impurity immersed in a dilute Bose gas at zero temperature using quantum Monte Carlo methods. The interactions between bosons are modeled by a hard-sphere potential with scattering length a, whereas the interactions between the impurity and the bosons are modeled by a short-range, square-well potential where both the sign and the strength of the scattering length b can be varied by adjusting the well depth. We characterize the attractive and the repulsive polaron branch by calculating the binding energy and the effective mass of the impurity. Furthermore, we investigate the structural properties of the bath, such as the impurity-boson contact parameter and the change of the density profile around the impurity. At the unitary limit of the impurity-boson interaction, we find that the effective mass of the impurity remains smaller than twice its bare mass, while the binding energy scales with $\hbar^2 n^{2/3}/m$, where n is the density of the bath and m is the common mass of the impurity and the bosons in the bath. The implications for the phase diagram of binary Bose-Bose mixtures at low concentrations are also discussed.

A 9.17 Mon 16:30 Empore Lichthof

Interaction-Induced Topological Phases in the Hofstadter-Hubbard Model — •Pramod Kumar, Thomas Mertz, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt/Main, Germany

Interaction effects have been the subject of contemporary interest in topological phases of matter. In the presence of interactions, the accurate determination of topological invariant gets cumbersome due to its dependence on multiple integrals containing Green's functions and their derivatives. We employ the recently proposed, "topological Hamiltonian" method (Z. Wang and S.-C. Zhang) to explore interaction-induced topological phases in the time-reversal-invariant Hofstadter-Hubbard model. Within this approach, the zero frequency part of the self-energy is sufficient to determine the correct topological invariant. We combine the topological Hamiltonian approach with the local self-energy approximation within Hartree-Fock and dynamical mean field theory (DMFT), and present the corresponding phase diagram in the presence of many-body interactions. We investigate the presence of quantum spin Hall (QSH) states for different interactions by calculating the $\mathbb{Z}_2$ invariant.

References:

1. Z. Wang and S.-C. Zhang, Phys. Rev. X 2, 031008 (2012).

A 9.18 Mon 16:30 Empore Lichthof

Atom laser based quantum sensors — •Tobias Menold, Carola Rogulj, Malte Reinschmidt, Peter Federsel, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

Developing new quantum sensors is the biggest challenge in today's quantum technology. Thereby, quantum fluctuations play an important role as they provide direct access to the quantum information of a system. Our goal is to develop a new quantum sensor for these quantum fluctuations. Using a quantum state transfer, they are transferred to an atom laser, whose output is measured with single atom sensitivity.

We demonstrate such a sensor, by transferring the dynamics of an ultra-cold atomic cloud onto an atom laser and reconstructing its dynamics using our time resolved, single atom detection scheme. In a second experiment we transfer classical field noise of a multi-mode mi-

crowave field onto the atom laser and analyze its statistics. We find that the atom laser output allows for measuring not only the power spectral density of the noise but also the field correlations.
Using our sensor, a quantum galvanometer comes into direct reach. It should allow the investigation of quantum transport phenomena in various solid state systems.

A 9.19 Mon 16:30 Empore Lichthof

Towards Dysprosium Quantum Gases — •Florian Mühlbauer, Niels Petersen, and Patrick Windpassinger — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Ultra-cold dipolar quantum gases enable the study of many-body physics with long-range, inhomogeneous interaction effects due to the anisotropic character of the dipole-dipole interaction. These systems are expected to show novel exotic quantum phases and phase transitions which can be studied with dysprosium atoms. Dysprosium is a rare-earth element with one of the largest ground-state magnetic moments (10 Bohr magnetons) in the periodic table. Therefore, the dipole-dipole interaction is not a small perturbation but becomes comparable in strength to the s-wave scattering. This influences significantly the physical properties of the trapped atomic sample, such as its shape and stability.

This poster presents the current status of our experimental setup to generate dysprosium quantum gases. We discuss the relevant properties of dysprosium and present our laser system and vacuum design.

A 9.20 Mon 16:30 Empore Lichthof

A quantum gas machine for studies of local losses induced by photoionization — •Tobias Kroker[1], Janine Franz[1], Bernhard Ruff[2,3], Tim Anlauf[1], Juliette Simonet[1], Philipp Wessels[1,3], Markus Drescher[2,3], and Klaus Sengstock[1,3] — [1]Zentrum für Optische Quantentechnologien, Hamburg, Germany — [2]Institut für Experimentalphysik, Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, 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 which allows resolving correlations among electrons photoionized from a BEC by a femtosecond laser pulse.

Here we report on our progress in setting up a quantum gas machine where the ultracold gases are optically transported into the focus region of the femtosecond laser beam. As photoionization induces local losses in the BEC, a theoretical model of the dissipative system is essential including a quantification of the quantum Zeno effect.

A 9.21 Mon 16:30 Empore Lichthof

Dynamics of nonlinear excitations of helically confined charges — •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

The confinement of long-range interacting particles on a curved manifold can modify significantly their effective interactions. In the special case of identical charges trapped on a helical geometry the effective two-body potential acquires an extraordinary oscillatory form [1].

For a closed helical trap the corresponding system of charges was recently found to exhibit an unconventional deformation of the linear spectrum when tuning the helix radius [2]. Here we show that the same geometrical parameter can affect significantly also the dynamical behaviour of an initially broad excitation for long times. In particular, for small values of the radius, the excitation disperses into the whole crystal whereas within a specific narrow regime of larger radii the excitation self-focuses, assuming finally a localized form. Beyond this regime, the excitation defocuses and the dispersion gradually increases again. We analyze this geometrically controlled nonlinear behaviour using an effective discrete nonlinear Schrödinger model, which allows us among others to identify a number of breather-like excitations.

[1] P. Schmelcher, EPL 95 50005 (2011).

[2] A. V. Zampetaki, J. Stockhofe and P. Schmelcher, Phys. Rev. A 91, 023409 (2015).

A 9.22 Mon 16:30 Empore Lichthof

Three-body recombination in a quasi-two-dimensional quantum gas — •Bo Huang[1,2], Alessandro Zenesini[3], and Rudolf Grimm[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation (IQOQI), Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria — [3]Institute of Quantum Optics, Leibniz Universität Hannover, 30167 Hannover, Germany

Quantum three-body recombination in three-dimensional systems is influenced by a series of weakly bound trimers known as Efimov states, which are induced by short-range interactions and exhibit a discrete scaling symmetry. On the other hand, two-dimensional systems with contact interactions are characterized by continuous scale invariance and support no Efimov physics. This raises questions about the behaviour of three-body recombination in the transition from three to two dimensions. We use ultracold caesium atoms trapped in anisotropic potentials formed by a pair of counter-propagating laser beams to experimentally investigate three-body recombination in quasi-two-dimensional systems with tunable confinement and tunable interactions. In our recent results, we observed a smooth transition of the three-body recombination rate coefficient from a three-dimensional to a deeply quasi-two-dimensional system. A comparison between the results obtained near two Feshbach resonances indicates a universal behaviour of three-body recombination in the quasi-two-dimensional regime.

A 9.23 Mon 16:30 Empore Lichthof

Local probing of two-dimensinonal superfluid gases in the BEC-BCS crossover — •Klaus Hueck, Keno Riechers, Wolf Weimer, Kai Morgener, Jonas Siegl, Niclas Luick, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

In this poster we present local measurements of the superfluid fraction of a strongly interacting two-dimensional gas of diatomic Li^6 molecules. Using a high resolution imaging system, we perform a local measurement of the phase fluctuations on a single layer 2D gas. From this we extract the algebraic scaling exponent of the first order correlation function $g^{(1)}(r)$. This exponent is directly proportional to the superfluid density.

We furthermore report on our progress towards the creation of homogeneous two-dimensional Fermi gases in the BEC-BCS crossover.

A 9.24 Mon 16:30 Empore Lichthof

Nonequilibrium Green functions approach to expansion dynamics in strongly correlated fermionic lattice systems — •Jan-Philip Joost, Niclas Schlünzen, Sebastian Hermanns, and Michael Bonitz — CAU Kiel, Germany

Experiments with ultracold atoms in optical lattices gained in importance over the last years and are of high current interest, since they allow to directly measure quantum behaviour and serve as a model for solid state systems [1]. The proper description of transport processes in quantum lattices in the regime of strong coupling is a challenging task, which has been limited, so far, to one-dimensional systems. The nonequilibrium Green functions [2] (NEGF) technique, however, is not restricted with respect to dimension or particle number. Combined with the T-matrix approximation [3], in particular, the NEGF method is well-suited to fill the gap for higher dimensions [4]. Here, we show results for strongly interacting fermions in 2D and 3D. The approach gives access to the short-time dynamics, as well as the long-time limit of the expansion. Beside the density and energy evolution, also the momentum distribution, dispersion relation and the site-resolved build-up of correlations are obtained, the latter of which can be verified experimentally using the recently developed fermionic atom microscopes.

[1] U. Schneider *et al.*, Nat. Phys. **8**, 213 (2012)
[2] K. Balzer and M. Bonitz, *NEGF Approach to Inhomogeneous Systems*, Lecture Notes in Physics (Springer, 2013)
[3] M. P. von Friesen *et al.*, Phys. Rev. B **82**, 155108 (2010)
[4] N. Schlünzen *et al.*, arXiv:1508.02947 (2015)

A 9.25 Mon 16:30 Empore Lichthof

Variational calculation of ^{4}He for Droplets — •Christopher Bate, Yaroslav Lutsyshyn, and Dieter Bauer — Universität Rostock Institut für Physik

We aim to study droplets of liquid ^{4}He at very low temperature with the variational ansatz that was recently proposed for the ground state of strongly correlated Bose liquids [1]. This ansatz goes beyond the traditional Jastrow-Feenberg functional form and when optimized, provides an excellent description of the correlations in the system. Even though this wavefunction is constructed of short-range two-body factors and does not contain one-body surface terms, phase separation and free surface emerge at appropriate densities. This allows to study the inhomogeneous phases such as the droplets of superfluid helium, and the formation of the inhomogeneous phase as well. Due to advances in computational techniques and the fact that we can study the system on a variational level, we are able to consider droplets with up to 10^4 particles.

[1] Y. Lutsyshyn, "A coordinated wavefunction for the ground state of liquid helium-4", arXiv 1506.03752 (2015), to be published.

A 9.26 Mon 16:30 Empore Lichthof

Interactions of Single Cesium Atoms with an Ultracold Rubidium Bath — •Daniel Mayer[1,2], Manuel Stein[1], Michael Hohmann[1], Farina Kindermann[1], Tobias Lausch[1], Felix Schmidt[1,2], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany

Our project aims on combining single, tightly controlled particles with a quantum many-body system by immersing single neutral Cesium (^{133}Cs) atoms into a Rubidium (^{87}Rb) Bose-Einstein condensate.

We store both species in a common, red detuned dipole trap which gives rise to dynamical interspecies interaction. To capture the dynamics of the Cs distribution interacting with a cold, thermal Rb cloud, a species selective, 1D optical lattice is used for position resolved fluorescence imaging of the single Cs atoms. The temperature for Rb and Cs atoms can be measured by release-recapture thermometry providing an additional, independent view on the interaction process.

We will give the current status on interaction dynamics between single impurities in an ultracold Rb gas.

A 9.27 Mon 16:30 Empore Lichthof

Lifetime Measurements of Topological Defects in Coulomb Crystals — •Miriam Bujak[1], Jonathan Brox[1], Philip Kiefer[1], Isabelle Schmager[1], Haggai Landa[2], 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) of Mg-Ions in Coulomb crystals. Simulations reveal a strong anharmonicity of the kink's internal mode of vibration, further enhanced by the controlled extension into three dimensions. As a consequence, the discrete kink experiences a self-induced globally confining potential, capable of trapping it at the centre of the crystal.

The formation of kink configurations in dependence of the trapping parameters is investigated and the lifetime of these defects is explored.

[1] M. Mielenz et al., Phys. Rev. Lett. **110**, 133004 (2013)

A 9.28 Mon 16:30 Empore Lichthof

Spectroscopy of Discrete Solitons in Coulomb Crystals — •Jonathan Brox[1], Miriam Bujak[1], Philip Kiefer[1], Isabelle Schmager[1], Haggai Landa[2], 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]. The occurrence of these structures is investigated in dependence of crystal size and axial as well as radial confinement.

Ion crystals with such structural defects feature localized vibrational modes in the spectrum of phonons [2]. We present first results on the spectroscopy of vibrational modes of the Coulomb crystal.

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

A 9.29 Mon 16:30 Empore Lichthof

Characterizing and Controlling the Structure of Topological Defects in Coulomb Crystals — •Isabelle Schmager[1], Jonathan Brox[1], Miriam Bujak[1], Philip Kiefer[1], Haggai Landa[2], 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) in Coulomb crystals of Mg-Ions in dependency on the ratio of radial to axial confinement and cooling conditions [1].

The formation of kink configurations and the transformation of kinks to different structures are investigated. We compare the properties of extended (2D) and blurred (3D) kinks for crystals consisting of 30 ions [2]. Furthermore, different creation and control processes are studied in detail.

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

A 9.30 Mon 16:30 Empore Lichthof

Motional Mode Analysis of Trapped Ions — •Frederick Hakelberg, Henning Kalis, Matthias Wittemer, Manuel Mielenz, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Trapped ions present a promising system for quantum simulations [1]. However scaling to large systems present a major challenge. Surface-electrode traps with individually controllable potential wells offer a promising approach by allowing the design of arbitrary patterns of trapped ions [2]. The Coulomb coupling of ions in two distinct traps (separated by $\approx 40\,\mu m$) has been shown [3]. In our experiment we trap ^{25}Mg$^+$ ions in a triangular surface-trap array with individual trap sites. The trap features 30 control electrodes which allow us to apply potentials for stray field compensation, and the control of motional-mode frequencies and mode orientations. We present two methods for measuring mode orientations and frequencies. The first is based on motional-sensitive two-photon stimulated-Raman transitions. The second makes use of oscillating control potentials generated by the control electrodes. We compare results with detailed models of both methods.

[1] Ch. Schneider *et al.*, Rep. Prog. Phys. **75**, 024401 (2012)
[2] T. Schaetz *et al.*, New J. Phys. **15**, 085009 (2013)
[3] K. R. Brown *et al.*, Nature **471**, 7337 (2013)

A 9.31 Mon 16:30 Empore Lichthof

SOC2: Neutral-atom Space Optical Clock — •Sruthi Viswam[1], Lyndsie Smith[1], Wei He[1], Dariusz Swierad[1], Joshua Hughes[1], Yeshpal Singh[1], Kai Bongs[1], Stefano Origlia[2], Soroosh Alighanbari[2], Stefan Schiller[2], Soren Dorscher[3], Stefan Vogt[3], Christian Lisdat[3], and Uwe Sterr[3] — [1]University of Birmingham, United Kingdom — [2]Heinrich-Heine Universität Düsseldorf, Germany — [3]Physikalisch-Technische Bundesanstalt, Germany

Several different atoms and ions are used to build ultra-stable clocks which might find application in time referencing, gravity measurement, data encryption, navigation etc. although it seems that it is strontium that is going to replace the current definition of time. Many groups around the world have already proven reliability and robustness of the strontium optical lattice clock and the next step is to make it more transportable and mobile. In this poster we report our progress and results from the robust transportable Space Optical Clock. So far, the robust preparation of cold Sr-88 atoms in a first stage magneto-optical trap (MOT) with 8E+6 and second-stage red broadband MOT with a transfer efficiency of 40 percent , single frequency MOT with 80 percent transfer efficiency and lattice with 1E+5 atoms is achieved. The compact atomic package is transported from the University of Birmingham, United Kingdom to Physikalisch-Technische Bundesanstalt , Germany.Next step is to lock the clock laser to the atomic transition. Lasers that are frequency stabilized by locking to the resonant mode of ultra low expansion cavities have been used for the cooling purpose.

A 9.32 Mon 16:30 Empore Lichthof

Experiments and theory of NaK molecules — •Kai K. Voges, Matthias W. Gempel, Torben A. Schulze, Torsten Hartmann, Alessandro Zenesini, and Silke Ospelkaus — Institut für Quantenoptik, Universität Hannover

Dipolar collisions between ultracold molecules are characterized by the amazing combination of long-range interaction and strong anisotropy. These properties and their tunability are powerful tools for the investigation of various phenomena, from the many-body dynamics of degenerate gases to the fundamental understanding of collisional physics and chemical processes.

In the experiment we are currently setting up, all these phenomena and many others will be investigated by involving ultracold ground-state NaK molecules. Our set-up has wide optical access, careful design of the electric field and large tunability of the experimental parameters for a wide control of the molecular properties. Here we present the current status of the experiment and an analysis of possible coherent two-photon transfer paths from weakly-bound Feshbach molecules to rovibronic ground state molecules.

A 9.33 Mon 16:30 Empore Lichthof

Dissipative preparation of antiferromagnetic order in the Fermi-Hubbard model — Jan Kaczmarczyk[1], Hendrik Weimer[2], and •Mikhail Lemeshko[1] — [1]IST Austria, Klosterneuburg, Austria — [2]Leibniz Universität Hannover, Germany

The realization of strongly correlated quantum phases such as the antiferromagnetic phase is one of the longstanding goals of quantum simulations with ultracold fermions in optical lattices. We show that a combination of two Raman-assisted hopping schemes gives rise to dissipative dynamics that exhibits a large amount of antiferromagnetic order in the steady state. We analyze the interplay between the familiar Fermi-Hubbard Hamiltonian and these additional dissipative terms using wave-function Monte-Carlo methods and a novel variational principle for dissipative quantum many-body dynamics [1]. We observe antiferromagnetic correlations appearing within experimentally accessible times on the order of 0.5 s, as well as a substantial reduction in entropy per particle compared to the current experimental setups without additional dissipation. Our considerations are based on the atomic level structure of fermionic 40K and can be implemented into existing experimental setups.

[1] H. Weimer, Phys. Rev. Lett. 114, 040402 (2015).

A 9.34 Mon 16:30 Empore Lichthof

An analytic model of quantum thermalization — •Gregory Szep[1], Mikhail Katsnelson[2], and Mikhail Lemeshko[1] — [1]Institute of Science and Technology Austria, Am Campus 1, Klosterneuburg 3400, Austria — [2]Radboud University of Nijmegen, Heijendaalseweg 135, 6525AJ Nijmegen, The Netherlands

The thermalisation of a subsystem, contained in a closed dynamical system - in both classical and quantum regimes - is an intuitive phenomenon by which the energy levels of the subsystem irreversibly approach the maximum entropy canonical distribution. Numerical evidence, based on single trajectories of both integrable and non-integrable systems, has been presented [1,2], while no analytic results exist that do not invoke the eigenstate thermalisation hypothesis or artificial thermostats. Here a method is proposed, that treats the eigenstates spanned by the equivalent closed subsystem as the basis set from which measurements are obtained. By considering how do the hybridised subsystem-system states, project onto the closed subsystem eigenstates, an attempt is made to derive a canonical distribution for the subsystem.

[1] F. Jin, et. al., New. J. Phys. 15, 033009 (2013) [2] S. Yuan, H. De Raedt, and M. I. Katsnelson, J. Phys. Soc. Jpn. 78, 094003 (2009).

A 9.35 Mon 16:30 Empore Lichthof

Geometrical pumping with a Bose-Einstein condensate — •Maximilian Schemmer[1], Lu Hsin-I[2], Lauren Aycock[2], Dina Genkina[2], Seiji Sugawa[2], and Ian Spielman[2] — [1]Institut d' Optique Graduate School, Palaiseau, France — [2]Joint Quantum Institute, National Institute of Standards and Technology, and University of Maryland, Gaithersburg, Maryland, USA

We realized a quantum "charge" pump for a Bose-Einstein condensate (BEC) in a novel bipartite magnetic lattice, whose bands are characterized by non-trivial topological invariants: the Zak phases. For each band, the Zak phase is determined by that band's integrated Berry curvature, a geometric quantity defined at each crystal momentum. We probed this Berry curvature in a charge pump experiment, by periodically and adiabatically driving the system. Unlike topological charge pumps in filled bands that yield quantized pumping, our BEC occupied just a single crystal momentum state allowing us to access its band's local geometry. Like topological charge pumps, for each pump cycle we observed an overall displacement (here, not quantized) and a temporal modulation of the atomic wavepacket's position in each unit cell, i.e., the polarization. Our magnetic lattice enabled us to observe this modulation by measuring the BEC's magnetization. While our periodic drive shifted the lattice potential by one unit cell per cycle, the displacement of the BEC, solely determined by the underlying Berry curvature, was always less than the lattice's displacement.

A 9.36 Mon 16:30 Empore Lichthof

Development of a deterministic ion source — •Jens Benary, Andreas Müllers, Cihan Sahin, and Herwig Ott — Technische Universität Kaiserslautern

We present a deterministic ion source based on an ultracold atom cloud. ^{87}Rb atoms are confined in a magneto-optical trap (MOT) and subsequently photo-ionized. The fast electrons are detected with a channel electron multiplier (CEM) and act as a trigger for the ions.

In addition to photoionization, we are implementing a three photon excitation to Rydberg states. Using the mechanism of Rydberg blockade, the source could be adapted to control the number of emitted ions down to a single particle.

Currently, the ions are detected with a second CEM. However, future applications may include ion interferometry or semiconductor doping. These will benefit from the high repetition rate and low energy spread of this type of source.

The three photon excitation via the intermediate $5P_{3/2}$ and $5D_{5/2}$ states gives access to nP or nF Rydberg states. This can be realized in a simple manner using IR diode lasers with wavelengths between 776 nm and 1260 nm. In addition, the $5D_{5/2}$ state has a decay channel to $6P_{3/2}$, which can be excited to nS or nD Rydberg states with an additional laser at 1016 nm.

We discuss the status of the experiment and present results obtained so far.

A 9.37 Mon 16:30 Empore Lichthof

Sympathetic cooling of OH- ions using Rb atoms in a MOT — •Ji Luo[1], Bastian Höltkemeier[1], Henry Lopez[1], Pascal Weckesser[1], Andre de Olivera[1,2], Eric Endres[3], Roland Wester[3], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, INF 226, 69120 Heidelberg — [2]Departamento de Física, Universidade do Estado de Santa Catarina-Joinville, SC, Brazil — [3]Institut f. Ionenphysik und angewandte Physik, Universität Innsbruck, Technikerstraße 25/3, 6020 Innsbruck

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 setup consists of an octupole rf ion trap with thin wires providing sufficient optical access to combine the ion trap with a dark-spontaneous-force optical trap for the atoms. The motional and internal temperature of the anions will be probed by photodetachment spectroscopy.

A 9.38 Mon 16:30 Empore Lichthof

Mode frequency stability of individually trapped ions in a two-dimensional array — •Yannick Minet, Manuel Mielenz, Henning Kalis, Frederick Hakelberg, Matthias Wittemer, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs-Universität, Hermann-Herder-Straße 3, 79104 Freiburg, Germany

A promising way to realise quantum simulations is based on trapped ions. Advanced micro-fabrication techniques and geometrical optimisation allows the construction of two-dimensional surface-electrode trap arrays [1] that may be used as large-scale simulators [2]. Prerequisites for such implementations are high-fidelity control of all motional degrees of freedom and a high-level of mode stability.

We present measurements of the stability of mode frequencies of a single $^{25}Mg^{+}$ ion trapped in one out of three sites, which are arranged in an equilateral triangle and separated by 40 μm. Our results are discussed in the context of future experiments, where we aim to establish inter-ion Coulomb couplings between all three trap sites.

[1] Ch. Schneider et al., Rep. Prog. Phys. **75**, 024401 (2012)
[2] T. Schaetz et al., New J. Phys. **15**, 085009 (2013)

A 9.39 Mon 16:30 Empore Lichthof

Fast and high-fidelity motional control of trapped ions — •Matthias Wittemer, Govinda Clos, Frederick Hakelberg, Henning Kalis, Manuel Mielenz, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs-Universität, Hermann-Herder-Straße 3, 79104 Freiburg, Germany

Laser-cooled ions, trapped in radio-frequency potentials, are promising candidates for experimental quantum simulations [1]. In addition to the precise manipulation of the electronic states (pseudo spin), control of the motional states of the trapped ions is crucial for adequate quantum simulations.

We report on experiments with Mg+ ions in a (conventional) linear Paul trap and a surface-electrode trap with three distinct trapping sites, arranged in an equilateral triangle. The implementation of an arbitrary waveform generator [2] into the experimental setups enables real-time control of the motional degrees of freedom within a few microseconds. This may allow precise studies of tunable spin-spin interactions [3] and phenomena like thermalization [4] or squeezed-state emergence [5] in isolated quantum systems.

[1] T. Schaetz *et al.*, New J. Phys. **15**, 085009 (2013)

[2] R. Bowler *et al.*, Rev. Sci. Instrum. **84**, 033108 (2013)
[3] A.C. Wilson *et al.*, Nature **512**, 57-60 (2014)
[4] G. Clos *et al.*, arXiv:1509.07712 (2015)
[5] R. Schützhold *et al.*, Phys. Rev. Lett. **99**, 201301 (2007)

A 9.40 Mon 16:30 Empore Lichthof

Fermi-Fermi Mixtures of Dysprosium and Potassium — Cornee Ravensbergen[2], Slava Tzanova[1], Vincent Corre[2], •Marian Kreyer[1], Alexander Werlberger[1], and Rudolf Grimm[1,2] — [1]Intitut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation IQOQI, Innsbruck, Austria

Ultracold Fermi-Fermi mixtures with tunable interactions represent an intriguing test bed for exploring the physics of strongly interacting many-body quantum systems and few-body quantum states. Two-species Fermi gases extend the variety of phenomena thanks to mass imbalance. Mixtures of a fermionic isotope of dysprosium (^{161}Dy or ^{163}Dy) and the fermionic ^{40}K provide a mass ratio of about four, which is big enough to experience strong asymmetries while avoiding losses from Efimov states. Furthermore, the large magnetic moment of dysprosium offers an additional feature to study anisotropic effects. In our experimental setup, we have implemented a Zeeman slower for dysprosium and a 2D magneto-optical trap (2D-MOT) for potassium to load a two-species MOT in the main vacuum chamber. It is planned to load both clouds into a dipole trap for evaporative cooling to achieve degeneracy of both species.

A 9.41 Mon 16:30 Empore Lichthof

Dimensional Phase Transitions of Bosons in Optical Lattices with Tunable Hopping — •Bernhard Irsigler[1], Denis Morath[2], Dominik Strassel[2], Sebastian Eggert[2], and Axel Pelster[2] — [1]Physics Department, Freie Universität Berlin, Germany — [2]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

Here we investigate in detail how the dimensionality affects the critical temperature of Bose-Einstein condensation. Motivated by the recent experiment [1] we consider bosons in an optical lattice, where the hopping along the three spatial dimensions is assumed to be tunable. With this we model all possible continuous transitions between the dimensions $D = 1, 2, 3$ and determine the respective critical temperatures in the vicinity of pure integer dimensions, which turn out to agree with the Mermin-Wagner theorem. In the homogeneous case the critical temperature vanishes in $D = 1, 2$ and therefore also in the dimensional transition $1 \rightarrow 2$. However in $D = 3$ the critical temperature is finite and vanishes for $3 \rightarrow 2$ logarithmically and for $3 \rightarrow 1$ like a power law. For the harmonically trapped case in any dimension $D = 1, 2, 3$ the critical temperature remains finite.
[1] A. Vogler, R. Labouvie, G. Barontini, S. Eggert, V. Guarrera, and H. Ott, Phys. Rev. Lett. **113**, 215301 (2014).

A 9.42 Mon 16:30 Empore Lichthof

Variational calculation of ^{4}He droplets — •Christopher Bate, Yaroslav Lutsyshyn, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock

We aim to study droplets of liquid ^{4}He at very low temperature with the variational ansatz that was recently proposed for the ground state of strongly correlated Bose liquids [1]. This ansatz goes beyond the traditional Jastrow-Feenberg functional form and, when optimized, provides an excellent description of the correlations in the system. Even though this wavefunction is constructed of short-range two-body factors and does not contain one-body surface terms, phase separation emerges and a free surface is formed at appropriate densities. This allows to study the inhomogeneous phases such as the droplets of superfluid helium, and the formation of the inhomogeneous phase as well. Due to advances in computational techniques and the fact that we can study the system on a variational level, we are able to consider droplets with up to 10^4 particles.

[1] Y. Lutsyshyn, "A coordinated wavefunction for the ground state of liquid helium-4", arXiv 1506.03752 (2015), to be published.

A 9.43 Mon 16:30 Empore Lichthof

Investigating and Minimizing Surface Effects in Cold Atom magnetic Field Microscopy — •Xiaoke Li[1], Amruta Gadge[1], Tim James[1], Bo Lu[2], Christopher Mellor[1], Nephtali Garrido-Gonzalez[1], Christian Koller[3], Fedja Orucevic[1], and Peter Krüger[1] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, UK — [2]Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong — [3]Mirco and Nano systems FH,Wiener Neustadt, Austria

Using cold atom as magnetic field sensor is one of the promising directions towards quantum technology. The advantage is that it can measure the magnetic field (and electric field) with both high spatial resolution and good field sensitivity, compared with magnetic force microscopy and SQUIDs. The limitation of achieved resolution is met while minimizing the distance between atoms and surface, which leads to loss of atoms due to Casimir force and Johnson noise. To reduce the surface effects and achieve submicron trapping, we investigate different surfaces such as silicon nitride membranes. The positioning of atoms over different samples is carried out by an on-chip magnetic transport system, which is generated by a 10-layer printed circuit board containing wires with 10μm to 20mm widths. Before loading the ^{87}Rb atoms into the magnetic trap, we use a novel dual color magneto-optical trap to improve the atom number. We will present the results of simulation and current progress of experiment.

A 9.44 Mon 16:30 Empore Lichthof

High resolution ion imaging of cold atoms — •Markus Stecker, Hannah Schefzyk, Malte Reinschmidt, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

Spatially resolved optical detection methods of cold atomic clouds are in general diffraction limited. In our novel approach we ionize atoms out of the cloud and image them via an ion optics with variable magnification up to 1000 and a spatial resolution above the optical diffraction limit. This allows the observation of trapped quantum gases with single atom sensitivity and high temporal and spatial resolution. In such a system, local statistic like temporal and spatial correlations can be studied, and global cloud properties or dynamical processes can be investigated.

We present the ion optics setup and the corresponding simulations, which show the theoretical limits of the system in terms of magnification and resolution. We also show the experimental implementation to an ultra-cold atom setup. The current ionization scheme uses a 480nm laser to ionize atoms out of a magneto-optical trap. In order to characterize the imaging quality, we imprint test structures with the ionization laser onto the MOT and analyze the generated ion patterns. Furthermore, we present the first steps to use this system for excitation and spatially resolved detection of Rydberg atoms.

A 9.45 Mon 16:30 Empore Lichthof

Towards the micromotion energy limit in a hybrid atom-ion experiment — •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

In our hybrid atom-ion experiment, we investigate the interaction of a laser-cooled trapped ^{138}Ba ion with an ultracold cloud of ^{87}Rb atoms [1].
Induced by micromotion, in this system there are three main sources of atom-ion collision energy. The excess micromotion caused by static electrical fields, the phase micromotion resulting from a phase delay between the radio frequency blades and a collision induced micromotion energy.
In this poster we show our recent progress in the minimization of phase micromotion and excess micromotion. We are then essentially left with collision induced micromotion and plan to measure this quantity for the first time in the near future.

[1] A. Krükow et al., arXiv:1510.04938 (2015)

A 9.46 Mon 16:30 Empore Lichthof

Towards high resolution imaging in a strongly imbalanced Bose Fermi mixture — •Alexander Mil, Fabian Olivares, Arno Trautmann, Marcell Gall, and Fred Jendrzejewski — Kirchhoff-Institut für Physik, Heidelberg, Deutschland

Strongly imbalanced Bose-Fermi mixtures are an ideal tool for the study of impurity problems, which are of great interest in modern condensed matter physics e.g. the polaron or the Kondo problem. A generic property of such systems is the screening cloud surrounding the impurity. While these screening clouds are central to the properties of most systems with impurities, they still remain hard to detect and to control. The current state of our experiment is well suited to tackle this problem. Using a mixture of bosonic sodium and fermionic lithium, with one of the species tightly trapped, leads to well localized impurities. Recent experiments on this system led to the observation of the phonon-induced lamb shift, which is characteristic for the presence of the screening cloud. Next goal is the direct observation of the screening cloud in real space.

We present our progress towards high resolution imaging in a sodium lithium mixture for direct observation of the screening cloud. Key feature here is a new imaging lens design enabling diffraction limited resolution for both species at a numerical aperture of 0.4. Moreover we elaborate on the imaging algorithm and the experimental setup allowing for high detection efficiencies.

A 9.47 Mon 16:30 Empore Lichthof

Towards ultracold mixtures of lithium and caesium — •Elisa Da Ros, Pierre Jouve, Jonathan Nute, Jizhou Wu, Nathan Cooper, and Lucia Hackermüller — University of Nottingham, United Kingdom

Ultracold mixtures hold the promise of understanding new phases of matter and collisions at very low energies. We showcase here our experiment capable of producing ultracold clouds of both bosonic caesium-133 and fermionic lithium-6 using a crossed-beam optical dipole trap.

We present the results of in situ optical density measurements of molecular lithium-6 Bose-Einstein condensates, aiming to compare different theoretical models. We also explain the design, construction and characterization of a dual species effusive oven for fast loading of magneto-optical traps integral to our experiments involving ultracold mixtures of both species. Finally, we exhibit our progress towards a quantum integrated light and matter interface (QuILMI) using waveguide chips in collaboration with the University of Jena, University of Vienna and the Max Planck Institute for the Physics of Complex Systems.

A 9.48 Mon 16:30 Empore Lichthof

A Thouless quantum pump with ultracold bosonic atoms in an optical superlattice — •Christian Schweizer[1,2], Michael Lohse[1,2], Oded Zilberberg[3], Monika Aidelsburger[1,2], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, LMU München, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Institut für Theoretische Physik, ETH Zürich, Switzerland

Topological charge pumping enables the transport of charge through an adiabatic cyclic evolution of the underlying Hamiltonian. In contrast to classical transport, the transported charge is quantized and purely determined by the topology of the pump cycle, making it robust to perturbations. Here, we report on the realization of such a pump with ultracold bosonic atoms forming a Mott insulator in a dynamically controlled optical superlattice. By taking in situ images of the cloud,we observe a quantized deflection per pump cycle. We reveal the pump's genuine quantum nature by showing that, in contrast to groundstate particles, a counterintuitive reversed deflection occurs for particles in the first excited band. Furthermore, we directly demonstrate that the system undergoes a controlled topological transition in higher bands when tuning the superlattice parameters. These results open a route to the implementation of more complex pumping schemes, including spin degrees of freedom and higher dimensions.

A 9.49 Mon 16:30 Empore Lichthof

Coulomb explosion imaging of $^6Li_2$ Feshbach molecules in a reaction microscope — •Niels Kurz, Alexander Dorn, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

A reaction microscope enables the imaging of the spatial structure of complex molecules by instant ionization of all constituent particles using e.g. fs laser pulses, a technique coined "Coulomb Explosion Imaging". The use of ultracold targets in a reaction microscope has been successfully applied to investigate multi-photon ionization of ^{7}Li in 800 nm fs pulses or in intense VUV light at the FLASH facility in Hamburg [M. Schuricke, K. Bartschat, A. N. Grum-Grzhimailo, G. Zhu, J. Steinmann, R. Mooshammer, 2009].

Unprecedented is the combination of this technique with an ultracold target of weakly bound di-atomic molecules formed from fermionic atoms (^{6}Li in our case) by the use of Feshbach resonances. In the universal regime the spatial extension of Feshbach molecules can be tuned over a wide range, by using only one experimental parameter, to create molecules with a spatial extent of up to 10.000 Bohr radii.

We present a project aimed at creating firstly a BEC of di-atomic ^{6}Li molecules and secondly few-fermion systems as targets in a reaction microscope by the use of the so-called spilling technique [F. Serwane, S. Jochim, 2011]. This will result in the first measurement of interatomic distance in $^6Li_2$ Feshbach molecules with tunable interatomic distance.

A 9.50 Mon 16:30 Empore Lichthof

Full tomographic reconstruction of a two-mode squeezed state — •Jan Peise[1], Ilka Kruse[1], Karsten Lange[1], Bernd Lücke[1], Luca Pezzè[2], Jan Arlt[3], Wolfgang Ertmer[1], Klemens Hammerer[4], Luis Santos[4], Augusto Smerzi[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]INO-CNR and LENS, Firenze, Italy — [3]Institut for Fysik og Astronomi, Aarhus Universitet, Denmark — [4]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

Homodyne detection serves as a standard tool in quantum optics for a wide range of applications including full state reconstruction by tomography. Homodyne detection is not limited to quantum optics with photons but can be similarly employed as a detection tool in atomic systems. Up to now, it was utilized to demonstrate nonseparability or the many-particle realization of interaction-free measurements.

Here we present the full state reconstruction of a two-mode squeezed state which was created by spin dyanmics in a Bose-Einstein condensate. By unbalanced homodyning of the created state, we obtain an unbiased, complete density matrix via a Maximum-Likelihood reconstruction. The reconstructed state shows the characteristics expected from the spin-dynamics process. The created state is characterized by a dominant population of twin Fock states compared to other states with the same overall particle number. It resembles an ideal two-mode squeezed state with a fidelity of 78.4%. The created two-mode squeezed state has a large variety of application in the fields of quantum information and metrology.

A 9.51 Mon 16:30 Empore Lichthof

Motion of a rotating impurity in a Bose-Einstein condensate — •Bikashkali Midya[1], Richard Schmidt[2], and Mikhail Lemeshko[1] — [1]Institute of Science and Technology (IST) Austria, Am Campus 1, 3400 Klosterneuburg, Austria — [2]ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, USA

In this work, we consider the translational motion of a rotating quantum impurity coupled to a Bose-Einstein condensate with boson-boson contact interaction, and boson-impurity anisotropic interaction. The microscopic Hamiltonian to describe such system is derived by first eliminating the dynamical variable of impurity by Lee-Low-Pines transformation, and then approximating the boson system by Bogoliubov method. The effect of the linear momentum of the impurity on the quasiparticle "angulon", a quantum rotor dressed by quantum field [1], spectrum is investigated by the variational technique.

[1] Richard Schimdt and Mikhail Lemeshko, "Rotation of quantum impurities in the presence of a many-body environment", Phys. Rev. Lett. 114, 203001 (2015).

A 10: Precision Measurements and Metrology III (with Q)

Time: Monday 17:00–18:15 Location: a310

A 10.1 Mon 17:00 a310

Comparison of a $^{171}Yb^+$ single ion clock and a ^{87}Sr lattice clock with 2×10^{-17} uncertainty — •Nils Huntemann, Sören Dörscher, Ali Al-Masoudi, Sebastian Häfner, Christian Grebing, Burghard Lipphardt, Christian Tamm, Uwe Sterr, Christian Lisdat, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We report on a comparison of two optical clocks based on the $^2S_{1/2} \leftrightarrow {}^2F_{7/2}$ transition of a single $^{171}Yb^+$ ion stored in a radio-frequency Paul trap and on the $^1S_0 \leftrightarrow {}^3P_0$ transition of thousands of ^{87}Sr atoms confined in an optical lattice. While the lattice clock achieves frequency instabilities smaller than $2 \times 10^{-16}/\sqrt{\tau/s}$, a systematic uncertainty of 3×10^{-18} has been reported for the ion clock. From more than 80 h of acquired data, we determine the frequency ratio of the two clocks with a fractional uncertainty of 2.4×10^{-17}. This is the smallest uncertainty achieved between clocks of different types to date and enables consistency tests in other laboratories developing the same combination of optical clocks. Moreover, the experiment is well suited to search for temporal variations of the fine structure constant α due to the large sensitivity of the E3 transition frequency. Data from this measurement and a similar one performed 2.5 years earlier constrain a potential linear drift $\dot{\alpha}/\alpha$ to below 1×10^{-17}/yr.

This work is supported by QUEST, the DFG within CRC 1128 (geo-Q) and RTG 1729, and the EMRP within ITOC and QESOCAS. The EMRP is jointly funded by the EMRP-participating countries within EURAMET and the European Union.

A 10.2 Mon 17:15 a310

The magnesium optical lattice clock at the IQ — •Dominika Fim, Steffen Rühmann, Klaus Zipfel, Nandan Jha, Steffen Sauer, André Kulosa, Wolfgang Ertmer, and Ernst M. Rasel — Leibniz Universität Hannover, Institut für Quantenoptik, Hannover

Optical lattice clocks based on fermionic strontium already reached uncertainties in the low 10^{-18} regime and are studied among others by JILA and NIST. In Hannover at the IQ, we operate an optical lattice clock based on bosonic magnesium atoms. Magnesium has a relatively simple electronic structure and hence allows for the implementation of very precise atomic structure models.

Recent measurements of the magic wavelength, which we could determine to 468.48(21) nm, and the 2$^{\text{nd}}$ order Zeeman shift were limited due to tunneling effects which results in a 10 kHz broad clock transition linewidth. In this presentation we will give a status update, where we will report on the optical lattice with a reduced tunneling rate and in this context more accurate measurements on the magic wavelength and the 2$^{\text{nd}}$ order Zeeman shift. We also prepare the optical lattice clock for a frequency measurement and will give the first estimations for the frequency accuracy for our apparatus.

A 10.3 Mon 17:30 a310

A strontium-based atomic breadboard for the Space Optical Clock mission on the ISS — •Stefano Origlia[1], Stephan Schiller[1], Lyndsie Smith[2], Yeshpal Singh[2], Dariusz Świerad[2], Sruthi Viswam[2], Wei He[2], Joshua Huges[2], Kai Bongs[2], Uwe Sterr[3], Christian Lisdat[3], Stefan Vogt[3], and the SOC2 team[1] — [1]HHU, Düsseldorf, Germany — [2]University of Birmingham, UK — [3]PTB, Braunschweig, Germany

The rapid improvement in the performance of optical clocks are opening the door to new technological and scientific applications. Ultra-precise optical clocks in space will allow many experiments, as in the field of fundamental physics (Einstein's gravitational time dilation), time and frequency metrology (comparison between ground clocks using a master clock in space), geophysics (space-assisted relativistic geodesy) and astronomy (local oscillators for radio ranging and interferometry in space). The ESA candidate mission Space Optical Clocks project aims at operating an optical lattice clock on the ISS in approximately 2022.

Within an EU-FP7-funded project, a compact and robust strontium optical lattice clock demonstrator is being developed with a goal instability of $1 \times 10^{-15}\tau^{-1/2}$ and a goal inaccuracy of 5×10^{-17}. For the design of the clock, techniques and approaches suitable for later space application are used, such as modular design, diode lasers, low power consumption, and compact dimensions. The atomic part is operative at the point where atoms are reliably trapped into the optical lattice. The latest results and future perspectives will be presented.

A 10.4 Mon 17:45 a310

Squeezed vacuum for sub-shot-noise frequency metrology — •Ilka Kruse[1], Karsten Lange[1], Jan Peise[1], Bernd Lücke[1], Luca Pezzè[2], Jan Arlt[3], Wolfgang Ertmer[1], Luis Santos[4], Augusto Smerzi[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]QSTAR, INO-CNR and LENS, Firenze, Italy — [3]Institut for Fysik og Astronomi, Aarhus Universitet, Denmark — [4]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

All interferometers with classical input states are limited by the shot-noise limit due to the finite particle number. In particular, this effect imposes a limitation for the stability of state-of-the-art atomic microwave clocks. In optics, squeezed vacuum is widely used to overcome this limitation and to operate interferometers beyond the shot-noise limit. Here we create a squeezed vacuum state in an ultracold atomic ensemble by spin-changing collisions. We employ this entangled state to demonstrate a sub-shot-noise frequency measurement in ^{87}Rb. Our frequency measurement shows a minimal fractional instability of 6.1×10^{-10} and a sensitivity of 1.5 dB below shot-noise.

A 10.5 Mon 18:00 a310

Decoherence related limitation of light shift immune Ramsey schemes — •Sergey Kuznetsov[1,2], Nils Huntemann[1], Christian Sanner[1], Burghard Lipphardt[1], Christian Tamm[1], and Ekkehard Peik[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institute of Laser Physics SB RAS, Novosibirsk 630090, Russia

Over the last years generalizations of Ramsey's method of separated oscillatory fields were proposed that provide immunity to probe-induced frequency shifts [1-3]. They are of particular importance for optical clocks, based on strongly forbidden transitions, where the probe light field induces a significant light shift via non-resonant coupling to higher lying levels. We apply such a technique for our optical clock based on the $^2S_{1/2} \leftrightarrow {}^2F_{7/2}$ transition of a single $^{171}Yb^+$ ion stored in a radio-frequency Paul trap [4]. Heating of the ion's motion during the probe period, however, degrades the cancellation of the light shift. We present a theoretical investigation of the effect and compare it with experimental data. We furthermore present a way to compensate for the effect of motional heating.

S.K. acknowledges the DAAD (German Academic Exchange Service) for financial support.

[1] V.I. Yudin, *et al.*, PRA **82**, 011804 (2010).
[2] R. Hobson, *et al.*, arXiv:1510.08144.
[3] T. Zanon-Willette, E. de Clercq, E. Arimondo arXiv:1511.04847.
[4] N. Huntemann *et al.*, PRL **109**, 213002 (2012).

A 11: Atomic clusters I (with MO)

Time: Monday 17:00–18:45 Location: f107

A 11.1 Mon 17:00 f107

Time-resolved luminescence detection from noble gas clusters after photon excitation — •Andreas Hans[1], Philipp Schmidt[1], Florian Wiegandt[2], Christian Ozga[1], Xaver Holzapfel[1], Till Jahnke[2], Martin Pitzer[1], Uwe Hergenhahn[3], Reinhard Dörner[2], Arno Ehresmann[1], and André Knie[1] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel — [2]Institut für Kernphysik, J.W. Goethe Universität, Max-von-Laue-Straße 1, 60438 Frankfurt — [3]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstraße 15, 04318 Leipzig

Fluorescence spectrometry is a powerful technique to investigate the electronic structure and decay mechanisms of atomic clusters. In these clusters the lifetimes of excited states can deviate significantly from those in the atomic case. It was shown that time-resolved detection enables an efficient discrimination of cluster and monomer signal [1]. This way features can be seperated, even if they overlap in excitation energy or emission wavelength. The lifetimes of excited states can give further information about the nature of the emission mechanism, e.g. emission from excitonic states, from evaporated atoms, or due to radiative charge transfer. We illustrate the experimental technique of time-resolved fluorescence spectrometry upon excitation by synchrotron radiation and present results from experiment on neon and argon clusters.

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

A 11.2 Mon 17:15 f107

The X-Ray Movie Camera: filming exploding xenon clusters by using a novel XUV imaging setup — •Mario Sauppe[1], Leonie Flückiger[2,1], Katharina Kolatzki[1], Bruno Langbehn[1], Maria Müller[1], Björn Senfftleben[1], Anatoli Ulmer[1], Jannis Zimbalski[1], Julian Zimmermann[1], Tobias Zimmermann[1], Tais Gorkhover[1,3], Christoph Bostedt[4,3], Cédric Bomme[5], Stefan Düsterer[5], Benjamin Erk[5], Marion Kuhlmann[5], Daniel Rolles[6,5], Dimitrios Rompotis[5], Rolf Treusch[5], Torsten Feigl[7], Thomas Möller[1], and Daniela Rupp[1] — [1]TU Berlin — [2]La Trobe University, Melbourne — [3]SLAC — [4]Argonne National Laboratory, Northwestern University, Chicago — [5]DESY — [6]Kansas State University — [7]optiX fab

From the first theoretical concepts on, the development of x-ray free electron lasers has been accompanied by the vision of the "molecular movie". Here we present a very recently performed XUV pump-probe experiment at the free-electron laser FLASH, using a novel two-detector setup for capturing "two-frame movies". While the scattering image on the first detector shows the intact single xenon cluster, delivering information about initial size, shape and exposed intensity, the second detector images the same cluster at a later stage. The new, permanently at FLASH installed, multilayer based split and delay stage DESC was used to study the light induced dynamics in large xenon clusters up to the longest possible delay of 650 ps.

A 11.3 Mon 17:30 f107

Influence of wavelength and pulse duration on single-shot x-ray diffraction patterns from non-spherical nanoparticles — •Katharina Sander[1], Christian Peltz[1], Charles Varin[2], Stefan Scheel[1], Thomas Brabec[2] und Thomas Fennel[1] — [1]Institute of Physics, University of Rostock — [2]Institute of Physics, University of Ottawa

The availability of intense femtosecond x-ray laser pulses from FELs has made it possible to visualize the structure and dynamics of nanosystems via single-shot diffractive imaging. It has been demonstrated that such experiments can be conducted on single free clusters to measure their size as well as their three-dimensional shape and orientation [1]. To model the corresponding diffraction patterns we use a microscopic model based on the discrete dipole approximation (DDA) [2]. We introduce a complex scaling DDA (CSDDA) and study single-shot x-ray diffraction patterns from non-spherical, absorbing nanotargets in the limit of linear response [3]. We employed the method to the scattering by icosahedral silver clusters and compare the scattering pattern for soft and hard x-ray radiation. Our results confirm that 3D structure information is only accessible for long wavelength, i. e. with soft x-ray pulses, but remains visible even for attosecond pulse durations for which the interference fringes vanish.

[1] I. Barke *et al.*, Nat. Comm. **6**, 6187, (2015)
[2] E. M. Purcell *et al.*, Astrophysical Journal **186**, 705-714, (1973)
[3] K. Sander *et al.*, J. Phys. B **48**, 204004 (2015)

A 11.4 Mon 17:45 f107

Interatomic coulombic decay (ICD) in He nanodroplets — •Mykola Shcherbinin[1], Aaron Laforge[1], Sai Smruti Samantaray[2], Vandana Sharma[3], Robert Richter[4], and Marcel Mudrich[1] — [1]University of Freiburg - Faculty of Mathematics und Physics, Freiburg, Germany — [2]Indian Institute of Technology - Dept. of Physics, Chennai, India — [3]Indian Institute of Technology, Department of Physics, Ordnance Factory Estate, India — [4]Elettra - Sincrotrone Trieste, Basovizza, Trieste, Italy

ICD is an important relaxation process for electronically excited atoms which are weakly bound in molecules and clusters [1]. While ICD has been observed in van der Waals clusters containing Ne, Ar, and Xe before, for He, ICD has so far been studied only for the He dimer [2]. We present a synchrotron study of ICD induced in He nanodroplets by simultaneously ionizing and exciting one He atom of the droplet in a shakeup process. Subsequent transfer of internal energy to the neighbouring atoms leads to the formation of He^+ atomic ions as well as small He_n^+ cluster ions, which we observe in electron-ion-ion coincidence. The corresponding photoelectron as well as ion kinetic energy spectra reveal the details of the ICD and subsequent fragmentation processes.

[1] L. S. Cederbaum et al., Phys. Rev. Lett. 79, 4778 (1997) [2] T. Havermeier et al., Phys. Rev. Lett. 104, 133401 (2010)

A 11.5 Mon 18:00 f107

Control of NIR avalanching in clusters by XUV-driven seed electrons — •Bernd Schütte[1,2], Mathias Arbeiter[3], Alexandre Mermillod-Blondin[1], Marc Vrakking[1], Thomas Fennel[3], and Arnaud Rouzée[1] — [1]Max-Born-Institut Berlin, Germany — [2]Imperial College London, UK — [3]Universität Rostock, Germany

The interaction of intense NIR laser pulses with clusters induces highly nonlinear dynamics on attosecond to nanosecond timescales. Recently, we made progress in understanding the relaxation dynamics of clusters in the picosecond to nanosecond range, where electron-ion recombination [1] and correlated electronic decay [2] play an important role.

Novel experimental approaches are required in order to gain access to the ionization dynamics on an attosecond to femtosecond timescale. Here we report on a method, in which cluster ionization is ignited by generating a few (< 10) seed electrons using an XUV pulse. The clusters become strongly ionized (charges up to Ar^{4+} are observed) by a time-delayed NIR laser pulse at an intensity of 3×10^{12} W/cm^2. This is far below the tunnel ionization threshold and corresponds to a ponderomotive potential of only 170 meV. The results are explained by avalanching via efficient inverse bremsstrahlung and electron impact ionization, as well as by resonant absorption of laser energy [3]. In the future, we will apply our concept in order to time-resolve the strong-field ionization of solid-density targets with attosecond resolution.

[1] B. Schütte *et al.*, Phys. Rev. Lett. **112**, 253401 (2014).
[2] B. Schütte *et al.*, Nat. Commun. **6**, 8596 (2015).
[3] B. Schütte *et al.*, arXiv:1509.03250 (2015).

A 11.6 Mon 18:15 f107

Ionization avalanching in clusters ignited by extreme-ultraviolet driven seed electrons — •Mathias Arbeiter[1], Bernd Schütte[2], Alexandre Mermillod-Blondin[3], Marc J. J. Vrakking[3], Arnaud Rouzée[3], and Thomas Fennel[1] — [1]University of Rostock, Germany — [2]Imperial College London, United Kingdom — [3]Max-Born-Institut, Berlin, Germany

Nanoplasma formation in rare-gas clusters under intense near-infrared (NIR) fields is triggered by atomic tunnel ionization. Subsequently, the ionization dynamics is dominated by impact ionization avalanching, efficient heating via inverse Bremsstrahlung (IBS), and resonant collective plasmon excitation. This ionization ignition, however, requires high intensities to reach the tunnelling threshold [1].

Recent experiments show that a few photo-activated seed electrons from an additional weak XUV pulse allow the control of ionization avalanching [2]. In this two-color scenario, highly charged ion emission occurs at NIR intensities far below the tunnel ionization threshold and is switched by the XUV field. We studied the XUV-induced nanoplasma formation as well as its subsequent NIR-driven evolution by molecular dynamics simulations. We find that avalanching starts with even very few seed electrons and that resonance effects are crucial to explain the observed ion emission. Further, our results support that the XUV-NIR scenario might enable the so far unprecedented investigation of IBS at low ponderomotive potentials.

[1] Rose-Petruck et al., Phys. Rev. A 55:1182 (1997).
[2] B. Schütte et al., arXiv:1509.03250 (2015)

A 11.7 Mon 18:30 f107

Cluster size determination of clusters by fluorescence spectrometry — •Xaver Holzapfel[1], Andreas Hans[1], Philipp Schmidt[1], Florian Wiegandt[2], Ltaief Ben Ltaief[1], Philipp Reiss[1], Reinhard Dörner[2], Arno Ehresmann[1], and André Knie[1] — [1]University of Kassel, Institute of Physics and Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), D-34132 Kassel, Germany — [2]Institute of Nuclear Physics, J. W. Goethe University, D-60438 Frankfurt, Germany

Clusters are finite aggregates and cover the gap between molecular and condensed matter physics and are thus used to study microscopic phenomena for many decades [1]. Rare gas clusters are created randomly by supersonic expansion and a scaling law is widely applied to express the mean cluster size of the distribution [2]. Different experiments report deviations between calculated and measured mean cluster size and further investigations are necessary for quantification [3]. Resonant excitation of outer valence electrons in rare gas clusters by synchrotron radiation yield characteristic informations in the resulting fluorescence yield about the mean cluster size. In the ongoing contribution we present a novel way of cluster size determination of clusters by photon induced fluorescence spectrometry (PIFS) [4].

[1] J. Jortner: Z. Phys. D 24, 247 (1992). [2] U. Buck et al.: J. Chem. Phys. 105, 5408 (1996). [3] H. Bergersen et al.: PCCP 8, 1891 (2006). [4] A. Knie et al.: New Journal of Physics 16, 102002 (2014).

A 12: Ultracold plasmas and Rydberg systems I (with Q)

Time: Monday 17:00–18:45 Location: f303

A 12.1 Mon 17:00 f303

Rydberg Spectroscopy in a Bose-Einstein Condensate — •Kathrin Sophie Kleinbach[1], Michael Schlagmüller[1], Tara Cubel Liebisch[1], Felix Engel[1], Fabian Böttcher[1], Karl M. Westphal[1], Robert Löw[1], Sebastian Hofferberth[1], Tilman Pfau[1], Jesús Pérez-Ríos[2], and Chris H. Greene[2] — [1]5. Physikalisches Insitut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Department of Physics and Astronomy, Purdue University, 47907 West Lafayette, IN, USA

Spectroscopy of a single Rydberg atom excited within a Bose-Einstein condensate is presented. Not only a frequency shift proportional to the density is observed, as discovered by Amaldi and Segre in 1934, but an assymetric broadening, which depends on the principal quantum number n. The line broadening depends on the interaction potential energy curves of the Rydberg electron scatterer with the neutral atom perturber. In Rb there is a shape resonance for the triplet p-wave scattering of e-Rb(5s) at 0.02 eV leading to a potential with a large energy shift, which crosses the lower lying nS, (n-2)D, and (n-1)P states. When a nS +N x 5S1/2 state is photoassociated, neutral atom perturbers near the crossing with the shape resonance potential become relevant, leading to large n-dependent line broadenings. We present a simple microscopic model for the spectroscopic line shape by treating the atoms overlapped with the Rydberg orbit as zero-velocity, independent, point-like particles, with binding energies associated with their ion-neutral separation, and good agreement is found.

A 12.2 Mon 17:15 f303

Non adiabatic quantum state preparation with Rydberg atoms — •Jiří Minář, Matteo Marcuzzi, Emanuele Levi, and Igor Lesanovsky — School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom

We propose a non-adiabatic protocol to create antiferromagnetic GHZ states in a chain of Rydberg atoms. The proposed implementation relies on the blockade mechanism between atoms in Rydberg states and individual site addressing. The procedure is then generalized in order to create ground states of a many body Rokhsar-Kivelson Hamiltonian, which describes the physics of a one dimensional spin-half chain with repulsive long range interactions. We analyze the performance of the scheme accounting for various effects, such as the interplay between the repulsive interaction strength and the Rabi frequency of the addressing beam, the effect of the tails of the long range interaction or the robustness with respect to the noise in the experimental parameters.

A 12.3 Mon 17:30 f303

Electron pair formation in He (Cooper pair) — •Hubert Klar — DHBW Lörrach

The empirical shell modell for atoms predicts for two-electron atoms an infinity of high double Rydberg states of the form He(nl,n'l'). A ficticiuos force presented in this conference elsewhere, however, distroys this oversimplified picture. In e-He+(nl) scattering we observe a spontanious time-reversal symmetry breaking. The incoming wavefront is turned towards the top of a potential ridge which leads to an e-e attraction. A Cooper pair is born. After reflection at a centrifugal barrier the outgoing wave diverges from the ridge. Slightly below the threshold for double escape the wave may be reflected at an outer barrier or slightly above threshold the Cooper pair decays immediately. Our quantum mechanical result compares favorably with Wannier's classical ionization theory and with experimental data.

A 12.4 Mon 17:45 f303

Coherence in a cold atom photon switch — •Weibin Li and Igor Lesanovsky — School of Physics and Astronomy, University of Nottingham, Nottingham, UK

We study coherence in a cold atom single photon switch where the gate photon is stored in a Rydberg spinwave. With a combined field theoretical and quantum jump approach and by employing a simple model description we investigate systematically how the coherence of the Rydberg spinwave is affected by scattering of incoming photons. With large-scale numerical calculations we show how coherence becomes increasingly protected with growing interatomic interaction strength. For the strongly interacting limit we derive analytical expressions for the spinwave fidelity as a function of the optical depth and bandwidth of the incoming photon.

A 12.5 Mon 18:00 f303

Emergent devil's staircase without particle-hole symmetry in Rydberg quantum gases with competing attractive and repulsive interactions — •Zhihao Lan, Jiří Minář, Emanuele Levi, Weibin Li, and Igor Lesanovsky — School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

The devil's staircase is a fractal structure that characterizes the ground state of one-dimensional classical lattice gases with long-range repulsive convex interactions. Its plateaus mark regions of stability for specific filling fractions which are controlled by a chemical potential. Typically such staircase has an explicit particle-hole symmetry. Here we introduce a quantum spin chain with competing short-range attractive and long-range repulsive interactions, i.e. a non-convex potential. In the classical limit the ground state features generalized Wigner crystals that - depending on the filling fraction - are either composed of dimer particles or dimer holes which results in an emergent complete devil's staircase without explicit particle-hole symmetry of the underlying microscopic model. In our system the particle-hole symmetry is lifted due to the fact that the staircase is controlled through a two-body interaction rather than a one-body chemical potential. The introduction of quantum fluctuations through a transverse field melts the staircase and ultimately makes the system enter a paramagnetic phase. For intermediate transverse field strengths, however, we identify a region, where the density-density correlations suggest the emergence of quasi long-range order. We discuss how this physics can be explored with Rydberg-dressed atoms held in a lattice.

A 12.6 Mon 18:15 f303

Dynamics of cluster formation and non-equilibrium phases of Rydberg excitations in the anti-blockade regime — •Fabian Letscher[1,2], Thomas Niederprüm[1], Oliver Thomas[1,2], Tanita Eichert[1], Herwig Ott[1], and Michael Fleischhauer[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

Motivated by recent experiments we discuss theoretically the dynamics and temporal correlations of Rydberg excitations in the anti-blockade regime. In this regime spatially extended regions of atoms in the ground state coexist with connected clusters of Rydberg excitations. Measurements performed on an atomic lattice gas show that the non-equilibrium dynamics in the steady state is characterized by strong temporal bunching and large correlation times. The latter arise from two competing intrinsic timescales: In the two-step excitation process, the first Rydberg excitation is highly suppressed, while the second excitation is strongly enhanced. We simulate the dynamics of large lattice systems using a many-body rate equation model which shows good agreement with the experiments. To understand the main features of the two-particle correlations we introduce a simplified cluster model and discuss its many-body dynamics.

A 12.7 Mon 18:30 f303

Enhancement of a Single-Photon Transistor by Stark-Tuned Förster Resonances — •Christoph Tresp[1], Hannes Gorniaczyk[1], Przemyslaw Bienias[2], Asaf Paris-Mandoki[1], Weibin Li[3], Ivan Mirgorodskiy[1], Christian Zimmer[1], Hans Peter Büchler[2], Igor Lesanovsky[3], and Sebastian Hofferberth[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Institut für theoretische Physik III, Universität Stuttgart, Germany — [3]School of Physics and Astronomy, University of Nottingham, United Kingdom

We report on the use of Stark-tuned Förster resonances to enhance the gain of a Rydberg mediated single-photon transistor and the non-destructive detection of single Rydberg atoms. We show that our all-optical detection scheme enables high-resolution spectroscopy of Förster resonances, revealing the fine structure splitting of Rydberg states and the splitting of Zeeman-substates. We discuss how excitation hopping between a stored Rydberg excitation and incoming source polaritons can be minimized by choice of the Rydberg states. We then proceed to use a particularly suited two-color resonance to demonstrate scattering of over 100 source photons from a single Rydberg excitation, demonstrating efficient all optical Rydberg detection. Finally, we investigate the Rydberg transistor in coherent operation by reading out the gate photon after scattering source photons. Due to projection of the stored spin wave and phase imprinting, the coherence of the gate excitation is affected by scattered and transmitted source photons.

A 13: Precision Measurements and Metrology IV (with Q)

Time: Tuesday 11:00–13:00 Location: a310

A 13.1 Tue 11:00 a310

A micromechanical proof-of-principle experiment for measuring the gravitational force of milligram masses — •Jonas Schmöle and Markus Aspelmeyer — Faculty of Physics, University of Vienna

We address a simple question: how small can one make a gravitational source mass and still detect its gravitational coupling to a nearby test mass? We describe an experimental scheme based on micromechanical sensing that should allow to observe gravity between milligram-scale source masses, thereby improving the current smallest source mass values by three orders of magnitude. We also discuss the implications of such measurements both for improved precision measurements of Newton's constant and for a new generation of experiments at the interface between quantum physics and gravity.

A 13.2 Tue 11:15 a310

Fundamental uncertainty of the speed of light in vacuum — •Daniel Braun[1], Fabienne Schneiter[1], and Uwe R. Fischer[2] — [1]Institute of Theoretical Physics, University Tübingen, 72076 Tübingen, Germany — [2]Seoul National University, Department of Physics and Astronomy, Center for Theoretical Physics, 151-747 Seoul, Korea

The speed c of light in vacuum is a natural constant of crucial importance for the foundations of physics and many applications. Advanced theories predict quantum fluctuations of c or even a time-evolution. Combining arguments from quantum parameter-estimation-theory and classical general relativity, we here establish rigorously the existence of lower bounds on the precision to which c can be determined *in principle*. They result in minimal uncertainties of lengths measured through the propagation of light signals that are comparable to predictions from quantum gravity theory. However, the minimal uncertainties depend on the quantum state of light used for the measurement, challenging thus the idea of quantum fluctuations of geometry that exist independently of a measurement prescription. In particular, our novel, measurement-based approach predicts that fluctuations on the length scale of the Planck length are only accessible through quantum-enhanced measurements that use highly non-classical states of light.

A 13.3 Tue 11:30 a310

Laser Interferometer Space Antenna Optical Bench Test Bed — •Michael Tröbs[1], Germán Fernandez Barranco[1], Michael Chwalla[2], Ewan Fitzsimons[2], Oliver Gerberding[1], Gerhard Heinzel[1], Christian Killow[3], Maike Lieser[1], Neda Meshksar[1], Vitali Müller[1], Michael Perreur-Lloyd[3], David Robertson[3], Sönke Schuster[1], Thomas Schwarze[1], Henry Ward[1], Max Zwetz[1], and Karsten Danzmann[1] — [1]Albert Einstein Institut — [2]Airbus Defense and Space — [3]University of Glasgow

The Laser Interferometer Space Antenna (LISA) is a future space-based interferometric gravitational-wave detector consisting of three spacecraft in a triangular configuration in Earth-like orbits around the sun. The interferometric measurements of path length changes between satellites will be performed on so-called optical benches in the satellites. Angular misalignments of the interfering beams will couple into the length measurement and represent a significant noise source (tilt-to-length coupling). Imaging systems are foreseen to reduce this tilt-to-length coupling. We report on an optical bench test bed to investigate imaging systems and the test results. The tilt-to-length coupling requirement of 25 um/rad was met with a two-lens imaging system.

A 13.4 Tue 11:45 a310

The journey to noise reduced and ultra stable interferometers for high-precision metrology — •Katharina-Sophie Isleif, Oliver Gerberding, Moritz Mehmet, Michael Tröbs, Karsten Danzmann, and Gerhard Heinzel — Albert Einstein Institut, Institut für Gravitationsphysik, 30167 Hannover

Laser interferometry achieving pm/$\sqrt{\text{Hz}}$ sensitivities in the mHz-frequency range is the key technology for satellite missions in the area of gravitational wave detection and geodesy, but it requires sophisticated interferometer layouts that suppress classical interferometer noise sources like scattered light, ghost beams, laser frequency noise and misalignments just by design. We present the recipe for a successful low-noise interferometer construction, starting with a digital design of the interferometer using the C++ library IfoCad, followed by an optimisation in which we are looking at the simulated interferometer data. Different optimisation parameters, like the overall interferometer architecture, the usage of wedged components and the correct positions, are discussed on the basis of two examples: A Mach-Zehnder interferometer used for the test mass readout in future geodesy missions via deep frequency modulation interferometry, and the 3-Backlink-Setup, an experiment for the laser interferometer space antenna (LISA). The interferometer construction combines the manufacture of a template, a thermally stable quasi-monolithic assembly of the components and a Coordinate Measuring Machine. We compare the simulation with a setup assembled by hand and an optimally designed interferometer.

A 13.5 Tue 12:00 a310

Initial measurements using the eLISA Phasemeter optical testbed — •Germán Fernández Barranco, Daniel Penkert, Thomas Schwarze, Oliver Gerberding, and Gerhard Heinzel — Max Planck Institute for Gravitational Physics, Callinstraße 38 30167 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. 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 as well as initial measurements. The testbed 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 in the eLISA band (0.1 mHz - 1 Hz) with a dynamic range of 10 orders of magnitude using beatnotes between 2 and 25 MHz. The initial measurements presented here fulfill the 1 microcycle/sqrt(Hz) requirement down to 100 mHz. Once performance over the full bandwidth is achieved, other components of the eLISA metrology chain (clock noise transfer and removal, inter-satellite ranging and communication) can be tested in this setup.

A 13.6 Tue 12:15 a310

Deep frequency modulation interferometry — •Oliver Gerberding[1,2], Katharina-Sophie Isleif[1], Thomas Schwarze[1], Moritz Mehmet[1], Gerhard Heinzel[1], and Felipe Guzman Cervantes[2] — [1]Albert Einstein Institut, Institut für Gravitationsphysik, Callinstraße 38, 30167 Hannover — [2]Joint Quantum Institute, National Institute of Standards and Technology, Maryland, USA

Laser interferometry with pm/$\sqrt{\text{Hz}}$ precision and multi-fringe dynamic range at low frequencies is a core technology to measure the motion of various objects (test masses) in space and ground based experiments for gravitational wave detection and geodesy. Even though available interferometer schemes are well understood, their construction remains complex, often involving the need to build quasi-monolithic optical benches with dozens of components. Here we present a new scheme that uses strong laser frequency modulations in unequal arm-length interferometers in combination with a fit algorithm originally developed for the readout of strong phase modulations, the so-called deep phase modulation interferometry. This combination is the basis for the development of a more elegant interferometric sensing toolset for future missions that requires much smaller and simpler interferometric sensors while using advanced digital signal processing for the phase recovery. We discuss noise influences, both from classic sources and new, technique-specific couplings and we present first results achieved in simulations and experiments.

A 13.7 Tue 12:30 a310

Seismische Isolationsplattform für den AEI 10m-Prototypen — •Robin Kirchhoff — AEI 10m Prototype Team

Im Albert-Einstein-Institut in Hannover wird zur Zeit ein Michelson-Interferometer mit 10m Armlänge aufgebaut, an dem neuartige Techniken für die Gravitationswellendetektion entwickelt und getestet werden. Ein elementarer Bestandteil ist die seismische Isolationsplattform AEI-SAS, welche als Grundlage für die Optiken und weitere Komponenten des Interferometers dient. Das Ziel dieser Plattform ist es, die Störungen durch im Boden vorhandene Seismik bestmöglich zu minimieren. Dies wird einerseits durch passive Mechanismen umgesetzt, welche auf dem Prinzip des Pendels basieren, andererseits wird eine aktive Isolation verwendet, bei der die Bewegung der Plattform ausgelesen, das entstandene Signal bearbeitet und die Bewegung über Aktuatoren minimiert wird. Die Umsetzung dieser passiven und aktiven Techniken am AEI 10m-Prototypen ist Thema dieses Vortrages.

A 13.8 Tue 12:45 a310

Dreifachpendelaufhängung für das AEI 10m-Prototypinterferometer — •Johannes Lehmann — AEI 10m Prototype Team

Im AEI in Hannover wird ein Interferometer mit 10m Armlänge aufgebaut, dessen Empfindlichkeit durch das Standard Quanten Limit begrenzt sein soll. Dafür müssen andere Rauschquellen wie die Seismik reduziert werden. Als Vorisolation werden dazu Seismische Isolationsplattformen verwendet, auf denen die Komponenten des Interferometers aufgebaut werden. Für die Spiegel des Interferometers wird eine weitere Isolation benötigt, die durch ein Dreifachpendel als Aufhängung gewährleistet werden soll. Das Design und der Aufbau dieser Aufhängung wird im Vortrag vorgestellt.

A 14: Ultracold Atoms, Ions and Molecules III (with Q)

Time: Tuesday 11:00–13:15 Location: f342

A 14.1 Tue 11:00 f342

Towards an optical phase shift based on Rydberg blockade — •Daniel Tiarks, Steffen Schmidt, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, 85748 Garching, Deutschland

Controlling the interaction between single photons is important for many quantum information technologies. Recently we demonstrated [1,2,3] that an opaque medium in which single photons are converted into stationary Rydberg excitations can be used to control the transmission of a subsequent light pulse by using electromagnetically induced transparency. Manipulation of coherent superpositions requires, however, non-dissipative interactions that only affect the phase of the light.

In this work we report on our recent progress towards realizing controlled phase shifts of single photons extending the work of [4,5]. We store photons in highly exited Rydberg states which change the refractive properties of the medium due to Rydberg blockade. A subsequent light pulse will thus experience a significant phase shift.

[1] S. Baur et al., PRL 112, 073901 (2014)
[2] D. Tiarks et al., PRL 113, 053602 (2014)
[3] H. Gorniaczyk et al., PRL 113, 053601 (2014)
[4] O. Firstenberg et al., Nature 502, 71 (2013)
[5] A. Feizpour et al., Nature Physics 11, 905 (2015)

A 14.2 Tue 11:15 f342

Towards a single-photon source based on Rydberg FWM in thermal vapors — •Fabian Ripka, Yi-Hsin Chen, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

Photonic quantum devices based on atomic vapors at room temperature combine the advantages of atomic vapors being intrinsicly reproducable as well as semiconductor-based concepts being scalable and integrable. One key device in the field of quantum information are on-demand single-photon sources. A promising candidate for realization relies on the combination of two atomic effects, namely four-wave mixing (FWM) and the Rydberg blockade effect.

Coherent dynamics to Rydberg states on ns timescales [1] and sufficient Rydberg interaction strengths [2] have already been demonstated in thermal vapors. These effects could also be observed in a pulsed FWM scheme [3]. Recently, we investigated a storage-retrieval scheme by means of two pulses. We could determine the collective lifetime of the Rydberg coherence to be 1.1ns, limited by motional dephasing. Additionally, this double-pulsed FWM scheme enables an enhanced generation efficiency of output photons up to tens of photons per pulse. The goal is then to reduce this number of photons by interaction-induced suppression of the Rydberg coherence, in order to obtain non-classical photon states and even single photons per FWM cycle.

[1] Huber et al., PRL 107, 243001 (2011)
[2] Baluktsian et al., PRL 110, 123001 (2013)
[3] Huber et al., PRA 90, 053806 (2014); Chen et al., accepted by Appl. Phys. B

A 14.3 Tue 11:30 f342

Imaging of Rydberg atoms and light propagation through a non-linear non-local medium — •Vladislav Gavryusev, Miguel Ferreira-Cao, Adrien Signoles, Gerhard Zuern, Renato Ferracini, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Electronically highly excited (Rydberg) atoms constitute a system with long range interactions which allows to study many intriguing phenomena, ranging from quantum non-linear optics to dipole-mediated energy transport. To optically image Rydberg atoms we use the interaction enhanced imaging technique [1] which exploits interaction-induced shifts on highly polarizable excited states of probe atoms, that can be spatially resolved via an electromagnetically induced transparency resonance. The sensitivity is tunable up to few Rydberg excitations by using strong dipole-dipole interactions, induced via a Förster resonance or by direct dipolar coupling between the involved states. By monitoring the Rydberg distribution we observed the migration of Rydberg electronic excitations, driven by quantum-state changing interactions [2], and we are working towards controlling this dynamic. The strong interactions also affect the optical properties of the medium and can allow to explore a highly non-linear and non-local regime, where the response will depend both on local light intensity and atom density, leading to pattern formation and effective photon-photon interactions.

[1] G. Günter et al., Phys. Rev. Lett. 108, 013002 (2012)
[2] G. Günter et al., Science 342, 954 (2013)

A 14.4 Tue 11:45 f342

Two-body interactions and decay of three-level Rydberg-dressed atoms — •Stephan Helmrich, Alda Arias, Nils Pehoviak, Emil Pavlov, Tobias Wintermantel, and Shannon M Whitlock — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

We theoretically analyse the interactions and decay rates for atoms dressed by multiple laser fields to strongly interacting Rydberg states using a quantum master-equation approach. In this framework a comparison of two-level and three-level Rydberg-dressing schemes is presented. We identify a resonant enhancement of the three-level dressed interaction strength which originates from cooperative multiphoton couplings. This feature can be effectively used for Rydberg dressing under electromagnetically-induced-transparency condition combined with small single-photon detunings. The cooperative enhancement in interaction is accompanied by low levels of distance-dependent dissipation. We will present first experimental studies of Rydberg dressing of ultracold potassium atoms with dressing times comparable to the timescales for atomic motion. In the future, near-resonant Rydberg dressing in three-level atomic systems may enable the realization of laser driven quantum fluids with long-range and anisotropic interactions and with controllable dissipation.

A 14.5 Tue 12:00 f342

Dissipative Preparation of Entangled Many-Body States with Rydberg Atoms — •Maryam Roghani and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

We study a one-dimensional atomic lattice gas where interactions are mediated by a weak admixture of a Rydberg state. This Rydberg dressing is combined with dissipative dynamics induced by optical pumping. We derive an effective quantum master equation for the ground state manifold and show that this driven dissipative dynamics can result in highly entangled stationary states. For a defined set of parameters, this non-trivial entangled many-body steady state is the ground state of a Hamiltonian which possesses a manifold of approximate Rokhsar-Kivelson points. This Rokhsar-Kivelson state is a coherent superposition of all possible configurations respecting the dipole blockade induced by the Rydberg dressing [1].

[1] I. Lesanovsky, Phys. Rev. Lett. 106,025301 (2011).

A 14.6 Tue 12:15 f342

Dipolar photon- and excitation-transport in Rydberg-EIT media — •Daniel Viscor and Thomas Pohl — Max Planck Institut für Physik komplexer Systeme

We investigate the effects of excitation-exchange interactions on the propagation dynamics of quantum light through a strongly interacting Rydberg gas under conditions of electromagnetically induced transparency (EIT). Considering the most simple setting of a single Rydberg-polariton interacting with a stored collective Rydberg excitation, we show that long-range excitation-exchange between the two spin wave components gives rise to a photon propagation that differs fundamentally from the more common case of static van der Waals interactions. Using numerical simulations and analytical arguments, we characterise the resulting dissipative and dispersive optical response of the medium and discuss potential applications of the emerging new features.

A 14.7 Tue 12:30 f342

Nonlinear Optics in a Rydberg-Excited Semiconductor Cavity — •Valentin Walther, Robert Johne, and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden

Recent experiments have demonstrated excitons with extraordinarily large binding energies in some two-dimensional semiconductors (TMDCs), whose Rydberg states give rise to giant interactions and, therefore, hold great promise for optical utility.

We evaluate the optical response under conditions of electromagnetically induced transparency (EIT), accounting for the full excited level structure and numerous decoherence mechanisms in a semiconductor. Strong exciton-exciton interactions result in enormous effective photon-photon potentials. Using experimental parameters, we show that the photonic nonlinearity exceeds that of traditional semiconductors by several orders of magnitude and we assess the material properties required for coherent optical applications.

Further, we investigate interesting optical effects in the transverse mode structure of a driven-dissipative cavity arising from the unusually large nonlinearity.

A 14.8 Tue 12:45 f342

Multicritical behaviour in dissipative Ising models — •Vincent Overbeck[1], Mohammad Maghrebi[2], Alexey Gorshkov[2], and Hendrik Weimer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Deutschland — [2]Joint Quantum Institute, NIST/University of Maryland, College Park, MD, USA

Stationary states of dissipative quantum many-body systems are of great interest, having the possibility to undergo dissipative phase transitions that are fundamentally different from thermal equilibrium. We consider a dissipative extension of the Ising model, where the dissipation preserves the Z_2 symmetry. Using a variational approach [1,2], we find a second order and a first order phase transition line, which meet at a multicritical point that is not found in the equilibrium case. We make an analysis of the full phase diagram, discussing in detail the role of fluctuations in this model. Finally, we present a possible experimental realization based on Rydberg-dressed spin interactions.

[1] H. Weimer, Variational Principle for Steady States of Dissipative Quantum Many-Body Systems, Phys. Rev. Lett. **114**, 040402 (2015).

[2] H. Weimer, Variational analysis of driven-dissipative Rydberg gases, Phys. Rev. A **91**, 063401 (2015).

A 14.9 Tue 13:00 f342

Effect of lattice geometry on bosonic quantum phases of Rydberg dressed lattice gases — •Andreas Geissler[1], Mathieu Barbier[1], Yongqiang Li[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe Universität Frankfurt am Main, Germany — [2]Department of Physics, NUDT, China

Our recent reults [1] have shown the rich diversity of quantum phases which are induced by the strong correlations inherent to Rydberg dressed bosonic atoms trapped in optical lattices. While experimental feasibility of the dressing itself has just recently been demonstrated for the first time [2], a better understanding of the crystallisation is still required. We analyse Rydberg dressed lattice systems for various lattice geometries by further applying our real space dynamical mean-field theory (RB-DMFT) methods. These results serve as a benchmark of Gutzwiller type mean-field simulations where dissipative dynamics can be simulated within the Lindblad master equation approach. Within the latter approach we can observe crystallisation dynamics and the stability of crystalline structures. We additionally focus on quasiparticle excitations which we determine from linearised Gutzwiller equations.

[1] A. Geißler et al., arXiv:1509.06292, [physics.cond-mat]

[2] Y.-Y. Jau et al., Nat. Phys., nphys3487 (2015)

A 15: Atomic clusters II (with MO)

Time: Tuesday 14:30–16:30 Location: f107

A 15.1 Tue 14:30 f107

Laser-induced delayed electron emission of Co_4^- clusters — •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, 67663 Kaiserslautern, Germany

The Cryogenic Trap for Fast ion beams CTF located at the Max-Planck-Institute for nuclear physics is an electrostatic ion beam trap setup for the study of dynamical processes of stored ion beams. A tunable optical parametric oscillator laser is used to induce delayed electron detachment, monitored by the rate of neutralized particles leaving the trap region as a function of time after laser excitation. By comparing the count rates after laser excitation at various photon energies ranging from 0.95 eV to 1.88 eV and different storage times the ions' internal energy distribution can be reconstructed. Two types of ion sources have been used to produce Co_4^-: First, a caesium ion sputter source, known to produce ro-vibrationally excited ions at temperatures of more than 1000 K, and second, a laser vaporization source with helium expansion to produce ions with ro-vibrational excitation levels corresponding to low temperatures. The cooling and heating process of Co_4^- has been observed.

A 15.2 Tue 14:45 f107

Quantum Monte Carlo study of Mg-doped droplets of helium-4 at zero temperature — •Yaroslav Lutsyshyn and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Mg-doped helium droplets are believed to have an observable metastable state in which the alkali atoms remain separated by a considerable distance, thus forming so-called "atomic foam". The exact nature of such a state is not well understood. We study the long-distance interaction induced between a pair of Mg atoms due to the confinement effects in the superfluid. We will present quantum Monte Carlo results for the effective interaction of the dopants.

A 15.3 Tue 15:00 f107

Slow electrons from intense NIR laser-cluster interactions — •B. Schütte[1,2], M. Arbeiter[3], T. Fennel[3], A. I. Kuleff[4], J. Lahl[5,6], T. Oelze[5], M. Krikunova[5], D. R. Austin[1], C. Strüber[1], P. Ye[1], M. J. J. Vrakking[2], J. P. Marangos[1], and A. Rouzée[2] — [1]Imperial College London, UK — [2]Max-Born-Institut Berlin, Germany — [3]Universität Rostock, Germany — [4]Universität Heidelberg, Germany — [5]TU Berlin, Germany — [6]Lund University, Sweden

Clusters in intense NIR fields absorb laser energy extremely efficiently, resulting in the observation of keV electrons. Here we report on a surprisingly dominant contribution of slow electrons with kinetic energies < 2 eV following the ionization of rare-gas clusters by NIR pulses ($I = 5 \times 10^{14}$ W/cm^2). Our THz streaking results reveal that these electrons are emitted with a significant delay in the picosecond to nanosecond range. We show that the emission of slow electrons can be expected from correlated electronic decay (CED) [1], which may involve autoionization processes [2]. In comparison to CED, where one electron relaxes from a Rydberg state to the ground state and transfers its excess energy to a nearby electron [1], the rates of intra-Rydberg CED processes can be orders of magnitude larger, and are associated with slow-electron emission. Our results may be the key to explaining the emission of highly charged ions from clusters that are observed in spite of the very efficient recombination of ions and electrons [3].

[1] B. Schütte *et al.*, Nat. Commun. **6**, 8596 (2015).
[2] B. Schütte *et al.*, Phys. Rev. Lett. **114**, 123002 (2015).
[3] B. Schütte *et al.*, Phys. Rev. Lett. **112**, 253401 (2014).

A 15.4 Tue 15:15 f107

Photo excitation of size and charge-state selected multi-anionic aluminum clusters — •Markus Wolfram[1], Stephan König[1], Franklin Martinez[2], Gerrit Marx[1], Lutz Schweikhard[1] und Albert Vass[1] — [1]Felix-Hausdorff-Straße 6,Institut für Physik, Greifswald, Deutschland — [2]University of Rostock, Germany

Studies of photo excited di-anionic gold clusters indicated that in addition to the well known competing mechanisms of electron detachment and cluster fragmentation the simultaneous emission of two electrons is another possible decay channel. However, in this case the neutral product cluster was no longer stored in the Penning trap and therefore could not be detected. In the meantime, by simultaneously storing cluster anions and electrons the production of gold and aluminum cluster anions of up to the sixth and tenth charge state, respectively, has been achieved. Furthermore, the experimental procedures for cluster preparation have been refined using the SWIFT (Stored Waveform Inverse Fourier Transform) technique. Thus, it is now possible to investigate the photo-induced decay pathways of stored anionic clusters as a function of cluster size n and charge state z beyond the dianions. After preliminary experiments with Nd:YAG laser beams, it is planned to extend the available photon energies by use of an OPO laser. In this contribution the recent modifications of the experimental setup and first results on the photo excitation of size and charge-state selected multi-anionic aluminum clusters will be presented. The project is funded by the Collaborative Research Center (SFB) 652

A 15.5 Tue 15:30 f107

Energetic Highly-charged Ion Emission from Laser-induced Coulomb Explosion of Silver Clusters — •Dzmitry Komar, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universitaet Rostock, Institut fuer Physik, Albert-Einstein-Str. 24, D-18059 Rostock

Silver nanoparticles of about 4000 atoms are exposed to intense 130 fs optical single and double laser pulses (in the range 10^{13}-10^{14} W/ cm^2). The detection system includes a newly developed momentum spectrometer which operates similar to a classical Thomson parabola spectrometer. However, the new setup features practically underground free measurement which allows for a huge dynamic range, an improved energy resolution and a significantly enhanced transmission. Charged resolved energy ion spectra from the laser-exposed Coulomb explosion of small silver clusters have been recorded. Under single laser pulse excitation conditions, multiply charged ions Ag q+ (up to q=12) with energies exceeding 14 keV have been detected. Optical delay studies show the impact of nanoplasmonic oscillations on the ionization dynamics which reflects in the ion charge states as well as the recoil energies. Under optimal pump-probe conditions, i.e. when the Mie-frequency of the expanding nanoplasma matches the laser-nanoparticle resonance, significantly higher charge states (up to q=19) and more energetic ions (up to 300 keV) are observed. The collective electron motion most pronounced at the plasmon resonance has an impact on the angular emission distribution of the ions. Especially the highly charged ions are predominantly emitted along the laser polarization axis.

A 15.6 Tue 15:45 f107

Slow electrons from direct photoionization in clusters — •Abraham Camacho Garibay, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS, Dresden

Sequential ionization of clusters by intense XFEL pulses is known to give a broad plateau like photoelectron spectrum. For sufficiently high charge states, the coulomb potential can be deep enough to trap the outgoing photoelectron, giving rise to a nanoplasma (an effect known as frustrated ionization). This nanoplasma eventually thermalizes and evaporates, giving rise to a high peak near zero. We have found that this high peak is formed not only by evaporating plasma electrons, but it also has a component from directly emitted photoelectrons that naturally arises during the transition between the sequential ionization regime into the frustrated ionization one. We have found that this effect can be explained in a simple way by noting that plasma electrons do not increase the system charge, which requires a small modification in the probability of electron emission as a function of position. By making a simple approximation it is possible to obtain an analytical formula with good agreement with the results obtained by means of molecular dynamics simulations.

A 15.7 Tue 16:00 f107

Surface composition of free mixed NaCl/Na_2SO_4 nanoscale aerosols — •Burkhard Langer, Egill Antonsson, Christopher Raschpichler, Dmitry Marchenko, and Eckart Rühl — Physikalische Chemie, Freie Universität Berlin

Nanoscopic NaCl/Na_2SO_4 aerosols (d ≈ 70 nm) serve as a model for marine salt aerosols. The crystallization process of droplets of such binary salt solutions was measured using synchrotron radiation from BESSY II by photoelectron spectroscopy, which is particularly surface sensitive. Intensities of the chlorine 2*p* and the sulfur 2*p* lines in photoelectron spectra taken at a photon energy of 270 eV are compared for different mixing ratios of the salts. This allows us to determine the chemical surface composition of free, mixed NaCl/Na_2SO_4 aerosols grown by drying aqueous saline droplets. It turns out that the ratio of the surface constituents deviates significantly from the mixing ratio in the aqueous solution, whereby the minority species in droplets are increasingly found on the surface of the solid mixed aerosols. This result can be explained by the nucleation process during crystallization, in which each of the two salts produces its own pure crystal nuclei rather than crystallizing together. The variation of the surface ion concentration as a function of the mixing ratio in the droplets, as observed here for nanoscopic aerosols, is in contrast to earlier findings suggesting a core-shell structure of mixed salt aerosols that are in the micron range [1].

[1] Z. Ge *et al.*, J. Colloid Interface Sci. **183**, 68-77 (1996).

A 15.8 Tue 16:15 f107

Assigning cluster size and laser intensity specific features to single cluster ion spectra — •M. Müller[1], M. Sauppe[1], A. Ulmer[1], B. Langbehn[1], Y. Ovcharenko[1], L. Flückiger[1], S. Toleikis[2], H. Höppner[2], S. Stephan[2], T. Gorkhover[1], J.-P. Müller[1], D. Rupp[1], and T. Möller[1] — [1]TU Berlin, Hardenbergstr. 36, 10623 Berlin — [2]DESY, Notkestr. 85, 22607, Hamburg

Intense laser-cluster interaction results in nanoplasma formation which is a topic of current interest. Due to the finite size of clusters and their availability in the gas phase, no energy can dissipate into surroundings. An inherent difficulty in the analysis of most experimental results of laser-cluster interaction has been the convolution of the cluster size distribution and focal density distribution. Single-shot-single-particle experiments avoid averaging over the two mentioned distributions and allows for uncovering a large variety of individual processes. We present results from an experiment at the Free-Electron Laser FLASH (Hamburg, Germany) with a strong NIR and XUV-FEL source available at the same time. The ion-time-of-flight (TOF) spectra from clusters induced by intense and short NIR laser pulses taken in the single-shot-single-particle mode exhibit features depending either mainly on the laser intensity or the cluster size. For the latter we will compare our results with the size distribution derived from the FEL induced diffraction patterns. These assignments will be relevant for all kinds of single cluster experiments using optical lasers.

A 16: Collisions, scattering and correlation phenomena II

Time: Tuesday 14:30–16:30 Location: f142

Invited Talk A 16.1 Tue 14:30 f142

Observation of the Efimov state of the helium trimer — •Maksim Kunitski[1], Stefan Zeller[1], Jörg Voigtsberger[1], Anton Kalinin[1], Lothar Ph. H. Schmidt[1], Markus Schöffler[1], Achim Czasch[1], Wieland Schöllkopf[2], Robert E. Grisenti[1], Till Jahnke[1], Dörte Blume[3], and Reinhard Dörner[1] — [1]Institut für Kernphysik, Goethe-Universität Frankfurt/M — [2]Department of Molecular Physics, Fritz-Haber-Institut, Berlin — [3]Department of Physics and Astronomy, Washington State University, USA

In 1970 Vitali Efimov predicted remarkable counterintuitive behaviour of a three-body system made up of identical bosons. Namely, a *weakening* of pair interaction in such a system brings about in the limit appearance of *infinite* number of bound states of a huge spatial extent. The helium trimer has been predicted to be a molecular system having an excited state of this Efimov character under natural conditions.

Here we report experimental observation of the Efimov state of $^4He_3$ by means of Coulomb explosion imaging of mass-selected clusters [1]. Structures of the excited Efimov state of the $^4He_3$ are about eight times larger than those of the ground state, which is in accordance with theory. Whereas the ground state corresponds to an almost randomly distributed cloud of particles [2], the excited Efimov state is dominated by configurations in which two atoms are close to each other and the third one further away.

[1] M. Kunitski et al, *Science* 348, 551-555, 2015
[2] J. Voigtsberger et al, *Nat. Comm.* 5, 5765:1-6, 2014

A 16.2 Tue 15:00 f142

Universal three-body recombination and Efimov resonances in an ultracold Li-Cs mixture — •Stephan Häfner[1], Juris Ulmanis[1], Rico Pires[1], Felix Werner[2], Dmitry S. Petrov[3], Eva D. Kuhnle[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Laboratoire Kastler Brossel, ENS-PSL, UPMC-Sorbonne Université, Collège de France, CNRS, 24 rue Lhomond, 75231 Paris Cedex 05, France — [3]LPTMS, CNRS, Univ. Paris Sud, Université Paris-Saclay, 91405 Orsay, France

Universality of few-body systems has been a driving force in fundamental quantum physics. One paradigm is the Efimov effect, where a infinite geometical progession of bound three-body states emerges from pairwise resonantly interacting particles. In an ultracold Bose-Fermi mixture of ^{133}Cs and ^6Li the scaling factor is drastically reduced due to its large mass imbalance, making it an indeal system for the experimental observation of a series of Efimov resonances. Here we present our recent measurements of the three-body event rate constant of the Li+Cs+Cs scattering channel close to a broad Feshbach resonance. We observe a series of three consecutive Efimov resonances at temperatures of 450nK and 120nK and compare the recombination spectra with the universal zero-range theory at finite temperature [1]. For the first and second excited Efimov resonance, located in the window of universality, good agreement is found, whereas for the ground state deviations from universality become apparent.

[1] D.S. Petrov and F. Werner, Phys. Rev. A 92, 022704 (2015)

A 16.3 Tue 15:15 f142

Two-channel model for cold collisions of metastable neon atoms — •Christian Cop and Reinhold Walser — TU Darmstadt, Institut für Angewandte Physik, Hochschulstr. 4a, D-64289 Darmstadt

Although metastable noble gas has begun in the 1980s for various species, Bose-Einstein condensation has only been demonstrated for metastable helium so far. At the technical university of Darmstadt, the group of G. Birkl investigates experimentally the prospects to condense metastable neon atoms (Ne*) to degeneracy. High internal energy of Ne* (16 eV) leads to loss rates through Penning ionization (PI). PI may be suppressed by spin polarization of the atoms, which has been demonstrated for Ne* [1]. Additionally, experimental data is now available on cross sections and loss rates of isotope- and spin-mixtures of the three stable isotopes of Ne*.

We set up a two-channel model, where the scattering channel is given by a realistic interaction potential for Ne*, coupled to an arbitrary loss channel via an arbitrary coupling. Suppression of PI is modeled by varying the coupling strength [2]. We present recent results and show, that the calculated values of the loss rates and cross sections of the different isotope- and spin-mixtures are in very good agreement with the experimental data points.

[1] P. Spoden, M. Zinner, N. Herschbach, W.J. Van Drunen, W. Ertmer, G. Birkl, 2005, Phys. Rev. Lett. 94, 223201
[2] C. Cop, A. Martin, G. Birkl, R. Walser, to be published

A 16.4 Tue 15:30 f142

Spontanious symmetry breaking in He resonances — •Hubert Klar — DHBW Lörrach

A ficticious force acting between the electrons breaks the electron exchange symmetry. This is not in contradiction with experimental data, because this effect is extremely small in the ground state, in singly excited states, and in lower double Ryberg states. Very high resonaces near threhold for double escape, hwoever, are neither singlets nor triplets.

A 16.5 Tue 15:45 f142

Laser-driven relativistic charged and neutral twisted matter waves — •Armen Hayrapetyan[1] and Jörg Götte[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, U.K.

With an advent of improved instrumentation it has recently become possible to generate vortex beams of electrons and neutrons. These new types of waves propagate with twisted wavefronts and carry a non-zero topological charge resulting in a vortex-type distribution of beams' profile. In this work, we explore how the profile of such charged and neutral matter waves can be controlled and manipulated by means of intense laser fields. For this purpose, we develop an exact relativistic quantum theory by constructing Bessel-type solutions to generalized Dirac equations that describe the interaction of charged and neutral spin-half fermions with electromagnetic fields. Given the different mechanisms for the "minimal coupling" scheme of charged and neutral particles with external fields, we discuss the similarities and peculiar differences between laser-driven twisted electrons and neutrons.

A 16.6 Tue 16:00 f142

Quantum interference in bichromatic Kapitza-Dirac scattering — •Matthias Maximilian Dellweg and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

In this contribution, we study Kapitza-Dirac scattering of an electron from a bichromatic standing light wave of commensurate frequency ratio. On the one hand, we investigate the underlying quantum dynamics within a dimensionally reduced model based on the involved ponderomotive potentials. This approach is complemented, on the other hand, by numerical simulations of the associated Schrödinger equation [1]. Our analysis allows us to predict the Rabi frequency of the only possible scattering transition in the Bragg regime. Furthermore we describe how this frequency can be coherently controlled – up to total suppression – by quantum interference via variations of the laser parameters.

[1] M. M. Dellweg and C. Müller, Phys. Rev. A 91 (2015) 062102

A 16.7 Tue 16:15 f142

Scattering Processes with Relativistic Twisted Electrons: Mott– and Compton Scattering — •Daniel Seipt[1,2], Stephan Fritzsche[1,2], Andrey Surzhykov[1], Valery G. Serbo[3], and Igor P. Ivanov[4] — [1]Helmholtz-Institut Jena — [2]Friedrich-Schiller-Universität Jena — [3]Novosibirsk State University — [4]CFTP, Instituto Superior Tecnico, University of Lisbon

Twisted electrons, also known as electron vortex beams, are novel types of electron beams characterized by a well defined projection of total angular momentum onto their beam axis. We investigate two different fundamental scattering processes involving high–energetic twisted electrons based on Dirac's relativistic wave equation: Mott scattering of twisted electrons on atoms and the inverse Compton scattering of laser light off twisted electron beams.

For the Mott scattering, special attention is placed on the angular distribution and the polarization of the outgoing electrons. It is shown that the distribution of scattered electrons depends sensitively on the properties of the initial twisted electron states, thus, rendering the Mott scattering a promising diagnostic tool for relativistic vortex beams.

In the process of inverse Compton back-scattering of laser light off ultra-relativistic electrons, the frequency of the photons is Doppler up-shifted to the x-ray regime. We analyze how the characteristics of the backscattered x-ray beam can be controlled by tuning the properties of the twisted electrons, in order to synthesize tailor-made x-ray beam profiles with a well-defined spatial structure.

A 17: Ultracold plasmas and Rydberg systems II (with Q)

Time: Tuesday 14:30–16:30 Location: f303

A 17.1 Tue 14:30 f303

Dynamically probing ultracold lattice gases via Rydberg molecules — •Oliver Thomas[1,2], Torsten Manthey[1], Thomas Niederprüm[1], Tanita Eichert[1], Philipp Geppert[1], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

Rydberg Molecules have been an ongoing field of interest since their first theoretical prediction and experimental realization in ultra cold gases nearly 7 years ago. Since then great progress, theoretically and experimentally, has been made in understanding these exotic states, in which one or more ground state atoms are bound in the electronic wave function of an highly excited Rydberg state by a Fermi contact type interaction.

We show that the excitation of long-range Rydberg molecules can be used to probe position- and time-sensitive the occupation of sites in an ultra-cold many body system, by using the natural decay of the excited molecular state into an ion as a continuous probe. We use this technique to dynamically probe the occupation in a many body quantum system when crossing the superfluid to Mott insulator transition. With the technique of scanning electron microscopy, we also show the position sensitiveness of the used scheme, depleting only atoms located in the inner region of the prepared many body system.

A 17.2 Tue 14:45 f303

Pumping squeezed states of a micro-mechanical oscillator with Rydberg atoms. — •Robin Stevenson[1], Jiri Minar[1], Sebastian Hofferberth[2], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, United Kingdom — [2]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We investigate a system comprising of a stream of Rydberg atoms passing close by a micro-mechanical oscillator. We show in the situation where the atomic transition is resonant with a single-phonon transition of the oscillator, this system is equivalent to a micromaser, realised for example by atoms passing one by one through a cavity. This in principle allows the observation of a lasing transition and the creation of coherent states.

Furthermore, we demonstrate that when the atoms are on resonance with a two-phonon transition of the oscillator we can generate non-classical states in the oscillator. In the small interaction limit, the oscillator is driven towards coherent superpositions of coherent states with opposite sign. In the presence of thermal coupling the oscillator is driven towards squeezed states that can have variance lower than the vacuum state. Finally, we discuss experimental parameters and explore whether the non-classical states discussed here are achievable with current technology.

A 17.3 Tue 15:00 f303

Optimal preparation of the crystalline states and the GHZ states on Rydberg many-body systems — •Jian Cui[1], Rick van Bijnen[2], Thomas Pohl[2], Simone Montangero[1], and Tommaso Calarco[1] — [1]Institute for Complex Quantum Systems, Ulm, Germany — [2]Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany

Rydberg atoms, characterized by their exaggerated strong and long-range interactions, serve as one of the most promising candidate platforms for quantum simulators. The finite lifetimes of Rydberg atoms set the duration limits within which experiments have to be performed. To identify the dynamics satisfying this lifetime condition based on the current experimental technologies in Rydberg many-body systems, however, turns out to be highly nontrivial. Presently, most methods in this regard rely on the adiabatic evolution, which is slow by definition. Here, we apply the methods from optimal control theory to solve this problem. Optimized control pulses for preparing the crystalline states and the GHZ states on the ultra-cold Rydberg atomic gases with much less time cost than the corresponding adiabatic schemes have been numerically identified. Besides the lifetimes, other realistic experimental constraints and imperfections including the lost of atoms, finite detuning and coupling strengths as well as the limited bandwidths of control pulses, among others, have been taken into account in deriving the results, so that they can be readily applied in real experiments.

A 17.4 Tue 15:15 f303

Resolved quadrupole shifts of a single trapped Rydberg ion — •Gerard Higgins[1,2], Fabian Pokorny[1,2], Weibin Li[3], Christine Maier[2], Johannes Haag[2], Florian Kress[2], Quentin Bodart[1], Yves Colombe[2], Igor Lesanovsky[3], and Markus Hennrich[1,2] — [1]Stockholm University, Sweden — [2]Universität Innsbruck, Austria — [3]University of Nottingham, United Kingdom

Trapped Rydberg ions are a novel approach to quantum information processing, which joins the advanced quantum control of trapped ions with the strong dipolar interactions between Rydberg atoms [1-2]. The strong electric fields used for trapping Rydberg ions give rise to fundamental phenomena which are not usually observed in neutral Rydberg atom experiments. Here we present recent experimental results in which effects of the trap on a Rydberg ion were observed.

A single strontium ion was trapped in the center of the electric quadrupole field of a linear Paul trap and excited to Rydberg S- and D-states using two ultraviolet photons. The Rydberg ion was subjected to both the DC and the radio-frequency electric quadrupole fields of the trap as well as an applied magnetic field. The Rydberg states were split by the magnetic field due to the Zeeman effect, which explains the observed resonance structure of the excited Rydberg S-states. Rydberg D-states possess an electric quadrupole moment and couple to the gradients of the trapping fields, which has allowed effects of both the DC and RF trapping fields to be resolved in D-state resonances.

[1] M. Müller, et al., New J. Phys. **10**, 093009 (2008)
[2] T. Feldker, et al., Phys. Rev. Lett. **115**, 173001 (2015)

A 17.5 Tue 15:30 f303

Rydberg-atom interfaces between photons and superconducting cavities — •Wildan Abdussalam, Daniel Viscor, and Thomas Pohl — Max Planck Institute for the Physics and Complex Systems, Dresden, Germany

Owing to their large polarisability Rydberg atoms hold promise for realising strong coupling between microwave photons and superconducting cavities. Yet, the very same property makes Rydberg states prone to surface noise which has thus far hampered efficient interfacing.

Here, we study the coupled dynamics of a single cavity photon and a strongly interacting ensemble of Rydberg atoms and show that available Rydberg-Rydberg atom interactions can be utilised to overcome this problem. Using realistic noise sources and accounting for additional decay of Rydberg states, we demonstrate that collective photon coupling to interacting Rydberg ensembles provides a promising to noise-resistant quantum interfaces.

A 17.6 Tue 15:45 f303

Quantum state tomography of a nano-mechanical oscillator using Rydberg atoms — •Adrián Sanz Mora, Sebastian Wüster, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

Rydberg atoms have proven to be an excellent tool to observe the quantum dynamical features of a microwave cavity mode[1]. Here we investigate their applicability to characterize instead the motional state of a nano-mechanical oscillator. Attaching a ferroelectric domain to the oscillator supplies it with a permanent electric dipole moment. Coupling between mechanical vibrations of such oscillator and a Rydberg transition dipole is thus enabled via an electric dipole-dipole interaction. Atomic Ramsey interference measurements of phase-shifts acquired by Rydberg atom-oscillator states in an off-resonance scenario provides a non-destructive detection of discrete mechanical quanta. Translations in phase space of the mechanical oscillator, required for its full tomographical reconstruction[2], are performed using the aforementioned coupling while the atoms are simultaneously driven by optical fields in an off-resonant Raman scenario. The Wigner function for a given initial motional state of the mechanical oscillator is recreated by applying several sequences of Ramsey measurements at many different sampling points in the phase space of the mechanical oscillator.

[1] S. Deléglise et al., *Nature* **455**, 510 (2008).
[2] M.R. Vanner et al., Ann. Phys. **527**, 15 (2014).

A 17.7 Tue 16:00 f303

Decoherence dynamics in a single photon switch — •Callum Murray[1], Alexey Gorshkov[2], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]University of Maryland, Maryland, USA

In this talk, we will discuss the decoherence processes affecting the performance of a dissipative single photon switch. A device of this kind uses a single gate photon to block the transmission of many other target photons via conditional absorption, and has recently been demonstrated in a Rydberg EIT medium. However, the decoherence processes affecting the gate photon in this case are still not very well understood. In this talk, a complete characterisation of this decoherence will be presented along with the impact this has on the maximum achievable switch fidelity.

A 17.8 Tue 16:15 f303

Experimental demonstration of Rydberg dressing in a many-body system — •Johannes Zeiher[1], Peter Schauss[1], Sebastian Hild[1], Antonio Rubio Abadal[1], Jae-Yoon Choi[1], Rick van Bijnen[2], Thomas Pohl[2], Immanuel Bloch[1,3], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Rydberg atoms offer the possibility to study long range interacting systems of ultracold atoms due to their strong van der Waals interactions. Admixture of a Rydberg state to a ground state, known as Rydberg dressing, allows for greatly increased experimental tunability of these interactions.Here we report on our results of the realization of Rydberg dressing in a many-body spin system. Starting from a two-dimensional spin-polarized Mott insulator state of rubidium-87, we optically couple one spin component to a Rydberg p-state on a single photon ultra-violet transition at 297 nm. Using Ramsey interferometry in the ground state manifold, we measure the spin-spin correlations induced by the long range interactions. To show the predicted versatility of Rydberg dressing, we realize an increased interaction range by selecting a different Rydberg state and experimentally study anisotropic interactions by tilting the quantization axis.

A 18: Highly charged ions and their applications

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

A 18.1 Tue 16:30 Empore Lichthof

APPA R&D — Verbundforschung bei FAIR — •Stefan Schippers[1], Thomas Stöhlker[2,3] und für die APPA-Kollaborationen[4] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]GSI-Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]Helmholtzinstitut Jena, Jena — [4]

Der vom BMBF im Rahmen der Verbundforschung geförderte Forschungsverbund APPA R&D umfasst die deutschen Universitätsgruppen, die sich im Rahmen des internationalen APPA-Verbunds für die Forschung an der zukünftigen internationalen Beschleunigeranlage FAIR engagieren, die derzeit auf dem GSI Gelände in Darmstadt errichtet wird. APPA („Atomic, Plasma Physics and Applications") ist eine der vier Forschungssäulen von FAIR. Die unter dem gemeinsamen Dach von APPA agierenden internationalen Forschungskollaborationen BIOMAT, FLAIR, HEDgeHOB, SPARC und WDM, konzentrieren sich auf die Erforschung der Bausteine und Phänomene der Materie unter extremen Bedingungen (hohe Felder, Dichten, Drücke und Temperaturen). Gegenstand des Forschungsverbunds APPA R&D sind thematisch abgestimmte Forschungsprojekte im Bereich beschleunigergestützter Experimente mit schweren Ionen an der zukünftigen FAIR-Anlage. Zentrale Punkte dabei sind: 1) Fortentwicklung der Großgeräteinfrastruktur, vor allem Forschung und Entwicklung zur Steigerung der wissenschaftlichen Leistungsfähigkeit vorhandener Anlagen sowie zukünftiger Beschleuniger- und Detektorsysteme einschließlich der entsprechenden Basistechnologien und 2) Aufbau der APPA-Experimente bei FAIR.

A 18.2 Tue 16:30 Empore Lichthof

A new electron beam ion source as charge breeder for rare isotope beams — •Michael A. Blessenohl[1], Stepan Dobrodey[1], Zachary Hockenbery[1], Renate Hubele[1], Thomas Baumann[2], José R. Crespo López-Urrutia[1], and Jens Dilling[3] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]European XFEL, Hamburg, Germany — [3]TRIUMF, Vancouver, Canada

TRIUMF is the Canadian national nuclear research facility. Its key equipment is the largest cyclotron in the world, which accelerates protons to 500 MeV. These hit a target composed of heavy elements to produce heavy isotopes, which are then studied in two post-accelerators: ISAC (Isotope Separator and ACcelerator) I and ISAC II.

Currently, the TRIUMF facility is upgraded with ARIEL (Advanced Rare IsotopE Laboratory), which will include a new EBIS (Electron Beam Ion Source) for charge breeding these rare isotopes. Highly charged ions of heavy elements are used to keep the charge-to-mass ratio A/Q low, which is required by ISAC I and II. Because the isotopes of interest have short half-lives in the millisecond range and also low abundancies, the whole process of injection, charge breeding and extraction has to be very efficient. The repetition rate of 100 Hz requires fast high voltage control and switching. The goal is to achieve a charge breeding efficiency of at least 20 % in one single charge state. In this work the latest design is presented, including finite element and Monte Carlo simulation results, concepts for the on-line diagnostics and a fast control system.

A 18.3 Tue 16:30 Empore Lichthof

EBIT spectroscopy of $Sn^{8+\cdots14+}$ in the optical and extreme ultraviolet range — •Alexander Windberger[1], Francesco Torretti[1], Hendrik Bekker[2], Anastasia Borschevsky[3], Stepan Dobrodey[2], Wim Ubachs[1,4], Ronnie A. Hoekstra[1,5], José R. Crespo López-Urrutia[2], and Oscar O. Versolato[1] — [1]Advanced Research Center for Nanolithography, Amsterdam, The Netherlands — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [4]Department of Physics and Astronomy, VU Amsterdam, The Netherlands — [5]Zernike Institute for Advanced Materials, University of Groningen, The Netherlands

The charge state resolved fluorescence of $Sn^{8+\cdots14+}$ ions was simultaneously detected in the optical and extreme ultra-violet region using the electron beam ion traps (EBIT) at the Max-Planck-Institute for Nuclear Physics. Spectra were obtained while gradually increasing the electron beam energy, thus enabling us to assign the measured spectral lines to their respective charge states. A comparison with theory and complementary data leads to tentative identifications of several transitions. Our measurements contribute to an analytical understanding of atomic processes and new diagnostic tools for EUV light sources.

A 18.4 Tue 16:30 Empore Lichthof

Resonant excitation of highly charged ions at ultrabrilliant light sources — •Sven Bernitt[1,2], René Steinbrügge[1], Stepan Dobrodey[1], Jan K. Rudolph[1,3], Sascha W. Epp[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität, Jena, Germany — [3]IAMP, Justus-Liebig-Universität. Gießen, Germany — [4]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Germany

The transportable electron beam ion trap FLASH-EBIT was used to provide targets of trapped highly charged ions for VUV and X-ray radiation from the free-electron lasers FLASH and LCLS, as well as the synchrotron light sources BESSY II and PETRA III. By observing resonantly excited fluorescence we were able to measure transition energies and natural line widths. By simultaneously detecting changes of ion charge states we were able to deduce branching ratios and absolute radiative and Auger decay rates.

Our measurements provide valuable data for the interpretation of spectra from astrophysical and laboratory plasmas, and by studying high-Z few-electron systems, we can provide tests of atomic theory on the level of QED contributions.

A 18.5 Tue 16:30 Empore Lichthof

Geometrical and statistical simulations of the CANREB Electron Beam Ion Source for charging rare isotope beams — •Zachary Hockenbery[1], Michael A. Blessenohl[1], Stepan Dobrodey[1], Renate Hubele[1], Thomas Baumann[2], Jens Dilling[3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]European XFEL, Hamburg, Germany — [3]TRIUMF, Vancouver, Canada

The Canadian rare-isotope facility with electron beam ion source (CANREB) will be used for charge breeding and mass separation of rare isotope beams for experiments at TRIUMF, the Canadian National Laboratory for Particle and Nuclear Physics. The CANREB Electron Beam Ion Source (EBIS) will consist of a trapping region, electron gun, and collector, and will accept pulsed bunches of isotopes for charge breeding towards mass-to-charge ratios < 7. A software library to accurately simulate the dynamics of the injection, charge breeding, and extraction processes is being developed as a tool for engineering design and future diagnostics of the experiments. The software utilizes finite element methods to prescribe geometrical constraints, solve electrostatic and magnetostatic equations, and for self-consistent trajectory calculations of particles. Furthermore, it includes semi-empirical calculations and Monte Carlo probability to track the charge state evolution of the injected isotopes in combination with electronic structure cross-section calculations. This poster will focus on the methods employed in the software libraries and the accuracy of the calculations.

A 19: Collisions, scattering and correlation phenomena

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

A 19.1 Tue 16:30 Empore Lichthof

Floquet-DMFT and its application to the time-periodically driven Hubbard model — •Tao Qin and Walter Hofstetter — Institut für Theoretische Physik, Goethe Universität Frankfurt/Main 60438, Germany

A time-periodically driven system is a well-controlled versatile quantum simulator. The Hofstadter- and Haldane Hamiltonians, which are under intense studies because of their interesting topological properties, have been realized with time-periodically driven cold atoms in the optical lattice. Using the effective Hamiltonian approach, previous studies mainly focused on the non-interacting situation. It is very interesting to introduce 2-particle interactions and study their effect on topological properties. Floquet-DMFT is one possible tool for studying the interacting case. In our work, we study the time-periodically driven Hubbard Hamiltonian with Floquet-DMFT. In the calculation, we use the Bethe lattice and the infinite-dimensional simple cubic lattice. We identify the Mott metal-insulator transition with the increase of the Hubbard U. Comparing with the static Hubbard model, we study the role of the driving. We further calculate the optical conductivity and discuss its potential for indentifying effects of the interaction on topological properties.

A 19.2 Tue 16:30 Empore Lichthof

Proton-impact ionization cross sections of tetrahydrofuran measured from 0.3 to 3.0 MeV by electron spectroscopy — •Mingjie Wang, Benedikt Rudek, Daniel Bennett, Marion Bug, Ticia Buhr, and Hans Rabus — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Within the framework of the EMRP Project "BioQuaRT", the track structure simulation codes GEANT4-DNA [1] and PTra [2] have been extended with experimental DNA interaction cross sections to simulate ionizing radiation interactions with biological matter on cellular (micrometric) and subcellular (nanometric) scales.

For this purpose, double differential cross sections (DDCS) for ionization of tetrahydrofuran by protons with energies from 0.3 to 3.0 MeV were measured at the PTB ion accelerator facility. The electrons emitted at angles between 15° and 150° in 15° steps relative to the proton beam direction were detected with an electrostatic hemispherical electron spectrometer. The experimental DDCS are compared to the semi-empirical Hansen-Kocbach-Stolterfoht model [3] as well as to the recently reported calculation based on the dielectric response function formalism [4]. This comparison shows a good agreement in a broad range of emission angles and energies of secondary electrons.

[1] S. Incerti et al., Med. Phys. 37, 4692 (2010).
[2] M. U. Bug et al., Radiat. Phys. Chem. 81, 1804 (2012).
[3] M. A. Bernal et al., Nucl. Instrum. Methods Phys. Res., Sect. B 251, 171 (2006).
[4] P. de Vera et al., Phys. Rev. Lett. 114, 018101 (2015).

A 19.3 Tue 16:30 Empore Lichthof

Manipulating electron vortex beams with crossing laser beams — •Armen Hayrapetyan[1], Marco Ornigotti[2], Karen Grigoryan[3], Alexander Szameit[2], and Jörg Götte[4] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]Institute of Applied Physics, Friedrich-Schiller Universität Jena, Germany — [3]Yerevan State University, Armenia — [4]School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, U.K.

Recent advances in technology have made it possible to generate electron vortex beams with subnanometer spot size and quantized orbital angular momentum along their axes of propagation. In this present work, we explore the interaction of such electron vortices with plane wave laser fields propagating perpendicularly to each other. In such a crossed-beam scenario, we develop a relativistic scalar theory for laser-driven electron vortices and find Bessel-type solutions to the Klein-Gordon equation. By constructing distributions of the probability density and the transverse current, we examine two distinct cases when the electron is incident on either of the maximum or minimum of the laser field. On each of these cases we derive different coupling constants and demonstrate the possibility of controlling and manipulating the electron vortices via lasers.

A 19.4 Tue 16:30 Empore Lichthof

A powerful new electron gun for electron-ion crossed-beams experiments — •Benjamin Ebinger[1,2], Alexander Borovik Jr.[1,2], Stefan Schippers[1,2], and Alfred Müller[2] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

In an electron-ion crossed-beams experiment, the experimental sensitivity is mainly determined by the densities of both beams in the interaction region. Aiming at the extension of the available range of accessible electron energies and densities, a new high-power electron gun has been developed and fabricated. It delivers a ribbon-shaped beam with high currents at all energies variable between 10 and 3500 eV [1,2]. We report on recent progress in the development and the performance of this electron gun. First experiments have demonstrated the expected high electron currents in the interaction region and very good beam transmission. Meanwhile, the tests have entered the final phase as the electron gun has been integrated into the experimental crossed-beams setup in Gießen. Employing the *animated crossed-beams* technique [3], first ionization signals were measured. Several challenging issues connected with space-charge effects in the high-density electron beam were revealed and are currently being investigated.

[1] Shi et al., Nucl. Instr. Meth. Phys. Res. B 205 (2003) 201-206
[2] Borovik et al., J. Phys.: Conf. Ser. 488 (2014) 142007
[3] Müller et al., J. Phys. B. 18 (1985) 2993-3009

A 19.5 Tue 16:30 Empore Lichthof

Measuring and modeling of anisotropic and polarized x-ray emission following resonant recombination into highly charged ions — •Chintan Shah[1,2], Pedro Amaro[1], Holger Jörg[1], René Steinbrügge[2], Sven Bernitt[2], Christian Beilmann[1,2], Stephan Fritzsche[3,4], Andrey Surzhykov[3], José Ramón Crespo López-Urrutia[2], and Stanislav Tashenov[1] — [1]Physikalisches Institute, Heidelberg, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Helmholtz-Institut Jena, Jena, Germany — [4]Theoretisch-Physikalisches Institut, Jena, Germany

The angular distribution and polarization of x rays emitted due to resonant recombination into highly charged ions were studied experimentally using an electron beam ion trap. In the first experiment, the linear polarization of x rays produced by dielectronic recombination into highly charged krypton ions was measured using the Compton polarimetry technique. In the second experiment, the electron-ion collision energy was scanned over the K-shell dielectronic, trielectronic and quadruelectronic recombination resonances in highly charged iron and krypton ions. The angular distribution of x rays following resonant recombination was measured by two detectors mounted along and perpendicular to the beam axis. The measured polarization and emission asymmetries comprehensively benchmarked full-order atomic calculations, confirming their suitability for the polarization diagnostics of hot plasmas under the premise of inclusion of higher order processes that were neglected in earlier work.

A 20: Atomic systems in external fields

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

A 20.1 Tue 16:30 Empore Lichthof

Following the Evolution of ICD in Time — •Fawad Karimi, Markus Pfau, Martin Ranke, Anastasios Dimitriou, and Ulrike Frühling — Institute of Experimental Physics, University of Hamburg, Center of Ultrafast Imaging (CUI), Center for Free Electron Lasers (CFEL)

Interatomic Coulombic Decay (ICD), a non-local auto-ionization process predicted by Lorenz Cederbaum in 1997, 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 an aperture in vacuum. Ultrashort XUV pulses generated by the process of HHG initiates the ICD process by ionizing an inner valence electron of Ne. The relaxation energy of Ne is transferred to the neighbouring Kr atom in form of a virtual photon. 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 THz field, which is superimposed with the XUV pulses. The temporal profile of this wave carries the desired temporal information about the underlying dynamics.

A 20.2 Tue 16:30 Empore Lichthof

Simulation of attosecond-streaking in dielectric nanospheres — •Lennart Seiffert[1], Sergey Zherebtsov[2], Philipp Rupp[2], Philipp Henning[1], Matthias Kling[2], and Thomas Fennel[1] — [1]Universität Rostock — [2]Ludwig-Maximilians-Universität München

Electron transport in dielectrics is of fundamental importance for electronic devices and plays a crucial role in photoelectron spectroscopy and microscopy. The effective escape depth of photoemission from dielectrics depends strongly on inelastic collisions that typically take place on attosecond timescales and may thus be accessible with attosecond metrology [1]. So far, attosecond-streaking has been applied to atomic systems to study ionization delays [2] and utilized to investigate electron transport in metals [3] and adlayer-covered metals [4]. A promising approach to establish attosecond-streaking in dielectrics relies on the utilization of isolated nanosolids to circumvent space charge problems. Here, we simulate attosecond-streaking at isolated SiO_2 nanospheres and investigate the impact of electron transport on the streaking spectra. Our semi-classical Monte-Carlo trajectory simulations [5] support that attosecond-streaking can be used as a universal tool to directly clock the inelastic scattering time in dielectrics [6].

[1] R. Kienberger et al., Nature 427, 817-821 (2004)
[2] M. Schultze et al., Science 328, 1658-1662 (2010)
[3] A. L. Cavalieri et al., Nature 449, 1029-1032 (2007)
[4] S. Neppl et al., Nature 517, 342-346, (2015)
[5] F. Süßmann et al., Nat Commun. 6, 7944 (2015)
[6] F. Calegari et al., in preparation

A 20.3 Tue 16:30 Empore Lichthof

Using GAS-CI to extract atomic and molecular structure factors for tunneling ionization — •Sebastian Bauch[1], Lun Yue[2], Henrik Larsson[3], Michael Bonitz[1], and Lars Bojer Madsen[2] — [1]Institut für Theoretische Physik und Astrophysik, CAU Kiel, Germany — [2]Institute for Physics and Astronomy, Aarhus University, Denmark — [3]Institut für Physikalische Chemie, CAU Kiel, Germany

The accurate description of tunneling ionization of many-electron atoms and molecules is a challenging task. The recently formulated weak field asymptotic theory (WFAT) [1] addresses this topic and allows for the calculation of ionization rates of molecules with inclusion of electron correlation. One of its central ingredients is the asymptotic form of the Dyson orbital. Its accurate determination by means of standard tools is in many cases not possible due to the commonly chosen localized basis functions. These offer a highly accurate description close to the nuclei but fail to reproduce the wave function at large distances. In order to circumvent this problem for diatomic molecules, we therefore employ the generalized-active-space configuration interaction (GAS-CI) framework [2] applied within a prolate spheroidal grid [3]. We present the essence of our method and demonstrate its application to H_2 and larger systems. The ionization rates for different orientations of the molecule are extracted.

[1] O.I. Tolstikhin, L.B. Madsen, and T. Morishita, PRA 89 013421 (2014) [2] D. Hochstuhl, and M. Bonitz, PRA 86 053424 (2012); S. Bauch, L.K. Sørensen, and L. B. Madsen, PRA 90 062508 (2014) [3] H.R. Larsson, S. Bauch, and M. Bonitz, arXiv:1507.04107 (2015)

A 20.4 Tue 16:30 Empore Lichthof

Dirac: Computer algebra tools for studying the properties of hydrogen-like atoms — •Jiri Hofbrucker[1,2], Andrey Surzhykov[1], and Stephan Fritzsche[1,2] — [1]Helmholtz Institute Jena, Germany — [2]University of Jena, Germany

The model of hydrogen-like ions plays a significant role in various research fields such as atomic and molecular physics, plasma physics or astrophysics. Hence, an easy access to the analytical as well as numerical properties of the model is of the interest of a wide community of researchers. Here, we present an updated and extended Mathematica version of the algebraic software DIRAC, which aims to provide the user with interactive tools for studying the properties of hydrogen-like atoms. Apart from the original procedures[1][2] including the Coulomb-field solutions to the Schroedinger and Dirac equations, Greens functions and radial integrals, this version adds on a number of high level procedures to describe the total and angular differential cross sections for the interaction of radiation with hydrogen-like atoms. Moreover, the documentation centre for this package has been updated to deliver a clear description of individual functions in order to offer a user friendly environment of the DIRAC package. [1] A. Surzhykov, P. Koval, S. Fritzsche, Comput. Phys. Comm. 165 (2005) 139. [2] S. McConnell, S. Fritzsche, A. Surzhykov, Comput. Phys. Comm. 181 (2010) 711-713

A 20.5 Tue 16:30 Empore Lichthof

Instabilities and Inaccuracies of Multi-Configuration Time-dependent Hartree-Fock Applied to Atomic Systems — •Christopher Hinz, Sebastian Bauch, and Michael Bonitz — ITAP, Christian-Albrechts-Univeristät Kiel, Leibnizstraße 15, 24098 Kiel

We demonstrate that the widely used multi-configuration time-dependent Hartree-Fock method [1] is restricted to a certain class of applications and fails for scenarios where small parts of the wave function are important, such as typically occurring in strong-field physics and attosecond methodology. By using illustrative and physically relevant examples, we show the existence of serious instabilities in the method itself and demonstrate that for several important cases the assumed convergence of the method with respect to electron correlations is virtually absent [2,3].

[1] D. Hochstuhl, C. Hinz and M. Bonitz, EPJ ST **223**, 177-336

(2014)
[2] C. M. Hinz, S. Bauch, and M. Bonitz, submitted to *JPCS* (2015)
[3] C. M. Hinz, S. Bauch, and M. Bonitz, submitted to *Phys. Rev.* A (2016)

A 20.6 Tue 16:30 Empore Lichthof

Frequency tunable microwave field imaging with sub-100 μm resolution using atomic vapor cells — •Andrew Horsley, Guan-Xiang Du, and Philipp Treutlein — University of Basel, Switzerland

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 (e.g. atom chips or ion traps), as there are currently no established microwave imaging techniques. Our technique may also find applications in medical imaging. We have built a high resolution imaging system, whose $50 \times 50 \times 140\,\mu m^3$ spatial resolution, $1\,\mu T/Hz^{1/2}$ sensitivity, and $150\,\mu$m approach distance are now sufficient for characterising a range of real world devices at fixed microwave frequencies [1].

Frequency tunability is essential for wider applications, however we can only detect microwaves that are resonant with an atomic transition. Our solution is to use a large dc magnetic field to Zeeman shift the hyperfine ground state transitions to any desired frequency. In addition to high resolution images of 6.8 GHz microwave fields, we present results from a proof-of-principle setup, where we have used a 0.8 T solenoid to detect microwaves from 2.3 to 26.4 GHz.

[1] A. Horsley, G.-X. Du and P. Treutlein, *Imaging of Electromagnetic Fields in Alkali Vapor Cells with sub-100 μm Resolution,* New Journal of Physics, 17(11), 112002, (2015)

A 20.7 Tue 16:30 Empore Lichthof

Phase-of-the-phase spectroscopy in the multiphoton regime — •Mohammad Adel Almajid and Dieter Bauer — Institut für Physik , Universität Rostock , Rostock 18051, Deutschland

Recently, phase-of-the-phase (PoP) spectroscopy has been introduced and applied to the tunneling regime of strong-field ionization [1]. Briefly, the momentum-resolved photoelectron yield as a function of the relative phase between the strong ω and weak 2ω component of a colinearly polarized ω-2ω two-color pulse is measured and Fourier-transformed. This tells us how much and with which phase lag the yield changes with varying relative phase (cf. talk by Slawomir Skruszewicz). The canonical two-club structure of PoP spectra in the tunneling and rescattering regime were analyzed in Ref. [1]. On our poster, we present the corresponding results for the multiphoton regime. We find that the alternating PoP along the above-threshold ionization rings generates a characteristic checkerboard pattern in the PoP spectra, which corresponds to the "carpet" structure in ordinary photoelectron spectra found previously [2]. The pattern is most clearly visible when the strong-field approximation (SFA) is applied. Within SFA, even an analytical formula can be derived. However, results obtained via the ab initio solution of the time-dependent Schrödinger equation show a more complex behavior of the momentum-resolved PoP due to long-range Coulomb effects on the outgoing electrons.

[1] S. Skruszewicz, et al. Phys. Rev. Lett. 115, 043001 (2015)
[2] Ph. A. Korneev, et al. Phys. Rev. Lett. 108, 223601 (2012)

A 20.8 Tue 16:30 Empore Lichthof

Slow electrons from non-adiabatic transitions in a two-electron system — •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

Atomic systems exposed to short high-frequency laser pulses release unexpectedly slow electrons which are the consequence of non-adiabatic transition [1,2]. In single-active-electron atomic system, the relevant mechanisms can be clearly formulated and explained by means of the envelope hamiltonian defined recently [3].

Here we extend the study to a two-electron model atom. Both double and single ionization have been calculated and show the peaks of slow electrons. It is confirmed these slow electrons are also generated from non-adiabatic transitions. The role played by electron-electron correlation has been studied.

[1] M. Førre, S. Selstø, J. P. Hansen, and L. B. Madsen, Phys. Rev. Lett. **95**, 043601 (2005).
[2] K. Toyota, O. I. Tolstikhin, T. Morishita, and S. Watanabe, Phys. Rev. Lett. **103**, 153003 (2009).
[3] K. Toyota, U. Saalmann, and J. M. Rost, New J. Phys. **17**, 073005 (2015).

A 20.9 Tue 16:30 Empore Lichthof

Characterization of the Mainz atomic magnetometer for GNOME — •Hector Masia-Roig, Arne Wickenbrock, and Samer Afach — Johannes Gutenberg-Universität Mainz

GNOME is a novel experimental scheme which enables the investigation of exotic spin couplings between nuclei and exotic fields generated by astrophysical sources measuring spin precession. It consist of a network of geographically separated (>100km), time synchronized, ultrasensitive ($\sim fT/\sqrt{Hz}$) optical magnetometers in a magnetically shielded environment. Such a configuration enables the study of global transient effects.

Several atomic magnetometric setups are currently under construction around the globe in order to complete a reliable network for the successful characterization of hypothetical exotic fields. Here is presented the current work of the atomic magnetometer constructed in Mainz as a part of the GNOME collaboration. The main characteristics of the magnetometer, such as sensitivity, response to pulses, long term stability and sources of noise are discussed. These quantities are related to the sensitivity of the network to global transient effects.

A 21: Interaction with strong or short laser pulses

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

A 21.1 Tue 16:30 Empore Lichthof

Dynamic interference in the photoionization of helium by coherent intense high-frequency pulses — •Anne D. Müller[1], Anton N. Artemyev[1], David Hochstuhl[2], Lorenz S. Cederbaum[3], and Philipp V. Demekhin[1] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [2]Institut für Theoretische Physik und Astrophysik, Leibnizstrasse 15, 24098 Kiel — [3]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, INF 229, 69120 Heidelberg

The direct ionization of the helium atom by intense coherent high-frequency laser pulses is investigated theoretically from first principles. To this end, we solve numerically the time-dependent Schrödinger equation for the two-electron wave-packets by the efficient time-dependent restricted-active-space configuration-interaction method (TD-RASCI, [1]). Thereby we investigate how the dynamic interference of the photoelectrons of the same kinetic energy emitted at different times along the pulse [2] is modified for systems with several electrons. In particular, we consider photon energies which are nearly resonant for the subsequent 1s–2p excitation in the He^+. In order to enable observations of the dynamic interference patterns in the computed photoionization spectrum, the two-electron wave-packets were propagated on large spatial grids over long times.

References.

[1] D. Hochstuhl, M. Bonitz, Phys. Rev. A, 053424 (2012).
[2] Ph.V. Demekhin, L.S. Cederbaum, Phys. Rev. Lett., 253001 (2012).

A 21.2 Tue 16:30 Empore Lichthof

Beyond the dipole approximation for Coulomb focusing of tunnelled electrons in intense laser fields — •Jiří Daněk, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

In recent experiments, the breakdown of the dipole approximation in strong-field ionization was demonstrated and the important role of magnetic field on the photoelectron spectra (PES) was investigated. Although many simulations are in agreement with the experiments, a comprehensible theoretical picture is still missing even for rather simple atoms. Meanwhile, the full understanding of the nondipole effects on the PES is essential for further development of the holography for atoms.

In our poster, we present quasi-classical Monte Carlo simulation for xenon atom in a strong mid-infrared laser field with linear polarization beyond the dipole approximation. We demonstrate how the magnetic component of the laser field influences the Coulomb focusing and modifies the final PES with respect to the dipole case. The modified PES shows a “bend” in the opposite direction towards the magnetic pressure caused by the laser field. This seemingly counterintuitive feature is explained as a modification of the Coulomb focusing under the magnetic force in the well known recollision picture.

A 21.3 Tue 16:30 Empore Lichthof

CEP Dependence of Alkali ATI Spectra — •Danilo Zille and Daniel Adolph — Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Exposing atoms to short, intense laser pulses reveals a number of interesting effects in their photoelectron spectra. In the last 25 years much time and effort has been devoted to investigate and understand the origin of these effects, primarily for rare gases.

So far the literature offers only very few results regarding alkali metal atoms, despite having multiple properties that make the investigation of their ATI spectra highly interesting.

To start, they fulfill the commonly used single active electron approximation better than other atoms. In addition, they have much lower ionization potentials than what is usually considered. This places the problem in the multiphoton regime. Another point of interest are strong atomic resonances.

We present results of our investigation of the carrier-envelope phase dependence of the photoionization spectra of alkali metal vapors at near-infrared wavelengths. These results are important for a potential application of alkali metals in a CE-phase meter. The experimental findings are compared with calculations obtained from solving the time-dependent Schrödinger Equation. As a first result, we confirm the previously made theoretical prediction that asymmetries occur predominantly between the ATI peaks.

A 21.4 Tue 16:30 Empore Lichthof

***In* and *ex situ* characterization of few-cycle NIR laser pulses for strong-field quantum dynamics measurements— Three complementary methods compared** — •Maximilian Hartmann[1], Alexander Blättermann[1], Huipeng Kang[1,2], Paul Birk[1], Veit Stooss[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan 430071

Strong few-cycle laser pulses are nowadays routinely generated by amplified Ti:sapphire lasers combined with spectral broadening in gas-filled hollow-core fibers and temporal compression by chirped–mirror compressors. They can be used to drive high–harmonic generation in gases in order to produce attosecond bursts of XUV radiation. Both XUV and NIR pulses can then be used to capture electron dynamics in atomic and molecular systems on their natural time scale.

To fully understand and optimize the experimental setup, and in order to compare experimental results and theoretical calculations quantitatively, characterization of the laser pulses is mandatory. Here, we compare three methods for the characterization of femtosecond NIR laser pulses. These methods comprise two *ex situ* techniques, namely the dispersion scan [Miranda et al., Opt. Express 20, 688-697 (2012)] and the interferometric autocorrelation. They are compared to an *in situ* optical scheme where the pulse properties are extracted from transient absorption spectra of XUV-excited atoms [Blättermann et al., Opt. Lett. 40, 3464-3467 (2015)].

A 21.5 Tue 16:30 Empore Lichthof

Multi-photon vs. quasi-static regime of strong field dynamics for atomic bound states — •Veit Stooss[1], Andreas Kaldun[2], Christian Ott[3], Alexander Blättermann[1], Paul Birk[1], Thomas Ding[1], Kristina Meyer[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]Stanford University, Stanford, CA — [3]University of California, Berkeley, CA

In his work introducing the framework for atomic ionization in strong-field physics Keldysh characterized two regimes for the dynamic process of ionization [1]: (i) the multi-photon regime that treats the ionization as the result of the interaction with many photons, and (ii) the regime of tunnel ionization where the electric field is considered as quasi-static and electrons can leave through a barrier created by the influence of the strong laser field on the coulomb potential of the atoms. We investigate the dynamics of bound states with respect to these regimes that apply for ionization in strong fields. We examine signatures that depend on both intensity and wavelength [2] to separate the regimes of the few-photon-perturbative and the quasi-static picture. We performed time-resolved measurements of perturbed polarization decay in helium and compare them to numerical simulations in order to study the transition between photon- and quasi-static regime as a function of intensity and wavelength. [1] Keldysh L. V., Sov. Phys. JETP 20, 1945-1950 (1964) [2] Gaarde, Schafer, Physical Review A 86, 063408 (2012)

A 21.6 Tue 16:30 Empore Lichthof

Molecular wave-packet dynamics on laser induced 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, Heidelberg — [2]Dipartimento di Fisica, Politecnico Milano, Milano — [3]Institut für Physik, Universität Kassel, Kassel — [4]Physikalisch-Technische Bundesanstalt, Braunschweig

Using a XUV-pump IR-probe experiment in combination with a Reaction Microscope, we studied the dissociation dynamics of hydrogen molecules by varying the time delay between an ultra-short extreme-ultraviolet (XUV) and a near-infrared (IR) control pulse. The measured fragment momenta 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 curves.

A 21.7 Tue 16:30 Empore Lichthof

Spin dynamics in tunneling as well as multiphoton 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 linearly as well as circularly polarized laser fields are investigated. The impact of the polarization of a laser field on the spin effects are analyzed. Analytical expressions for spin asymmetries and spin flip probability, depending on the laser's polarization, are obtained for the photoelectron momentum corresponding to the maximum of tunneling probability [1]. Then, the results are extended to an arbitrary Keldysh parameter in order to reveal the nonadiabatic effects. It is shown that the spin flip is independent from the Keldysh parameter, whereas the spin asymmetries highly depend on it. All the results are comprehensively explained by an intuitive model which incorporates the spin dynamics in tunneling as well as multiphoton ionization.

[1] E. Yakaboylu, M. Klaiber, and K. Z. Hatsagortsyan Phys. Rev. A 91, 063407 (2015).

A 21.8 Tue 16:30 Empore Lichthof

Spatial electron correlation and ionization of helium in strong, ultrashort laser pulses — •Gergana Borisova, Andreas Fischer, Veit Stooss, Alexander Blättermann, Thomas Ding, Andreas Kaldun, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Motivated by a transient-absorption spectroscopy experiment, where a difference in the ionization of singly and doubly excited states with similar ionization energy was observed, the electron-electron correlation dynamics was investigated.

Here, we show results from the investigation of the electron dynamics in the helium atom interacting with strong laser fields on an attosecond time scale. We analyzed the electron-electron correlation dynamics responsible for the enhancement of the ionization in doubly excited helium by means of the time-dependent population of these states during and right after the laser pulse.

For this we employ a numerical quantum-mechanical model based on solving the one-dimensional time-dependent Schrödinger equation for two electrons.

A 21.9 Tue 16:30 Empore Lichthof

Electron-positron-photon jets generated by circularly polarized lasers — •suo tang, naveen kumar, and christoph h. keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69126, Heidelberg, Germany

With the next generation of ultra-intense laser pulse with intensities ($I \sim 10^{24}\text{W/cm}^2$), pair production and QED cascades can be induced by slow electrons or positrons. The generated pairs are accelerated by the laser fields to ultrarelativistic energy. High quality electron-positron-photon jets can be emitted from the field formed by the two counterpropagating circular polarized laser pulses. By adjusting the relative frequency and intensity of the laser pulses, the direction and energy of the jets can be controlled.

A 21.10 Tue 16:30 Empore Lichthof

Two-color strong-field ionization of methane — •Martin Laux, Yonghao Mi, Nicolas Camus, Lutz Fechner, Robert Moshammer, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Laser pulses with an asymmetric electric field like those created by the superposition of two-color laser fields or single-cycle pulses with fixed carrier-envelope phase may serve as an excellent tool for the study of site- and channel-selective strong-field ionization of molecules. Here, we present experimental results for ionization of methane exposed to 25 fs two-color pulses in a reaction microscope. We investigate and compare the effects of the tunable phase between the fundamental 800 nm near-infrared pulse and its second harmonic on the 3-dimensional momenta of ions and electrons created in the various reaction channels, for example single ionization with and without dissociation, double ionization and Coulomb explosion.

A 21.11 Tue 16:30 Empore Lichthof

Comparison of time-dependent strong-field effects in atoms and molecules observed by attosecond XUV absorption spectroscopy — •Paul Birk, Veit Stooss, Maximilian Hartmann, Alexander Blättermann, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Extreme ultraviolet (XUV) light pulses in the attosecond regime produced by high-harmonic generation of near-infrared (NIR) light are powerful tools to achieve ultra-high time resolution of intra-atomic and -molecular processes. With the help of an all optical approach we get access to bound state dynamics and correlations between electronic states in atoms and molecules. In previous work [1], it was possible to reconstruct and control a time-dependent two-electron wave packet in a measurement of perturbed polarization decay in helium. Based on this work on atoms, we investigate and compare time-dependent strong-field effects in argon and molecular nitrogen by exciting electronic and vibrational states of the target gas by a weak XUV pulse and perturbing the system via a strong NIR pulse. We present first results and interpretations of absorption spectra in the XUV-range and their changes depending on both the time delay and intensity of the strong NIR pulse.

[1] C. Ott, et al., Nature 516, 374-378

A 21.12 Tue 16:30 Empore Lichthof

Finding the global minimum using Gaussian processes — •Mehrdad Baghery, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Minimising functions is crucial to many problems in ranging from astrophysics to quantum optimal design. Among these lies the problem of finding the minimum of expensive-to-evaluate functions, rendering the fact that the minimum has to be found by making as few observations as possible.

In order to tackle this problem, we introduce an auxiliary function (expressed as a Gaussian process) which mimics the original function as more and more observations are made. This function is relatively cheap-to-evaluate, and more importantly, its derivatives are analytically expressible. By finding the minimum of this auxiliary function using textbook gradient-based minimisation algorithms, it is possible to find the minimum of the original function.

As a physical application, we will use the algorithm to find a laser pulse shape which, when shone on a hydrogen atom, maximises the charge yield.

A 21.13 Tue 16:30 Empore Lichthof

The orbital-truncation error in TDRNOT — •Felix Steinmeyer, Julius Rapp, and Dieter Bauer — Universität Rostock

In time-dependent renormalized-natural-orbital theory (TDRNOT), the complete and generally infinite basis of natural orbitals (NOs) is used to derive equations of motion (EOM) for few-body systems [1,2]. In the case of two particles, the *exact* EOM of the NOs are known explicitly. However, numerical calculations require a truncation of the number of NOs to a finite value N_o. This truncation introduces an error to the method which may spoil the (nonlinear) NO time evolution [3,4].

We analyze the impact of the truncation error by comparing the exact NOs with the NO subset of TDRNOT calculations considering exactly solvable model systems. Furthermore, we discuss our efforts in constructing an effective potential which mimics the effect of the omitted NOs on a mean-field level.

[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)
[4] M. Brics, J. Rapp, and D. Bauer, arXiv:1510.01682 (2015)

A 21.14 Tue 16:30 Empore Lichthof

OPCPA meets Reaction Microscope — •Claus Peter Schulz, Federico Furch, Felix Schell, Achut Giree, Sascha Birkner, Jochen Mikosch, and Marc Vrakking — Max Born Institute, Berlin, Germany

Spectroscopy derived from intense laser fields and with energetic XUV photons from High Harmonic Generation promises to bring unprecedented temporal and spatial resolution to studies of molecular dynamics. In particular for polyatomic molecules a complete detection scheme of the full manifold of 3D momentum vectors of all outgoing charged particles is invaluable for the interpretation of results. So-called reaction microscopes, which have already been developed more than a decade ago, enable this type of complete experiments by detecting the energy and angular distribution of photo electrons and ions in coincidence. Coincidence experiments benefit highly from increased repetition rates to boost the signal rates. Recently, we have set-up a laboratory where we combine a 400 kHz repetition rate laser system based on Optical Parametric Chirped-pulse Amplification (OPCPA) providing pulses with sub-7 fs duration and energies up to 10 μJ with a reaction microscope. First results on atoms and small hydrocarbon chains will be presented as well as our plans for XUV-IR spectroscopy.

A 21.15 Tue 16:30 Empore Lichthof

Photoelectrons and light from laser-driven 1D helium using TDRNOT — •Martins Brics, Julius Rapp, Adrian Hanusch, and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 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 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 test cases we consider nonsequential double ionization and single photon double ionization. Both are strongly correlated processes and therefore many RNOs are needed to describe them. Our main observable for this purpose is correlated photoelectron spectra. The other aspect we look at is what advantages offers TDRNOT over time-dependent density function theory (TDDFT) for cases where TDDFT already gives quite good results. For that purpose we test TDRNOT on high-order harmonic spectra.

[1] M. Brics, D. Bauer, *Phys. Rev. A* **88**, 052514 (2013).

A 22: Interaction with VUV and X-ray light

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

A 22.1 Tue 16:30 Empore Lichthof

Complete characterization of the Lyman band continuum emissions of molecular hydrogen and deuterium by photon-induced fluorescence spectrometry — •Philipp Schmidt[1], Andreas Hans[1], Christian Ozga[1], Philipp Reiss[1], Ltaief Ben Ltaief[1], Arno Ehresmann[1], André Knie[1], and Michèle Glass-Maujean[2] — [1]Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Laboratoire de Physique Moléculaire pour l'Atmosphère et l'Astrophysique, Université P. et M. Curie/CNRS, 4 pl Jussieu, 75252 Paris Cedex 05, France

The emission of molecular hydrogen and its isotopes in the far ultraviolet regime contains a continuous spectrum with particular fluctuations next to the discrete band transitions from the B and C electronic states. While these have been attributed to the dissociative transition into the continuum of the X ground state for quite some time, the investigations with simulated spectra are severely limited at these wavelengths due to a multitude of overlapping features. Here we present a complete analysis of these continuous emission features after selective excitation by photoexcitation with monochromatized synchrotron radiation as part of a greater investigation encompassing all the emission features and electronic transitions in the far ultraviolet regime. Separated by their electronic state and upper vibrational level, the individual spectra are compared to theoretical calculations and their effect on the emission in general are discussed.

A 22.2 Tue 16:30 Empore Lichthof

Time domain interferometry with Mössbauer nuclei — •Salvatore Castrignano and Jörg Evers — Max Planck Institute for Nuclear Physics, Heidelberg

We will present our recent results on time domain interferometry [1] with Mössbauer nuclei driven by hard x-ray light. This technique enables one to measure the intermediate scattering function to determine the dynamics of a given sample. In particular, we discuss novel interferometry schemes and extensions to other types of dynamics.

[1] A. Q. R. Baron et al, Phys. Rev. Lett 79, 2823 (1997)

A 22.3 Tue 16:30 Empore Lichthof

Spatial overlap for XUV pump-probe experiments using the permanently installed split and delay unit DESC at the FLASH FEL — •J Zimbalski[1], L Flückiger[2,1], K Kolatzki[1], B Langbehn[1], M Müller[1], M Sauppe[1], B Senfftleben[1], A Ulmer[1], J Zimmermann[1], T Zimmermann[1], T Gorkhover[1,3], C Bostedt[3,4], C Bomme[5], S Düsterer[5], B Erk[5], M Kuhlmann[5], D Rolles[5,6], D Rompotis[5], R Treusch[5], T Feigl[7], T Möller[1], and D Rupp[1] — [1]TU Berlin — [2]La Trobe University, Melbourne — [3]SLAC — [4]Argonne National Lab, Northwestern University, Chicago — [5]DESY — [6]Kansas State University — [7]optiX fab

Short wavelength free-electron lasers (FELs) enable novel experiments with a very high temporal and spatial resolution. Interaction of the ultra intense light pulses with matter results in complex dynamics on different timescales. To investigate such processes on a very broad timescale, long range split and delay units are required. The **DE**lay **S**tage for **C**AMP *DESC* uses multilayer mirrors at almost perpendicular incidence to enable XUV-XUV pump-probe experiments with delays ranging from 0 fs to 650 ps.

A common problem when operating split and delay units is the loss of beam alignment and thus spatial overlap in the focus when changing the delay due to inaccuracies of the mirror actuators. In DESC a closed-loop mirror mount allows for fast beam realignment. Therefore a compensation curve was measured by establishing overlap on a YAG-screen using a high resolution microscope as well as optimizing time-of-flight spectra of Xe clusters on high kinetic energies.

A 22.4 Tue 16:30 Empore Lichthof

Transition probabilities of the titanium L3 fluorescence lines as a function of the oxidation state — •Rainer Unterumsberger, Matthias Müller, and Burkhard Beckhoff — Physikalisch-Technische Bundesanstalt, Abbestrasse 2-12, 10587 Berlin, Deutschland

The increase of the sensitivity of a wavelength-dispersive spectrometer (WDS) [1] in the soft X-ray range enables the access to high resolved X-ray emission spectrometry at nanoscaled materials like lights elements and transition metals. The increase could be achieved by focusing of the incident undulator radiation using a single bounce monocapillary [2]. The spectrometer was well characterized and the response behavior was experimentally determined. Due to the knowledge of the response function of the spectrometer, a reliable deconvolution of the emission spectra is possible. That enables the determination of the fluorescence intensity of each emission line with low uncertainties. Here, the relative intensity was estimated to 15 %. The transition probabilities of the titanium L3 fluorescence lines were determined as a function of the oxidation state. The measurements were carried out at the plane-grating monochromator (PGM) beamline in the PTB laboratory at BESSY II using monochromatized undulator radiation and calibrated instrumentation [3,4].

[1] R. Unterumsberger et al., Spectrochim. Acta B 78 (2012) 37-41
[2] M. Müller et al., Phys. Rev. A 79, 032503 (2009)
[3] B. Beckhoff et al., Anal. Chem. 79, 7873 (2007)
[4] B. Beckhoff, J. Anal. At. Spectrom. 23, 845 (2008)

A 22.5 Tue 16:30 Empore Lichthof

Phase modulated harmonic detection to facilitate time-resolved coherent XUV spectroscopy — •Ulrich Bangert, Lukas Bruder, Marcel Binz, Marcel Mudrich, and Frank Stienkemeier — Physikalisches Institut, Universität Freiburg, 79104 Freiburg

Coherent time-resolved spectroscopy is a powerful tool to study ultrafast dynamics in complex systems. Extending these techniques to the XUV spectral region would allow studying core excitations, thus providing site specific information. However, demands on phase stability increase significantly when going to short wavelengths and advanced pulse manipulation in the XUV is challenging. We suggest an approach based on acousto-optical phase modulation on the fundamental frequency combined with lock-in detection at the harmonics. In this way, pulse manipulation can be performed with standard optics. Moreover, demands on phase stability are drastically reduced and signals are efficiently isolated and amplified. We demonstrate this scheme in a proof of principle experiment incorporating second harmonic generation to measure electronic wave packet dynamics in atomic systems. The high quality of our data shows promise for implementation of the scheme in table top HHG or seeded FEL sources.

A 22.6 Tue 16:30 Empore Lichthof

Probing O_2^+ potential curves with an XUV–IR pump–probe experiment — •Philipp Cörlin[1], Andreas Fischer[1], Tomoya Mizuno[1], Michael Schönwald[1], Uwe Thumm[2], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Insitut für Kernphysik — [2]Kansas State University

We study dissociative photo-ionization of O_2 in a kinematically complete XUV–IR pump–probe experiment, preparing a vibrational wave packet in the potential of the binding $O_2^+(a\,^4\Pi_u)$ state by ionization with a single XUV photon. After a variable time–delay the wave packet is promoted to the repulsive $O_2^+(f\,^4\Pi_g)$ state by a weak IR probe pulse. Comparing the results of a coupled–channel simulation with the experimental kinetic–energy-release and quantum–beat spectra, we are able to discriminate between the adiabatic O_2^+ potential–energy curves (PECs) calculated by Marian et al., Mol. Phys. 46, 779 (1982) and Magrakvelidze et al., Phys. Rev. A 86, 023402 (2012). The overall agreement between simulated and experimental results is good; however, not all features of the experimental spectra could be reproduced using these PECs. Using a Morse potential adjusted to the experimental data instead, most features of the experimental spectra are well reproduced by our simulation. This optimized Morse potential is remarkably similar to the theoretically predicted PECs, demonstrating the sensitivity of our experimental method to small changes in the shape of the binding potential.

A 22.7 Tue 16:30 Empore Lichthof

Real time observation of Interatomic Coulombic decay (ICD) in Ar dimers with XUV-pump IR-probe experiments — •Tomoya Mizuno, Philipp Cörlin, Andreas Fischer, Michael Schönwald, Lukas Palm, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We determined the ICD lifetime of Ar dimers by using XUV-pump IR-probe experiments. The first XUV pulse, which is generated from a 10 fs IR laser pulse via HHG in Ar gas, creates the lowly excited ionic states, which can decay rapidly via ICD leading to a dissociative kinetic energy release (KER) of 3.8 eV. Afterwards, the delayed IR probe pulse further ionizes into dicationic states at one site (Ar^{2+}-Ar) or excite into highly excited states if the ICD did not occur yet. These states are long lived, therefore contraction of the dimers occurs. Then these states decay via radiative charge transfer and ICD respectively, resulting in a high KER of 5.2 eV. Finally, the ion pair emerging from the Ar dimer is detected by a reaction microscope. The apparatus enables us to record the ion yield of Ar^{+} +Ar^{+} ion pairs as a function of the pump-probe delay and KER. We found that the delay-dependent ion yield at a KER of 5.2 eV shows an exponential decay with a time constant of 30.1±8.4 fs. We assigned this time constant to the ICD lifetime of the $Ar^{+*}(3p^{-2}$(1D)3d 2D)-Ar state based on the photoionization cross section and the potential energy curves. This is in good agreement with previous calculations of 28 fs [1].

[1]T. Miteva et. al. JCP 141, 064307 (2014)

A 22.8 Tue 16:30 Empore Lichthof

Electron-Ion Coincidence Studies on Multiphoton Ionization of Krypton — •Hannes Lindenblatt[1], Kirsten Schnorr[1], Sven Augustin[1], Georg Schmid[1], Severin Meister[1], Arne Senftleben[1,2], Moritz Kurka[1], Artem Rudenko[3], Tatiana Marchenko[4], Marc Simon[4], Benjamin Erk[5], Rolf Treusch[5], Joachim Ullrich[6], Thomas Pfeifer[1], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Universität Kassel — [3]J.R. Macdonald Laboratory, Kansas State University — [4]UPMC and CNRS, Paris — [5]DESY, Hamburg — [6]PTB, Braunschweig

For all applications of XUV and X-ray free-electron lasers (FELs), in particular imaging of single-molecules, detailed understanding of multiphoton absorption and secondary relaxation processes in those wavelength regimes is mandatory. Here, we investigate electron-ion coincidences in multiphoton ionization of krypton by 210 eV FEL pulses delivered by FLASH using a reaction microscope. The production yields of charge states up to Kr^{11+} are analyzed by intensity-dependent ion spectra. The involved mechanisms are studied by charge state selective electron energy spectra.

A 22.9 Tue 16:30 Empore Lichthof

X-Ray Movie Camera for time resolved single particle imaging: raytracing the focussing multilayer optics — •Björn Senfftleben[1], Leonie Flückiger[1,2], Katharina Kolatzki[1], Bruno Langbehn[1], Maria Müller[1], Mario Sauppe[1], Anatoli Ulmer[1], Jannis Zimbalski[1], Julian Zimmermann[1], Tobias Zimmermann[1], Cédric Bomme[3], Stefan Düsterer[3], Benjamin Erk[3], Marion Kuhlmann[3], Daniel Rolles[3,4], Dimitrios Rompotis[3], Rolf Treusch[3], Christoph Bostedt[5,7], Tais Gorkhover[5], Torsten Feigl[6], Thomas Möller[1], and Daniela Rupp[1] — [1]TU Berlin — [2]La Trobe University, Melbourne — [3]DESY, Hamburg — [4]Kansas State University — [5]SLAC, Menlo Park — [6]optiX fab, Jena — [7]Northwerstern University / Argonne National Lab, Chicago

Short wavelength free-electron lasers (FELs) can be used to image nanostructures via x-ray scattering. Time-resolved studies of non-reproducible structures often lack of information on the initial state of the structure. A novel setup named x-ray movie camera overcomes this limitation by taking two separate time-delayed images of the same gas-phase particle by two beams from different directions. To optimize and overlap the micron foci, which are created by two opposed ellipsoidal multilayer mirrors, precise alignment is required. Raytracing the setup allows to simulate the experimental alignment and reveals the quality and shape of desired focus. By taking the adjustment operations and their effect into account the experiment's and the simulation's data can be compared. The results from raytracing are presented.

A 22.10 Tue 16:30 Empore Lichthof

An Experimental Setup for Multidimensional XUV/soft X-Ray Spectroscopy — •Lennart Aufleger, Thomas Ding, Marc Rebholz, Veit Stooss, Alexander Blättermann, Kristina Meyer, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

In recent years multidimensional spectroscopy with visible and ultraviolet light has given insight into the structure and dynamics of electronic excitations in both atoms as well as in larger molecular systems. In particular the XUV spectral range is of high interest since it represents the photo-excitation region of spatially localized inner-valence electrons. However, due to the increased technical demands of creating adequate multi-pulse sequences in this energy domain and the low photon flux of laboratory-based sources, the extension of two-dimensional absorption spectroscopy to the XUV has, to the best of our knowledge, not yet been realized. Here we present an experimental setup for a multidimensional XUV/soft x-ray spectroscopy scheme suitable for both attosecond high-harmonic sources and ultra-intense free-electron lasers. The heart of the setup is a dynamic monolithic four-segment mirror generating four identical and temporally well-controlled pulses with independent time delays as well as high phase stability out of one incoming pulse, allowing 4-wave mixing experiments with both homodyne and heterodyne detection techniques. The next step will be the femtosecond-time-resolved and site-specific multidimensional spectroscopy of inner-valence electron excitation and charge migration in molecules as a function of time.

A 22.11 Tue 16:30 Empore Lichthof

Stepwise contraction of the nf Rydberg shells in the 3d photoionization of multiply-charged xenon ions — •S. Schippers[1], A. Borovik Jr.[1], T. Buhr[2], J. Hellhund[1], K. Holste[1], A. L. D. Kilcoyne[3], S. Klumpp[4], M. Martins[4], A. Müller[1], S. Ricz[5], and S. Fritzsche[6,7] — [1]Justus-Liebig-Universität Gießen — [2]PTB, Braunschweig — [3]Lawrence Berkeley National Laboratory, USA — [4]Universität Hamburg — [5]ATOMKI, Debrecen, Hungary — [6]Helmholtz-Institut Jena — [7]Friedrich-Schiller-Universität Jena

We report on recent experimental and theoretical results for triple photoionization of Xe^{q+} ($3 \leq q \leq 5$) ions [1]. The measurements were carried out using the photon-ion spectrometer PIPE [2] at the Hamburg PETRA III synchrotron light source. The strongest photoionization resonances are associated with the photoexcitation of a $3d$ electron to an atomic nf subshell ($n = 4, 5, 6, ...$) and the subsequent multiple autoionization of the associated hole states. The $3d^{-1}_{3/2} - 3d^{-1}_{5/2}$ fine structure splitting ($\sim$ 13 eV) of the $3d$ hole leads to two distinct Rydberg series of resonances in each spectrum. Progressively more ionization-resonance structures are observed as the primary charge state of the ions is increased. This visualizes the re-ordering of the εf continuum into a regular series of (bound) Rydberg orbitals as the ionic core becomes more attractive.

[1] S. Schippers et al., J. Phys. B **48** (2015) 144003.
[2] S. Schippers et al., J. Phys. B **47** (2014) 115602.

A 22.12 Tue 16:30 Empore Lichthof

Observation of four-electron Auger processes — A. Müller[1], A. Borovik Jr.[1], T. Buhr[2], J. Hellhund[1], K. Holste[1], A. L. D. Kilcoyne[3], S. Klumpp[4], M. Martins[4], S. Ricz[5], J. Viefhaus[6], and •S. Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]PTB, Braunschweig — [3]Lawrence Berkeley National Laboratory, USA — [4]Universität Hamburg — [5]ATOMKI, Debrecen, Hungary — [6]FS-PE, DESY, Hamburg

We report on the observation of triple-Auger decay processes [1] in which $C^{+}(1s2s^{2}2p^{2}\,^{2}D,^{2}P)$ terms were selectively excited by irradiating singly charged carbon ions by VUV photons at the PETRA III synchrotron light source. Subsequent to the decay of the intermediate resonantly excited K-vacancy terms, product ions C^{2+}, C^{3+} and C^{4+} were recorded. Absolute cross sections for processes $\gamma + C^{+}(1s^{2}2s^{2}2p\,^{2}P) \rightarrow C^{+}(1s2s^{2}2p^{2}\,^{2}D,^{2}P) \rightarrow C^{1+m+}(1s^{2}\ell^{3-m}) + me$ leading to net photoionization with $m = 1, 2, 3$ were determined. In addition, the natural linewidths of the intermediate resonant states could be measured. By combining all this information, the absolute transition rates for radiative as well as single and multiple Auger decays were inferred. The triple-Auger decay rate was found to be 2.0×10^{10} s^{-1} for the $C^{+}(1s2s^{2}2p^{2}\,^{2}D)$ and 9.7×10^{9} s^{-1} for the $C^{+}(1s2s^{2}2p^{2}\,^{2}P)$ intermediate resonantly-excited terms investigated in this study. The ratios of single- to double- to triple-Auger rates of the ^{2}D and ^{2}P terms are about 100 : 2.7 : 0.013 and 100 : 3.3 : 0.013, respectively.

[1] A. Müller et al., Phys. Rev. Lett. **114** (2015) 013002.

A 22.13 Tue 16:30 Empore Lichthof

Experimental determination of Oxygen K-shell fluorescence yield of different Silicon sub-oxides — •Malte L. Wansleben, Philipp Hönicke, Michael Kolbe, and Burkhard Beckhoff — Physikalisch-Technische Bundesanstalt, 10587 Berlin, Germany

The ongoing development of thin film materials for applications in different fields of research and production requires an accurate and reliable composition analysis. If a non destructive quantitative characterization of the elemental composition is needed, often only fundamental parameter based - or even reference free X-ray fluorescence (XRF) spectroscopy is a suitable analytical method. This is due to the extremely low availability of reference materials with sufficient similarity to the analytical problem.

The accuracy of the quantitative results highly depends on the availability of atomic fundamental parameters with uncertainties as low as possible. Especially tabulated fundamental parameters for low Z elements are only available with insufficient large uncertainties. In addition, the question if fundamental parameters of an element are influenced by its chemical environment has to be answered.

To address this question here, the dependency of the oxygen K-shell fluorescence yield - being one of the atomic fundamental parameters - as a function of the oxidation state of silicon is experimentally determined. The experiments were carried out at the plane grating monochromator beamline in the PTB laboratory at the electron storage ring BESSY II, where monochromatized synchrotron radiation of high spectral purity was employed.

A 22.14 Tue 16:30 Empore Lichthof

Gas Monitor Detector (GMD) for FEL, Synchrotron and Laser Sources — •Stephan Klumpp, Markus Braune, Andrey A. Sorokin, and Kai Tiedtke — FS-FL, DESY, Hamburg

The users at different radiation facilities like PETRA III, FLASH or ELI need for the evaluation of their data the intensity of the exciting radiation with low uncertainty, but measuring the intensity of a photon beam in the soft and hard x-ray regime is a non-trivial task. For soft x-rays like e.g. at P04, PETRA III, calibrated photo diodes will be sufficient to determine the intensity on absolute scale. They work on radiation sources with stable beam conditions. For the ever changing pulses of FLASH the non-destructive gas monitor detectors (GMD) were developed, but the concept is based on a high number of photons, above 10^{10} photons per pulse, to create data having a good signal-to-noise ratio. At a FEL this condition is fulfilled, but not necessarily for HHG laser sources, for example. The aim of the "Pulse Characterization and Control" (PUCCA) work package of the European Cluster of Advanced Laser Light Sources (EUCALL) is to realize, beside wavefront sensors and timing tools, an intensity monitor bridging from the soft to the hard x-ray regime and from low intensity sources, below 10^6 photons per pulse, to high intensity sources, above 10^{10} photons per pulse. We will discuss different approaches to meet the challenge.

EUCALL and WP7 PUCCA has received funding from the European Unions Horizon 2020 research and innovation program under grant agreement No 654220.

A 22.15 Tue 16:30 Empore Lichthof

High-intensity narrow-band 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

Intense ultrashort x-ray free electron laser (XFEL) pulses can create population inversion through K-shell ionization of highly charged ions. This allows the generation of an x-ray laser pulse with better coherence properties than the original XFEL pulse. Our time-depenent density matrix simulations show that the bandwidth of the x-ray laser can be reduced if one uses certain highly charged ions. The saturation intensity of the x-ray laser is no longer limited by the lifetime of the upper lasing level, and can be increased significantly by implementing more intense XFEL pulses. Furthermore, the frequency of the laser can be extended to the hard x-ray regime when heavy ions are employed.

A 22.16 Tue 16:30 Empore Lichthof

Directional control of the photodissociation of SF6 by using THz and XUV fields — •Severin Meister[1], Georg Schmid[1], Sven Augustin[1], Kirsten Schnorr[1], Hannes Lindenblatt[1], Yifan Liu[1], Viktor Adam[1], Ann-Sophie Hilkert[1], Patrick Paluch[1], Artem Rudenko[2], Matthias Kübel[3], Christian Burger[3], William Okell[3], Matthias Kling[3], Torsten Golz[4], Nikola Stojanovic[4], Thomas Pfeifer[1], Claus-Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]Kansas State University, Manhattan, USA — [3]Ludwig Maximilians Universität, München, Deutschland — [4]DESY, Hamburg, Deutschland

In a two-color coherent-control experiment at FLASH, we used a THz pulse to excite anti-symmetric vibrational modes in SF_6 and singly ionized the molecule with a delayed 60 eV XUV pulse. The emission direction of the emitted F atom is controlled by the phase of the superimposed stretching vibrational modes. The ionization leads to a Coulomb explosion, fragmenting mainly in SF_5^+ and F. As a result the directionality of the de-halogenation can be controlled, which manifests as an asymmetric ejection of F atoms along the laser polarization. The experiment was performed with a Reaction Microscope (REMI), where all charged fragments (e^-, F, SF_5^+) can be detected in coincidence and their associated momenta reconstructed. An oscillation in the preferential direction (along the polarization direction of the THz pulse) of the F emission, as a function of pulse delay Δt, serves as the signature of the successful control of the dissociation direction.

A 22.17 Tue 16:30 Empore Lichthof

IR-assisted XUV Multiphoton Ionization of Noble Gases at FLASH — •Georg Schmid[1], Kirsten Schnorr[1], Sven Augustin[1], Severin Meister[1], Hannes Lindenblatt[1], Defu Luo[1], Patrick Paluch[1], Lutz Fechner[1], Thomas Ding[1], Yifan Liu[1], Rolf Treusch[2], Stefan Düsterer[2], Harald Redlin[2], Christian Ott[3], Kamal P. Singh[4], Mathieu Gisselbrecht[5], Claus-Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]DESY, Hamburg, Germany — [3]UC Berkely, USA — [4]IISER, Mohali, India — [5]Lund University, Sweden

IR-XUV pump-probe experiments on atomic noble gases were performed at the free-electron laser in Hamburg (FLASH). Using a reaction microscope, we were able to measure photoions and -electrons as a function of the delay between intense IR ($\sim10^{14}$ W/cm^2) and XUV pulses. For delay values with IR being present, an enhancement in the yield of Ar ions produced by multiple absorption of 27 eV photons is observed up to high ionic charge states (Ar^{5+}). The increase is especially pronounced in the Ar^{2+} channel. Sequential absorption of two XUV photons excites Ar^{+*} ($3s^2 3p^4 (^1D) 3d$) states which are further ionized by the IR pulse to Ar^{2+}. The ion yield dependence on the XUV and IR intensity is investigated and different IR-assisted XUV multiphoton ionization pathways are distinguished. Our findings show how XUV multiphoton ionization can be controlled by IR laser pulses. For Helium at 24 eV, differences in the He^+ photoion and -electron momentum distributions are observed with and without IR laser.

A 22.18 Tue 16:30 Empore Lichthof

Inner shell excitation of Mn with short intense x-ray pulses — •Stephan Klumpp[1,2], Karolin Mertens[1], Nils Gerken[1], Bernd Sonntag[1], Mathias Richter[3], Andrey Sorokin[2], Markus Braune[2], Kai Tiedtke[2], Peter Zimmermann[4], and Michael Martins[1] — [1]Dept. Physik, UHH — [2]FS-FL, DESY — [3]PTB — [4]TU Berlin

Within one single pulse of a FEL like FLASH at DESY in Hamburg, with a duration in the order of 10 fs the neutral xenon atom can absorb more than 50 photons and hence can be ionised up to Xe^{21+}. The physics driving the ionisation to this high charge state is still under debate, but it is presumed that the existence of resonances of the neutral atom and the intermediate (highly charged) ions play an important role in the sequential absorption process of so many photons. By varying the atomic target from Xe, with its completely filled 4d subshell, to Mn, with its half filled 3d subshell, we study the influence of the correlative nature of the resonances involved in the photoionisation process. The atomic manganese was therefore excited with two different photon energies using high flux FEL pulses from the BL2 beamline of FLASH. With photons of 23.8 nm (52.1 eV) Mn was excited resonantly in its giant resonance, with photons of 20.3 nm (61.2 eV) non-resonantly above it. m/q spectra were obtained by the means of ion time-of-flight spectrometer depending on the irradiance of the FEL pulses. Charge states of Mn ions up to Mn^{6+} have been observed at resonant excitation and even up to Mn^{7+} for non-resonant excitation. The dependence of the m/q spectra can be explained in a sequential excitation scheme.

A 22.19 Tue 16:30 Empore Lichthof

Cross sections of iodine-containing molecular ions after inner-shell excitation — •Stephan Klumpp[1], Kaja Schubert[1], Karolin Mertens[1], Alexander Guda[2], Sadia Bari[3], Jonas Hellhund[4], Stefan Schippers[4], Alfred Müller[4], and Michael Martins[1] — [1]Department Physik, University of Hamburg — [2]Southern Federal University, Rostov-on-Don, Russia — [3]FS-SCS, DESY, Hamburg — [4]Justus-Liebig-Universität Giessen

We have measured partial cross sections for the production of atomic fragments I^{q+} (q=2..5) by photofragmentation of the parent ion IH^{1+}

with the Photon-Ion-Spectrometer (PIPE) at P04 of PETRA III at DESY in Hamburg. The molecular ion parent has been excited with x-ray photons in the energy range of the iodine 3d excitation threshold. The cross sections show two broad prominent features similar to the cross sections of Xe. In contrast, the partial cross sections of the fragments I^{q+} (q=2..5) for the atomic parent ion I^{1+} are much more structured.

Determining absolute absorption cross sections of atomic ions in a merged-beam set-up is a well established method. For molecular ions the kinetic energy release (KER) of each fragmentation process has to be taken into account, in addition because the charged molecular fragments are driven apart. We introduce a kinematic model regarding the KER for IH^{1+} calculating the ratio between the atomic I^{n+} (n=2..5) fragments hitting the detector and the ones hitting the chamber walls. The ratio is then used to calibrate the measured spectra. The obtained values are compared to DFT calculations.

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

Time: Wednesday 11:00–13:00 Location: f107

A 23.1 Wed 11:00 f107

Polaronic effects in one- and two-band quantum systems — •Tao Yin[1], Daniel Cocks[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt/Main, Germany — [2]College of Science, Technology & Engineering, James Cook University, Townsville 4810, Australia

In this work we study the formation and dynamics of polarons in a system with a few impurities in a lattice immersed in a Bose-Einstein condensate (BEC). This system has been experimentally realized using ultracold atoms and optical lattices. Here we consider a two-band model for the impurity atoms, along with a Bogoliubov approximation for the BEC, with phonons coupled to impurities via both intra- and inter-band transitions. We decouple this Fröhlich-like term 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 shifts and induced long-range interaction. A Lindblad master equation approach is used to take into account residual incoherent coupling between polaron and bath. This polaronic treatment yields a renormalized inter-band relaxation rate compared to Fermi's Golden Rule. For a strongly coupled two-band Fröhlich Hamiltonian, the polaron is tightly dressed in each band and can not tunnel between them, leading to an *inter-band self-trapping* effect.

[1] T. Yin, D. Cocks and W. Hofstetter, arXiv:1509.08283 (2015).

A 23.2 Wed 11:15 f107

Probing superfluidity of Bose-Einstein condensates via laser 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, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany

We investigate the superfluid behavior of a Bose-Einstein condensate of ^6Li molecules. In the experiment by Weimer *et al.*, Phys. Rev. Lett. **114**, 095301 (2015) a condensate is stirred by a weak, red-detuned laser beam along a circular path around the trap center. The rate of induced heating increases steeply above a velocity v_c, which we define as the critical velocity. Below this velocity, the moving beam creates almost no heating. In this paper [1], we demonstrate a quantitative understanding of the critical velocity. Using both numerical and analytical methods, we identify the non-zero temperature, the circular motion of the stirrer, and the density profile of the cloud as key factors influencing the magnitude of v_c. A direct comparison to the experimental data shows excellent agreement.

[1] V. P. Singh, W. Weimer, K. Morgener, J. Siegl, K. Hueck, N. Luick, H. Moritz, and L. Mathey, arXiv: 1509.02168.

A 23.3 Wed 11:30 f107

Robustness of many-body localization in the presence of dissipation — •Emanuele Levi[1], Markus Heyl[2], Igor Lesanovsky[1], and Juan P. Garrahan[1] — [1]School of Physics and Astronomy, University of Nottingham, University Park, NG7 2RD, United Kingdom — [2]Physik Department, Technische Universität München, 85747 Garching, German

Many-body localization (MBL) has emerged as a novel paradigm for robust ergodicity breaking in closed quantum many-body systems. However, it is not yet clear to which extent MBL survives in the presence of dissipative processes induced by the coupling to an environment. In this talk I will discuss the findings of [1] about heating and ergodicity for a paradigmatic MBL system –an interacting fermionic chain subject to quenched disorder in the presence of dephasing. Even though the system is eventually driven into an infinite-temperature state, heating as monitored by the von Neumann entropy can progress logarithmically slowly, implying exponentially large time scales for relaxation. This slow loss of memory of initial conditions make signatures of non-ergodicity visible over a long, but transient, time regime. Time allowing I will discuss a potential controlled realization of the considered setup with cold atomic gases held in optical lattices.

[1] E. Levi, M. Heyl, I. Lesanovsky, J.P. Garrahan, What survives of many-body localization in the presence of dissipation, arXiv:1510.04634

A 23.4 Wed 11:45 f107

Observation of mixing between singlet and triplet scattering channels in Rb_2 Rydberg molecules — •Karl Magnus Westphal, Fabian Böttcher, Anita Gaj, Michael Schlagmüller, Kathrin Sophie Kleinbach, Robert Löw, Tara Cubel Liebisch, Tilman Pfau, and Sebastian Hofferberth — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We present high-resolution spectroscopy of Rb_2 ultralong-range Rydberg molecules bound by mixed singlet-triplet electron-neutral atom scattering [1]. The mixing of the scattering channels is a consequence of the hyperfine interaction in the ground-state atom, as predicted recently by Anderson et al. [2]. Using our experimental data we determine the effective zero-energy singlet s-wave scattering length. Furthermore, we calculate molecular potentials using a full diagonalization approach including the p-wave contribution and all orders in the relative momentum k, and compare the obtained molecular binding energies to the experimental data. We show that an applied external magnetic field changes the contributions of the singlet and the triplet scattering and therefore the binding energies of the observed molecules. Ultimately, we extract the molecular magnetic moments, which differ from the magnetic moments of the asymptotic atomic states.

1 F. Böttcher et al., **arXiv:1510.01097**, (2015)

2 D. A. Anderson et al., **Phys. Rev. A 90**, 062518 (2014)

A 23.5 Wed 12:00 f107

Towards the production of RbCs ground-state molecules from degenerate gases in an optical lattice — •Andreas Schindewolf[1], Lukas Reichsöllner[2], Silva Mezinska[1], Beatrix Mayr[1], Rudolf Grimm[1,2], and Hanns-Christoph Nägerl[1] — [1]Institut für Experimentalphysik, Universität Innsbruck — [2]Institut für Quantenoptik und Quanteninformation IQOQI, Innsbruck

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 a low entropy sample of dipolar RbCs molecules in the rovibronic and hyperfine ground-state. To be able to mix degenerate samples of Rb and Cs, the inter-species scattering length a_{RbCs} has to be tuned close to zero by means of a magnetic Feshbach resonance. Since Cs three-body losses would cause a breakdown of a Cs BEC in the magnetic-field region, in which RbCs Feshbach resonances are available, we initially prepare a Cs Mott insulator with unity filling spatially separated from the Rb sample. The optical lattice wavelength and depth are chosen in a way that Rb is still superfluid and can be overlapped with Cs after switching the magnetic field to achieve $a_{\mathrm{RbCs}} = 0$. Precise control over the relative position of the two degenerate samples and high magnetic field stability will enable the formation of RbCs Feshbach molecules with a high filling factor of the optical lattice followed by the application of the STIRAP transfer to the absolute molecular ground-state, as demonstrated in Ref. [1].

[1] T. Takekoshi et al., Phys. Rev. Lett. **113**, 205301 (2014)

A 23.6 Wed 12:15 f107

Out-of-equilibrium dynamics of two interacting bosons — •Tim Keller and Thomás Fogarty — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

We study the out-of-equilibrium dynamics of two interacting bosons in a one-dimensional harmonic trap after a quench by a centrally located delta-function potential. We are interested in the role of interactions and correlations on this dynamics and have observed many complex phenomena. We make use of an approximate variational calculation called the Lagrange-mesh method to solve the Schrödinger equation numerically. We examine the dynamics by calculating the single particle density and through the time-dependent fidelity (Loschmidt echo) we investigate the irreversibility of the quenched system and its nonlinear dependence on the particles interactions. We discern distinct scattering states created by the quench through a thorough examination of its dynamical properties described by the spectral function. We link the probability distribution of the Loschmidt echo after a long-time evolution to the structure of the spectral function and identify four characteristic distributions which are dependent on quench strength and particle interactions. We lay special focus on the case of a distorted bell-shaped distribution which is caused by a distinct beating in the Loschmidt echo due to the interference of different spectral components. This resonance also has consequences for the particles correlations which mirrors that of the Loschmidt echo.

A 23.7 Wed 12:30 f107

Molecular ion formation in atom-ion three body recombination — •Amir Mohammadi, Artjom Krükow, Joschka Wolf, Amir Mahdian, and Johannes Hecker Denschlag — Universität Ulm, Institut für Quantenmaterie, Albert-Einstein-Allee 45, D-89069 Ulm, Deutschland

Producing transitionally and internally cold molecular ions is one of the challenges and long standing goals in cold atom-ion experiments. One good strategy for this purpose is creating initially cold molecular ions by associating cold ions and cold atoms. In our hybrid atom-ion experiment, we investigate the interaction of a laser-cooled trapped ^{138}Ba ion with an ultracold cloud of ^{87}Rb atoms. At very low kinetic energies (i.e. sub-mK) and densities of 10^{12} cm^{-3}, three-body atom-atom-ion recombination is the dominant reaction process in our experiment[1]. It has been predicted [2] that a weakly bound $BaRb^+$ ion should be the dominant molecular product. In this talk, we indeed report on the first experimental observation of these molecules after three-body recombination. Furthermore, we discuss the effects of secondary and ternary collisions of $BaRb^+$ with cold Rb atoms.

[1] A. Krükow et al., arXiv:1510.04938 (2015)
[2] J.Pérez-Rios and C.H. Greene, The journal of Chemical Physics **143**, 041105 (2015)

A 23.8 Wed 12:45 f107

Nontrivial topological phases in quantum mechanical many-body systems with gain and loss effects — •Marcel Klett, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Non-Hermitian $\mathcal{PT}$-symmetric potentials are capable of effectively describing quantum systems with balanced in- and outfluxes. They allow for the existence of a $\mathcal{PT}$-symmetric phase with purely real energy spectra of the non-Hermitian Hamiltonian. Good candidates for the realization of a genuine $\mathcal{PT}$-symmetric quantum system are Bose-Einstein condensates. Recently a possible relation between the appearance of the $\mathcal{PT}$-symmetric phase and topologically nontrivial states were found in two studies of simple model systems. However, they came to opposite conclusions. In the Su-Schrieffer-Heeger (SSH) model [1] the topological phase has a major influence. As soon as topologically nontrivial states appear $\mathcal{PT}$ symmetry gets broken. This is in contrast to the non-Hermitian Kitaev model [2], in which $\mathcal{PT}$ symmetry breaking does not depend on the topological phase. Our work is based on including different non-Hermitian potentials in the SSH model as well as the Kitaev model. We perform exact calculations of the eigenvalues and the eigenstates, clarify the relation between $\mathcal{PT}$ symmetry and topological phases, and explain why opposite results were found in the above mentioned systems. Consequences for $\mathcal{PT}$-symmetric Bose-Einstein condensates are discussed.

[1] Baogang Zhu et al., Phys. Rev. A **89**, 062102 (2014)*
[2] Xiaohui Wang et al., Phys. Rev. A **92**, 012116 (2015)

A 24: Interaction with strong or short laser pulses I

Time: Wednesday 11:00–13:00 Location: f303

A 24.1 Wed 11:00 f303

Strong-Field Breit-Wheeler Pair Production in Short Laser Pulses — •Martin J.A. Jansen and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

We study the creation of electron-positron pairs induced by the collision of an intense short laser pulse with a high-energy gamma quantum. Employing detailed S matrix calculations in the framework of laser-dressed quantum electrodynamics, energy spectra of emitted particles are obtained. These spectra reveal a rich structure, which lies in the focus of our present study [1]. Combining concepts known from bichromatic laser fields with the continuous frequency spectrum inherent to the short pulse, an intuitive model is developed which allows to understand the global form of the energy spectra in terms of multiphoton processes. Furthermore, fine structures in the spectra can be traced back to multiphoton interferences which are sensitive to the carrier-envelope phase of the short pulse.

[1] M.J.A. Jansen and C. Müller, arXiv:1511.07660 [hep-ph]

A 24.2 Wed 11:15 f303

Spin effects in high-intensity light-matter interactions — •Heiko Bauke[1], Rico Erhard[1], Anton Wöllert[1], Sven Ahrens[1], Rainer Grobe[2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Intense Laser Physics Theory Unit and Department of Physics, Illinois State University, Normal, Illinois 61790-4560 USA

Various spin effects are expected to become observable in light-matter interaction at relativistic intensities, in particular if electromagnetic fields with elliptical polarization are involved. It is shown that there is a coupling of the spin angular momentum of light beams with elliptical polarization to the spin degree of freedom of free electrons. This coupling is of similar origin as the well-known spin-orbit coupling and can lead to spin precession [1, 2] as well as spin dynamics in Kapitza-Dirac scattering [3]. Remarkably, these effects are caused by relativistic corrections to the Pauli equation but may be observed even at nonrelativistic intensities. Furthermore, it is demonstrated how the ellipticity of ultra-strong counterpropagating electromagnetic fields affects pair creation and can lead to spin-polarized electron-positron pairs [4].

[1] H. Bauke, S. Ahrens, C. H. Keitel and R. Grobe, New Journal of Physics **16**, 103028 (2014)

[2] H. Bauke, S. Ahrens and R. Grobe, Phys. Rev. A **90**, 052101 (2014)

[3] R. Erhard and H. Bauke, Phys. Rev. A **92**, 042123 (2015)

[4] A. Wöllert, H. Bauke and C. H. Keitel, Phys. Rev. D **91**, 125026 (2015)

A 24.3 Wed 11:30 f303

Photoionization of hydrogen-like ions by twisted attosecond light pulses — •Robert A. Müller[1,2], Daniel Seipt[2], Stephan Fritzsche[1,2], and Andrey Surzhykov[2] — [1]Friedrich-Schiller-University Jena, Germany — [2]Helmholtz-Institute Jena, Germany

In the recent years a number of theoretical studies has been attributed to the interaction between atomic systems and twisted light. It has been found for instance that if an atom is ionized by twisted light, the emission pattern of the photoelectrons remarkably depends on the so called *impact parameter* which is the distance between the target atom and the beam axis [1]. This sensitivity is caused by the spatial inhomogeneity of vortex light beams, which have intensity maxima lying on concentric rings. The loci of these rings depend on the frequency of the twisted light. This frequency has been assumed to be monochromatic in all former studies. Nowadays however it is possible to create twisted pulses in the attosecond regime [2]. Naturally these pulses are not monochromatic but have a frequency distribution. Therefore the beam profiles of the pulses become frequency dependent. In this contribution we discuss how this dependency affects the photoionization of atoms by twisted light. We will present calculations for the angular distribution and the spectrum of the emitted photoelectrons depending on both the impact parameter and the pulse duration which limits the width of the frequency distribution.

[1] Matula *et al.*, J. Phys. B **46**, 205002 (2013)
[2] Géneaux *et al.*, arXiv:1509.07396 (2015)

A 24.4 Wed 11:45 f303

Two-step semiclassical model with quantum interference — •Nikolay Shvetsov-Shilovski[1], Manfred Lein[1], Lars Madsen[2], Esa Räsänen[3], Christoph Lemell[4], Joachim Burgdörfer[4,6], Diego Arbo[5], and Karoly Tökési[6] — [1]Leibniz Universität Hannover, Hannover, Germany — [2]Aarhus University, Aarhus, Denmark — [3]Tampere University of Technology, Tampere, Finland — [4]Vienna University of Technology, Vienna, Austria — [5]Institute for Astronomy and Space Physics, Buenos Aires, Argentina — [6]Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary

Trajectory-based semiclassical models are widely used in strong-field physics. A recent quantum trajectory Monte-Carlo (QTMC) approach [1] allows to describe interference effects in above-threshold ionization. The QTMC accounts for the Coulomb potential using the first-order semiclassical perturbation theory.

Here we present a two-step semiclassical model with interference (TSMI) for strong-field ionization [2]. The TSMI accounts for the Coulomb potential beyond the semiclassical pertrubation theory. In TSMI the phase associated with every trajectory is calculated using the matrix element of the semiclassical propagator. By comparison with the numerical solution of the time-dependent Schrödinger equation we show that generally the TSMI describes the interference patterns better than the QTMC.

[1] M. Li et al., Phys. Rev. Lett. 112, 113002 (2014).
[2] N. I. Shvetsov-Shilovski et al., in preparation.

A 24.5 Wed 12:00 f303

Coulomb-corrected complex trajectories in strong-field ionization — •Thomas Keil and Dieter Bauer — Universität Rostock, Institut für Physik

The strong-field approximation (SFA) is known to roughly reproduce photoelectron spectra of atoms in strong laser fields (see [1] for a review). However, there is no $2U_p$ plateau in plain SFA. SFA with rescattering generates a plateau up to $2U_p$ but qualitatively wrong and with an ambiguous dependence on a screening parameter. Simple man's theory (SMT) reproduces the $2U_p$ cutoff-law but gives vanishing probability at the cutoff, and thus no plateau as well.

We show that by applying a Coulomb-correction inspired by [2] to the trajectory-based SFA [3,4] we can reproduce the plateau and cutoff as seen in results obtained by solving the time-dependent Schrödinger equation (TDSE) numerically. This approach uses complex trajectories everywhere and therefore does not require the concept of a "tunnel exit". We compare this method to the plain SFA, the TDSE and a different Coulomb-corrected SFA used in previous works. The generation of the $2U_p$ plateau and cutoff is demonstrated, and the mechanism behind it is analyzed. The problem of branch cuts in the complex-time plane due to the Coulomb potential (as described in [5]) is discussed.

[1] S.V. Popruzhenko, J. Phys. B 47 204001 (2014)
[2] S.V. Popruzhenko, JETP 118, 580 (2014)
[3] T.-M. Yan et al., Phys. Rev. Lett. 105, 253002 (2010)
[4] Th. Keil et al., J. Phys. B 47, 124029 (2014)
[5] E. Pisanty et al., arXiv:1507.00011 [quant-ph]

A 24.6 Wed 12:15 f303

Optical response in femtosecond filaments dominated by resonantly enhanced ionization — •Michael Hofmann[1,2] and Carsten Brée[1,3] — [1]Weierstraß Institut für angewandte Analysis und Stochastik (WIAS) — [2]Institut für theoretische Physik, TU Berlin — [3]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie (MBI)

Although the standard model of femtosecond filamentation is quite successful in many applications, its validity has been under discussion over the last years (initiated by [1]). For example, the employed ionization rate does not account for resonances between laser-dressed states. We show exemplarily for a hydrogen atom that resonances locally enhance the ionization which in turn saturates the nonlinear refractive index [2]. Such a saturation can easily be misinterpreted as a higher-order Kerr effect if resonances are neglected. By modifying the standard model to include resonantly enhanced ionization, we obtain a remarkable agreement between model and TDSE simulations in the adiabatic regime of a slowly varying pulse envelope. Our goal is to go beyond this adiabatic regime and to derive the optical response for arbitrary pulses without the need to solve the time-dependent Schrödinger equation, thus keeping large-scale filament simulations feasible.

[1] Loriot et al., Opt. Express **17** 13429 (2009).
[2] Hofmann and Brée, Phys. Rev. A **92** 013813 (2015).

A 24.7 Wed 12:30 f303

Spatio-temporal dynamics along a femtosecond filament — •Martin Kretschmar[1], Carsten Bree[2], Tamas Nagy[1,3], Heiko Kurz[1], Uwe Morgner[1], and Milutin Kovacev[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Hannover — [2]Weierstrass-Institut für angewandte Analysis und Stochastik, Berlin — [3]Laser-Laboratorium Göttingen, Göttingen

Filaments occur as the nonlinear balance between self-focusing due to the Kerr-effect and defocusing due to free electrons generated by ionizing the surrounding medium. As a result, complex spatio-temporal dynamics take place during the filamentation process, which strongly influence the propagating pulse. We report on the direct observation of pulse dynamics along the filament and its connection to directly emitted high-order harmonic radiation. The nonlinear nature of the high-harmonic generation process is used to gain further insight into the fundamental pulses propagation dynamics. Theoretical modeling of the fundamental pulse propagation confirms our experimental observations and gives further insight into the nonlinear dynamics occurring along a filament.

A 24.8 Wed 12:45 f303

Double-slit electron interference in strong-field ionization of neon dimer — •Maksim Kunitski, Pia Huber, Jonas Köhler, Kevin Henrichs, Nikolai Schlott, and Reinhard Dörner — Institut für Kernphysik, Goethe-Universität Frankfurt am Main, Max-von-Laue-Straße 1, D-60438 Frankfurt am Main

The double-slit experiment has been widely utilized in order to learn different aspects of quantum mechanics, as, for instance, in famous Bohr-Einstein debates. In 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].

Here we report the observation of photo-electron double-slit interference in single ionization of neon dimer by a strong ultra-short laser field (40 fs, 790 nm, $6.0 \cdot 10^{14}$ W/cm^2). An electron and a single Ne ion resulting from break-up of Ne^{2+} along the repulsive $II(1/2)_g$ potential were measured in coincidence by means of COLd Target Recoil Ion Momentum Spectroscopy (COLTRIMS) [2]. The interference pattern in the angular distribution has been found to be governed by the parity of the molecular orbital from which the electron is freed. The electron removed from an *ungerade* orbital shows constructive interference perpendicular to the molecular axis, whereas the one from a *gerade* orbital shows destructive interference.

[1] H. D. Cohen, U. Fano, Phys Rev 150, 30-33 (1966).
[2] J. Ullrich et al., Rep. Prog. Phys. 66, 1463 (2003).

A 25: Interaction with strong or short laser pulses II

Time: Wednesday 14:30–16:30 Location: f107

Invited Talk A 25.1 Wed 14:30 f107

Describing the correlated electron dynamics in atoms and molecules — •Sebastian Bauch — Institut für Theoretische Physik und Astrophysik, CAU Kiel, Germany

The description of the correlated dynamics of electrons in atoms and molecules is a theoretically challenging task and, for systems consisting of more than two electrons, only possible by employing approximative schemes. Among these methods, time-dependent approaches based on the configuration-interaction (CI) expansion of the wave function play an important role. In particular, the time-dependent generalized-active-space CI method offers a promising possibility for the accurate description of the multi-electron dynamics which are initiated by external laser fields. This talk sketches the ideas of this recently established method, discusses its relation to alternative approaches, and reviews applications. These include photoionization of many-electron atoms [1], strong-field effects in molecular model systems [2,3], correlation effects in the enhanced ionization phenomenom of diatomic molecules [4], and the full-dimensional description of multi-electron molecules in strong laser fields [5].

[1] D. Hochstuhl, and M. Bonitz, Phys. Rev. A 86 053424 (2012) [2] S. Bauch, L.K. Sørensen, and L. B. Madsen, Phys. Rev. A 90 062508 (2014) [3] S. Bauch, H.R. Larsson, C. Hinz, and M. Bonitz, submitted (2015) [4] S. Chattopadhay, S. Bauch and L.B. Madsen, in press, Phys. Rev. A [5] H.R. Larsson, S. Bauch, L.K. Sørensen and M. Bonitz, submitted (2015)

A 25.2 Wed 15:00 f107

Novel experimental approach for the detection of correlated ionization dynamics — •Philipp Wustelt[1,2], Lukas Wolf[1], Max Möller[1,2], Tim Rathje[1,2], A. 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

The investigation of correlated ionization dynamics in the photoionization process of atoms in intensive laser fields has been the subject of many experimental as well as theoretical studies and is still not fully understood. The identification of possible ionization delays associated with multielectron dynamics in the strong-field ionization is part of intensive discussions.

Here, we present a novel experimental approach to study the multiple ionization process in a systematic way by comparing the double ionization process and the two individual single ionization steps. To this end, the momentum distribution of the fragments after ionization of the same atomic species, but with different initial charge state are measured in the identical experimental apparatus and under the same experimental conditions. In order to exclude correlation induced by recollision we apply elliptically polarized laser fields. The observed momenta spectra of He/He^{+} and Ne/Ne^{+} are discussed and compared to classical simulations.

A 25.3 Wed 15:15 f107

Exact simulation of intense-laser-driven helium using TDRNOT — •Julius Rapp, Martins Brics, and Dieter Bauer — Universität Rostock, Germany

Recently-introduced time-dependent renormalized-natural-orbital theory (TDRNOT) [1-4] is a method to simulate correlated dynamics of few-body quantum systems. In the case of two particles, the exact equations of motion for the natural orbitals are explicitly known [2]. Using the common 1D He model as a test case, TDRNOT has been proven to capture laser-atom-interaction phenomena including double excitation followed by autoionization [1], resonant interaction [2], non-sequential double ionization [3], and high-harmonic generation [4] with proper accuracy.

The extension to 3D is conceptionally simple and yet very desirable since it enables one to combine theoretical and experimental techniques when studying correlated electron dynamics. After an introduction to TDRNOT, this talk concerns the progress on reproducing the 1D benchmark results in full dimensionality.

We also compare effort and gain of TDRNOT to the imposing exact 3D two-electron calculations presented in Ref. [5].

[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)
[4] M. Brics, J. Rapp, and D. Bauer, arXiv:1510.01682 (2015)
[5] A. Zielinski, V. Majety, and A. Scrinzi, arXiv:1511.06655 (2015)

A 25.4 Wed 15:30 f107

Towards Ionization Channel-Resolved Electron Rescattering in the Molecular Frame — •Felix Schell, Federico Furch, Serguei Patchkovskii, Marc Vrakking, Claus Peter Schulz, and Jochen Mikosch — Max Born Institute, Berlin, Germany

In laser-induced electron diffraction (LIED), the field of an intense fs laser pulse first ionizes a molecule and then accelerates the released electron back to the core, where an elastic scattering event can imprint structural information on the electron [1]. However, for polyatomic molecules, multiple continua originating from the ionization of states lying lower than the HOMO are expected to contribute to the signal of diffracted electrons and thus complicate the interpretation of LIED experiments. In order to separate contributions to electron rescattering from multiple channels, we extend the CRATI technique [2]. We align 1,3-butadiene molecules non-adiabatically using an 800nm laser pulse and drive strong-field ionization and electron rescattering with a subsequent laser pulse at 1.3μm. A reaction microscope is used to acquire electron momentum maps in coincidence with the parent ion and its fragments. Recording these maps in the molecular frame while varying the driving light's ellipticity is expected to yield insight into the shape of the electron continuum wavepackets emerging from different orbitals.

[1] Blaga *et al.*, Nature **483**, 194 (2012).
[2] Boguslavskiy *et al.*, Science **335**, 1336 (2012).

A 25.5 Wed 15:45 f107

Non-instantaneous nonlinear optical response in tailored dielectric media — •Chanteau Bruno[1], Jusko Chirstoph[1], Nagy Tamas[1,2], Tajalli Ayhan[1], Willemsen Thomas[3], Jupé Marco[3], Ristau Detlev[3], and Morgner Uwe[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, D-30167 Hannover, Germany — [2]Laser-Laboratorium Göttingen e.V., Hans-Adolf-Krebs-Weg 1, 37077 Göttingen, Germany — [3]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany

Nowadays it is common to generate sub-10 fs pulses. When dealing with such short pulses, the third-order electronic polarization decay time, usually neglected because expected to be in the fs-range, becomes relevant for third-order nonlinear optical processes.

We investigate this non-instantaneous electronic polarization in the case of amorphous dielectrics. Since the decay time depends on the difference between the resonance frequency of the medium, i.e. optical bandgap, and the laser frequency, we use as non-linear medium ternary oxydes layers, in which, through the ratio of the oxydes, we can tune the bandgap.

The measurements are performed with a THG D-scan setup, with 6-fs TiSa femtosecond laser, on ScO2/SiO2 samples. The thickness of the samples is below 100 nm, in order to avoid any propagation effects. The different behavior of the polarizations of these samples, whose bandgaps range within 5.5 to 7 eV (compared to the third harmonic beam of 4.8 eV), will be shown.

A 25.6 Wed 16:00 f107

Phase-dependent photoemission from C_{60} in intense $\omega/2\omega$ fields — •Slawomir Skruszewicz, Michael Zabel, Mohammad-Adel Almajid, Dieter Bauer, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universität Rostock, Institut für Physik, Albert-Einstein-Str. 23, 18059 Rostock, Deutschland

We present recent results on ionization of C_{60} in intense $\omega/2\omega$ fields. By applying phase-of-the-phase spectroscopy we are able to substract coheerent emission of photoelectrons from thermonic and statistical contributions. Phase-of-the-phase (PP) and Relative Phase Contrast (RPC) spectra reveals distinct nature of the rescattering process in such a large system which differs significantly of that from atoms. Possible expanation will be briefly discussed.

A 25.7 Wed 16:15 f107

Circularly polarized high harmonics from Ne atoms — •Lukas

Medišauskas[1,2,3], Jack Wragg[4], Hugo van der Hart[4], and Misha Ivanov[1,2,5] — [1]Imperial College London, United Kingdom — [2]Max-Born-Institute, Berlin, Germany — [3]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [4]Queens University Belfast, United Kingdom — [5]Humboldt University, Berlin, Germany

An elegant solution to generate circularly polarized harmonics relies on combining circularly polarized fundamental with counter-rotating second harmonic. The harmonic spectra generated by such driving field consists of pairs of left- and right- circularly polarized harmonics. Here, we theoretically investigate this process for a model Ne atoms.

We demonstrate that the harmonic spectra is distinctively different when atomic orbitals with non-zero angular momentum, e.g., 2p, and orbitals with zero angular momentum, e.g., 1s, are considered. Namely, the height of left- and right- circularly polarized harmonics is different by an order of magnitude when 2p orbitals are used. The effect is due the the suppression of the contribution from orbitals counter-rotating with the driving field, i.e., 2p-, and involves the interplay of ionization, recombination and continuum electron propagation dynamics.

In the time domain, the generated spectra from Ne corresponds to a train of attosecond pulses with close to circular polarization. Hence, we demonstrate an amplitude gating scheme that allows to isolate a single attosecond radiation burst and thus attain highly elliptical isolated attosecond pulses.

A 26: Ultra-cold atoms, ions and BEC II (with Q)

Time: Wednesday 14:30–16:30 Location: f303

A 26.1 Wed 14:30 f303

Time-resolved Scattering of a Single Photon by a Single Atom — •Victor Leong[1,2], Mathias Alexander Seidler[1], Matthias Steiner[1,2], Alessandro Cerè[1], and Christian Kurtsiefer[1,2] — [1]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore 117543 — [2]Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117542

The efficiency of light-matter interfaces between single photons and single atoms depends on the bandwidth and temporal shape of the single photon, and is crucial for realistic implementations of many quantum information protocols. In particular, an exponentially rising single photon is predicted to excite a single atom with a higher efficiency compared to any other temporal shape [1].

A four-wave mixing photon pair source, in conjunction with an asymmetric cavity, generates heralded single photons of tunable bandwidth with exponentially decaying or rising shapes [2,3]. We combine the photon pair source with a trapped single atom and investigate the free space scattering for different bandwidths and temporal shapes.

We study the scattering dynamics by measuring the atomic emission and the reduction in the number of transmitted photons. We observe that the atomic absorption dynamics are imprinted in the single-photon excitation mode.

[1] Y. Wang et al., PRA **83**, 063842 (2011)
[2] B. Srivathsan et al., PRL **111**, 123602 (2013)
[3] B. Srivathsan et al., PRL **113**, 163601 (2014)

A 26.2 Wed 14:45 f303

Fermi-Bose mixture of ^{6}Li and ^{41}K — Rianne S. Lous[1,2], •Isabella Fritsche[1,2], Bo Huang[1], Michael Jag[1,2], Marko Cetina[1,2], Jook T.M. Walraven[1,3], and Rudolf Grimm[1,2] — [1]Inst. for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Science, Austria — [2]Inst. for Experimental Physics, University of Innsbruck, Austria — [3]Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, Amsterdam, Netherlands

We report on the production of a double-degenerate, strongly mass-imbalanced Fermi-Bose mixture of ^{6}Li and ^{41}K. In our experimental sequence the potassium atoms are sympathetically cooled by the lithium atoms, which are evaporatively cooled in an optical dipole trap at a magnetic field of 1190 G. We obtain 10^4 ^{41}K atoms with a 33 % BEC fraction and a $T/T_F \approx 0.1$ with 10^5 Li atoms in each spin state. We are currently implementing a species-selective optical dimple potential to increase the BEC fraction. This paves the way to observing the collective behavior of two coupled superfluids with strong mass imbalance. We also scan the magnetic field in a region from 0 G to 1200 G and we observe multiple interspecies Feshbach resonances, which can be exploited for interaction control in strongly interacting Fermi-Bose mixtures.

A 26.3 Wed 15:00 f303

Interaction-free measurements with ultracold atoms — Jan Peise[1], •Bernd Lücke[1], Luca Pezzé[2], Frank Deuretzbacher[1], Wolfgang Ertmer[1], Jan Arlt[3], Augusto Smerzi[2], Luis Santos[1], 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]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 26.4 Wed 15:15 f303

Resonant quantum dynamics of few ultracold bosons in periodically driven finite lattices — •Simeon Mistakidis[1], Thomas Wulf[1], Antonio Negretti[1,2], and Peter Schmelcher[1,2] — [1]Zentrum fuer Optische Quantentechnologien, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The out-of-equilibrium dynamics of few ultracold bosons in periodically driven one-dimensional optical lattices is investigated. Our study reveals that the driving enforces the bosons in different wells to oscillate in-phase and to exhibit a dipole-like mode. A wide range from weak-to-strong driving frequencies is covered and a resonance-like behaviour of the intra-well dynamics is discussed [1]. In the proximity of the resonance a rich intraband excitation spectrum is observed. The single particle excitation mechanisms are studied in the framework of Floquet theory elucidating the role of the driving frequency. The impact of the interatomic repulsive interactions is examined in detail yielding a strong influence on the tunneling period and the excitation probabilities. Finally, the dependence of the resonance upon a variation of the tunable parameters of the optical lattice is examined. Our analysis is based on the ab-initio Multi-Configuration Time-Dependent Hartree Method for bosons.

[1] S. I. Mistakidis, T. Wulf, A. Negretti, and P. Schmelcher, J. Phys. B: Atomic, Molecular and Optical Physics, 48(24), 244004 (2015).

A 26.5 Wed 15:30 f303

Transport through Bose-Einstein condensates with vortices — •Lukas Schwarz, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Vortex solutions of the nonlinear Schrödinger equation, which describes Bose-Einstein condensates in a mean-field approximation as well as several other physical systems such as optical lattices, have attracted wide interest in the last years. In these systems complex potentials can be used to effectively describe gain and loss effects. If this gain and loss is spatially separated but balanced, the underlying Hamiltonian is $\mathcal{PT}$ symmetric. We investigate Bose-Einstein condensates in such a non-Hermitian $\mathcal{PT}$ symmetric external potential with the goal to find vortices describing a net transport through the condensate. Due to the $\mathcal{PT}$ symmetry truly stationary solutions with real eigenvalues exist in spite of a coherent and balanced in- and outcoupling of atoms. We present vortex solutions of a two-dimensional Bose-Einstein condensate trapped in different potentials with varying in- and outcoupling.

A 26.6 Wed 15:45 f303

temperature measurement of a BEC with tunable interaction by in-situ imaging using semi-classical and hartree-fock model — •Pierre Jouve — University of Nottingham UK

Various model of differing complexity can be used to model the density of Bose-Einstein condensate (BEC) in an harmonic trap to extract quantities such as temperature and chemical potential. We present two diff*erent method, the semi-classical thermal cloud and Hartree Fock model. We demonstrate that the Hatree-Fock method leads to more accurate result for temperature of the system close to Tc, the Bose-Einstein condensation temperature transition.

A 26.7 Wed 16:00 f303

Towards Ultracold Interaction and Chemistry - Ba^+ and Rb in an optical dipole trap — •Alexander Lambrecht, Julian Schmidt, Pascal Weckesser, Leon Karpa, and Tobias Schaetz — Universitaet Freiburg

Examining collisions of atoms and ions at extremely low temperature will permit gaining information about the corresponding sympathetic cooling rates and subsequent quantum effects, such as cluster formation of an ion binding atoms within the common $1/r^4$ potential[1]. In the last years several experimental groups investigated cold collisions between atoms and ions, leading to a better understanding of the atom-ion interaction [2-5]. Our approach to reach the regime of ultracold interaction is to precool a Ba^+ ion, trapped in a conventional Radio-Frequency (RF) trap by Dopper cooling. By transfering the ion into an optical dipole trap[6], followd by sympathetic cooling via an ambient Rb MOT we plan to overcome the current limitations set by heating due to RF micromotion. We describe our apparatus and present first experimental results on optical trapping of ions and atoms.

[1] R. Côté et al., Phys. Rev. Lett. 89, 093001 (2002)
[2] A. Härter et al., Contemp. Phys. 55, 33 (2014)
[3] A.T. Grier et al., Phys. Rev. Lett. 102, 223201 (2009)
[4] L. Ratschbacher et al., Nature Phys. 8, 649 (2012)
[5] F. H. J. Hall et al., Mol. Phys. 111, 1683-1690 (2013)
[6] T. Huber et al., Nat. Comm. 5, 5587 (2014)

A 26.8 Wed 16:15 f303

Satisfying the Einstein-Podolsky-Rosen criterion with massive particles — Jan Peise[1], Ilka Kruse[1], •Karsten Lange[1], Bernd Lücke[1], Luca Pezzè[2], Jan Arlt[3], Wolfgang Ertmer[1], Klemens Hammerer[4], Luis Santos[4], Augusto Smerzi[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]QSTAR, INO-CNR and LENS, Firenze, Italy — [3]Institut for Fysik og Astronomi, Aarhus Universitet, Denmark — [4]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

Entanglement was first discussed in the thought experiment of Einstein, Podolsky, and Rosen (EPR). They considered a quantum-mechanical state consisting of two maximally correlated particles. A measurement of one subsystem seemingly allows for a prediction of the second subsystem with a precision beyond the Heisenberg uncertainty relation. We utilize spin-changing collisions in a ^{87}Rb BEC to generate a two-mode entangled state. By employing an atomic homodyne detection, we verify the EPR correlation according to Reid's criterion. We find an EPR entanglement parameter of 0.18 which is 2.4 standard deviations below the threshold of 1/4. This demonstration of continuous-variable EPR correlations is the first realization with massive particles [1]. Furthermore, the state is fully characterized by a tomographic reconstruction of the underlying many-particle quantum state. This reconstruction is obtained via a Maximum Likelihood algorithm.

[1] J. Peise et al., *Nat Commun* **6**, 8984 (2015)

A 27: Precision spectroscopy of atoms and ions I (with Q)

Time: Wednesday 14:30–16:30 Location: f428

Invited Talk A 27.1 Wed 14:30 f428

Atomic level scheme of neutral actinium — •Sebastian Raeder[1], Randolf Beerwerth[2], Rafael Ferrer[3], Camilo Granados[3], Amin Hakimi[4], Mustapha Laataoui[1], Volker Sonnenschein[5], Norbert Trautmann[6], and Klaus Wendt[4] — [1]Helmholtz Institut Mainz — [2]Helmholtz Institut Jena — [3]KU Leuven — [4]Institut für Physik, Universität Mainz — [5]University of Jyväskylä — [6]Institut für Kernchemie, Universität Mainz

The atomic structure of actinium was investigated as preparation for laser spectroscopy on short lived radio isotopes. Albeit it is the name-giving element of the actinide series the available information on the atomic level scheme of neutral actinium is insufficient for laser spectroscopic applications. Using wide range tunable Ti:sa lasers allowed for the identification of new atomic energy levels, resulting in a precise determination of the first ionization potential and provided the information on auto-ionizing states for further resonance ionization spectroscopy. Additionally, the hyperfine structure of several levels was investigated using an injection-locked narrow bandwidth pulsed Ti:sa laser. Besides the identification of a suitable optical transition with high sensitivity to nuclear properties some errors in the available literature on the atomic levels were identified. The measured level properties are compared to theoretical multi configuration Dirac-Fock (MCDF) calculations resulting in a revised level scheme for low lying atomic levels in actinium.

A 27.2 Wed 15:00 f428

MCDF Isotope-Shift Calculations for Medium and Heavy Elements — •Randolf Beerwerth[1,2] and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Universit{\"a}t Jena, 07743 Jena, Germany

The isotope shift is described in terms of the mass and field-shift parameters. The former arises due to the nuclear recoil, while the latter links the electronic response to changes in the nuclear radius. This allows to use optical spectroscopy to obtain information about the nucleus, when the isotope-shift parameters are known. When it is infeasible to determine the isotope-shift parameters purely experimentally, atomic calculations can instead be utilized to provide estimates.

We apply the Multi-Configuration Dirac-Fock (MCDF) method to calculate the isotope-shift parameters for medium to heavy elements. After computation of the wave function, we utilize the configuration-interaction method to calculate the isotope-shift parameters for a chain of isotopes.

Since the isotope shift of heavy elements is dominated by the field shift, we put special emphasis on its computation. Very often it is estimated from the electronic charge density inside the nucleus, however this estimate is only precise for light elements. For light to medium elements, our method agrees very well with this estimate. However, for heavy elements we obtain significantly lower values.

We present results for Actinium and Nobelium, where several experiments were recently performed. The extracted nuclear parameters compare well with results for other elements.

A 27.3 Wed 15:15 f428

Design and commissioning of the ALPHATRAP ion transfer beamline — •Alexander Egl[1,2], Ioanna Arapoglou[1,2], J.R. Crespo Lopez-Urrutia[1], Henrik Hirzler[1,2], Sandro Kraemer[1,2], Peter Micke[1,3], Tim Sailer[1,2], Andreas Weigel[1,2], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik, Universität Heidelberg — [3]Physikalisch-Technische Bundesanstalt, QUEST, 38116 Braunschweig

The Penning-trap experiment ALPHATRAP at the Max-Planck-Institut für Kernphysik aims to test bound-state quantum electrodynamics by determining the *g*-factor of the bound electron in the electric field of highly charged ions (HCI) with ultra-high precision. HCI up to hydrogen-like $^{208}Pb^{81+}$ will be provided by the Heidelberg Electron Beam Ion Trap (Heidelberg-EBIT). Therefore, an ultra-high vacuum room temperature ion transfer beamline will be used to guide HCI to the ALPHATRAP setup, consisting of a custom-made cryostat and a superconducting magnet containing the precision Penning-trap system. Superior vacuum conditions are essential to reduce recombination reactions of the HCI to negligible levels. In addition to the Heidelberg-EBIT, a compact room temperature EBIT is available, which allows flexible creation of HCI from injected gas, e.g. $^{40}Ar^{15+}$ or $^{129}Xe^{25+}$.

These ions in turn will be used during the commissioning phase of ALPHATRAP. The design and commissioning of the ion transfer beamline as well as results from the compact room temperature EBIT will be presented.

A 27.4 Wed 15:30 f428

Investigation of Ir^{17+} as a sensitive detector of variation of the fine-structure constant — •Hendrik Bekker[1], Alexander Windberger[1,2], Oscar O. Versolato[2], Anastasia Borchevsky[3], Natalia S. Oreshkina[1], Julian C. Berengut[4], Zoltán Harman[1], Christoph H. Keitel[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Advanced Research Center for Nanolithography, Amsterdam — [3]Van Swinderen Institute for Particle Physics and Gravity, Groningen — [4]University of New South Wales, Sydney

Many highly charged ions have been proposed for use in next generation optical clocks for metrology purposes. We aim at implementing one of the original proposals, to use Ir^{17+} to investigate variation of the fine-structure constant [1]. But as with all the proposed systems, theory is not capable of predicting the energy level structure to the precision required for laser spectroscopy. Therefore we investigated Ir^{17+} which we produced, trapped, and collisionally excited in the Heidelberg electron beam ion trap. The wavelengths of subsequent optical fluorescence light were determined at the ppm-level using a grating spectrometer. Direct identification of the 30 observed lines was not possible due to their dense spacing and uncertainties on the predictions. But by employing several other techniques we identified transitions important for future high-precision laser spectroscopy experiments. The identification techniques and additional new results will be presented.

[1] J. C. Berengut *et al.*, Phys. Rev. Lett. **106**, 210803 (2011)
[2] A. Windberger *et al.*, Phys. Rev. Lett. **114**, 150801 (2015)

A 27.5 Wed 15:45 f428

Influence of ion movement in a particle trap on the bound-electron *g*-factor — •Niklas Michel, Jacek Zatorski, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

The bound-electron *g*-factor is defined via the energy difference of a spin-up and spin-down state of the electron in an external magnetic field and its measurement provides one of the most stringent tests of QED in strong external fields. When measured in a Penning trap, the electron spin also couples to the external electric trapping potential and the total momentum of the ion. Therefore, the motional state of an ion in a particle trap influences measurements of internal observables such as energy levels or the *g*-factor [1]. We calculated the resulting relativistic shift of the Larmor frequency and the corresponding *g*-factor correction for a bound electron in a hydrogenlike ion in the 1S state due to the ion moving in a Penning trap.

[1] N. Michel, J. Zatorski, C. H. Keitel, Phys. Rev. A **92**, 052509 (2015).

A 27.6 Wed 16:00 f428

A highly sensitive single particle detector at 75 MHz — •Matthias Borchert[1], Klaus Blaum[2], Takashi Higuchi[3,4], Yasuyuki Matsuda[4], Teresa Meiners[1], Andreas Mooser[3], Hiroki Nagahama[3,4], Malte Niemann[1], Christian Ospelkaus[1], Wolfgang Quint[6], Georg Schneider[7], Stefan Sellner[3], Christian Smorra[3,8], Jochen Walz[5,7], Yasunori Yamazaki[9], and Stefan Ulmer[3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Ulmer Initiative Research Unit, RIKEN, Wako, Japan — [4]Graduate School of Arts and Sciences, University of Tokyo, Tokyo, Japan — [5]Helmholtz-Institut Mainz, Mainz, Germany — [6]GSI-Helmholzzentrum für Schwerionenforschung, Darmstadt, Germany — [7]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [8]CERN, Geneva, Switzerland — [9]Atomic Physics Laboratory, RIKEN, Wako, Japan

The BASE collaboration aims at a stringent test of the CPT symmetry by comparing the magnetic moments of the proton and the antiproton with high precision. The magnetic moment in units of the nuclear magneton is determined by measuring the ratio of the spin-precession frequency to the cyclotron frequency, respectively, in an advanced cryogenic Penning trap system.

One limitation in current state of the art experiments is given by noise induced quantum transitions in the modified cyclotron mode of the trapped particles. Higher magnetic field strengths reduce the heating rate of the cyclotron mode, which inspires the development of a non-destructive image-current detector for the modified cyclotron frequency at 75 MHz. For a proton this corresponds to a magnetic field strength of about 5 Tesla.

In this talk I will present the development of such a detector based on a superconducting resonator.

A 27.7 Wed 16:15 f428

Comparison of the Lγ(2,3) line shape for Ba2+ compounds and metal — •Malkhaz Jabua, Detlev Gotta, and Thomas Strauch — Institüt für Kernphysik, Forschungszentrum Jülich, D-52425 Jülich, Deutschland

The Lγ(2,3) line from Ba2+ compounds shows a complex structure. Nevertheless, both peak energy and shape of the complex are apparently unaffected by the nature of the anion. Therefore, a comparison measurement was performed using metallic barium. For the measurement was used the Johann spectrometer at the institute of nuclear physics (IKP) at Forschungszentrum Jülich (FZJ). The set-up allows to record simultaneously an energy interval covering the complete structure Ba Lγ(2,3) structure. As Bragg crystal a spherically bent quartz crystal was used. The diffracted X-rays were recorded with a 24 mm x 24 mm charge-coupled device having a pixel size of 40 micrometer x 40 micrometer. The spectra of metallic Ba complete a series of measurements including the spectra from the salts BaCl2, BaCO3, Ba(OH)2, and BaSO4. The X-ray energies were determined to an accuracy of about 40 meV. The talk aims to describe the experimental setup, measurement techniques, and to present the data analysis methodology and some recent results.

A 28: Ultracold plasmas and Rydberg systems (with Q)

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

A 28.1 Wed 16:30 Empore Lichthof

Building up a two-species Rydberg experiment with a spatially resolving ion detector — •Thomas Schmid, Christian Veit, Nicolas Zuber, Robert Löw, and Tilman Pfau — 5th Physical Insitute, University of Suttgart, Stuttgart, Germany

We are building up an experiment for the production of an ultracold mixture of lithium and rubidium gases with the possibility of Rb Rydberg excitation. The machine, to that end, comprises a two-species Zeeman slower [1]. In the science chamber, a high numerical aperture optical lens is incorporated for focused Rydberg excitation. Besides, eight field plates arranged in a clover leaf configuration allow for ultrastable electric field control and field-ionization of the Rydberg atoms. Single ions can be detected temporally and spatially resolved with a delay-line detector [2]. The time resolution is approximately 100 ps, the spatial resolution at the detector is around 100 μm. The detector can handle single particle rates up to several MHz. In order to get a spatial resolution in the micrometer regime at the position of the ultracold cloud in the centre of the science chamber an ion microscope with a magnification above 100 is planned. It consists of three electrostatic triple-cylinder-lenses and has a total length of about 1.5 m.

[1] G. E. Marti, D. M. Stamper-Kurn et al.; *Phys. Rev. A* **81**, 043424 (2010).
[2] O. Jagutzki, H. Schmidt-Böcking et al.; *Nucl. Instrum. Meth. A* **477**, 244 (2002).

A 28.2 Wed 16:30 Empore Lichthof

Correlations and many-body dynamics of Rydberg excitations in the anti-blockade regime — •Fabian Letscher[1,2], Oliver Thomas[1,2], Thomas Niederprüm[1], Tanita Eichert[1], Michael Fleischhauer[1], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

We present experimental and theoretical studies of the many-body dynamics of Rydberg excitations in an optically driven lattice gas in the dissipative anti-blockade regime. Making use of continuous ionization of atoms in a Rydberg state we monitor the time evolution and temporal correlations of Rydberg excitations. We observe large relaxation times (compared to the lifetime of a Rydberg excitation) and strong bunching. To describe the approximate dynamics of the system, we use an efficient many-body rate equation method and compare them with experimental results. Moreover, we construct a simple cluster model which allows a qualitative understanding of the experimental data.

A 28.3 Wed 16:30 Empore Lichthof

Storage of coherences and single-photon sources via Rydberg state in thermal vapors — •Yi-Hsin Chen, Fabian Ripka, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

Photons are good information carriers, which can be stored and retrieved among different quantum devices. We perform the storage of coherences via a highly excited Rydberg state in thermal vapors. These photonic quantum devices are intrinsically reproducible and scalable, towards the potential application of the photonic-based quantum security communication and information processing. The scheme is based on the combination of four-wave-mixing (FWM) and Rydberg blockade effects in a 220 micrometer thick vapor cell. In the pulsed FWM scheme, we observe coherent dynamics [1] and measure the lifetime of the stored coherence, which is around 1 ns, limited by motional dephasing of the thermal vapors. Moreover, we are going to reduce the excitation volume towards below the Rydberg interaction range by use of high-NA optics and spatial confinement for generating a deterministic single-photon source [2].

[1] Huber et al., PRA 90, 053806 (2014) [2] M. M. Müller et al., PRA 87, 053412 (2013)

A 28.4 Wed 16:30 Empore Lichthof

Towards coherence measurements of Rydberg atoms with all-optical detection — •Lara Torralbo-Campo, Jens Grimmel, Florian Karlewski, Carola Rogulj, and József Fortágh — Physikalisches Institut der Universität Tübingen, Germany

We have developed a non-destructive and time-resolved method to optically detect the population of atoms in a selected Rydberg state as alternative to selective field ionization. This scheme is based on electromagnetically induced transparency (EIT). By monitoring the optical density of the probe laser over time, we can imply the initial population of the Rydberg state. We have tested the new method as proof-of-principle in a cold gas of 87-Rb atoms where lifetimes of Rydberg states under various environment conditions were measured. This method promises also to provide information regarding the initial coherence of the system. We present the ongoing work towards measurements of the coherence in a Rydberg gas.

A 28.5 Wed 16:30 Empore Lichthof

Rydberg P-state-molecules — •Tanita Eichert[1], Philipp Geppert[1], Thomas Niederprüm[1], Oliver Thomas[1,2], Torsten Manthey[1], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

We report on the experimental realization of P-state Rydberg-molecules. These molecules are created by photoassociation in a dense sample of ultracold rubidium. High resolution spectroscopy is carried out over a range of more than 10 GHz allowing us to precisely determine the binding energies of molecular states around the 25P state. By characterizing the observed molecular states by their permanent dipole moments and their lifetimes we can distinguish between pure long range Rydberg molecules and bound states in the vicinity of the crossing butterfly state. Rydberg molecules show significantly shortened lifetimes compared to resonant Rydberg excitations caused by the bound ground state atom. Furthermore we demonstrate how the obtained knowledge on the bound states can be used to probe the site occupancy in optical lattices.

Additionally we report on a laser system that will be used to excite Rydberg S- and D-states in ultracold rubidium gases. For this purpose, two external cavity diode lasers for both 420 nm and 1030 nm have been assembled. Due to small linewidths and without the necessity of second harmonic generation, we achieve a high spectroscopic resolution and efficient excitation with increased stability.

A 28.6 Wed 16:30 Empore Lichthof

Stable optical lattices for creating and imaging ultracold quantum fluids of potassium — •Emil Pavlov, Stephan Helmrich, Alda Arias, Tobias Wintermantel, and Shannon Whitlock — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

Ultracold Rydberg atoms with their long-range interactions offer a controllable environment for realizing synthetic model systems to be studied, e.g. unconventional superfluids and extended Hubbard models. The strength and range of their interactions can be controlled via coherent coupling of the Rydberg states to the ground states (Rydberg dressing). In our experiment we plan to reveal the resulting quantum phases using a quantum gas microscope with single-site resolution. For this purpose we have designed a novel two-dimensional optical lattice induced by three-beam interference, which, when combined with a pancake-shaped trap, provides the necessary two-dimensional geometry. In order to minimize adverse heating effects on the atoms, the whole setup must exhibit high intensity, phase and pointing stability. We will present our evaluation of the lattice stability as well as initial experimental results.

A 28.7 Wed 16:30 Empore Lichthof

Measurements and numerical calculations of ^{87}Rb Rydberg Stark and Zeeman maps — •Jens Grimmel, Manuel Kaiser, Lara Torralbo-Campo, Markus Mack, Florian Karlewski, and József Fortágh — Physikalisches Institut der Universität Tübingen

Rydberg atoms are extremely sensitive to external electric and magnetic fields and consequently have a rich Stark and Zeeman spectrum. We present measurements and numerical calculations of Stark and Zeeman shifts for Rydberg states of ^{87}Rb. We have extended our previous calculations [1] to take into account the differential Zeeman shifts as well as the transition strength between all states in the EIT ladder scheme. We have also performed high precision measurements of Zeeman maps in a heated vapour cell with magnetic fields up to 10mT. Recently, we have implemented a new heatable microcell setup for measurements of Stark and Zeeman maps at different temperatures and atomic densities.

[1] J. Grimmel, M. Mack, F. Karlewski, F. Jessen, M. Reinschmidt, N. Sándor and J. Fortágh, N. J. Phys. 17, 053005 (2015).

A 28.8 Wed 16:30 Empore Lichthof

Probing electric fields spatially resolved inside hollow core fibers with Rydberg atoms — •Daniel Weller[1], Georg Epple[1,2], Josephine Gutekunst[1], Christian Veit[1], Tilman Pfau[1], Philip Russel[2], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Max Planck Institute for the Science of Light and Department of Physics, University of Erlangen, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany

The exceptional large polarizability of highly excited Rydberg atoms makes them of great interest for sensitive AC and DC electric field sensors. In addition, long-range interactions between the Rydberg atoms give rise to phenomena such as the Rydberg blockade, enabling the creation of optical nonlinearities at the single photon level. A promising route to technically feasible, miniaturized, room-temperature devices is based on the excitation of Rydberg atoms inside hollow-core photonic crystal fiber (HC-PCF). The confinement of both atoms and light enforces a large inline interaction region, resulting in perfect atom-light coupling. Recently, we demonstrated coherent three-photon excitation to Rydberg states in a cesium vapor confined in both kagome-style HC-PCF and capillaries. Spectroscopic signals exhibiting sub-Doppler features for principal quantum numbers up to $n = 46$ revealed line shifts. To investigate these shifts in detail, two kinds of spacially resolved spectroscopy were implemented: one uses an array of field plates along the fiber, the other relies on higher order modes of the excitation beams, to locally select atoms within the fiber.

A 28.9 Wed 16:30 Empore Lichthof

The bound and scattering properties in waveguide around Feshbach resonance — •gaoren wang[1], panagiotis giannakeas[2], and peter schmelcher[1,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Hamburg, Germany — [2]Department of Physics and Astronomy, Purdue University, Indiana, USA — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Hamburg, Germany

The two-body bound and scattering properties in an one-dimensional harmonic waveguide around the free-space magnetic Feshbach resonance are investigated based on the K matrix method. The multichannel characteristics of the interatomic interaction is taken into account, and the free-space phase shift is calculated in the frame work of quantum defect theory. We emphasize the following point: the bound state in the waveguide crosses the ground level of the transversal confinement at the magnetic field where the effective one-dimensional scattering length diverges.

A 28.10 Wed 16:30 Empore Lichthof

Flexible Rydberg aggregates — •Karsten Leonhardt, Sebastian Wüster, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems

Rydberg aggregates [1] are assemblies of highly excited atoms, where all atoms experience strong dipole-dipole interactions. Due to their simple structure and strong interactions, it makes them a fertile platform to study the link between motion, energy and entanglement transport. The transport can be almost coherent, since the quantum properties in Rydberg interacting systems are maintained on the relevant time and length scales. Another feature of Rydberg aggregates is that electronic excitation and atomic motion can propagate as a combined pulse, a so called exciton pulse [2-5]. We identified structural elements in flexible Rydberg aggregates [4,5] that significantly affect exciton dynamics, enabling coherent splitting of an exciton pulse, control of its propagation direction and coherence properties. **References**

[1] C. Ates, A. Eisfeld, J. M. Rost, NJP **10**, 045030 (2008).
[2] S. Wüster, C. Ates, A. Eisfeld, J. M. Rost, PRL **105**, 195392 (2010).
[3] S. Möbius, S. Wüster, C. Ates, A. Eisfeld, J. M. Rost, J. Phys. B. **44**, 184011 (2011).
[4] K. Leonhardt, S. Wüster, J. M. Rost, PRL **113**, 223001 (2014).
[5] K. Leonhardt, S. Wüster, J. M. Rost, arXiv:**1511**.06629 (2015).

A 29: Atomic clusters (with MO)

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

A 29.1 Wed 16:30 Empore Lichthof

Cooling Dynamics of Superheated Nanoplasmas — •Theresia Ziegs, Christian Peltz, and Thomas Fennel — Universität Rostock, Insitut für Physik, Germany

When atomic clusters are irradiated with short and intense laser pulses they are turned into highly excited nanoplasmas on the sub-picosecond time scale, eventually resulting in the emission of fast electrons, highly charged and energetic ions and high energy radiation [1, 2]. Theoretical studies concentrated on the early phase of the laser driven cluster dynamics (<1ps), shining light on the fundamental laser-cluster interaction processes and thereby allowing to understand and interpret a multitude of experimental observations. In the subsequent cluster relaxation the dynamics is mainly dictated by expansion cooling of the electrons and electron-ion recombination, which significantly influences the final energy and charge spectra [3, 4, 5]. In this work we analyze the so far barely studied long-term relaxation of laser-driven rare gas clusters with molecular dynamics simulation. Irrespective of the particular expansion conditions we observe an abrupt change of the electron cooling rate after roughly 1 ps that can be attributed to a transition from weak to strong coupling [6].

[1] U. Saalmann et al., J. Phys. B 39, R39 (2006)
[2] T. Fennel et al., Rev. Mod. Phys. 82, 1793 (2010)
[3] M. Arbeiter et al., Phys. Rev. A 89, 043428 (2014)
[4] B. Schütte et al., Phys. Rev. Lett. 112, 253401 (2014)
[5] T. Gorkhover et al., Phys. Rev. Lett. 108, 245005 (2012)
[6] Yu. V. Dumin, Plasma Phys. Rep. 37, 858 (2011)

A 29.2 Wed 16:30 Empore Lichthof

X-Ray Movie Camera: First results and analysis of single cluster images — •Katharina Kolatzki[1], Mario Sauppe[1], Leonie Flückinger[1,2], Bruno Langbehn[1], Björn Senfftleben[1], Jannis Zimbalski[1], Maria Müller[1], Anatoli Ulmer[1], Tobias Zimmermann[1], Julian Zimmermann[1], Tais Gorkhover[5], Christoph Bostedt[5], Benjamin Erk[3], Marion Kuhlmann[3], Daniel Rolles[3,4], Dimitrios Rompotis[3], Rolf Treusch[3], Stefan Düsterer[3], Cédrik Bomme[3], Torsten Feigl[6], Thomas Möller[1], and Daniela Rupp[1] — [1]TU Berlin — [2]La Trobe University — [3]DESY — [4]Kansas State University — [5]SLAC — [6]optiX fab

Free-electron lasers with high spatial and temporal resolution open a completely new field of atomic frontier physics. In order to get further insights into the generation and light-induced dynamics of large xenon clusters, we performed an XUV pump-probe experiment. In this novel two detector set-up, we were able to capture a "two-frame movie" with delays of 0 ps, 70 ps and 650 ps. The data sets that were taken at the free-electron laser FLASH in Hamburg consist of an ion spectrum and two scattering images: The first one pictures the intact initial xenon cluster and the second one images the exploding cluster. The analysis of the single-shot data will be discussed and first results will be presented.

A 29.3 Wed 16:30 Empore Lichthof

A new He droplet spectrometer for nanoplasma experiments — •Dominik Schomas[1], Robert Moshammer[2], Thomas Pfeifer[2], and Marcel Mudrich[1] — [1]Albert-Ludwigs-Universtität, Freiburg — [2]Max-Planck-Institut für Kernphysik, Heidelberg

Ultrashort laser pulses have opened up a new field of ultrafast spectroscopy with femtosecond and even attosecond time resolution. With such short pulses we want to explore the ultrafast ignition dynamics of He nanodroplets turning into a nanoplasma induced by dopant atoms such as other rare gases. The dynamics of ignition and explosion of the plasma depends on the number and the kind of dopants but also on the droplet size. We want to build a new apparatus to investigate those dependencies and to resolve the ignition dynamics in real time on an attosecond time scale via pump probe experiments. For our experiments we have designed a velocity-map imaging (VMI) spectrometer which is capable of mapping the occurring high-energy electrons from Coulomb-exploded clusters. Furthermore, the VMI technique allows us to investigate anisotropy effects in photoelectron emission.

A 29.4 Wed 16:30 Empore Lichthof

Production of size and charge-state selected poly-anionic metal clusters with a multipole RF-trap — •Stefan Knauer, Gerrit Marx, and Lutz Schweikhard — Institut für Physik, Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald

Poly-anionic metal clusters are experimentally not yet investigated to large extent, they may well reveal particularly interesting properties and behavior [1]. The aim is to lift initially mono-anionic clusters to higher charge states by subsequent electron attachment inside a RF-trap [2-4]. These traps cannot store electrons and clusters at the same time. However, electron attachment is facilitated by providing field-free conditions for the passage of an electron beam. This can be accomplished by use of a multipole ring-electrode trap, which provides continuously an almost field free region [5]. The experiment is build to provide defined charge states for laser interaction experiments. The contribution will present the ring-electrode trap mentioned above as well as first cluster confinement tests. The project is supported by a Collaborative Research Center 652 of the DFG.

[1] A. Herlert et al., New J. Phys. 14, 055015 (2012), DOI: 10.1088/1367-2630/14/5/055015 [2] C.Yannouleas et al., Phys. Rev. Lett. 86 2996 (2001), DOI: 10.1103/PhysRevLett.86.2996 [3] F. Martinez et al., Int. J. Mass Spectrom. 365, 266 (2014), DOI: 10.1016/j.ijms.2013.12.018 [4] S. Bandelow et al., Int. J. Mass Spectrom. 336, 47 (2013), DOI: 10.1016/j.ijms.2012.12.013 [5] D. Neuwirth et al., Int. J. Mass Spectrom 387, 8 (2015), DOI: 10.1016/j.ijms.2015.06.011

A 29.5 Wed 16:30 Empore Lichthof

Time-resolved X-ray Imaging of Anisotropic Nanoplasma Expansion — •Christian Peltz[1], Christoph Bostedt[2], Mathias Kling[3], Thomas Brabec[4], Björn Kruse[1], Eckart Rühl[5], Artem Rudenko[6], Tais Gorkhover[7], and Thomas Fennel[1] — [1]Institute of Physics, University of Rostock, Germany — [2]Argonne National Laboratory, Argonne, USA — [3]Faculty of Physics, LMU Munich, Germany — [4]Department of Physics and Centre for Photonics Research, University of Ottawa, Canada — [5]Physical Chemistry, FU Berlin, Germany — [6]Department of Physics, Kansas-State University, USA — [7]LCLS,

SLAC National Accelerator Laboratory, Menlo Park, USA

We investigate the time-dependent evolution of laser-heated solid-density nanoparticles via coherent diffractive x-ray imaging, theoretically and experimentally. Our microscopic particle-in-cell calculations for R = 25 nm hydrogen clusters reveal that infrared laser excitation induces continuous ion ablation on the cluster surface which 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 [1]. In addition corresponding experimental results, obtained just recently at the LCLS facility with SiO2 nanoparticles (R=100 nm), are presented and compared to the theoretical findings above.

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

A 29.6 Wed 16:30 Empore Lichthof

Photobleaching in the XUV: A test for XUV-cluster collective phenomena — •Edward Ackad[1], Kasey Barrington[1], Rishi Pandit[1], Nicolas Bigaouette[2], and Lora Ramunno[2] — [1]Department of Physics, Southern Illinois University Edwardsville, Edwardsville Il, USA — [2]Department of Physics, University of Ottawa, Ottawa, On, Canada

The XUV offers an ideal regime to test collective phenomena since the laser communication with rare gas clusters is almost exclusively through single photon ionization. We propose and model an experiment to test whether any collective phenomena do occur by saturating the single photon ionization channel, inducing transparency termed photobleaching. This is done with an XUV pump pulse of sufficient intensity to saturate the single photon ionization channel. A second equally intense XUV probe pulse then follows. Any collective phenomena will deviate from the current atomistic model, if any exist. Results are presented for the clusters at peak intensity and expected time-of-flight signals for Argon and Xenon.

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

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

A 30.1 Wed 16:30 Empore Lichthof

Quantum Algorithmic Readout in Multi-Ion Clocks — •Marius Schulte[1], Niels Lörch[1], Ian D. Leroux[2], Piet O. Schmidt[2,3], and Klemens Hammerer[1] — [1]Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute), Leibniz University Hannover, Callinstrasse 38, 30167 Hannover, Germany — [2]QUEST Institut, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [3]Institute for Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany

The methods of quantum information theory have already found many applications in trapped ion technologies. Even today, new generations of ion clocks often rely on quantum logic readouts in order to reference to a specific optical transition. Thereby they use two ion species in the same trap to exploit their different properties. Guided by a quantum algorithm, we present a non-demolition measurement strategy to transfer excitation probabilities among the two species. This method can be used for clocks with larger ion crystals in order to improve their short term stability. Our approach scales favorable in the number of logic ions and entangling-gates needed for the information transfer. We also discuss a possible realization based on a five ion crystal with Al and Ca ions, taking the full normal mode spectrum into account.

A 30.2 Wed 16:30 Empore Lichthof

The ALPHATRAP *g*-Factor Experiment — •Andreas Weigel[1,2], Ioanna Arapoglou[1,2], Alexander Egl[1,2], Henrik Hirzler[1,2], Sandro Kraemer[1,2], Tim Sailer[1,2], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg

The Penning-trap based 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 performed the most sensitive test of bound-state quantum electrodynamics (BS-QED) by measuring the g-factor of the remaining electron bound in hydrogen-like $^{28}Si^{13+}$ at an uncertainty level of 10^{-11} [1] in a cryogenic double Penning-trap system. ALPHATRAP aims for g-factor measurements on even heavier highly charged ions up to hydrogen-, lithium- and boron- like lead, with simultaneously improved accuracy. To achieve this, the ALPHATRAP experiment, consisting of an improved cryogenic double Penning-trap setup, will be coupled via an ultra-high vacuum beamline to the Heidelberg Electron-Beam Ion Trap, which provides the highly charged ions. In combination with currently conducted BS-QED calculations, the measurements are expected to further contribute to the exploration of the limits of BS-QED and also aim for an independent determination of the fine-structure constant α with high precision. An overview and the current status of the project will be presented.

A 30.3 Wed 16:30 Empore Lichthof

Metallic Magnetic Calorimeters for high resolution X-ray spectroscopy — •M. Krantz, D. Hengstler, C. Schötz, M. Keller, J. Geist, P. Schneider, S. Kempf, L. Gastaldo, A. Fleischmann, and C. Enss — KIP Heidelberg University.

We develop microfabricated, energy dispersive particle detector arrays based on metallic magnetic calorimeters (MMCs) for high resolution x-ray spectroscopy to challenge bound-state QED predictions. Our MMCs are usually operated below 30 mK and use a paramagnetic temperature sensor placed in a weak magnetic field, read-out by a SQUID, to measure the energy deposited by single X-ray photons. MMCs combine the properties of high energy resolution, high energy bandwidth and near perfect linearity in one detector. We discuss the microfabricated devices and performances of three different detector arrays. The maXs-20 is a 1x8 pixel linear array optimized for x-rays up 20 keV with an achieved energy resolution of 1.6 eV for 6 keV x-rays and experiments with maXs-20 at the MPI-K yielded new reference measurements of V-like and Ti-like tungsten. The maXs-200 is a 1x8 pixel linear array optimized for x-rays up 200 keV with an achieved energy resolution of 45 eV for 60 keV x-rays. We discuss sucessfully performed measurements at the Experimental Storage Ring (ESR) at GSI with the maXs-200. Our first 2d prototype with 8x8 pixels, maXs-30, is optimized for x-rays up to 30 keV with an estimated energy resolution below 6 eV.

A 30.4 Wed 16:30 Empore Lichthof

The new CRYRING facility at GSI / FAIR and experiments with optical ion polarization — •Zoran Andelkovic[1], Wolfgang Geithner[1], Frank Herfurth[1], Michael Lestinsky[1], Wilfried Nörtershäuser[2], and Gleb Vorobyev[1] — [1]GSI Darmstadt — [2]TU Darmstadt

The CRYRING storage ring, the Swedish in-kind contribution to FAIR, is in the final installation phase. Tests of ion injection from the ESR are foreseen for the upcoming GSI beamtime period, followed by the commissioning of the ring within the following year.

A new transfer line has been designed for the injection from the Experimental Storage Ring (ESR). Thus all ion species presently accessible in ESR can be transferred to CRYRING. In addition, a local injector is available for ring commissioning and first operation. This local injector transfer line has been significantly modified compared to the former Stockholm configuration to meet the requirements at GSI. It provides stand-alone operation from a 40 kV platform where different ion species can be produced, transported to the RFQ and accelerated to the necessary 300 keV/u for injection into the ring.

One of the first experiments which can be performed with the offline source and the local injection is the investigation of polarized ion beams inside a storage ring. Recently, in an experiment at the ESR, an indication for optical polarization of an ion beam has been observed. Further systematic tests of optical pumping and polarization conservation of singly charged Mg or Be ions are foreseen at CRYRING.

A 30.5 Wed 16:30 Empore Lichthof

Laser system for Precise High Voltage measurements — •Tim Ratajczyk, Phillip Imgram, Kristian König, Jörg Krämer, Bernhard Maass, Johannes Ullmann, and Wilfried Nörtershäuser — Institut für Kernphysik, TU Darmstadt

The ALIVE experiment at the TU Darmstadt is a new collinear laser spectroscopy setup. The goal of the experiment is the measurement of high voltages in the range of 10 to 100 kV using precise laser spectroscopy of ions with a well-known transition frequency [1]. The aim is to achieve a precision of at least 1 ppm, which is of interest for many applications.

For first experiments using a $^{40}Ca^{+}$ beam, a diode laser based system has been established. The well-known $4s_{1/2} \rightarrow 4p_{3/2}$ transition is used to identify the ion velocity by the Doppler shift. The laser system consists of an external cavity diode laser at 786 nm in combination with a tapered amplifier to provide a narrow bandwidth beam with sufficient power for frequency doubling in an LBO crystal. We present the current status of the experiment and an outlook for the laser system that will be used for spectroscopy on indium.

[1] O. Poulsen, Nuclear Instruments & Methods in Physics Research 202 (1982) 503.

A 30.6 Wed 16:30 Empore Lichthof

Simulation and characterization of a multiwire backgammon gaseous detector for soft X-ray detection — •Mykhailo Dumchev, Jens Oberrath, and Anthimos Georgiadis — Institut für Produkt- und Processinnovation, Leuphana Universität Lüneburg, Deutschland

To proof the QED corrections of the 1s Lamb shift, high precision X-ray spectroscopy of low energetic transitions in high Z-ions is necessary. Since photons will be detected in coincidence with down-charged ions, a time resolution less than 50 ns and spatial resolution less than 100 μm is required.

A promising candidate to meet these requirements is a multiwire backgammon gaseous detector (MWB). It consists of a spacer, an inlet gas plate, an array of seven wires as anode plane, and a cathode plane shaped like a backgammon surface. This anode-cathode arrangement allows for the required spatial resolution in two dimensions as shown by Beyer and Deslattes [1]. To proof that such a detector is able to fulfill the required time resolution, simulations with the software tool Garfield were performed. It turned out that a time resolution of about 26 ns can be reached. Based on these results a MWB is constructed and tested. Within this contribution measurements with this detector will be presented and compared to simulation results.

[1] H. F. Beyer and R. D. Deslattes, GSI Scientific Report 1983, p. 350

A 30.7 Wed 16:30 Empore Lichthof

Integrated electronic and photonic structures in vapor cells for quantum optics and sensing — •Johannes Schmidt[1,2], Ralf Ritter[1], Nico Gruhler[3], Patrick Schalberger[2], Holger Baur[2], Harald Kübler[1], Robert Löw[1], Wolfram Pernice[3], Norbert Frühauf[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Institut für Großflächige Mikroelektronik, Universität Stuttgart, Germany — [3]Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany

Rydberg atoms in thermal vapor are discussed as promising candidates for the realization of quantum devices such as single photon sources and sensors [1]. We present a sealing method based on anodic bonding, which is compatible with state of the art thin film technology offering both scalability and miniaturization [2]. We show that we are able to integrate electronic devices ranging from simple electrode structures to complex circuits like operational amplifiers into the vapor cell. Properties of different electrode materials and encapsulation methods are discussed as well.

Furthermore, we can implement integrated optics such as waveguide structures, which offer dozens of applications, like miniaturized atomic vapor spectroscopy, signal processing and sensing [3].

[1] J. A. Sedlacek, et al., Phys. Rev. Lett. 111, 063001 (2013)
[2] R. Daschner, et al., Appl. Phys. Lett. 105, 041107 (2014)
[3] R. Ritter, et al., Appl. Phys. Lett. 107, 041101 (2015)

A 30.8 Wed 16:30 Empore Lichthof

High precision measurement of the Ho-163 electron capture spectrum — •Gastaldo Loredana for the ECHo Collaboration — Kirchhoff-Institut für Physik, Universität Heidelberg, INF 227, 69120 Heidelberg, Germany

The sensitivity to the neutrino mass achievable with the analysis of the calorimetrically measured electron capture spectrum of Ho-163 is strongly dependent on the precise understanding of the expected spectral shape. Already at the level of energy resolution that is presently achieved in the ECHo experiment for the Ho-163 spectrum it is obvious that several parameters for the theoretical description of the spectral shape need to be defined with higher accuracy. The determination of higher order processes to the atomic de-excitation within the daughter atom dysprosium might play an important role for achieving sub-eV sensitivity on the electron neutrino mass. 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 discuss recently theoretical models to achieve a better accuracy in the determination of the parameters describing the Ho-163 spectrum.

A 30.9 Wed 16:30 Empore Lichthof

Towards a quantum logic based CPT test using single trapped (anti-)protons — •Teresa Meiners[1], Malte Niemann[1], Anna-Greta Paschke[1], Matthias Borchert[1], Alexander Idel[1], Johannes Mielke[1], Amado Bautista-Salvador[1,2], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Universität Hannover — [2]Physikalisch Technische Bundesanstalt, Braunschweig — [3]Ulmer Initiative Research Unit, RIKEN

We present sympathetic laser cooling and detection concepts for a CPT test based on a g-factor comparison between single protons and antiprotons in a Penning trap. Following the proposal by Heinzen and Wineland [1] the (anti-)proton can be coupled to a laser-cooled (beryllium) ion to achieve reliable preparation near the motional ground state, reducing systematic uncertainties and difficulties in state detection using the continuous Stern-Gerlach effect. Using sideband cooling techniques to the motional ground state, quantum logic spectroscopy can provide an alternative readout scheme.

We discuss ion trap geometries and state transfer schemes as well as laser systems and optical systems for loading, manipulating and detecting the atomic ion. We acknowledge funding by the ERC (ERC StG QLEDS). This project is supported by the BASE collaboration.

[1] Heinzen and Wineland, PRA 42, 2977 (1990)

A 30.10 Wed 16:30 Empore Lichthof

Towards a nuclear clock based on ^{229}Th: Internal conversion rates for Th ions — •Pavlo Bilous and Adriana Pálffy — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, D-69117 Heidelberg, Germany

The thorium isotope ^{229}Th bridges atomic and nuclear physics with its unique long-lived nuclear excited state with the energy of 7.8 eV [1]. The advantages of this nuclear transition are its very narrow width, the stability with respect to external perturbations and an accessible frequency within the VUV region, rendering it a candidate for a nuclear clock system. Due to the small excitation energy, typical for outer shell electron transitions, the strongest decay channel of the 7.8 eV nuclear state in a Th atom is internal conversion.

Here we carry out *ab initio* calculations of internal conversion rates for Th using multi-configurational Dirac-Fock wave functions [2] for the bound atomic electron. We consider internal conversion in atoms and ions with charge states Th^{+} and Th^{2+} and several ground and excited state configurations. These results are required for a better understanding of the decay properties of the ^{229}Th clock transition in different materials and experimental setups.

[1] B. R. Beck *et al.*, Phys. Rev. Lett. **98**, 142501 (2007).
[2] P. Jönsson *et al.*, Comput. Phys. Commun. **184**, 2197 (2013).

A 30.11 Wed 16:30 Empore Lichthof

Search for optical excitation of the low-energy nuclear isomer of ^{229}Th — •Johannes Thielking, David-Marcel Meier, Maxim V. Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, 38116 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. To excite the nuclear isomer via electronic bridge [1]/NEET processes, we use two-photon laser excitation of high-lying electronic levels in Th^{+} within the energy range from 7.3 to 8.3 eV [2,3]. We investigate the hyperfine structure of electronic levels of Th^{+} as means for detection of the isomeric state and to examine its nuclear structure. We also study a possible two-photon excitation scheme in Th^{2+} for energies higher than 8.3 eV, since this range is hardly accessible in Th^{+} because of resonantly enhanced three-photon ionisation in our experiment.

[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 30.12 Wed 16:30 Empore Lichthof

The g-factor of the muon bound in a nuclear potential — •Bastian Sikora, Nikolay Belov, Zoltán Harman, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We present the theory of the g-factor of the muon bound in a nuclear potential. One-loop self-energy and vacuum polarization corrections are included, taking into account the interaction with the nuclear potential exactly. Moreover, we incorporate finite nuclear size and finite nuclear mass corrections.

The theory of the bound-muon g-factor, combined with possible future experiments involving bound muons can be used in principle to test quantum electrodynamics in stronger electric fields than possible with bound electrons. Furthermore, since contributions due to nuclear effects are large for bound muons, nuclear parameters can be determined by comparing the theoretical and experimental bound-muon g-factor.

A 30.13 Wed 16:30 Empore Lichthof

Investigations of nuclear effects in highly charged ions — •Hendrik Bekker[1], Sebastian Kebrich[1], Kathrin Kromer[1], Andrey V. Volotka[2], Zoltán Harman[1], Christoph H. Keitel[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Helmholtz-Institut Jena

Treatment of the interaction between electrons and nucleus beyond the point-like Coulomb potential approximation leads to modification of the energy level structure of bound electrons. Nuclear properties such as its spin, magnetic moment, charge and magnetization distributions can be investigated by measuring how they affect the electronic structure of atoms and ions. Highly charged ions (HCI) belonging to the H-like isoelectronic sequence are specially suitable for this. We aim to measure the hyperfine splitting of the $^2S_{1/2}$, $F = 3-2$ ground state in H-like Pr^{58+}, which is predicted to be at approximately 847 nm.

We use the Heidelberg electron beam ion trap to produce, trap, and collisionally excite HCI. Fluorescence light in the optical domain is measured using a grating spectrometer with which a precision of 1 ppm can be reached. Using this setup we have also measured the $J = 2-3$ transition in the $3d^4$ ground term of Ti-like Pr^{37+} and Re^{53+}. The many hyperfine levels and the strong magnetic field at the trap center give rise to a complex line shape, which is accurately reproduced by theory. Additionally, we have investigated the *KLL* dielectronic recombination in He- to O-like Pr, which is an important tool for trap optimization. Current efforts are towards the efficient production and trapping of H-like Pr^{58+}.

A 30.14 Wed 16:30 Empore Lichthof

Spectroscopy of trapped $^{138}Ba^+$ ions for atomic parity violation and optical clocks — •Elwin A. Dijck, Amita Mohanty, Nivedya Valappol, J. Olivier Grasdijk, Oliver Böll, Andrew T. Grier, Klaus Jungmann, Mayerlin Nuñez Portela, and Lorenz Willmann — Van Swinderen Institute, University of Groningen, The Netherlands

The heavy alkaline earth ions Ba^+ and Ra^+ are good candidates for a precision measurement of the weak mixing angle at low energy as well as for building an optical atomic clock. One requirement for these applications is to determine the atomic structure to percent level. We have studied the lifetime of the metastable 5d $^2D_{5/2}$ level in $^{138}Ba^+$ as a benchmark for theory calculations. Systematic effects are investigated by comparing multiple measurement schemes on a single and multiple trapped ions. In addition, we have measured the transition frequencies between the 6s $^2S_{1/2}$, 6d $^2P_{1/2}$ and 5d $^2D_{3/2}$ levels in $^{138}Ba^+$ to 100 kHz accuracy [1], improving the knowledge of these frequencies by more than two orders of magnitude.

[1] E. A. Dijck et al., Phys. Rev. A **91**, 060501(R) (2015)

A 30.15 Wed 16:30 Empore Lichthof

Atomic Parity Violation in Ytterbium — •Anne Fabricant[1], Dionysios Antypas[2], Lykourgos Bougas[2], Nathan Leefer[2], Konstantin Tsigutkin[3], and Dmitry Budker[1,2] — [1]Johannes Gutenberg Universität-Mainz, Mainz, Germany — [2]Helmholtz Institut-Mainz, Mainz, Germany — [3]ASML, Veldhoven, The Netherlands

Atomic-parity-violation (APV) experiments enable us to probe fundamental electroweak physics at low energies on a tabletop. Ytterbium (Yb) is a good candidate for APV measurements because of its particularly strong parity-violating effects and the availability of seven stable isotopes. The previous incarnation of the experiment, at UC Berkeley, succeeded in measuring the largest APV effect ever observed. Currently we are developing a new experimental apparatus in Mainz, in order to improve the accuracy of the measurements. This will enable us to investigate neutron distributions in the nucleus (the neutron skin), as well as the anapole moment arising from the weak interaction between nucleons.

A 30.16 Wed 16:30 Empore Lichthof

Development of a high resolution VUV grating spectrometer — •Stepan Dobrodey[1], Michael A. Blessenohl[1], Sven Bernitt[1,2], Laurent Mercadier[3], Clemens Weninger[4], Nina Rohringer[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität, Jena, Germany — [3]Centre for Free-Electron Laser Science, Hamburg, Germany — [4]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Germany

We present the design and development of a high resolution normal incidence grating spectrometer for the VUV range. First successful measurements have been carried out at the free-electron laser (FEL) FLASH in Hamburg to study the lasing activity of atomic transitions in xenon and krypton after inner-shell excitation with FEL pulses. With an achieved resolving power of 50000 this instrument will be utilized in the near future for observations of transitions in the VUV range in highly charged ions produced in an electron beam ion trap. This will allow for better understanding of astrophysical processes and tests of fundamental theories.

A 30.17 Wed 16:30 Empore Lichthof

A superconducting resonator-driven linear radio-frequency trap for long-time storage of highly charged ions — •Julian Stark[1], Lisa Schmöger[1,2], Andrii Borodin[1], Janko Nauta[1], 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 (HCIs) are particularly interesting candidates for novel frequency standards at a potential 10^{-19} level relative accuracy and searches for physics beyond the Standard Model, such as possible drifts in the value of the fine structure constant α. For sympathetic cooling of HCIs, these are simultaneously trapped with laser-cooled Be^+ ions in a cryogenic linear radio-frequency (RF) Paul trap [1,2]. Stable localization requires a high voltage RF drive with low noise. Currently, a new RF resonator is commissioned which includes the quadrupole trapping electrodes in the cavity. The high quality factor Q of the resonator will drastically reduce Paul trap heating rates as well as improve the overall stability of the trapping conditions. This will render electrodynamical losses of trapped ions negligible and enables precise localization of HCIs which is needed for high precision laser spectroscopy.

[1] M. Schwarz et al., Rev. Sci. Instrum. 83, 083115 (2012)
[2] L. Schmöger et al., Science 347, 6227 (2015)

A 30.18 Wed 16:30 Empore Lichthof

Line shape of frequency modulation spectroscopy of molecular iodine — •Nivedya Valappol, Amita Mohanty, Elwin A. Dijck, Oliver Böll, Klaus Jungmann, and Lorenz Willmann — Van Swinderen Institute, FMNS, University of Groningen, The Netherlands

High resolution saturated absorption spectroscopy of $^{127}I_2$ hyperfine transitions deliver a natural frequency grid in the 500 nm-900 nm range. An external-cavity diode laser system at 650 nm is stabilized to the frequency modulated absorption signal of the R(25)(6-5) transition in molecular I_2 which is 412 MHz above the 6p^{2}P$_{1/2}$ - 5d^{2}D$_{3/2}$ transition in Ba^+ ions. The diode laser can be phase locked to a frequency comb which transfers the stability of the GPS disciplined Rb clock of 10^{-12} optical range. We present a well-defined line shape which permits an accurate description of the observed signals. The stability of the frequency modulated saturated spectroscopy of I_2 lines reaches a precision of kHz level. We find that the residual amplitude modulation, which is inherent in modulation spectroscopy, shifts the zero crossing of the line. The line shape model provides for accurate extraction of density shift, broadening and hyperfine splitting.

A 30.19 Wed 16:30 Empore Lichthof

Resonant excitation of the 136 eV $2s$-$2p$ transition in Li-like

Kr^{33+} at FLASH — •Sven Bernitt[1,2], Günter Brenner[3], René Steinbrügge[1], Stepan Dobrodey[1], Michael A. Blessenohl[1], André Cieluch[1], Zachary Hockenbery[1], Steffen Kühn[1], Janko Nauta[1], Miguel-Angel Sanchez[1], Sascha W. Epp[4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]IOQ, Friedrich-Schiller-Universität, Jena, Germany — [3]DESY, Hamburg, Germany — [4]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Germany

We use the transportable electron beam ion trap FLASH-EBIT to provide a target of Li-like Kr^{33+} for monochromatized VUV light from the the free-electron laser FLASH. By detecting resonantly excited fluorescence as a function of the photon energy, we were able to perform high precision spectroscopic studies of the $1s^2 2s$-$1s^2 2p$ transition at 136 eV. We reached an accuracy of 6 meV, providing an improvement by a factor of 7 over previous measurements. These results serve as a benchmark for atomic theory and help with the interpretation of VUV spectra from astrophysical and laboratory plasmas. Future work aims at investigations of nuclear size effects which currently impede the full analysis of QED experimental data of H-like systems.

A 30.20 Wed 16:30 Empore Lichthof

Stopping of highly charged ions in laser-cooled Be^+ Coulomb crystals — •Lisa Schmöger[1,2], Maria Schwarz[1,2], Thomas M. Baumann[1], Oscar O. Versolato[1,2], Baptist Piest[1], Thomas Pfeifer[1], Joachim Ullrich[2], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, QUEST, Braunschweig, Germany — [3]Leibniz Universität Hannover, Germany

Cold highly charged ions (HCIs) are promising candidates for the development of novel ultra-precise clocks and the search for possible variations of fundamental constants. However, in the laboratory HCIs are produced by energetic processes, such as electron impact ionization, leaving the trapped ensemble at translational temperatures on the order of MK. We demonstrate a versatile preparation technique for cold HCIs which are nearly at rest in space. It is based on the generic modular combination of a pulsed HCI source with a cryogenic linear Paul trap [1]. A beamline for deceleration and precooling connects both instruments. Slow HCIs, specifically Ar^{13+} ions, are injected into the linear Paul trap where they are forced to perform an oscillatory motion along the trap axis. Finally, the HCIs are stopped by damping this motion through multiple interactions with a prestored and continuously laser-cooled Be^+ Coulomb crystal.

[1] L. Schmöger, *et al., Rev. Sci. Instrum.* **86**, 103111 (2015)

A 30.21 Wed 16:30 Empore Lichthof

Coulomb crystallized highly charged ions for fundamental physics research — •Lisa Schmöger[1,2], Oscar O. Versolato[1,2], Maria Schwarz[1,2], Matthias Kohnen[2], Alexander Windberger[1], Baptist Piest[1], Stefanie Feuchtenbeiner[1], Jofre Pedregosa-Gutierrez[4], Tobias Leopold[2], Thomas M. Baumann[1], Michael Drewsen[5], Joachim Ullrich[1,3], Piet O. Schmidt[2,3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, QUEST, Braunschweig, Germany — [3]Leibniz Universität Hannover, Germany — [4]Aix-Marseille Université, France — [5]Aarhus University, Denmark

Production of cold, strongly localized highly charged ions (HCIs) has been an experimental challenge for two decades. We succeeded in re-trapping and sympathetically cooling HCIs [1] - produced with an electron beam ion trap - in our cryogenic radiofrequency linear Paul trap. The strongly suppressed thermal motion (mK scale) of the co-crystallized HCIs will be a great advantage for high precision laser spectroscopy of forbidden transitions in HCI. Those are particularly interesting both for fundamental research, such as searching for physics beyond the Standard Model, and for technological applications such as high accuracy atomic optical clocks. Our first test experiment will be the study of the $^2P_{3/2}$-$^2P_{1/2}$ M1 transition in Ar^{13+} at 441nm.

[1] L. Schmöger, *et al., Science* **347**, 6227 (2015)

A 30.22 Wed 16:30 Empore Lichthof

High resolution spectroscopy in HCI using High-order Harmonic Generation — •Janko Nauta[1], Andrii Borodin[1], Peter Micke[1,2], Lisa Schmöger[1,2], Maria Schwarz[1,2], Julian Stark[1], José R. Crespo López-Urrutia[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Highly charged ions (HCI) are atomic systems with a few tightly bound electrons. HCI exhibit much more pronounced quantum-electrodynamics effects than neutrals and singly charged particles, thus allowing accurate tests of fundamental theory to be performed, and high precision determination of values of fundamental constants. Most observations in HCI are made with ions at temperatures of more than 10^2 eV using electron-beam ion traps. Recent progress in trapping HCI in a cryogenic linear quadrupole trap, and sympathetic cooling with Be^+ ions [M. Schwarz *et al*, Rev. Sci. Inst. **83**, pp. 1-10 (2012), L. Schmöger *et al*, Science **347**, pp. 1233-1236 (2015)], opens up the possibility for high-precision laser spectroscopy. Many transitions in HCI 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 high-order harmonics generated by femtosecond laser pulses, which are amplified by an enhancement cavity. An experimental scheme for realizing this approach will be presented.

A 30.23 Wed 16:30 Empore Lichthof

A vibration-free cryogenic system for ion traps — Maria Schwarz[1,2], •Peter Micke[1,2], Lisa Schmöger[1,2], Tobias Leopold[2], Thomas Pfeifer[1], José R. Crespo López-Urrutia[1], and Piet O. Schmidt[2,3] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, QUEST, Braunschweig, Germany — [3]Leibniz Universität Hannover, Germany

Cold highly charged ions (HCI) can be sensitive detectors for possible small variations of fundamental constants, e.g. of the fine-structure constant on a level of 10^{-19} per year. High precision spectroscopy, such as quantum logic spectroscopy, is needed to probe the highly forbidden optical transitions in HCIs. A cryogenic environment is essential to suppress charge exchange with residual gas in order to achieve long HCI storage times. We have set up a cryogenic system based on the one of CryPTEx [1], using a pulse-tube cryocooler and nested temperature stages. In the upgraded CryPTEx-II, the cryocooler and the trap are 2 m apart, located in separate rooms for acoustic decoupling, and thermally linked by a vibration-suppression system. Mechanical vibrations due to pumps and the cryocooler are decoupled by means of edge-welded bellows, flexible ultra-pure copper links and a massive inertial pendulum.

[1] M. Schwarz *et al., Rev. Sci. Instrum.* **83**, 083115 (2012)

A 30.24 Wed 16:30 Empore Lichthof

Polar-maXs: Micro-calorimeter based X-ray polarimeters — •Christian Schötz[1], Daniel Hengstler[1], Loredana Gastaldo[1], Sebastian Kempf[1], Andreas Fleischmann[1], Christian Enss[1], Günter Weber[2,3], and Thomas Stöhlker[2,3,4] — [1]Kirchhoff Institute for Physics, Heidelberg University — [2]Helmholtz-Institute Jena — [3]GSI Darmstadt — [4]IOQ, Jena University

We are presently developing the x-ray detector system Polar-maXs, which will combine for the first time the high energy resolution, large dynamic range and excellent linearity of magnetic micro-calorimeters with the sensitivity to polarization caused by polarization-dependent Compton or Rayleigh scattering in an array of scatterers.

Polar-maXs consists of two layers. The first layer comprises a 4 x 4 array of x-ray scatterers behind a corresponding array of collimator holes. Depending on the energy range of interest and whether Compton or Rayleigh scattering is to be used, these scatterers are fabricated from low-Z or high-Z material. The scattered x-rays are detected by an array of 576 x-ray absorbers read-out by paramagnetic temperature sensors as metallic magnetic micro-calorimeters (MMC). Each absorber covers an area of 0.5mm x 0.5mm and is made of 15 micrometer thick gold, to guarantee high stopping power for x-ray with energies up to 20 keV and an energy resolution of better than 20eV (FWHM) in the complete energy range. We discuss general design considerations as well as the results of Monte-Carlo simulations for a variety of detector designs. We present micro-fabricated devices and discuss the results of first experimental tests.

A 31: Attosecond physics

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

A 31.1 Wed 16:30 Empore Lichthof

Tunneling time in attosecond experiments, strong field and ultra-fast science — •Ossama Kullie — Theoretical physics, institute for physics, university of Kassel, Germany.

I present a theoretical model of the tunneling time and the tunneling process in attosecond and strong field experiments, leading to a relation which performs an excellent estimation for the tunneling time, where we address the important case of the He-atom [2]. The tunneling time is also featured as the time of passage similar to the Einstein's photon box Gedanken experiment (EPGE), and our model can be seen as a realization of the EPGE. Our work tackles an important case study 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 new fundamental step in dealing with the tunneling time in strong field and ultra-fast science, and is appealing for more elaborate treatments using quantum wave packet dynamics and especially for complex atoms and molecules. [1] O. Kullie, Phys. Rev. A, (2015) accepted. arXiv:1505.03400v2. [2] Eckle et al. Science. 322, 1525 (2008).

A 31.2 Wed 16:30 Empore Lichthof

Time delay in photoionization with light carrying orbital angular momentum — •Jonas Wätzel and Jamal Berakdar — Institut für Physik, Martin-Luther Universität Halle-Wittenberg, Karl-Freiherr-von-Fritsch-Str. 3, 06120 Halle/Saale

The experiment of Schulze et al. on time delay in photoemission triggered large experimental and theoretical activities with the aim to understand and quantitatively reproduce the results of the measurements. Up to date various mechanisms and calculation techniques were put forward but some differences between theory and experiment remain, calling for further investigation to understand this effect.

To add yet a new aspect to this issue we consider using a twisted light beam, also called optical vortex. Such a beam has a phase singularity at its centre and carries orbital angular momentum (OAM), characterized by the topological charge, which can be transferred to the electron. The usage of OAM light leads to a complete new set of selection rules because the magnetic quantum number m is not preserved and they are directly determined by the choice of the topological charge.

We present results of calculations of the atomic time of the photoionization process of the argon 3p subshell initiated by a twisted light XUV pulse. We show that in different directions either the co-rotating electron (relative to the field) or the counter rotating electron dominates photoionization amplitude. Furthermore the corresponding time delays are completely different. Therefore, the time delay represents an interesting measure to identify the origin of the photoelectron with respect to the initial magnetic (sub-)state.

A 31.3 Wed 16:30 Empore Lichthof

A Figure of Merit for Ionization during HHG — •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 study the impact of an ionized background medium onto HHG in an in-situ pump-probe experiment by using high-density liquid water droplets as a target. By increasing the intensity of the pump pulse, ionization within the target is enhanced. A second, time-delayed probe pulse is used to generate harmonic radiation. A medium consisting of ions which surround the electron-ion couple during HHG therein can critically influence the electronic trajectories along their excursion in the continuum since the ionic Coulomb field may deflect the electron in a way, that the recombination process is inhibited. In combination with numerical simulations, our measurements allow us to develop a figure of merit for ionization within the macroscopic target.

A 32: Ultra-cold atoms, ions and BEC III (with Q)

Time: Thursday 11:00–13:00 Location: f107

A 32.1 Thu 11:00 f107

Toolbox for tunable ion-ion interactions in a 2D surface trap — •Henning Kalis, Frederick Hakelberg, Matthias Wittemer, Manuel Mielenz, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Geometrical frustration has turned out to be a machanism for inducing exotic quantum disordered phases [1], whose dynamics can not be adressed efficiently on classical computers. To get around this difficulty we follow Feynman's approach of quantum simulations [2]. We chose a bottom up approach based on trapped $^{25}Mg^+$ ions [3]. Static and real-time control of the motional degrees of freedom has been demonstrated in a triangular surface trap with 80 μm inter-ion distance [4]. In our setup we have three dictinct trap sites seperated by 40 μm, aranged in an equilateral triangle. We report on different techniques for analysis of the motional mode orientations, that represent the key ingredient for a tunable ion-ion interaction.

[1] Moessner, R. & Sondhi, S. L, Phys. Rev. B **63**, 224401 (2001).
[2] R.P. Feynman, Int. J. Theor. Phys., VoL **21**, Nos. 6/7, (1982).
[3] Schaetz et al., New J. Phys. **15**, 085009 (2013).
[4] Mielenz et. al., In Preperation

A 32.2 Thu 11:15 f107

Purity oscillations in Bose-Einstein condensates with balanced gain and loss — Dennis Dast, Daniel Haag, •Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

We present a new generic feature of $\mathcal{PT}$-symmetric Bose-Einstein condensates by studying the many-particle description of a two-mode condensate with balanced gain and loss. This is achieved using a master equation in Lindblad form whose mean-field limit is a $\mathcal{PT}$-symmetric Gross-Pitaevskii equation. It is shown that the purity of the condensate's single-particle density matrix periodically drops to small values but then is nearly completely restored. This indicates that during the oscillations the particles leave the single-particle orbital of the condensed phase and return afterwards to an almost perfect mean-field state. We show that this has a direct impact on the average contrast in interference experiments which periodically vanishes and recurs.

A 32.3 Thu 11:30 f107

Local Ionization of Ultracold Gases by Femtosecond Laser Pulses — •Bernhard Ruff[1,3], Philipp Wessels[1,2], Juliette Simonet[1,2], Klaus Sengstock[1,2], and Markus Drescher[1,3] — [1]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [2]Zentrum für Optische Quantentechnologien, Hamburg, Germany — [3]Institut für Experimentalphysik, Hamburg, Germany

The combination of ultracold atomic systems and ultrafast laser pulses promises insight into the coherence properties of macroscopic dissipative quantum systems and enables the preparation of hybrid quantum systems through local ionization of atoms in strong laser fields.

We report on the investigation of ultracold ^{87}Rb gas exposed to femtosecond laser pulses at 515 nm wavelength and 290 fs pulse duration. The light pulses ionize atoms of the atomic cloud within the focus region (7 μm waist) of the beam via two-photon absorption. The number of ions generated can be controlled by tuning the intensity or the wavelength of the laser pulses. The remaining atoms are detected by resonant absorption imaging either in situ or after time of flight.

Atomic losses evident as a hole in the trapped cloud are evaluated and show a non-linear increase with respect to the pulse energy corroborating the generation of ions in a multiphoton process. Additionally results on the relaxation dynamics of thermal clouds and condensates after exposure to a single pulse will be discussed as well as further perspectives on the detection of charged fragments.

A 32.4 Thu 11:45 f107

Measurements of spectral functions of ultra-cold atoms in a speckle potential — •Vincent Denechaud, Valentin Volchkov, Mukhtar Musawwadah, Jérémie Richard, Alain Aspect, and Vincent Josse — Laboratoire Charles Fabry - Institut d'Optique, Palaiseau, France

We present a spectroscopic study of ultra-cold atomic states in a disordered potential created by a laser speckle. Atoms are first prepared in a spin state which is insensitive to disorder. In a second step, a radio-frequency spin-flip towards a disorder-sensitive spin state is performed. The transfer rate $A(E,k)$ of such operation is referred to as spectral function, which correspond to the probability of populate an atomic state with a momentum k and an energy E within the disorder [1].

Measurements of such spectral function for various disorder configurations will be presented and discussed. We will highlight two kinds of regimes : the so-called "classical" disorder where the atomic states are shaped by the fluctuations of the random potential, and the "quantum" disorder where the states are dominated by tunelling effects. We will also explore peculiar features of spectral functions for a repulsive or an attractive speckle potential.

In principle, the spin-flip transfer allows us to create states with narrow energy distributions within the disorder. This paves the way to a precise study of the metal/insulator Anderson phase transition [2].

[1] M.I.Trappe et al, J.Phys.A: Math.Theor.48, 245102 (2015)
[2] A.Lagendijk et al, Physics Today, 62, 24 (2009)

A 32.5 Thu 12:00 f107

Dynamics of strongly correlated fermions—first principle results for two and three dimensions — •Niclas Schlünzen, Sebastian Hermanns, Jan-Philip Joost, and Michael Bonitz — CAU Kiel, Germany

Quantum transport of strongly correlated fermions is of central interest in condensed matter physics. While the stationary expansion dynamics have recently been measured with cold atoms in two-dimensional (2D) optical lattices [1], ab initio simulations have been limited, so far, to 1D setups. Using the nonequilibrium Green functions method with the T-matrix approximation [2,3], it becomes possible to precisely predict the fermionic quantum dynamics for 2D and 3D [4]. The simulations give access to the short-time dynamics, including the spatially resolved build-up of correlations, as well as the long-time limit of the expansion. The latter is investigated concerning the differences between 1D, 2D and 3D and the dependence of the expansion velocity on the particle number N, for which a universal scaling is discovered. These predictions can be verified experimentally using the recently developed fermionic atom microscopes.

[1] U. Schneider *et al.*, Nat. Phys. **8**, 213 (2012)
[2] K. Balzer and M. Bonitz, *NEGF Approach to Inhomogeneous Systems*, Lecture Notes in Physics (Springer, 2013)
[3] M. P. von Friesen *et al.*, Phys. Rev. B **82**, 155108 (2010)
[4] N. Schlünzen, S. Hermanns, M. Bonitz, and C. Verdozzi, arXiv:1508.02947 (2015)

A 32.6 Thu 12:15 f107

A High-Speed Single Ion Beam Source using a Cold Atom Beam and Rydberg Blockade — •Benjamin Sparkes, Richard Taylor, Dene Murphy, Rory Speirs, Dan Thompson, Joshua Torrancd, Andrew McCulloch, and Robert Scholten — School of Physics, University of Melbourne, Melbourne, Australia

We propose a novel single ion source based on Rydberg excitation from a cold atom beam. This source will have the ability to place ions into target surfaces with high precision due to their low temperature, allowing for the possibility of new types of nanofabricated devices and processes in material sciences. For instance, it could be used for ion implantation in solid-state quantum computers, as well as for high-resolution ion microscopy and lithography. The ideal single ion source would be fast, precise and fully deterministic, but current technologies are either slow or stochastic. Combining our second generation cold atom-beam based ion source with the phenomena of Rydberg blockade and stimulated Raman adiabatic passage (STIRAP) will allow us to overcome these issues to create a source that is fast, heralded and quasi-deterministic.

We will present simulations of the proposed single ion beam source as well as our latest experimental results demonstrating high-efficiency excitation using STIRAP in our MOT-based cold atom electron and ion source, with a total efficiency of 60% (peak efficiency of 80%).

A 32.7 Thu 12:30 f107

Topological bands in cold gases — •Sebastian Weber, David Peter, and Hans Peter Büchler — Institute for Theoretical Physics III, University of Stuttgart, 70550 Stuttgart, Germany

Topological band structures are the basis for interesting phenomena like integer and fractional topological insulators that are of high research interest. Recently it has been demonstrated that topological bands characterized by a Chern number can be realized with dipolar exchange interaction [1].

We present a proposal for the implementation of this idea using Rydberg atoms. We analyze finite geometries and investigate the appearance of edge states as a signature of topological bands. In particular, we search for minimal systems that show experimentally accessible edge states.

We study the robustness of edge states to lattice defects. Remarkably, it turns out that their stability allows the realization of interesting systems in optical lattices with slight imperfections. We can increase the robustness further if we use cutoff potentials that suppress the interaction on small length scales. This method paves the way for a novel continuum model that exhibits topological bands.

[1] D. Peter et al., *Topological flat bands with Chern number $C = 2$ by dipolar exchange interactions*, Phys. Rev. A **91**, 053617 (2015)

A 32.8 Thu 12:45 f107

Satellite-borne quantum test of the weak equivalence principle — •Naceur Gaaloul, Christian Schubert, Sina Loriani, Wolfgang Ertmer, and Ernst Maria Rasel — Leibniz University of Hanover, Germany

The high sensitivity of atom interferometer sensors makes it a promising tool for performing tests of fundamental theories. One timely challenge is to experimentally bound an eventual violation of the weak equivalence principle (WEP), a corner stone of General Relativity, by tracking the trajectories of two different atomic species in free fall. When operating on a satellite, the interferometry time of few seconds would allow to target an inaccuracy of $10^{-}15$ in differential acceleration between two atomic ensembles of different masses. In this presentation, we present the principle of such a measurement based on the use of a degenerate mixture of potassium and rubidium atoms. Several experimental arrangements have to be made in order to tackle a space operation and mitigate for significant systematic effects. This concept is proposed as a medium-size mission in the frame of the Cosmic Vision program of the European Space Agency.

A 33: Interaction with strong or short laser pulses III

Time: Thursday 11:00–12:45 Location: f303

Invited Talk A 33.1 Thu 11:00 f303

Imaging single nanoparticles with intense XUV pulses from a high-order harmonic generation source — •D. Rupp[1], B. Langbehn[1], M. Sauppe[1], N. Monserud[2], A. Ulmer[1], J. Zimmermann[1], T. Möller[1], F. Frassetto[3], A. Trabattoni[3], F. Calegari[3], M. Vrakking[2], and A. Rouzee[2] — [1]TU Berlin — [2]Max-Born-Institut, Berlin — [3]Politecnico di Milano

Single shot imaging of individual nanoparticles in free flight has become possible using highly intense, femtosecond short-wavelength pulses from free-electron-lasers (FELs). This method allows the study of transient and rare phenomena in gas-phase nanosized objects, such as particle shape evolutions during growth processes, non-equilibrium melting phenomena or ultrafast changes of optical or electronic properties after pulsed laser excitation. Up to now, FELs were seen as the only light sources with this desired ultrafast imaging capability. With only four X-FEL-facilities worldwide, this exciting field of research has so far been constrained to a few experiments only.

For the first time we performed single-shot imaging of individual gas-phase nanoparticles with a table-top light source. Single suprafluid helium nanodroplets were imaged using intense XUV pulses from high-order harmonic generation (HHG) with up to 1μJ pulse energy. The high-quality images generated in this proof-of-principle experiment promote exciting future prospects such as using the phase stable multicolor pulses from HHG and even attosecond XUV flashes to create, steer, and follow ultrafast coherent plasma dynamics.

A 33.2 Thu 11:30 f303

Charge Migration in Diffractive XFEL imaging — •Abraham Camacho Garibay, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS, Dresden

The possibility of using XFEL sources for diffractive imaging has been suggested long ago by Neutze et. al. with the scheme known as "diffraction before destruction". For this to become a reality, a proper understanding of the dynamics triggered from the pulse is fundamental. Recent results have suggested that both field ionization and charge transfer can have a huge impact over the time evolution of finite systems such as clusters, which can be exploited do reduce the radiation damage for the duration of the pulse. In the present work we study the dynamics of Lysozyme under XFEL pulses, a system that is multicomponent, non-symmetric and non-homogeneous. We have observed that a systematic migration of electrons from hydrogen (abundant in biological environments) to heavier, more absorbing and diffractive elements, take place. This migration has a consequence the stabilization of the heavy ion backbone, which allows for the use of longer pulses and/or weaker intensities in single-particle diffraction experiments, and has interesting implications for the coulomb explosion of heavier ions.

A 33.3 Thu 11:45 f303

In-flight-holography – a novel approach to image single nanoparticles with highly intense X-ray pulses — •A Ulmer[1], K Ferguson[2], M Bucher[2], T Ekeberg[3], M Hantke[3], B Daurer[3], C Nettelblad[3], J Andreasson[3], A Barty[4], J Bielecki[3], G Bortel[5], G Carlsson[3], D DePonte[2], G Faigel[5], D Hasse[3], D Larsson[3], M Liang[4], A Morgan[4], K Mühlig[3], M Müller[1], K Okamoto[3], G Oszlanyi[5], A Pietrini[3], D Rupp[1], M Sauppe[1], M Seibert[3], J Sellberg[3], M Svenda[3], A Szoke[6], M Tegze[5], E Timneanu[3], G van der Schot[3], A Zani[3], H Chapman[4], J Hajdu[3], F Maia[3], C Bostedt[2], T Möller[1], and T Gorkhover[1,2] — [1]TU Berlin — [2]LCLS@SLAC — [3]Uppsala University — [4]CFEL@Desy Hamburg — [5]Hungarian Academy of Sciences — [6]LLNL

Free-Electron Lasers (FEL) open the door to study the morphology of non-crystalline gas phase nanoparticles by single-shot coherent diffraction imaging. To extract full structural information the phase information has to be retrieved, as it is lost due to the imaging process. Hereby sophisticated techniques and the use of constraints were necessary in former approaches. For solid targets holographic methods were applied successfully which retrieve the phase directly by encoding it in the probe exit wave's amplitude. In-flight-holography (IFH) is a novel approach where the scattered light from xenon nanoclusters is used as a holographic reference. This talk will report on the first IFH experiment, where the LCLS FEL was used to image single free nanoparticles, e.g. viruses. First results and resolution limits through experimental constraints will be discussed.

A 33.4 Thu 12:00 f303

Imaging dynamics in xenon doped helium nanodroplets — •B. Langbehn[1], Y. Ovcharenko[1], D. Rupp[1], A. LaForge[2], O. Plekan[3], R. Cucini[3], P. Finetti[3], D. Iablonskyi[4], A. Matthews[5], V. Oliver Álvarez de Lara[5], P. Piseri[6], N. Toshiyuki[7], M. DiFraia[8], C. Callegari[3], K. C. Prince[3,9], K. Ueda[4], F. Stienkemeier[2], and T. Möller[1] — [1]TU Berlin — [2]Universität Freiburg — [3]Elletra-Sincrotrone Trieste — [4]Tohoku University, Sendai — [5]EPFL, Lausanne — [6]Università di Milano — [7]Kyoto University — [8]University of Trieste — [9]IOM-CNR TASC Laboratory, Trieste

With the recent availability of femtosecond x-ray pulses at free-electron laser (FEL) facilities, an insight into a new regime of laser-matter interaction has become feasible. Ultrashort and intense pulses allow for novel kind of experiments, as for example to study the structure and dynamics in gas-phase nanoparticles with x-ray imaging. In particular, helium nanodroplets are very interesting targets. On one hand, they have a simple electronic and geometric structure, on the other hand they are superfluid and can serve as an ultracold nanolaboratory for embedding atoms and molecules and growth studies. This talk will report on a pump-probe experiment using resonant XUV imaging of single helium nanodroplets with the FERMI FEL. The droplets were doped with xenon atoms and a plasma is ignited with a high power optical laser pulse. Using the single particle imaging technique we could follow the nanoplasma propagation and destruction of the droplet from fs to hundreds of ps after IR excitation.

A 33.5 Thu 12:15 f303

Towards multidimensional spectroscopy in the XUV and soft-X-ray spectral range — •Thomas Ding, Kristina Meyer, Christian Ott, Andreas Kaldun, Alexander Blättermann, Veit Stooss, Marc Rebholz, Lennart Aufleger, Paul Birk, Maximilian Hartmann, Martin Laux, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

As first steps towards multidimensional spectroscopy with extreme ultraviolet (XUV) pulses, we present time-resolved four-wave-mixing experiments on inner-valence transitions in neon with attosecond XUV and femtosecond near-infrared (NIR) pulses. The first two pulses (XUV-NIR) coincide in time and act as coherent excitation fields, while the third pulse (NIR) acts as a probe. This new approach allows for the coherent control of otherwise inaccessible coupling dynamics between odd- and even-parity states.

In addition, we present the design of a multidimensional XUV/soft-X-ray spectroscopy setup which will be applicable for both attosecond high-harmonic sources and ultra-intense free-electron lasers (FELs). The heart of the setup is a dynamic four-quadrant split mirror to generate temporally well-controlled pulse sequences for four-wave-mixing experiments as a function of multiple time delays. First experiments will again target benchmark systems such as helium, neon and small molecules. In the near future, one key application with FEL pulses will be the femtosecond-time-resolved multidimensional site-specific spectroscopy of molecules to follow charge migration as a function of time.

A 33.6 Thu 12:30 f303

Highly nonlinear nano-plasma formation and EUV light generation in gas-filled plasmonic waveguides — •Murat Sivis, Frederik Busse, and Claus Ropers — 4th Physical Institute - Solids and Nanostructures, University of Göttingen, 37077 Göttingen

Plasmonic nanostructures offer new means to study nonlinear optical phenomena in highly confined light fields. Specifically, resonant nanoantennas and tapered hollow waveguides allow for an efficient strong-field excitation and ionization of gas atoms accompanied by extreme-ultraviolet (EUV) light generation. Contrary to initial studies reporting plasmon-enhanced coherent high-harmonic generation [1, 2], it was shown that incoherent fluorescence photons dominate the EUV radiation under such conditions [3, 4].

Here, we present a detailed study of atomic gas excitation and EUV light generation in tapered plasmonic waveguides. In addition to the EUV emission, we record and analyze both photoelectron and ion yields from these structures as a function of incident intensity and gas pressure. Together with the experimental findings, finite element calculations of the local field distributions in the waveguides provide a comprehensive picture of the underlying excitation mechanisms.

[1] S. Kim *et al.*, Nature **453**, 757(2008). [2] I.-Y. Park *et al.*, Nat. Photon. **5**, 677 (2011). [3] M. Sivis *et al.*, Nature **485**, E1 (2012). [4] M. Sivis and C. Ropers, Phys. Rev. Lett. **111**, 085001 (2013).

A 34: Precision spectroscopy of atoms and ions II (with Q)

Time: Thursday 11:00–13:00 Location: f428

Invited Talk A 34.1 Thu 11:00 f428

The magnetic moment of the antiproton — •Stefan Sellner[1], Klaus Blaum[2], Matthias Borchert[3], Takashi Higuchi[1,4], Nathan Leefer[5], Yasuyuki Matsuda[4], Andreas Mooser[1], Hiroki Nagahama[1,4], Christian Ospelkaus[3], Wolfgang Quint[6], Georg Schneider[7], Christian Smorra[1,8], Toya Tanaka[4], Jochen Walz[5,7], Yasunori Yamazaki[9], and Stefan Ulmer[1] — [1]Ulmer Initiative Research Unit, RIKEN, Wako, Japan — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [4]Graduate School of Arts and Sciences, University of Tokyo, Tokyo, Japan — [5]Helmholtz-Institut Mainz, Mainz, Germany — [6]GSI-Helmholzzentrum für Schwerionenforschung, Darmstadt, Germany — [7]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [8]CERN, Geneva, Switzerland — [9]Atomic Physics Laboratory, RIKEN, Wako, Japan

The Standard Model describes the fundamental interactions and properties of elementary particles. Being a Lorentz-invariant theory, the absolute values of the properties like charge, mass, and magnetic moment, of matter and antimatter-conjugates, are invariant under the combined charge, parity, and time transformation. Any violation of this CPT symmetry would indicate new physics. The BASE experiment tests this symmetry at lowest energy and with highest precision. We use an advanced multi-Penning trap system to compare charge-to-mass ratios and magnetic moments of single protons and antiprotons, respectively.

Our aimed relative precision is 1 ppb (10^{-9}) for the magnetic moment measurement. Last year, we succeeded in measuring the charge-to-mass ratio of the antiproton and the proton [1], confirming CPT invariance down to the atto-electron volt scale with a measurement precision of 69 parts per trillion. Next, we will focus on magnetic moment measurements.

In my talk, I will present the techniques and recent results of our measurements at BASE and give an outlook on future improvements.

[1] S. Ulmer et al, Nature 524, p. 196-199 (2015)

A 34.2 Thu 11:30 f428

RIS studies of high-lying energy levels in erbium for the determination of the first ionization potential — •Dominik Studer[1], Patrick Dyrauf[1], Pascal Naubereit[1], Matsui Daiki[2], and Klaus Wendt[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz — [2]Department of Physics, Nagoya University

For most lanthanides, the extremely rich atomic spectrum is not completely known and proper level identification is still a challenge. Theoretical approaches are often incapable to deconvolute the stuffed structures, as obtained from atomic spectroscopy in particular for higher excitation energies, due to missing level assignments. In addition, precise and meaningful experimental data is still lacking in that range. Correspondingly, the ionization potentials of a number of lanthanide elements were determined with an insufficient precision of a few cm^{-1}. Here, we report on two-step resonance ionization spectroscopy in the spectrum of erbium. The accurate measurement of energy positions of a multitude of high-lying Rydberg-states in the range of principal quantum number $15 < n < 60$ was performed. To account for perturbations of the observed Rydberg-series from interloper states, an extension of the conventional Rydberg-Ritz formalism is required for a correct description of the observed s, d and g series. It allows for a determination of the ionization potential with a precision of better than 0,1 cm^{-1}. This talk presents the spectroscopic data and discusses the analysis of the Rydberg-series comparing two different approaches for the evaluation of perturbed Rydberg-series.

A 34.3 Thu 11:45 f428

Laser spectroscopy of the element Nobelium — •Felix Lautenschläger for the RADRIS Collaboration — Technische Universität Darmstadt

Laser spectroscopy is one of the most powerful tools to investigate the atomic properties of transfermium elements (Z≥100). In particular, finding atomic levels in such elements allows to benchmark theoretical predictions and to understand the influence of relativistic- and QED-effects on their shell structure. To this end, we employ the Radiation Detected Resonance Ionisation Spectroscopy (RADRIS) [1]. The latter method is well suited to reveal the atomic properties of such elements, which can be only artificially produced in a complete fusion reaction at on-line facilities such as GSI in Darmstadt.

In my talk I will introduce this technique and report on laser spectroscopy of the element nobelium (Z=102).

[1]: H.Backe et al., Eur. Phys. J. D 45, 99-106 (2007).

A 34.4 Thu 12:00 f428

Mass measurements of neutron-rich copper isotopes and technical developments at ISOLTRAP — •Andree Welker[1] and ISOLTRAP Collaboration[2] — [1]Institut für Kern- und Teilchenphysik, Technische Universität Dresden, 01069 Dresden, Germany — [2]CERN

We present very recent results from ISOLTRAP [1] measurements of neutron rich copper isotopes, where - with the help of the multi-reflection time-of-flight mass spectrometer (MR-ToF) [2] - ^{79}Cu was reached for the first time. With the gained knowledge of the copper binding energies, which are a really sensitive probe for the evolution of shell structure, we are only one proton above the $Z = 28$ core, close to the doubly-magic ^{78}Ni isotope. These measurements belong to an extended ISOLTRAP campaign on very neutron-rich nuclides for nuclear-structure and astrophysical cases. To be able to reach out even further exotic nuclides at very high precision, a position-sensitive ion detector was installed behind the precision Penning trap. This major step will allow the application of the Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) [3] method, which was developed at SHIPTRAP/GSI. The new technique offers higher precision in less measurement time as well as a much higher resolving power, and thus the ability to resolve low-lying isomers, compared to the present Time-of-Flight Ion-Cyclotron-Resonance (ToF-ICR) technique [4]. The current status and an outlook on the implementation of the PI-ICR technique at ISOLTRAP will be presented.

A 34.5 Thu 12:15 f428

The high-precision Penning-trap mass spectrometer PENTATRAP — •Alexander Rischka[1], Hendrik Bekker[1], Christine Böhm[1], José Ramón Crespo López-Urrutia[1], Andreas Dörr[1], Sergey Eliseev[1], Mikhail Goncharov[1], Pavel Filianin[1], Yuri Novikov[2], Rima Schüssler[1,3], Sven Sturm[1], Stefan Ulmer[4], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Petersburg Nuclear Physics Institute, 188300 Gatchina, Russia — [3]Universität Heidelberg, Fakultät für Physik und Astronomie, 69120 Heidelberg, Germany — [4]RIKEN, Ulmer Initiative Research Unit, Japan

The Penning-trap mass spectrometer PENTATRAP is currently in the commissioning phase at the Max-Planck-Institute for Nuclear Physics in Heidelberg. We are aiming at measurements of mass ratios using highly charged ions with a relative uncertainty of better than 10^{-11}. This allows, among others, contributions to neutrino physics research by a sub-eV measurement of the Q-value of ^{163}Ho/^{163}Dy. Furthermore, for a precision test of the energy-mass equivalence $E = mc^2$ and thus of special relativity, the Q-value of ^{35}Cl/^{36}Cl and the sum of energies of the gamma-rays emitted after the neutron capture in ^{35}Cl are needed. Former one will be measured at PENTATRAP and the latter one at ILL Grenoble. To reach trapping times of weeks for the highly charged ions and to perform a full characterization of the Penning-trap system in order to start first precision measurements, a major revision of the cryogenic setup and the ion transfer beamline is presently prepared and will be commissioned soon.

A 34.6 Thu 12:30 f428

A large array of microcalorimeters for high-precision X-ray spectroscopy — •Pascal Scholz[1], Victor Andrianov[2], and Saskia Kraft-Bermuth[1] — [1]Justus-Liebig-Universität, Gießen, Germany — [2]Lomonosov Moscow State University, Moscow, Russia

High-precision X-ray spectroscopy of highly-charged heavy ions, commonly performed at storage rings, provides a sensitive test of quantum electrodynamics. Silicon microcalorimeters, which detect the X-ray energy as heat rather than by charge production, have already demonstrated their potential to improve the precision of such experiments due to their excellent energy resolution for X-ray energies around 100 keV.

To improve their performance with respect to statistical as well as systematic uncertainties, a large array of silicon microcalorimeters for high-precision X-ray spectroscopy, especially optimized for experiments at storage rings, has now been designed. With an active area of about 100 mm^2, it will be the largest microcalorimeter array currently available for storage ring experiments. In addition, the large dynamic range will allow the intrinsic determination of the Doppler correction, which is a prominent source of systematic uncertainty in such experiments. The presentation will introduce the detection principle, present the new detector design as well as first tests of performance, and discuss potential applications.

A 34.7 Thu 12:45 f428

Precise high voltage measurements based on laser spectroscopy — •Kristian König, Phillip Imgram, Jörg Krämer, Bernhard Maass, Tim Ratajczyk, Johannes Ullmann, and Wilfried Nörtershäuser — Institut für Kernphysik, TU Darmstadt

The ALIVE experiment at the TU Darmstadt is a new collinear laser spectroscopy setup. The goal of the experiment is the measurement of high voltages in the range of 10 to 100 kV using precise laser spectroscopy of ions with a well-known transition frequency [1]. The aim is to achieve a precision of at least 1 ppm, which is of interest for many applications.

The setup consists of an ion source that provides $^{40}Ca^{+}$ ions and an acceleration region between two chambers of which one is equipped with a fluorescence detection. The well-known $4s_{1/2} \rightarrow 4p_{3/2}$ and the $3d_{3/2} \rightarrow 4p_{3/2}$ transitions are used to identify the ion velocities before and after acceleration based on the Doppler shift as proposed in [2]. In order to obtain the targeted accuracy, precise control and knowledge of the ion beam properties is required. We present the current status of the experiment.

[1] O. Poulsen, Nucl. Instr. Meth. Phys. Res. 202 (1982) 503.
[2] S. Götte, et al., Rev. Sci. Instrum. 75 (2004) 1039.

A 35: Attosecond physics

Time: Thursday 14:30–16:30 Location: f107

Invited Talk A 35.1 Thu 14:30 f107

History and current status of the Keldysh theory — •Sergey Popruzhenko — National Research Nuclear University MEPhI, Kashirskoe shosse 31, 115409, Moscow, Russia

This talk presents an overview of the Keldysh theory of strong field ionization. The historic development and applications of this analytic model of nonlinear ionization of atoms and solids by intense laser radiation proposed by L.V. Keldysh in his seminal work [1] more than 50 years ago are briefly described. The relationship between the Keldysh theory and other analytic approaches to the problem of strong field ionization, including the famous Strong Field Approximation [2,3] is discussed. Special attention is paid to open questions and to those aspects of the theory, which remain actively debated or frequently receive erroneous interpretations. This includes in particular the conditions of applicability, the problem of gauge invariance and the concept of the tunneling time. Finally, prospects for the future development of the theory are outlined.

[1] L.V. Keldysh, Sov. Phys. JETP 20, 1307 (1965).
[2] F.H.M. Faisal, J. Phys. B: At. Mol. Opt. Phys. 6, L89 (1973).
[3] H.R. Reiss, Phys. Rev. A 22, 1786 (1980).

Invited Talk A 35.2 Thu 15:00 f107

Multidimensional control of XUV-initiated high harmonic generation — Doron Azoury[1], •Michael Krüger[1], Henrik R. Larsson[2], Sebastian Bauch[2], David J. Tannor[1], Barry D. Bruner[1], and Nirit Dudovich[1] — [1]Weizmann Institute of Science, Rehovot 76100, Israel — [2]University of Kiel, Kiel D-20489, Germany

In XUV-initiated high harmonic generation (HHG), tunneling ionization is replaced by photoionization with an attosecond XUV pulse [1,2]. Ionization and subsequent IR-mediated propagation get decoupled from each other, allowing for a high degree of control and extending high harmonic spectroscopy to inner shells. Here we demonstrate XUV-initiated HHG from helium and neon atoms by combining an attosecond XUV pulse train and an IR pulse and show that the XUV-IR delay controls the timing of ionization. Moreover, by adding a weak second harmonic field and scanning its phase relative to the IR we retrieve even harmonics that oscillate completely out of phase with the odd harmonics [3]. These observations unambiguously reveal the involvement of electron trajectories and the insignificance of tunneling in the process, showing for the first time that ionization and propagation are decoupled and can be controlled independently. A strong-field model and *ab-initio* calculations corroborate our findings.

[1] K. Schafer et al., PRL 92, 023003 (2004).
[2] G. Gademann et al., NJP 13, 033002 (2011).
[3] O. Pedatzur et al., Nature Physics 11, 815 (2015).

A 35.3 Thu 15:30 f107

Tunneling time in attosecond experiments and time-energy uncertainty relation — •Ossama Kullie — Theoretical physics, institute for physics, university of Kassel, Germany.

In this work [1] we present a theoretical model of the tunneling time and the tunneling process in attosecond and strong field experiments, leading to a relation which performs an excellent estimation for the tunneling time, where we address the important case of the He-atom [2]. Our tunneling time estimation is found by utilizing the time-energy uncertainty relation and represents a quantum clock. The tunneling time is also featured as the time of passage similar to the Einstein's *photon box Gedanken experiment* (EPGE), and our model can be seen as a realization of the EPGE with the electron as a particle in a disturbed Coulomb potential (instead the photon and the gravitational potential in the EPGE). Our work tackles an important case study for the theory of time in quantum mechanics, and is very promising for the search for a (general) time operator in quantum mechanics. [1] O. Kullie, Phys. Rev. A, (2015) accepted. arXiv:1505.03400v2. [2] Eckle et al. Science. 322, 1525 (2008).

A 35.4 Thu 15:45 f107

Tunneling ionization time resolved by backward propagation — •Hongcheng Ni, Ulf Saalmann, and Jan M. Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany

We assess under which circumstances the attoclock can be used to determine the tunneling ionization time. This is achieved by a novel backward-propagation method, which involves a full quantum treatment of the tunneling process forward in time, followed by a classical backward propagation to identify the tunneling parameters. We find that, if the tunneling concept applies, the corresponding ionization time is around pulse center for single active electrons in helium and hydrogen. The range of validity, quite different for the two atoms, is limited towards low laser intensities by multiphoton ionization and towards high intensities by above-barrier ionization.

A 35.5 Thu 16:00 f107

Mechanisms for subcycle-dependent self-diffraction in transparent solids — •Jan Reislöhner, Aseem P. Pati, Christoph G. Leithold, and Adrian N. Pfeiffer — Institute for Optics and Quantum Electronics, Abbe Center of Photonics, Friedrich Schiller University, Max-Wien-Platz 1, 07743 Jena

A spatial analogue to the carrier-envelope offset phase of few-cycle laser pulses is the phase between the grooves of a grating and its envelope. Here, self-diffraction in a dielectric is studied in a two-pulse geometry where the laser-induced grating comprises only a few grooves. Two mechanisms lead to dependence on the grating-envelope offset phase, which is tuned by subcycle delays between the pulses: Interference, dominant in between the diffraction orders, and a mechanism that affects diffraction orders separately when the laser-induced grating acts as a micro-lens array.

A 35.6 Thu 16:15 f107

Carrier-envelope phase evolution in focused few-cycle laser pulses — •Dominik Hoff[1], Michael Krüger[2,3], Lothar Maisenbacher[3], 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 — [2]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen — [3]Max Planck Institute of Quantum Optics, Garching

Variation of the carrier-envelope phase (CEP) of few-cycle laser pulses has proven to be an effective way to control processes such as attosecond electron dynamics, chemical reactions, and high-harmonic generation. Thus, precise knowledge of the spatial dependence of the CEP is vital to understand and control these processes. Here we combine the recently developed techniques of high precision CEP measurement [1] and photoelectron re-scattering at metal nano-tips [2] to, respectively, provide the attosecond temporal and nanometer spatial resolution necessary to directly map the spatial dependence of the CEP. By scanning the focus with the nano-tip and recording the phase-tagged time-of-flight spectra, we are able to observe a substantial deviation from the monochromatic Gouy-phase. Further, with the help of a theory model we are able to relate our direct measurement of the focus to the chromatic properties of the beam prior to focusing.

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

A 36: Ultra-cold atoms, ions and BEC IV (with Q)

Time: Thursday 14:30–16:30 Location: f303

A 36.1 Thu 14:30 f303

Spectroscopy of Topological Defects in Coulomb Crystals — •Philip Kiefer[1], Jonathan Brox[1], Miriam Bujak[1], Isabelle Schmager[1], Haggai Landa[2], 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) experimentally, which we form during two related phase-transitions in Coulomb crystals. A cloud of ^{24}Mg-Ions is freezed into a crystalline structure, consisting of several tens of ions in a linear radiofrequency trap [1]. We observe the formation of topological defects with a structural phase transition from a linear chain to a 2D-zig-zag configuration. Numerical simulations predict a strong anharmonicity of the kink's internal mode of vibration [2].

We observe the defects' experimental occurrence, lifetime and annihilation due to controlled motional excitation of the localized mode. We reveal evidence for the (gapped) localized mode and present first data of spectroscopy results. Furthermore, the formation of kink configurations and the transformation of kinks between different structures in dependence on the trapping parameters are investigated.

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

A 36.2 Thu 14:45 f303

Quantum phases of ultracold dipolar bosons in a highly anisotropic trap — •Florian Cartarius[1,2], Anna Minguzzi[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Laboratoire de Physique et Modelisation des Milieux Condenses, Universite-Grenoble Alpes and CNRS, 25 avenue des martyrs, F-38042 Grenoble, France

We study two dimensional dipolar bosons in an optical lattice, tightly confined to a string by a highly anisotropic harmonic potential. The bosons are polarized perpendicular to the plane by an external field, so that they interact via the repulsive part of the dipolar potential. For very strong harmonic confinements, the dipoles are in the lowest energy state of the transverse harmonic oscillator. This breaks down when the transverse confinement frequency is decreased below a critical value. In this regime, we show that the system can be mapped onto several coupled extended Bose-Hubbard Hamiltonians, where the coefficients can be determined by means of a low energy theory [1]. We determine the ground state of this Bose-Hubbard Hamiltonian as a function of the trap aspect ratio and of the strength of the dipolar potential, and analyse the conditions under which Haldane-like phases and pair-superfluidity can occur.

[1] F. Cartarius, G. Morigi, and A. Minguzzi, Phys. Rev. A 90, 053601 (2014)

A 36.3 Thu 15:00 f303

On the heteronuclear Efimov effect with van der Waals interactions — •Juris Ulmanis[1], Stephan Häfner[1], Rico Pires[1], Yujun Wang[2], Chris H. Greene[3], Eva D. Kuhnle[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Department of Physics, Kansas State University, 116 Cardwell Hall, Manhattan, KS 66506, USA — [3]Department of Physics, Purdue University, West Lafayette, Indiana, 47907-2036, USA

Ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li atoms constitutes a prototypical system with mass imbalance that allows thorough exploration of the heteronuclear Efimov effect – the formation of an infinite geometrical series of bound three-body states for resonant two-body interactions. Here we present our measurements and analysis of three-body recombination spectra of Li+Cs+Cs close to two broad Li-Cs Feshbach resonances. Two series of consecutive Efimov resonances, each characterized by different sign and magnitude of Cs-Cs s-wave scattering length, are observed, showing deviations from the geometric scaling law. For positive Cs-Cs scattering lengths the three-body resonance that is associated to the Efimov ground state is missing. This is in agreement with the spinless van der Waals theory that predicts the transformation of the Efimov ground state into the Li + Cs_2 scattering channel, and modification of the scaling factors via short-range effects. These findings provide a comprehensive picture of universal and non-universal features in the heteronuclear Efimov scenario.

A 36.4 Thu 15:15 f303

Sympathetic cooling of ions inside a radio frequency trap — •Bastian Höltkemeier[1], Pascal Weckesser[1], Henry Lopez[1], Andre de Olivera[1,2], Ji Luo[1], Eric Endres[3], Roland Wester[3], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, INF 226, 69120 Heidelberg — [2]Departamento de Física, Universidade do Estado de Santa Catarina-Joinville, SC, Brazil — [3]Institut f. Ionenphysik und angewandte Physik, Universität Innsbruck, Technikerstraße 25/3, 6020 Innsbruck

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 to atom-to-ion mass ratios below unity. Using a localized buffer gas cloud and/or a higher order radio frequency trap this limitation can be overcome. A description of our model and the corresponding cooling limit for experimental applications will be presented. We show how the ion's final temperature can be tuned by adjusting the appropriate experimental parameters, such as the rf-voltage or the atom cloud size (Forced Sympathetic Cooling).

A 36.5 Thu 15:30 f303

Single particle dynamics in an ultracold environment: From superfluidity to finite size reheating — •Paula Ostmann and Walter Strunz — TU Dresden, Inst. f. Theor. Physik, Zellescher Weg 17, 01062 Dresden

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 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.

We find that we can divide the dynamical effect of the BEC on the ion into two parts: The initial energy loss and the return of energy to the ion dynamics. By considering just the initial decay we effectively study an ion coupled to an infinitely large environment and are able to identify a Landau Criterion for a quantum particle in a harmonic trap. Secondly we see that the finite size of the condensate causes the return of the energy, which results in a periodically reheating of the ion, which could be used as an additional cooling mechanism as well.

A 36.6 Thu 15:45 f303

Radio-frequency dressed detection of atomic clock states — •Sindhu Jammi, Tadas Pyragius, Mark Bason, and Thomas Fernholz — School of Physics and Astronomy, University of Nottingham

We introduce a new method to dispersively measure population and population difference of alkali atoms prepared in their two clock states (m=0). Linear birefringence of the atomic medium allows atom number detection via polarisation homodyning, i.e. common path interferometry. In order to achieve low technical noise levels, we perform sideband detection after adiabatically transforming the atomic states via radio-frequency dressing. The balanced homodyne signal then oscillates at twice the dressing frequency, independent of field fluctuations, thus allowing for robust, phase-locked detection that circumvents low-frequency noise. Using probe pulses of two optical frequencies consecutively, we can detect both atomic states separately and obtain population difference as well as total atom number in a single experimental cycle. Simultaneously pulsed detection can be used for direct subtraction of the homodyne signals, which we expect to enable quantum noise limited measurements and preparation of spin squeezed states. The method can thus be used in atomic clocks and atom interferometric measurements.

A 36.7 Thu 16:00 f303

Development of a deterministic ion source based on ultracold atoms — •Cihan Sahin, Andreas Müllers, Jens Benary, and Herwig Ott — Technische Universität Kaiserslautern

A deterministic ion source using ultracold atoms can provide ions with low energy spread at high repetition rates. These properties are beneficial for experiments on ion interferometry or semiconductor doping.

In our experiment, a magneto optical trap (MOT) storing ^{87}Rb atoms acts as an ion source. The atoms are photoionized from the $5P_{3/2}$ state with a 405 nm laser. Both electrons and ions are detected with channel electron multipliers (CEM). The electrons serve as triggers for the ions, which would enable us to predict and control the ions.

As a next step, the ions will be detected with a position sensitive multi channel plate (MCP) with a delay line detector (DLD) to characterize their energy spread and position resolution.

We discuss the status of the experiment and present results obtained so far.

A 36.8 Thu 16:15 f303

Dimensional phase transition from 1D behavior to a 3D Bose-Einstein condensate — Denis Morath, •Dominik Strassel, Axel Pelster, and Sebastian Eggert — Department of Physics and Research Center Optimas, University Kaiserslautern, 67663 Kaiserslautern, Germany

The emergence of new properties from low-dimensional building blocks is a universal theme in different areas in physics. The investigation of transitions between isolated and coupled low-dimensional systems promises to reveal new phenomena and exotic phases. Interacting 1D bosons, which are coupled in a two-dimensional array, are maybe the most fundamental example of a system which illustrates the concept of a dimensional phase transition. However, recent experiments using ultracold gases have shown a surprising discrepancy between theory and experiment [1] and it is far from obvious if the power laws from the underlying 1D theory can predict the transition temperature and order parameter correctly for all interaction strengths. Using a combination of large-scale Quantum Monte-Carlo simulations and chain mean-field calculations, we show that the behavior of the ordering temperature as a function of inter-chain coupling strength does not follow a universal powerlaw, but also depends strongly on the filling.

[1] A. Vogler, R. Labouvie, G. Barontini, S. Eggert, V. Guarrera, and H. Ott, Phys. Rev. Lett. 113, 215301 (2014)

A 37: Advanced Concepts for High Peak Power Ultrafast Lasers I

Time: Friday 11:00–13:20 Location: e415

Invited Talk A 37.1 Fri 11:00 e415

Exawatt laser concepts for extreme field science — •Chris Barty — Lawrence Livermore National Laboratory, Livermore, CA, USA

This presentation will review worldwide, high-intensity laser activities and introduce new concepts that will enable extension of existing petawatt laser capabilities to the exawatt scale. Modern inertial confinement fusion lasers based on Nd:glass have amplification bandwidths that are capable of supporting pulses of less than a picosecond in duration. With the implementation of chirped pulse amplification (CPA), it is possible for beam lines at the National Ignition Facility at the Lawrence Livermore National Laboratory, the Laser Mega-Joule (LMJ) facility in Bordeaux, France, the LFEX laser at the Institute for Laser Engineering in Osaka, Japan and the Omega EP facility at the Laboratory for Laser Energetics in Rochester, New York to create petawatt peak power laser pulses of nominally 1-ps duration and 1-kJ energy [1]. While these systems are at the forefront of present high-energy, high-peak power capabilities, they utilize only a small fraction of the potential of the underlying Nd:glass laser amplification system and as such are very inefficient. A single beam line at the NIF, for example, has a stored energy in excess of 25 kJ. This presentation describes short pulse amplification architectures based on chirped *beams* [2], novel pulse compressors and existing beam phasing technologies that are capable of extracting the full, stored energy of a NIF or NIF-like beam line and in doing so produce from one beam line a near-diffraction-limited, laser pulse whose peak power would be in excess of 200 petawatts or 0.2 exawatts. This architecture is well suited to either low-f-number focusing or to mulit-beam, dipole focusing concepts [3]. With dipole focusing, it is anticipated that a single beam line of a large-aperture, mixed-glass exawatt-scale system will be capable of reaching intensities in excess of 1026 W/cm2 or more than 5 orders of magnitude beyond that possible from existing CPA based PW systems at NIF, LMJ, LFEX and Omega EP. At such intensities proton motion becomes relativistic during interactions with the laser pulse. Full extraction of beam line energy will also be enabling to full scale demonstration of fast ignition concepts, etc.

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

[1] D. Zuegel, S. Borneis, C. P. J. Barty, B. Legarrec, C. Danson, N. Miyanaga, P. K. Rambo, C. Le Blanc, T. J. Kessler, A. W. Schmid, L. J. Waxer, J. H. Kelly, B. Kruschwitz, R. Jungquist, E. Moses, J. Britten, I. Jovanovic, J. Dawson, and N. Blanchot, "Laser challenges for fast ignition," Fusion Science and Technology 49, 453-482 (2006)
[2] C. P. J. Barty *Optical Chirped Beam Amplification and Propagation.* US Patent #6,804,045 B2, (2004) University of California.
[3] A.Gonoskov, A. Bashinov, I. Gonoskov, C. Harvey, A. Ilderton,A. Kim, M. Marklund, G. Mourou, and A. Sergeev Phys.Rev.Lett. 113, 014801 (2014)

Invited Talk A 37.2 Fri 11:50 e415

Generation of short pulses with ultra-high temporal contrast at the PHELIX petawatt facility — •Vincent Bagnoud — GSI-Darmstadt, Darmstadt, Germany

With the construction of laser facilities capable of delivering peak powers at the 10-petawatt level, the temporal contrast of short laser pulses has received a growing interest in the last decade. The standard amplification scheme based on chirped-pulse amplification (CPA) is long known to introduce temporal pedestals and artifacts that can be detrimental to experiments and their proper understanding. In the last 10 years, several technical solutions have been proposed to overcome this limitation with good success. The crossed-polarized wave cleaning technique associated with a double CPA laser system can be found now in several implementations and is available commercially from several vendors. An alternative method based on a fast OPA is also available at various facilities like the OMEGA EP laser in the US or the PHELIX facility in Germany. In this talk, I will cover the general problematic of temporal contrast at petawatt-class laser facilities from the requirements to the current limitations. The latest results obtained with the fast OPA at the PHELIX laser where a nanosecond contrast of 10^{-12} is routinely achieved will also be presented.

Invited Talk A 37.3 Fri 12:20 e415

Petawatt lasers for particle acceleration at HZDR Dresden — •Ulrich Schramm — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Focal intensities far beyond 10^{18} W/cm^2 have allowed for the development of compact laser plasma based particle accelerators. Applications are envisioned in the fields of cancer therapy or ultra-fast probing with energetic photons. However, such applications require peak power in the Petawatt range as well as average power.

Here, the development and status of the two Petawatt projects at the HZDR will be presented, one based on the upscaling of established Ti:Sapphire technology, the other on the energy efficient approach of exploiting directly diode laser pumped Yb:CaF_2. Special emphasis will be given on diagnostics concepts that allow for online monitoring of crucial parameters of these pulses as, e.g., temporal pulse contrast.

Invited Talk A 37.4 Fri 12:50 e415

High-intensity few-cycle pulses with ultrahigh temporal contrast — •Stefan Karsch[1,2], Alexander Kessel[1], Christoph Skrobol[1], Mathias Krüger[1], Christoph Wandt[1], Sandro Klingebiel[1], Olga Lysov[1], Izhar Ahmad[1], Sergei Trushin[1], Vyacheslav Leshchenko[1], Zsuzsanna Major[1,2], and Ferenc Krausz[1,2] — [1]Max-Planck-Institut für Quantenoptik — [2]Ludwig-Maximilians-Universität München

Increasing the single-shot photon flux of attosecond XUV-pulses by surface harmonic generation calls for novel few-cycle laser sources: Here, the XUV radiation is generated by reflecting a few-cycle pulse from a relativistically oscillating plasma surface driven by the pulse itself.This requires few-cycle light pulses with intensities well above 10^{19} W/cm^2 and a temporal contrast that prevents target expansion before the arrival of the main pulse.

The Petawatt Field Synthesizer (PFS) project at the MPQ follows a novel approach to generate energetic, ultrabroadband light pulses with unprecedented temporal contrast. By employing a chain of optical paramtetric amplifiers pumped by 1-ps green laser pulses from a purpose-built, diode-pumped high-energy CPA laser we ensure that no premature light can reach the target outside the 1-ps pumping window. The high-contrast requirements also call for a high-energy, temporally clean octave-bandwidth seed in the 700-1400 nm range.

We report on the status of the three project branches, namely the seed generation and optical synchronization, the pump laser development and finally the OPA amplification and dispersion control.

A 38: Ultra-cold atoms, ions and BEC V (with Q)

Time: Friday 11:00–13:00 Location: f107

A 38.1 Fri 11:00 f107

Production of ultracold atomic clouds at the shot noise limit through feedback — •Andrew Hilliard, Miroslav Gajdacz, Mick Kristensen, Jacob Sherson, and Jan Arlt — Institute for Physics and Astronomy, Ny Munkegade 120, 8000, Aarhus C, Denmark

The reliable production of cold atomic clouds with well-defined properties is a notoriously difficult task. Variations in the atom number and temperature typically arise due to technical fluctuations during the experimental sequence. However, non-destructive measurements of the ensemble properties during an experimental sequence allow for an active adjustment of the cooling procedure to obtain the desired outcome.

To achieve this, we use a dispersive imaging technique based on Faraday rotation combined with on-line digital image evaluation to provide feedback to the evaporative cooling sequence. Our imaging technique achieves a relative precision below 10^{-3} and thus allows for active feedback that can beat the atomic shot noise limit. We have implemented feedback based on the Faraday rotation signal and thus achieved run-to-run stability at the shot noise limit.

A 38.2 Fri 11:15 f107

Box traps for 2D Bose gases — •Saint-Jalm Raphaël[1], Ville Jean-Loup[1], Corman Laura[1], Bienaimé Tom[1,2], Nascimbene Sylvain[1], Beugnon Jérôme[1], and Dalibard Jean[1] — [1]Laboratoire Kastler-Brossel, Collège de France — [2]INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento

I will present a new experimental setup designed to investigate properties of ultracold bosons in low dimensions. In this setup, we produce a degenerate gas of rubidium atoms vertically confined into a single plane in an optical accordion. In the horizontal plane, we are able to engineer a flat-bottom potential whose shape can be chosen at will (disc, square, rings, boxes) by imaging the surface of a Digital Mirror Device (DMD). Thanks to this versatile system we aim at studying bosonic transport as well as implementing artificial gauge fields. I will present the first results that we have obtained in these directions.

A 38.3 Fri 11:30 f107

Topological Bogoliubov excitations of weakly interacting Bose-Einstein condensates — •Georg Engelhardt and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

Topological band structures have been mostly investigated for fermionic systems. In our talk, we explain how to generalize the notion of topology to Bogoliubov excitations on top of a Bose-Einstein condensate. We investigate the topology of these Bogoliubov excitations in inversion-invariant systems of weakly interacting bosons.

The excitations of the corresponding Bogoliubov Hamiltonian have to be diagonalized in a symplectic manner. Analogously to the fermionic case, we here establish a symplectic extension of the polarization characterizing the topology of the Bogoliubov excitations and link it to the eigenvalues of the inversion operator at the inversion-invariant momenta.

We show that the interaction of the particles influences the topology of the Bogoliubov excitations. Additionally, we demonstrate that this quantity is related to edge states in the excitation spectrum of a finite-size system with boundaries.

A 38.4 Fri 11:45 f107

Tuning Static and Dynamic Properties of a Quasi One-Dimensional Bose-Einstein Condensate — •Javed Akram[1] and Axel Pelster[2] — [1]Physics Department, Freie Universität Berlin, Germany — [2]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

Here we provide a detailed theoretical investigation in view of how to tune both static and dynamic properties of quasi one-dimensional confined Bose-Einstein condensates (BECs). At first we study ^{87}Rb atoms in a quasi one-dimensional trap geometry, which consists of a harmonic trap together with a red or blue-detuned Gaussian (Hermite-Gaussian) dimple trap [1,2]. After having switched off the dimple trap, shock-waves or gray pair-soliton (bi-)trains emerge, which oscillate with a characteristic frequency in the remaining harmonic trap. Afterwards, we analyze a quasi one-dimensional BEC in a nonlinear gravito-optical surface trap [3]. Studying a non-ballistic expansion of the BEC cloud, when the confining evanescent laser beam is shut off, turns out to agree quite well with results from a previous Innsbruck experiment. Finally, we investigate how the wave function of a trapped ^{87}Rb BEC changes due to the presence of a single ^{133}Cs impurity [4]. To this end, we determine the equilibrium phase diagram, which is spanned by the intra- and inter-species coupling strengths.

[1] J. Akram and A. Pelster, `arXiv:1508.05482`.
[2] J. Akram and A. Pelster, `arXiv:1509.03826`.
[3] J. Akram and A. Pelster, `arXiv:1509.05987`.
[4] J. Akram and A. Pelster, `arXiv:1510.07138`.

A 38.5 Fri 12:00 f107

Physical realization of third-order exceptional points — •Jan Schnabel, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Exceptional points are characterized by the coalescence of two or even more eigenstates in non-Hermitian quantum systems. While second-order exceptional points (EP2) have already been realized in experiments, an experimental observation of a third-order exceptional point (EP3) is still lacking. Encouraging systems for such an observation could be a setup of three coupled waveguides as proposed in [1] or $\mathcal{PT}$-symmetric Bose-Einstein condensates (BEC) in a triple-well trap. We investigate a realistic optical setup by numerically exact calculations, which shows the appearance of an EP3. Due to a formal analogy between the Schrödinger and the Helmholtz equation the same potential can also be realized in quantum mechanics. We introduce a realistic quantum system made up of a BEC in a three-dimensional potential, which should exhibit the characteristic behaviour of an EP3.

[1] E-M. Graefe, J. Phys. A: **45**, 2 (2012)

A 38.6 Fri 12:15 f107

Levy flight and Anderson localization of polar molecules — •Xiaolong Deng[1], Boris Altshuler[2], Gora Shlyapnikov[3], and Luis Santos[1] — [1]ITP, Uni. Hannover — [2]Physics Dept, Columbia Uni., USA — [3]LPTMS, CNRS, France

Rotational excitations in polar molecules in deep optical lattices realize a quantum percolation model with long-range hops, whose properties depend on both lattice filling and dimensionality. Using spectral and multi-fractal analysis, we show that whereas in 1D and 2D all eigenstates are localized, while in 3D all are delocalized.

A 38.7 Fri 12:30 f107

Photodetachment spectroscopy of OH- in a Hybrid Atom Ion Trap — •Henry Lopez[1], Bastian Höltkemeier[1], Ji Luo[1], Andre de Oliveira[2], Eric Endres[3], Roland Wester[3], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, INF 226, 69120 Heidelberg, Germany — [2]Departamento de Física, Universidade do Estado de Santa Catarina-Joinville, SC, Brazil — [3]Institut für Ionenphysik und angewandte Physik, Universität Innsbruck, Technikerstraße 25/3, 6020 Innsbruck, Austria

We report on the current status of our experiment, which combines an 8-pole radio-frequency trap for OH- anions and a dark-spontaneous-force optical trap for rubidium atoms. The laser-cooled atoms serve as an ultracold buffer gas for the trapped anions. The anions final internal state is probed by means of electron photodetachment spectroscopy (PDS). We further discuss how PDS can be used for determining the final translational temperature of the anions.

A 38.8 Fri 12:45 f107

Coupling Identical 1D Many-Body Localized Systems — •Pranjal Bordia[1,2], Henrik Lüschen[1,2], Sean Hodgman[1,2], Michael Schreiber[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]Facultät für Physik, LMU, München — [2]Max-Planck Institut für QuantenOptik

Many-Body Localization (MBL) marks a new paradigm in condensed matter and statistical physics. It describes a generic insulating phase in which an interacting many-body system fails to serve as its own heat bath and thermalization fails even in excited many-body states.

We experimentally study the dynamics of coupling identically disordered 1D MBL systems. Using a gas of ultracold fermions loaded in optical lattices, we prepare an out-of-equilibrium density wave and monitor its relaxation. We find striking difference between Anderson and MBL systems. While the Anderson case remains localized, coupling MBL systems with each other shows slow glassy relaxation and de-localizes the entire system.

A 39: Interaction with VUV and X-ray light

Time: Friday 11:00–13:15 Location: f303

Invited Talk A 39.1 Fri 11:00 f303

Enhanced ionization of embedded clusters by electron transfer mediated decay in helium nanodroplets — •A. C. LaForge[1], V. Stumpf[2], K. Gokhberg[2], J. von Vangerow[1], N. V. Kryzhevoi[2], P. O'Keeffe[3], A. Ciavardini[3], S. Krishnan[4], K. C. Prince[5], R. Richter[5], R. Moshammer[6], T. Pfeifer[6], L. S. Cederbaum[2], F. Stienkemeier[1], and M. Mudrich[1] — [1]Physikalisches Institut, Universität Freiburg, 79104 Freiburg, Germany — [2]Physikalisch-Chemisches Institut, Universität Heidelberg, 69120 Heidelberg, Germany — [3]CNR - Istituto di Struttura della Materia, CP10, 00016 Monterotondo Scalo, Italy — [4]Department of Physics, Indian Institute of Technology - Madras, Chennai 600 036, India — [5]Elettra-Sincrotrone Trieste, 34149 Basovizza, Trieste, Italy — [6]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

Here, we report the observation of electron transfer mediated decay involving Mg clusters embedded in helium nanodroplets which is initiated by the ionization of helium followed by removal of two electrons from the Mg clusters of which one is transferred to the He environment neutralizing it while the other electron is emitted into the continuum. The process is shown to be the dominant ionization mechanism for embedded clusters for photon energies above the ionization potential of He. The photoelectron spectrum reveals a low energy ETMD peak. For Mg clusters larger than 5 atoms we observe stable doubly-ionized clusters. We argue that ETMD provides a new pathway to the formation of doubly-ionized cold species.

A 39.2 Fri 11:30 f303

Two-photon double ionization of Neon using an intense high harmonic source — •Bastian Manschwetus[1,3], Linnea Rading[1], Fillipo Campi[1], Helene Coudert-Alteirac[1], Sylvain Maclot[1], Lahl Jan[1], Piotr Rudawski[1], Christoph M. Heyl[1], Balasz Farkas[2], Mohamed Tarek[2], Anne L'Huillier[1], and Per Johnsson[1] — [1]Department of Physics, Lund University, Box 118, SE-22100 Lund, Sweden — [2]ELI-HU Non-Profit Ltd., Dugonics tér 13, 6720 Szeged, Hungary — [3]Deutsches Elektronen-Synchrotron, Notkestrasse 85, D-22603 Hamburg, Germany

We present first results of two-photon double ionization of neon using an attosecond pulse train (APT) with an intensity of 3x1012 W/cm2 using the high-intensity high harmonic beamline at the Lund High-Power Laser Facility. It allows the efficient generation of an APT in argon or krypton with approximately 1 μJ pulse energy in a spectrum between 17 and 50 eV by loosely focusing up to 80 mJ of infrared pulse energy. Focusing the generated XUV light tightly into a Neon gas jet leads to photoionization and we detect Ne^{2+} ions with an ion time of flight spectrometer. By changing the spectral shape of the generated harmonic radiation, we can change the contribution from two different double ionization channels and get an indication if the sequential two-photon process or the direct two-photon process is dominant in our experimental conditions. The observation of two-photon double ionization shows that the beamline provides a sufficiently XUV flux to enable pump-probe experiments and we are currently implementing a time delay unit.

A 39.3 Fri 11:45 f303

Relativistic effect on x-ray multiphoton ionization dynamics of xenon atoms — •Koudai Toyota, Sang-Kil Son, and Robin Santra — Center for Free-Electron Laser Science, DESY, Notkestrasse 85, Hamburg 22607, Germany

In this talk, we further investigate the previous experimental results on charge state distribution of Xe created by X-ray free-electron laser (XFEL) pulses at 5.5 keV, which was conducted at SACLA in Japan [1]. It was found that the theoretical yields for highly charged ionic states clearly underestimate the experimental results. It was considered that these come from non relativistic treatment in theory and lack of shake-off mechanism [1]. We recently have implemented relativistic energy corrections, within perturbative approach, into our computer code, XATOM. The relativistic energy corrections introduce several effects in multiphoton multiple ionization dynamics induced by XFEL pulses. First, some Coster-Kronig channels open, which are energetically forbidden in non relativistic treatment. Second, our preliminary calculations show that a combination of relativistic treatment and resonant excitation may enhance ionization. We will present our formulation and numerical results compared with experimental data.

[1] H. Fukuzawa, S.-K. Son et al., Phys. Rev. Lett. 110. 173005 (2013).

A 39.4 Fri 12:00 f303

Dynamical Control Of Nuclear Line Shapes — •Kilian P. Heeg[1], Andreas Kaldun[1], Patrick Reiser[1], Stephan Goertler[1], Johann Haber[2], Cornelius Strohm[2], Hans-Christian Wille[2], Rudolf Rüffer[3], Christoph H. Keitel[1], Ralf Röhlsberger[2], Thomas Pfeifer[1], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]ESRF-The European Synchrotron, Grenoble, France

Signatures in spectroscopy arise from the interference between the probing light and the field scattered by the sample. Imprinting relative phases to the two channels enables one to engineer the spectrum, e.g., by turning absorption lines into Fano profiles [1,2].

In this contribution, we report on recent experiments, in which we implemented the phase control by mechanically displacing a target of Mössbauer nuclei after its excitation with resonant x-rays.

[1] C. Ott et al., Science **340**, 716 (2013).
[2] K. P. Heeg et al., Phys. Rev. Lett. **114**, 207401 (2015).

A 39.5 Fri 12:15 f303

Phase retrieval algorithms to reveal the temporal structure of the electron photoemission from atoms and clusters. — •Tim Oelze[1], Bernd Schütte[2,3], Jan Lahl[4], Stefan Apostel[1], Arnaud Rouzée[2], Marc Vrakking[2], and Maria Krikunova[1] — [1]Berlin Institute of Technology — [2]Max Born Institut Berlin — [3]Imperial College London — [4]Lund University

Light field streaking is a very powerful technique for the temporal characterization of ultrashort extreme ultraviolet (XUV) pulses. Upon ionization of atoms by the XUV pulse the electron distribution is created as a replica of the XUV pulse. In the presence of an oscillating electric field the released electrons acquire an additional momentum i.e. become streaked by the laser dressing field. By measuring electron spectra at different time-delays between the ionizing XUV pulse and the dressing field a streaking spectrogram is then obtained. It contains information about the temporal structure of the electron photoemission. Various algorithms can be then applied to retrieve the time and energy distribution of the electron photoemission from measured spectra. In our experiment argon atoms and medium-sized clusters were ionized by intense femtosecond XUV pulses produced through the high harmonic generation (HHG) and a single-cycle terahertz (THz) field is used for streaking. In this talk an iterative and a non iterative algorithm are compared by their performance on reconstruction of the streaked spectra. A particular focus of the talk is on the discussion of data post-processing routines needed to achieve reliable reconstruction results from measured spectra.

A 39.6 Fri 12:30 f303

Nuclear excitation with x-ray free-electron lasers — •Yuanbin Wu, Jonas Gunst, Naveen Kumar, Christoph H. Keitel, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

The direct and secondary nuclear excitation by an x-ray free electron laser interacting with a solid-state nuclear target is analyzed theoretically. When driven at the resonance energy, the x-ray free electron laser can produce direct photoexcitation. However, in this laser-target interaction, the dominant process is the photoelectric effect producing a cold and very dense plasma. In such a plasma, secondary processes such as nuclear excitation by electron capture may also occur [1]. We develop a realistic theoretical model to quantify the magnitude of the secondary excitation taking into account the temporal plasma dynamics after the laser pulse [2]. Numerical results show that depending on the nuclear transition energy and the temperature and charge states reached in the plasma, secondary nuclear excitation by electron capture may exceed by several orders of magnitude the direct photoexcitation, as it is the case for the 4.8 keV transition from the isomeric state of ^{93}Mo, or it can be negligible, as it is the case for the 14.4 keV Mössbauer transition in ^{57}Fe. These findings are most relevant for future nuclear experiments at x-ray free electron laser facilities.

[1] J. Gunst, Y. A. Litvinov, C. H. Keitel, and A. Pálffy, Phys. Rev. Lett. 112, 082501 (2014).
[2] J. Gunst, Y. Wu, N. Kumar, C. H. Keitel, and A. Pálffy, Physics of Plasmas 22, 112706 (2015).

A 39.7 Fri 12:45 f303

Ionization and fragmentation dynamics of molecules at high x-ray intensity — •Ludger Inhester[1,2], Kota Hanasaki[1,2], Oriol Vendrell[1,2], and Robin Santra[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Notkestrasse 85, 22607 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Department of Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany

X-ray free-electron lasers (XFELs) provide ultraintense and ultrashort x-ray pulses, which can sequentially ionize molecular samples many times. A molecule that is charged up by these many ionizations will dissociate rapidly into highly charged ion fragments. We have developed an ab-initio electronic structure toolkit, XMOLECULE [1], to describe coupled ionization and fragmentation dynamics induced by intense XFEL pulses. In this approach we solve rate equations for the electronic state populations using a kinetic Monte Carlo scheme while the nuclei are propagated classically. For all the visited electronic states transitions rates and forces on the nuclei are calculated on the fly based on the Hartree-Fock-Slater model. Our calculations show that charge rearrangement effects play an important role for the ion yield distribution. Remarkably, we also find that the total charge yield of a molecule is enhanced compared to the sum of charge yield of its constituent isolated atoms. These findings are supported by recent experiments with methyl iodide (CH3I) at LCLS.

[1] Struct. Dyn. 2, 041707 (2015).

A 39.8 Fri 13:00 f303

Non-adiabatic relaxation of multi-electronic dynamics in benzene cations — •Martin Galbraith[1], Christopher Smeenk[1], Geert Reitsma[1], Nickolai Zhavoronkov[1], Jochen Mikosch[1], Marc Vrakking[1], Oleg Kornilov[1], and Franck Lepine[2] — [1]Max-Born-Institut, Berlin, Germany — [2]Institut Lumiere Matiere, Universite Lyon 1, Villeurbanne Cedex, France

We experimentally investigate ultrafast relaxation dynamics in benzene cations. Neutral benzene molecules are ionised by XUV photons produced by high harmonic generation. At higher XUV photon energies ($\hbar\omega > 15$ eV) electron correlation effects begin to play a significant role leading to the excitation of satellite states. The relaxation dynamics of these electronic states are probed either by further excitation or ionisation with IR pulses. Previous theoretical studies predicted lifetimes for multiple states to be in the range of 10 fs. For this purpose the temporal resolution of the experiment was improved by IR pulse compression in a hollow-core fibre setup. This leads to XUV-IR cross correlations down to 6 fs. The non-adiabatic relaxation of the satellite states is found to occur on time scales of around 20 fs. The relaxation time scales accessed in this experiment have direct relevance to the recent theoretical investigations, which propose benzene as an interesting candidate for attosecond charge migration.

A 40: Precision spectroscopy of atoms and ions III (with Q)

Time: Friday 11:00–12:45 Location: f428

A 40.1 Fri 11:00 f428

Spectroscopy of hyperfine structures and isotope shifts in the sequence of 97-99 technetium — •Tobias Kron[1], Reinhard Heinke[1], Sebastian Raeder[2], Tobias Reich[3], Pascal Schönberg[3], and Klaus Wendt[1] — [1]Institute of Physics, Mainz University — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]Institute of Nuclear Chemistry, Mainz University

One of the dominant fission products of uranium is technetium-99, which is generally extremely rare in nature, due to the fact that all isotopes are unstable. With a long half-life and its strong β^--radioactivity, ^{99}Tc is one of the major radiotoxic long-term remnants of nuclear reactors and atomic bombs. On the other hand, knowledge on atomic and nuclear properties of technetium isotopes is rather scarce due to their rare occurrence. Both, ultra-trace determination as well as investigations of nuclear structure are of relevance and require extensive atomic spectroscopy as input.

This talk presents first results of high resolution resonance ionization spectroscopy on the isotopes $^{97-99}$Tc. Measurements were carried out on smallest samples in the order of 10^{12} atoms or less, using a high repetition rate laser system. The hyperfine structures and isotope shifts of several transitions were investigated, giving new information on nuclear structure and deriving the so-far unclear nuclear spin of ^{98}Tc. Experimental linewidths around 100 MHz were achieved by using a frequency-doubled pulsed injection-locked titanium:sapphire laser in combination with a newly developed ion source with a perpendicular laser-atom beam geometry in a radiofrequency quadrupole structure.

A 40.2 Fri 11:15 f428

Identification of the splitting and sequence of closely-spaced energy levels by analyzing the angle-resolved fluorescence light — •Zhongwen Wu[1,2], Andrey Surzhykov[1], Andrey Volotka[1], and Stephan Fritzsche[1,3] — [1]Helmholtz Institute Jena, Germany — [2]Northwest Normal University, China — [3]University of Jena, Germany

The energy-dependent photoexcitation and subsequent fluorescence radiation of atoms have been investigated within the framework of second-order perturbation theory and the density matrix theory. Special attention has been paid to the angular distribution of the characteristic x-rays from (partial) overlapping resonances and how they are affected by the level splitting and the sequence of these resonances, if analyzed as a function of the photon energy of the exciting light. Detailed computations within the multiconfiguration Dirac-Fock method were carried out for the $1s^2 2s^2 2p^6 3s\ J_0 = 1/2 + \gamma_1(\hbar\omega) \rightarrow (1s^2 2s 2p^6 3s)_1 3p_{3/2}\ J = 1/2, 3/2 \rightarrow 1s^2 2s^2 2p^6 3s\ J_f = 1/2 + \gamma_2$ excitation and decay of neutral sodium atoms. A remarkably strong dependence of the angular distribution of these x-rays upon the level splitting and even the sequence was found by crossing the resonances. This dependence arises from the finite lifetime of the overlapping resonances. We therefore suggest that accurate measurements of x-ray angular distribution could be used to identify the level splitting and sequence of closely-spaced atomic resonances following inner-shell excitations.

A 40.3 Fri 11:30 f428

Precision isotope shift measurements of calcium ions using photon recoil spectroscopy — Florian Gebert[1], Yong Wan[1], Fabian Wolf[1], Jan-Christophe Heip[1], •Chunyan Shi[1], Christian Gorges[2], Simon Kaufmann[2], Wilfried Nörtershäuser[2], and Piet O. Schmidt[1,3] — [1]QUEST Institut, PTB, Braunschweig, Germany — [2]Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany

In photon recoil spectroscopy (PRS), recoil kicks from photon absorption near a dipole-allowed transition in a single trapped ion are detected via motional coupling to a co-trapped cooling ion [1].

We present isotope shift measurements of the $^2S_{1/2} \rightarrow {}^2P_{1/2}$ (D1 line), $^2D_{3/2} \rightarrow {}^2P_{1/2}$ (non-closed transition) [2] and $^2S_{1/2} \rightarrow 2P_{3/2}$ (D2 line) transitions in the calcium isotopes $^{40}Ca^+$, $^{42}Ca^+$, $^{44}Ca^+$ and $^{48}Ca^+$ with an accuracy better than 100 kHz by employing the PRS technique. Furthermore, the isotope shift difference between the D1 and D2 line of calcium ions has been resolved for the first time. As a result from the precision isotope shift measurements, the uncertainties of the relative field and mass shift constants in the respective transitions as well as the mean square nuclear charge radii of these calcium isotopes have been improved.

[1] Y. Wan et al. Nat. Commun **5**, 4096 (2014)
[2] F. Gebert et al. Phys. Rev. Lett. **115**, 053003(2015)

A 40.4 Fri 11:45 f428

A tunable laser with a drift <100 kHz through stabilization to the Rb D2 line — •Tobias Leopold[1], Lisa Schmöger[1,2], Stefanie Feuchtenbeiner[2], Nils Scharnhorst[1], Ian D. Leroux[1], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig — [2]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [3]Institut für Quantenoptik, Universität Hannover

Stable lasers with a narrow linewidth are an important tool for precision spectroscopy. Here, we present a simple and versatile laser system for spectroscopy of trapped highly charged ions at sub-Kelvin temperatures. While covering the wavelength range from 780 - 890 nm we reach a linewidth and longterm frequency drift on the 50 kHz level, corresponding to a fractional instability of $< 1 \times 10^{-10}$.

As frequency reference we use a low-cost 780 nm DFB-laser stabilized to a hyperfine transition of the rubidium D2 line by modulation transfer spectroscopy. The stability of this laser is transfered to the spectroscopy laser by use of an optical reference cavity. Tunability over 1.5 GHz in closed-loop operation is possible by means of the offset sideband locking technique. We measure the instability of both reference and spectroscopy laser against a Maser-stabilized frequency comb.

The laser system presented here will be used for spectroscopy of the $1s^2 2s^2 2p\ {}^2P_{1/2} - {}^2P_{3/2}$ transition in trapped Ar^{13+} ions at 441 nm. Sympathetically cooled in a laser cooled cloud of beryllium ions the 100 Hz natural linewidth is expected to be Doppler broadened to several 100 kHz.

A 40.5 Fri 12:00 f428

The ALPHATRAP double Penning-trap experiment — •Ioanna Arapoglou[1,2], Alexander Egl[1,2], Henrik Hirzler[1,2], Sandro Kraemer[1,2], Tim Sailer[1,2], Andreas Weigel[1,2], Robert Wolf[1], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Fakultät für Physik und Astronomie, Universität Heidelberg

The ALPHATRAP experiment, being a follow-up of the g-factor experiment at Mainz, aims for high-precision tests of bound-state quantum electrodynamics in electric fields with strengths in the order of 10^{16} V/cm. These fields are provided by heavy highly charged ions, such as hydrogen-like $^{208}Pb^{81+}$. Furthermore, via the high-precision determination of the bound electron g-factor, fundamental constants such as the fine-structure constant α can be determined. The Heidelberg Electron-Beam Ion Trap delivers the desired heavy highly charged ions, which are injected into and manipulated by means of the ALPHATRAP cryogenic double Penning-trap system. The latter is optimised for heavy highly charged ions and consists of a 7-pole and a 5-pole cylindrical Penning trap that are used for high-precision measurements and spin orientation detection, respectively. This configuration together with the measurement principle and the current status of the experiment will be presented.

A 40.6 Fri 12:15 f428

Towards Electron Affinity Measurements of Radioactive Elements: Laser Photodetachment of Negative Ions at CERN/ISOLDE — Sebastian Rothe[2,3,5], •Reinhard Heinke[1], Valentin Fedosseev[2], Thomas Day Goodacre[2,5], Dag Hanstorp[3], Tobias Kron[1], Yuan Liu[4], Bruce Marsh[2], Annie Ringwall-Moberg[3], Ralf Erik Rossel[2], Julia Sundberg[3], Jakob Welander[3], and Klaus Wendt[1] — [1]JGU Mainz — [2]EN Department, CERN — [3]University of Gothenburg — [4]Oak Ridge National Laboratory — [5]University of Manchester

Modern on-line isotope separators such as ISOLDE at CERN yield access to a wide variety of exotic nuclei. Besides investigations on nuclear properties of rare isotopes, these facilities allow for detailed studies on the fundamental atomic structures of the few all-radioactive elements across the Periodic Table. In this respect, two values are of elementary importance: (a) The first ionization potential (IP), i.e. the required energy to remove an electron from the neutral atom and produce a positively charged ion, and (b) the electron affinity (EA), i.e. the binding energy of an extra electron to form a negatively charged ion. For all-radioactive elements, their knowledge is even more relevant, as they are required as input for quantum chemical calculations on the behaviour within chemical compounds. Whereas the IPs of the all-radioactive elements Polonium and Astatine were precisely measured at ISOLDE via Rydberg spectroscopy recently, the EAs of these elements are still under investigation.

The talk will give an overview of the experimental setup as well as on the measurement technique, applying laser photodetachment spectroscopy with a high performance, high repetition rate tuneable laser system. First results on iodine carried out on a negative ion beam at ISOLDE are discussed together with alternatives for negative ion production at ISOLDE and an outlook on the envisaged experiments.

A 40.7 Fri 12:30 f428

Resonance ionization studies in holmium and a redetermination of its ionization potential — •Pascal Naubereit[1], Yuan Liu[2], Tina Gottwald[1], and Klaus Wendt[1] — [1]Institute of Physics, Mainz University, D-55128 Mainz, Germany — [2]Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

The first ionization potential of Holmium as well as many other lanthanides was measured around 1978 with rather big uncertainties in the order of 5 cm^{-1} using early methods of laser spectroscopy. Values that are much more precise are obtained by using two or three step resonance ionization spectroscopy via high lying Rydberg states and applying detailed analyses of convergence limits of different Rydberg series.

Here we report on three step resonance ionization measurements into 6snp levels with principal quantum numbers 17<n<59 converging towards the two lowest members of the ionic ground state configuration. Strong interactions with interloper states, well known for most of the lanthanides, perturb the Rydberg series below the first IP for Ho. In contrary the auto-ionizing Rydberg series, observed just above the first ionization potential, exhibits a smooth behavior in the studied range from 33<n<57. Correspondingly, the latter was used to reevaluate the first ionization potential of Holmium with an uncertainty of better than 0.1 cm^{-1}. The spectroscopic measurements, which also led to the identification of a new efficient resonant excitation scheme for holmium isotope implantation within the ECHo project, as well as the Rydberg analysis are discussed.

A 41: Advanced Concepts for High Peak Power Ultrafast Lasers II

Time: Friday 14:00–15:30 Location: e415

Invited Talk A 41.1 Fri 14:00 e415

Coherent Combination of Ultrafast Fiber Lasers — •Jens Limpert — Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Albert-Einstein-Str.15, 07745 Jena, Germany

Even the most advanced laser technologies have been pushed to their specific limitations in labs around the world. A significant increase in performance can not be expected in the coming years. New concepts have to be considered to address these issues and to enable new application fields. In that context, I will review the basics and achievements of coherent combination of amplified femtosecond pulses, a concept which has already out-performed single aperture femtosecond laser systems and which allows for a scaling to unprecedented performance levels. The spatially and temporally separated amplification of ultrashort laser pulses followed by coherent beam and pulse addition can bypass all performance restrictions of a single aperture laser system, therefore, enabling a quantum leap in performance of ultrafast lasers.

Invited Talk A 41.2 Fri 14:30 e415

Cryogenic multipass amplifiers for high peak and average power ultrafast lasers — •Luis E. Zapata — Center for Free-Electron Laser Science, Deutsches Elektronen Synchrotron, Notkestrasse 85, 22607 Hamburg, Germany

Ultrafast laser sources are in demand for many scientific and industrial applications. For example, few-mJ pulses are useful for driving the OPCPAs in pump-probe experiments and, Joule class pulses are necessary for the generation of x-rays through inverse Compton scattering. Ultimately, high average power determines the usefulness of a given laser system by shortening the time necessary for the collection of data or, the throughput when a process yield is derived. The success of the laser system also markedly depends on its size, weight and reliability, which are strongly tied to its complexity. Liquid nitrogen cooled DPSSLs based on Yb3+ offer a clear advantage with regards to all the above points. Engineering leverage is gained by an intrinsic several-fold improvements in thermo-optic and thermo-mechanical properties as well as ~decade higher gain-coefficients, which enables simple, passively switched multipass geometries to be implemented. Our progress in scaling chirped-pulse amplifiers has produced 250-Watt at 100-kHz and 160-mJ at 250-Hz based on liquid nitrogen cooled Yb:YAG in rod and composite-disk geometries operating at high gain. Clear scaling towards 1-kW average power at 100 kHz in cryogenic rods and, one-Joule pulse energy in cryogenic composite disks has emerged. We propose an advanced monolithic array of gain-cells for scaling to multi-Joule energies and multi-kW average powers.

Invited Talk A 41.3 Fri 15:00 e415

Multi-TW infrared laser using Frequency domain Optical Parametric Amplification — •Bruno E. Schmidt[1], Philippe Lassonde[2], Guilmot Ernotte[2], Mathieu Giguere[1], Nicolas Thire[2], Antoine Laramee[2], Heide Ibrahim[2], and Francois Legare[2] — [1]few-cycle Inc., (few-cycle.com), 2890 Rue de Beaurivage, Montréal, Qc, H1L 5W5, Canada — [2]Institut National de la Recherche Scientifique, Centre ÉMT, 1650 bd Lionel Boulet, Varennes, Qc, J3X1S2, Canada

The universal dilemma of gain narrowing occurring in fs amplifiers prevents ultra-high power lasers from delivering few-cycle pulses. This problem is overcome by a new amplification concept: Frequency domain Optical Parametric Amplification - FOPA. A proof of principle experiment was carried out at the Advanced Laser Light Source (ALLS) on the sub-two cycle IR beam line and yielded record breaking performance in the field of few-cycle IR lasers. 100μJ two-cycle pulses from a hollow core fibre compression setup were amplified to 1.43mJ without distorting spatial or temporal properties [1]. Pulse duration at the input of FOPA and after FOPA remains the same. Recently, we have started upgrading this system to be pumped by 250 mJ to reach 40 mJ two-cycle IR few-cycle pulses and latest results will be presented at the conference.

[1] B. E. Schmidt, N. Thiré, M. Boivin, A. Laramée, F. Poitras, G. Lebrun, T. Ozaki, H. Ibrahim, and F. Légaré, *Frequency domain optical parametric amplification.,* Nature Commun. 5, 3643 (2014).