Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture rooms K 0.011, K 1.011, K 1.016, K 2.016, and K 2.019; Poster Redoutensaal, Orangerie, and Zelt Ost)

Invited Talks

A 2.1	Mon	10:30–11:00	K 1.011	**Phase measurement and control with attosecond self-probing spectroscopy** — •Michael Krüger
A 2.2	Mon	11:00–11:30	K 1.011	**Molecular Orbital Imprint in Laser-Driven Electron Recollision** — Felix Schell, Timm Bredtmann, Claus Peter Schulz, Serguei Patchkovskii, Marc Vrakking, •Jochen Mikosch
A 3.1	Mon	10:30–11:00	K 1.016	**Segmented ion traps with integrated solenoids for scalable microwave based QIP** — •Michael Johanning, Timm F. Gloger, Peter Kaufmann, Hendrik Siebeneich, Christof Wunderlich
A 8.1	Mon	14:00–14:30	K 1.011	**Attosecond timing with spectral resolution near resonances, and new opportunities with high-repetition rate attosecond sources** — •Anne Harth
A 8.2	Mon	14:30–15:00	K 1.011	**Towards attosecond pump-probe experiments at high repetition rates** — •Tobias Witting, Federico Furch, Felix Schell, Peter Susnjar, Carmen Menoni, Chih-Hsuan Lu, Andy Kung, Claus-Peter Schulz, Marc J.J. Vrakking
A 9.1	Mon	14:00–14:30	K 1.016	**A ppb measurement of the antiproton magnetic moment** — •C. Smorra, S. Sellner, M. Borchert, J. A. Harrington, T. Higuchi, H. Nagahama, A. Mooser, G. Schneider, M. Bohman, K. Blaum, Y. Matsuda, C. Ospelkaus, W. Quint, J. Walz, Y. Yamazaki, S. Ulmer
A 9.2	Mon	14:30–15:00	K 1.016	**Towards laser cooling of atomic anions** — •Alban Kellerbauer
A 13.1	Mon	16:15–16:45	K 1.011	**Quantum teleportation via electron-exchange collisions** — •Bernd Lohmann, Karl Blum, Burkhard Langer
A 13.2	Mon	16:45–17:15	K 1.011	**Probing the forces of blackbody radiation and dark energy with matter waves** — •Philipp Haslinger, Viktoria Xu, Matt Jaffe, Osip Schwartz, Paul Hamilton, Benjamin Elder, Justin Khoury, Matthias Sonnleitner, Monika Ritsch-Marte, Helmut Ritsch, Holger Müller
A 14.1	Mon	16:15–16:45	K 1.016	**Collinear Laser Spectroscopy for High Voltage Metrology at the 1 ppm accuracy level** — •Jörg Krämer, Kristian König, Christopher Geppert, Phillip Imgram, Bernhard Maass, Johann Meisner, Ernst W. Otten, Stephan Passon, Tim Ratajczyk, Johannes Ullmann, Wilfried Nörtershäuser
A 16.1	Mon	16:15–16:45	K 2.016	**Halo states in helium dimers/trimers** — •Reinhard Doerner, Maksim Kunitski, Stefan Zeller, Lothar Schmidt, Till Jahnke, Markus Schöffler, Dörte Blume, Jörg Voitsberger, Florian Trinter, Anton Kalinin
A 20.1	Tue	14:00–14:30	K 1.011	**Attosecond Streaking in Dielectrics** — •L. Seiffert, Q. Liu, S. Zherebtsov, A. Trabattoni, P. Rupp, M. C. Castrovilli, M. Galli, F. Süssmann, K. Wintersperger, J. Stierle, G. Sansone, L. Poletto, F. Frassetto, I. Halfpap, V. Mondes, C. Graf, E. Rühl, F. Krausz, M. Nisoli, T. Fennel, F. Calegari, M. Kling
A 20.2	Tue	14:30–15:00	K 1.011	**Controlling the refraction of ultrashort XUV pulses** — Lorenz Drescher, Oleg Kornilov, Tobias Witting, Geert Reitsma, Jochen Mikosch, Marc Vrakking, •Bernd Schütte

A 21.1	Tue	14:00–14:30	K 1.016	**High precision hyperfine measurements in bismuth challenge bound-state strong field QED** — •Rodolfo Sánchez
A 23.1	Tue	14:00–14:30	K 2.019	**Multiphoton Ionization of Chiral Molecules** — •Thomas Baumert
A 31.1	Wed	14:00–14:30	K 2.019	**H_2^+ and HeH^+: Two fundamentally important molecules in strong laser fields** — Philipp Wustelt, Max Möller, A. Max Sayler, •Gerhard G. Paulus
A 39.1	Thu	14:00–14:30	K 1.016	**News from the "Proton Radius Puzzle"** — •Randolf Pohl
A 40.1	Thu	14:00–14:30	K 2.019	**Electron vortices** — Dominik Pengel, Stefanie Kerbstadt, Lars Englert, Tim Bayer, •Matthias Wollenhaupt
A 40.2	Thu	14:30–15:00	K 2.019	**Magnetic Quantum Number in Strong Field Ionizaton** — •Sebastian Eckart, Maksim Kunitski, Martin Richter, Alexander Hartung, Jonas Rist, Florian Trinter, Kilian Fehre, Nikolai Schlott, Kevin Henrichs, Lothar Ph. H. Schmidt, Till Jahnke, Markus Schöffler, Kunlong Liu, Ingo Barth, Jivesh Kaushal, Felipe Morales, Misha Ivanov, Olga Smirnova, Reinhard Dörner

Invited talks of the joint symposium SYPS

See SYPS for the full program of the symposium.

SYPS 1.1	Mon	14:00–14:30	RW HS	**Floquet engineering of interacting quantum gases in optical lattices** — •André Eckardt
SYPS 1.2	Mon	14:30–15:00	RW HS	**Experiments on driven quantum gas and surprises** — •Cheng Chin
SYPS 1.3	Mon	15:00–15:30	RW HS	**Exploring 4D Quantum Hall Physics with a 2D Topological Pumps** — •Oded Zilberberg, Michael Lohse, Christian Schweizer, Immanuel Bloch, Hannah Price, Yaacov Kraus, Sheng Huang, Mohan Wang, Kevin Chen, Jonathan Guglielmon, Mikael Rechtsman
SYPS 1.4	Mon	15:30–16:00	RW HS	**Floquet Discrete Time Crystals in a Trapped-Ion Quantum Simulator** — •Guido Pagano, Jiehang Zhang, Paul Hess, Antonis Kyprianidis, Patrick Becker, Jacob Smith, Aaron Lee, Norman Yao, Tobias Grass, Alessio Celi, Maciej Lewenstein, Christopher Monroe

Invited talks of the joint symposium SYAD

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	10:30–11:00	RW HS	**Integrated photonic quantum walks in complex lattice structures** — •Markus Graefe
SYAD 1.2	Tue	11:00–11:30	RW HS	**Testing the Quantumness of Atom Trajectories** — •Carsten Robens
SYAD 1.3	Tue	11:30–12:00	RW HS	**Engineering and probing topological bands with ultracold atoms** — •Nick Fläschner
SYAD 1.4	Tue	12:00–12:30	RW HS	**Statistical signatures of many-particle interference** — •Mattia Walschaers

Invited talks of the joint symposium SYQC

See SYQC for the full program of the symposium.

SYQC 1.1	Thu	14:00–14:30	RW HS	**The resource theory of quantum coherence** — •Martin B Plenio
SYQC 1.2	Thu	14:30–15:00	RW HS	**Interferometric visibility and coherence** — •Andreas Winter
SYQC 1.3	Thu	15:00–15:30	RW HS	**Quantum coherence and interference patterns** — •Florian Mintert
SYQC 1.4	Thu	15:30–16:00	RW HS	**Experiments on directly measuring quantum coherence and using it for quantum sensing** — •Chuan-Feng Li

Invited talks of the joint symposium SYRP

See SYRP for the full program of the symposium.

SYRP 1.1	Fri	10:30–11:00	RW HS	**Attosecond seeding of high energy rescattered electrons** — •Kenneth Schafer

SYRP 1.2	Fri	11:00–11:30	RW HS	**The molecular selfie - atomic-scale imaging with a single electron** — Benjamin Wolter, Michael G. Pullen, Anh Thu Lee, Matthias Baudisch, Katharina Doblhoff-Dier, Arne Senftleben, Michael Hemmer, Claus Dieter Schröter, Joachim Ullrich, Robert Moshammer, Stefanie Gräfe, Oriol Vendrell, Chii Dong Lin, •Jens Biegert
SYRP 1.3	Fri	11:30–12:00	RW HS	**Multidimentional attosecond spectroscopy** — •Nirit Dudovich
SYRP 1.4	Fri	12:00–12:30	RW HS	**Recollision-based high-harmonic generation from solids** — •Giulio Vampa

Invited talks of the joint symposium SYMM

See SYMM for the full program of the symposium.

SYMM 1.1	Fri	13:30–14:00	RW HS	**Some experimental contributions to the study of thermodynamics in quantum systems.** — •Ian Walmsley
SYMM 1.2	Fri	14:00–14:30	RW HS	**Levitated Nanoparticle Micromachines** — •Nikolai Kiesel
SYMM 1.3	Fri	14:30–15:00	RW HS	**Autonomous quantum machines and timekeeping** — •Marcus Huber
SYMM 1.4	Fri	15:00–15:30	RW HS	**An autonomous thermal machine for amplification of coherence** — •Juan MR Parrondo, Gonzalo Manzano, Ralph Silva

Sessions

A 1.1–1.6	Mon	10:30–12:00	K 0.011	**Cold atoms I - Rydbergs (joint session A/Q)**
A 2.1–2.6	Mon	10:30–12:30	K 1.011	**Attosecond Science I (joint session A/MO)**
A 3.1–3.5	Mon	10:30–12:00	K 1.016	**Precision Spectrosocopy I - trapped ions (joint session A/Q)**
A 4.1–4.6	Mon	10:30–12:15	K 2.013	**Ultracold Plasmas and Rydberg Systems I (joint session Q/A)**
A 5.1–5.6	Mon	10:30–12:00	K 2.019	**Cold atoms II - interactions (joint session A/Q)**
A 6.1–6.6	Mon	14:00–15:30	K 0.011	**Cold atoms III - optical lattices (joint session A/Q)**
A 7.1–7.7	Mon	14:00–15:45	K 0.023	**Laser Development and Applications (joint session Q/A)**
A 8.1–8.5	Mon	14:00–15:45	K 1.011	**Attosecond Science II**
A 9.1–9.5	Mon	14:00–15:45	K 1.016	**Precision Spectrosocopy II - trapped ions (joint session A/Q)**
A 10.1–10.9	Mon	14:00–16:15	K 2.016	**Bose-Einstein Condensation (joint session A/Q)**
A 11.1–11.5	Mon	14:00–15:45	PA 2.150	**X-Ray and XUV Spectroscopy (joint session MO/A)**
A 12.1–12.5	Mon	16:15–17:30	K 0.011	**Cold atoms IV - topological systems (joint session A/Q)**
A 13.1–13.5	Mon	16:15–18:00	K 1.011	**Fundamentals**
A 14.1–14.5	Mon	16:15–17:45	K 1.016	**Precision Spectrosocopy III - trapped ions (joint session A/Q)**
A 15.1–15.5	Mon	16:15–17:30	K 2.013	**Ultracold Plasmas and Rydberg Systems II (joint session Q/A)**
A 16.1–16.5	Mon	16:15–17:45	K 2.016	**Atomic Clusters I (joint session A/MO)**
A 17.1–17.6	Mon	16:15–17:45	K 2.019	**Atoms in external fields**
A 18.1–18.5	Mon	16:15–17:45	PA 2.150	**Ultrafast Spectroscopy with XUV (joint session MO/A)**
A 19.1–19.6	Tue	14:00–15:30	K 0.011	**Cold atoms V - optical lattices (joint session A/Q)**
A 20.1–20.5	Tue	14:00–15:45	K 1.011	**Attosecond Science III**
A 21.1–21.6	Tue	14:00–15:45	K 1.016	**Precision Spectroscopy IV - highly charged ions (joint session A/Q)**
A 22.1–22.8	Tue	14:00–16:00	K 2.016	**Atomic Clusters II (joint session A/MO)**
A 23.1–23.6	Tue	14:00–15:45	K 2.019	**Strong laser fields - I (joint session A/MO)**
A 24.1–24.6	Tue	14:00–15:45	PA 2.150	**Cold Molecules and Reactions (joint session MO/A)**
A 25.1–25.50	Tue	16:15–18:15	Redoutensaal	**Poster Session I**
A 26.1–26.7	Wed	14:00–15:45	K 0.011	**Ultracold Plasmas and Rydberg systems (joint session A/Q)**
A 27.1–27.9	Wed	14:00–16:15	K 1.011	**XUV/X-ray Science**
A 28.1–28.7	Wed	14:00–15:45	K 1.016	**Precision Spectroscopy V - highly charged ions (joint session A/Q)**
A 29.1–29.5	Wed	14:00–15:30	K 2.013	**Precision Measurements and Metrology (Atom Interferometry) (joint session Q/A)**
A 30.1–30.6	Wed	14:00–15:30	K 2.016	**Atomic Clusters III (joint session A/MO)**

A 31.1–31.7	Wed	14:00–16:00	K 2.019	**Strong laser fields - II**
A 32.1–32.6	Wed	14:00–15:45	PA 2.150	**Molecules in Intense Laser Fields (joint session MO/A)**
A 33.1–33.44	Wed	16:15–18:15	Redoutensaal	**Poster Session II**
A 34.1–34.7	Thu	10:30–12:15	K 0.011	**Cold atoms VI - traps (joint session A/Q)**
A 35.1–35.7	Thu	10:30–12:15	K 1.022	**Ultracold Atoms I (joint session Q/A)**
A 36.1–36.6	Thu	10:30–12:00	K 2.013	**Precision Measurements and Metrology (Gravity and Miscellaneous) (joint session Q/A)**
A 37.1–37.6	Thu	10:30–12:15	PA 2.150	**Clusters IV (joint session MO/A)**
A 38	Thu	12:45–13:45	K 0.011	**Annual General Meeting of the Atomic Physics division**
A 39.1–39.7	Thu	14:00–16:00	K 1.016	**Precision Spectroscopy VI - neutrals and ions (joint session A/Q)**
A 40.1–40.6	Thu	14:00–16:00	K 2.019	**Strong laser fields - III**
A 41.1–41.31	Thu	16:15–18:15	Orangerie	**Poster Session IIIa**
A 42.1–42.23	Thu	16:15–18:15	Zelt Ost	**Poster Session IIIb**
A 43.1–43.5	Fri	10:30–11:50	K 0.011	**Cold atoms VII - micromachines (joint session A/Q)**
A 44.1–44.8	Fri	10:30–12:30	K 1.016	**Precision Spectrosocopy VII (nuclear systems) (joint session A/Q)**
A 45.1–45.8	Fri	10:30–12:30	K 1.022	**Ultracold Atoms II (joint session Q/A)**
A 46.1–46.7	Fri	10:30–12:15	K 2.013	**Precision Measurements and Metrology (Optical Clocks) (joint session Q/A)**

Annual General Meeting of the Atomic Physics Division

Thursday 12:45–13:45 K 0.011

A 1: Cold atoms I - Rydbergs (joint session A/Q)

Time: Monday 10:30–12:00 Location: K 0.011

A 1.1 Mon 10:30 K 0.011

Probing many-body dynamics on a 51-atom quantum simulator — •Ahmed Omran[1], Hannes Bernien[1], Alexander Keesling[1], Harry Levine[1], Sylvain Schwartz[1,2], Hannes Pichler[3,1], Soonwon Choi[1], Markus Greiner[1], Vladan Vuletic[2], and Mikhail D. Lukin[1] — [1]Department of Physics, Harvard University, Cambridge, MA 02138, USA — [2]Department of Physics and Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA — [3]Institute for Theoretical Atomic Molecular and Optical Physics, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

The realization and control of large-scale quantum systems is an exciting frontier of modern physical science. Using a novel cold atom platform, we trap single neutral atoms in an array of optical tweezers, and use real-time feedback to prepare defect-free chains of tens of atoms in one dimension with a high fidelity and repetition rate [1]. Excitation of the atoms to Rydberg states enables strong and tunable van der Waals interactions over long distances, which allows for engineering an Ising-type Hamiltonian with non-trivial spatial correlations between Rydberg atoms.

The flexibility and controllability of our platform enables us to perform powerful simulations of quantum many-body systems in and out of equilibrium and shed light on the quantum dynamics around different phase transitions and following sudden quantum quenches [2].

[1] M. Endres et al., Science 354, 1024-1027 (2016)

[2] H. Bernien et al., Nature 551, 579-584 (2017)

A 1.2 Mon 10:45 K 0.011

Spin-Interaction Effects for Ultralong-range Rydberg Molecules in a Magnetic Field — •Frederic Hummel[1], Christian Fey[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, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We investigate the fine and spin structure of ultralong-range Rydberg molecules exposed to a homogeneous magnetic field. Each molecule consists of a ^{87}Rb Rydberg atom whose outer electron interacts via spin-dependent s- and p-wave scattering with a polarizable ^{87}Rb ground state atom. Our model includes also the hyperfine structure of the ground state atom as well as spin-orbit couplings of the Rydberg and ground state atom. We focus on d-Rydberg states and principal quantum numbers n in the vicinity of 40. The electronic structure and vibrational states are determined in the framework of the Born-Oppenheimer approximation for varying field strengths ranging from a few up to hundred Gauß. The results show that the interplay between the scattering interactions and the spin couplings gives rise to a large variety of molecular states in different spin configurations as well as in different spatial arrangements that can be tuned by the magnetic field. We quantify the impact of spin couplings by comparing the extended theory to a spin-independent model.

A 1.3 Mon 11:00 K 0.011

Coupling Rydberg atoms and superconducting resonators — •Helge Hattermann, Li Yuan Ley, Conny Glaser, Daniel Bothner, Benedikt Ferdinand, Lörinc Sárkány, Reinhold Kleiner, Dieter Koelle, and József Fortágh — CQ Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

We report on the the coupling between ultracold ^{87}Rb Rydberg atoms and a driven coplanar waveguide resonator on a superconducting atom chip. The superconducting cavity at 20.5 GHz is near-resonant to the transition frequency between Rydberg states. Driven transitions are detected by state selective field ionization of the Rydberg states.

Close to the chip, Rydberg states are strongly affected by the electric field of adsorbates on the chip, leading to spatially inhomogeneous energy shifts.

Coupling Rydberg atoms to coplanar superconducting resonators has been proposed for efficient state transfer between solid state systems and ultracold atoms, the generation of an atomic quantum memory and the implementation of novel quantum gates [1].

[1] L. Sárkány et al., Phys. Rev. A 92, 030303 (2015).

A 1.4 Mon 11:15 K 0.011

Non-equilibrium criticality in driven Rydberg gases — •Graham Lochead[1,2], Stephan Helmrich[1], Alda Arias[1,2], Henrik Hirzler[1], Tobias Wintermantel[1,2], Michael Buchhold[3], Sebastian Diehl[4], and Shannon Whitlock[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Institut de Physique et de Chimie des Matériaux de Strasbourg (IPCMS), University of Strasbourg, France 67200 — [3]California Institute of Technology, 1200 E California Boulevard, CA 91125, Pasadena, U.S. — [4]Institut für Theoretische Physik, Universität zu Köln, D-50937 Cologne

We study the dynamics of well controlled systems of ultracold atoms excited to long-range interacting Rydberg states by an off-resonant laser field. Starting from an initial seed excitation, there is a characteristic distance at which the interaction energy precisely matches the laser detuning, thus facilitating further excitations. This interplay between coherent driving, dissipation and long-range interactions can lead to rich many body dynamics, including self similar evolution and scale invariant behavior. We present experiments on the temporal evolution of the system as a function of the amplitude of the driving field and investigate possible links to paradigmatic non-equilibrium universality classes such as directed percolation and self-organized criticality. This opens a new route to explore non-equilibrium critical phenomena in three-dimensions, and in settings where quantum and classical fluctuations can compete on an equal footing.

A 1.5 Mon 11:30 K 0.011

Accurate Rydberg quantum simulations of spin-1/2 models — •Sebastian Weber[1], Sylvain de Léséleuc[2], Vincent Lienhard[2], Daniel Barredo[2], Thierry Lahaye[2], Antoine Browaeys[2], and Hans Peter Büchler[1] — [1]Institute for Theoretical Physics III, University of Stuttgart, Germany — [2]Laboratoire Charles Fabry, Institut d'Optique, CNRS, Université Paris-Saclay, France

Using non-perturbative calculations of the interaction potentials between two Rydberg atoms taking into account both electric and magnetic fields, we can simulate a broad range of two-atom Rydberg systems. Benchmarks against varied experimental data show an excellent agreement between the simulations and experiments. We apply our simulation procedure to investigate under which experimental conditions spin-1/2 models can be accurately simulated using Rydberg atoms. More specifically, we determine experimental parameters for which a system of atoms that are laser driven to $nD_{3/2}$ Rydberg states and interacting via the van der Waals interaction can be mapped accurately to an Ising-like spin-1/2 model, despite the large number of Rydberg levels involved. Our investigations show the importance of a careful selection of experimental parameters in order not to break the Rydberg blockade mechanism which underlies the mapping. By selecting appropriate parameters, even in a large system of 49 Rydberg atoms, an excellent agreement is achieved between the measured time evolution and the numerically calculated dynamics of the Ising-like spin-1/2 model. This result opens exciting prospects for the realization of high-fidelity quantum simulators of spin Hamiltonians.

A 1.6 Mon 11:45 K 0.011

The impact of ionization laser polarization on spatio-temporal distribution of photoelectrons from Cs atoms in a MOT — •Olena Fedchenko[1], Sergey Chernov[1], Melissa Vielle-Grosjean[2], Gerd Schönhense[1], and Daniel Comparat[2] — [1]Institut für Physik, JGU Mainz, Germany — [2]University Paris-Sud, Orsay, France

We present results of investigation of the properties of a monochromatic photoelectron source based on near threshold photoionization of cold Cs atoms in MOT by time-of-flight momentum microscopy [1]. A 3D-stack of experimental results was obtained under absence of magnetic field. For this purpose a scheme with switched trapping B-field was used in the DC-MOT: 5 ms to load the MOT and 4 ms for excitation (@1470 nm, 1 ms exposition). Measurements were done for different linear polarizations of the ionizing Ti-sapphire fs-laser. Study of near-threshold photoionization with different gradients of the extracting electric field showed that the difference between signals with s- and p-polarization of the ionization light was due to real dichroism and partly due to contribution of field ionization of Rydberg states.

Variation of the bandwidth of the Ti-sapphire laser revealed that in case of broad bandwidth several photoionization paths took place simultaneously. Namely, excitation of Rydberg atoms had place in the combination with subsequent field ionization and photoionization from higher states. To study the energy and time spread of photoelectrons, an accelerator with homogeneous pulsed electric field is proposed.

[1] O. Fedchenko et al., Appl. Phys. Lett, 111, 021104 (2017).

A 2: Attosecond Science I (joint session A/MO)

Time: Monday 10:30–12:30 Location: K 1.011

Invited Talk A 2.1 Mon 10:30 K 1.011

Phase measurement and control with attosecond self-probing spectroscopy — •Michael Krüger — Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel

Attosecond spectroscopy is based steering electron dynamics by the electric field waveform of a strong laser field. High-harmonic generation (HHG), the mechanism underlying the production of attosecond pulses in the extreme ultraviolet (XUV), provides an in-built spectroscopic pump-probe measurement with extremely high spatial and temporal accuracy. The amplitude and phase of the emitted XUV radiation encodes all parts of the light-matter interaction in the recollision process, including ionization, propagation and photo-recombination. Here we present two applications of attosecond self-probing spectroscopy. In the first experiment, we initiate HHG with an XUV pulse instead of tunneling ionization, enabling us to measure and control the XUV photo-ionization dynamics in the presence of a strong infrared field in amplitude and phase [1]. In the second experiment, we compare HHG from two atomic species using linear XUV interferometry and extract the absolute difference in the photo-recombination dipole phase with high spatial resolution [2]. Our method gives access to hitherto inaccessible phase information, enabling attosecond control of HHG and tomographic reconstruction of the electronic structure of matter.

[1] D. Azoury et al., Nat. Comm. 8, 1453 (2017). [2] D. Azoury et al., manuscript in preparation (2017).

Invited Talk A 2.2 Mon 11:00 K 1.011

Molecular Orbital Imprint in Laser-Driven Electron Recollision — Felix Schell, Timm Bredtmann, Claus Peter Schulz, Serguei Patchkovskii, Marc Vrakking, and •Jochen Mikosch — Max-Born-Institute, Max-Born-Strasse 2A, 12489 Berlin

Electrons released by strong-field ionization from atoms, molecules, or in solids can be accelerated in the oscillating laser field and driven back to their ion core. The ensuing interaction, phase-locked to the optical cycle, initiates the central processes underlying attosecond science. A key long-standing assumption regards the returning electron wavepacket as a plane wave. Here we study laser-induced electron rescattering associated with two different ionization continua in the same, spatially aligned, polyatomic molecule [1]. We show by experiment and theory that the electron return probability is in fact molecular-frame dependent and carries structural information on the ionized orbital. Pronounced deviations of the returning wavepacket from plane-wave character have to be accounted for in analyzing attosecond experiments based on strong laser fields.

[1] F. Schell, T. Bredtmann, C.P. Schulz, S. Patchkovskii, M.J.J. Vrakking, and J. Mikosch (submitted)

A 2.3 Mon 11:30 K 1.011

Valley-resolved Electronic Coherences in Silicon Observed by Attosecond Transient Absorption Spectroscopy — •Michael Zürch[1], Peter M. Kraus[1], Hung-Tzu Chang[1], Scott K. Cushing[1], Daniel M. Neumark[1,2], and Stephen R. Leone[1,2,3] — [1]Department of Chemistry, University of California, Berkeley, CA 94720, USA — [2]Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA — [3]Department of Physics, University of California, Berkeley, CA 94720, USA

Understanding the absorption of light and subsequent carrier dynamics in semiconductors plays a crucial role for optimizing next-generation photonic devices for increasingly faster performance. Here, attosecond transient absorption spectroscopy is employed for studying electronic coherences in single crystalline silicon during excitation by an intense 5-fs optical pulse. Transient absorption changes in the conduction band (CB) of silicon are monitored by an attosecond pulse at the silicon L-edge. In a frequency-over-energy Fourier analysis of the recorded transient absorption in comparison to the band structure coherences are identified. The data suggests that the optical pulse can coherently couple the valence band (VB) and CB at various critical points of the band structure. The time domain measurement allows measuring lifetimes of these coherences as well as their sequence of generation. The results provide insight into complex couplings between bands that take place during excitation with broadband ultrashort laser pulses, an effect that should be general for most semiconductor materials.

A 2.4 Mon 11:45 K 1.011

Light-Field-Driven Landau-Zener-Stückelberg interferometry — •Takuya Higuchi and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

When electrons are placed under an optical field which is stronger than the internal field inside of a matter, their dynamics turn into nonperturbative regime. Recently, we have observed a transition from perturbative to non-perturbative electron dynamics in graphene [1]. The electron dynamics in the non-perturbative regime are well described by the light-field-driven dynamics. In particular, this field-driven dynamics has the same form as repeated Landau-Zener transitions and resultant quantum-path interference around the touching points of graphene's electron bands, known as Landau-Zener-Stückelberg (LZS) interference.

Such Landau-Zener like dynamics are found in various physical systems. Therefore, a comprehensive understanding of this light-field-driven LZS interferometry can provide a general prescription for formulating strong-field dynamics. The purpose of this presentation is to clarify the relations between the parameters involved in this light-field-driven LZS interferometry. For example, we clarify the condition defining the perturbative and the non-perturbative regimes. Relations with strong-field physics in atomic gaseous systems, such as the non-adiabaticity parameter and the intensity parameter, will be discussed.

[1] T. Higuchi, C. Heide, K. Ullmann, H. B. Weber, and P. Hommelhoff, Nature 550, 224 (2017).

A 2.5 Mon 12:00 K 1.011

Direct observation of a core-hole spin-orbit wave packet using strong-field spectroscopy — •Alexander Blättermann, Maximilian Hartmann, Paul Birk, Veit Stooss, Gergana Borisova, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

Spin-orbit coupling and its dynamics play an important role from atomic physics through chemical reactions of molecules up to magnetic properties in material science. Thus far, experimental studies were limited to spin-orbit dynamics in the valence shell of atoms [1]. Here, we present the time-domain observation of ultrafast coherent dynamics among 4d-core-hole states in xenon. The wave packet is created by an extreme-ultraviolet (XUV) light pulse, which lifts a 4d electron to the 6p shell. The natural time-scale of 2.1 fs is dictated by the intrinsically strong fine-structure splitting among the two possible core-hole configurations. Strong-field spectroscopy, i.e., probing the XUV-induced dynamics by means of an intense near-infrared laser pulse [2], allows us to observe these fast wave packet dynamics via a multiphoton-induced coupling of the studied states. These results open a route to site-selective and element-specific studies of coherent electron dynamics in larger systems such as polyatomic molecules and complex solids, where core electrons provide local probes of the electronic structure and dynamics.

[1] Nature 466, 739 (2010)
[2] Science 354, 738 (2016)

A 2.6 Mon 12:15 K 1.011

Observation of coherent spin-orbit wave packet dynamics in strong-field generated xenon ions — •Maximilian Hartmann, Alexander Blättermann, Paul Birk, Veit Stooss, Gergana

Borisova, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

Removing the p-shell valence electron of noble gas atoms generates ions, whose ground state forms a doublet due to spin-orbit interaction. As shown theoretically for neon and xenon [1] and experimentally for krypton [2], both ionic state configurations can be populated in a partially coherent way by means of strong-field ionization, which will give rise to coherent dynamics of the thus created wave packet. For the case of xenon, the fine structure splitting reaches 1.3 eV, which leads to dynamics on a time scale of 3 fs.

Here, we present the observation of coherent wave-packet dynamics in field-ionized xenon generated by intense sub-2 cycle laser pulses and probed by means of attosecond transient absorption spectroscopy. Our results constitute a promising step towards understanding the coherent response of multi-electron systems exposed to strong laser fields – especially in the regime of sub-cycle field-induced ionization.

[1] Phys. Rev. A 79, 053402 (2009)
[2] Nature 466, 739 (2010)

A 3: Precision Spectrosocopy I - trapped ions (joint session A/Q)

Time: Monday 10:30–12:00 Location: K 1.016

Invited Talk A 3.1 Mon 10:30 K 1.016

Segmented ion traps with integrated solenoids for scalable microwave based QIP — •Michael Johanning, Timm F. Gloger, Peter Kaufmann, Hendrik Siebeneich, and Christof Wunderlich — Faculty of Science and Technology, Department of Physics, University of Siegen, 57068 Siegen, Germany

Segmented traps have proven to be an essential ingredient for quantum information processing (QIP) using cold trapped ions, as they allow to control the position and shape of ion crystals, even in a time dependent fashion, and can be used to relocate or reshape ion crystals for transport, splitting and merging operations and tune normal modes and distances, e. g. to create strings of equidistant ions.

On the other hand, microwave manipulation has shown to be a way for internal state manipulation with near unit fidelity without requiring sub-Doppler cooling. Additional position dependent fields allow for high fidelity addressing and create an effective spin-spin coupling that can be used to create entangled states. The combination of segmented traps and magnetic gradient induced coupling (MAGIC) allows for tuning of coupling constants, e. g. to create long distance entanglement and thus facilitates scalable quantum simulations.

We give an overview over our ongoing projects which combine segmented microtraps with micro-structured solenoids. Experimental results obtained in such traps include robust Hahn Ramsey interferometry, high fidelity transport of internal states, and single ion addressing.

A 3.2 Mon 11:00 K 1.016

Trapping of anions for laser cooling — •Pauline Yzombard, Alban Kellerbauer, and Giovanni Cerchiari — Max Planck Institut für Kernphysik, Heidelberg, Germany

There is only a very small number of anions candidates with an optical dipole-allowed transition between two bound states that are potentially suitable for Doppler laser cooling. Detailed spectroscopic studies were needed to identify a proper candidate [1].

According to our latest results, the La- ion seems promising [2]. But the narrow width of its bound-bound transition implies a long interaction time for the laser cooling to take place. We have developed two traps, a cryogenic Penning trap and a room-temperature linear Paul trap, to trap the anions long enough to apply laser cooling. As the efficient Doppler laser cooling of La- would require pre-cooling, we are currently developing an evaporative cooling step assisted by laser excitation.

One of the main motivations for this work is the importance of an ultra-cold negative plasma for antimatter experiments. The established technique for antihydrogen formation is based on merging antiproton and positron plasmas at low energy. The ability of sympathetically cooling the antiprotons with laser-cooled anions would open the path to new precision measurements with antihydrogen [3].

[1] U.Warring et al. PRL 102 (2009) 043001. [2] E. Jordan and al. PRL 115 (2015) 113001 [3] A. Kellerbauer New J. Phys. 8 (2006) 45. 2005

A 3.3 Mon 11:15 K 1.016

Sympathetic cooling of OH- by a laser-cooled buffer gas — •Jonas Tauch[1], Henry Lopez[1], Jan Trautmann[1], Bastian Höltkemeier[1], Eric Endres[1], Roland Wester[3], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Deutschland — [2]University of Science and Technology of China, Shanghai Branch, Shanghai 201315, China — [3]Institut f. Ionenphysik und angewandte Physik, Universität Innsbruck, Österreich

Sympathetic cooling has become a powerful and universal method for preparing ultracold ions confined in radio frequency traps. In the past few year there has been a large debate about the limitations of this method. We recently developed a theoretical description which predicts that this limitations can be overcome by a localized buffer gas cloud and/or a higher order radio frequency trap. In this talk I present the recent results of our hybrid trap system, consisting of an 8-pole radio frequency trap and a dark spontaneous-force optical Rubidium trap. For probing the temperature of the ions, in particular OH-, we apply photodetachment tomography and time-of-flight detection of ions extracted from the trap. Via photodetachement spectroscopy we can also detect the energy distribution in the internal degree of freedom. We observe first evidence for sympathetic cooling and deviations from a thermal distribution of the ions, as predicted by our theoretical model.

A 3.4 Mon 11:30 K 1.016

Electronic coupling of laser-cooled ions stored in different traps — •Raúl A. Rica[1,2], Francisco Domínguez[1], Íñigo Arrazola[3], Javier Bañuelos[1], Manuel J. Gutiérrez[1], Lucas Lamata[3], Jesús J. del Pozo[1], Enrique Solano[3,4,5], and Daniel Rodríguez[1,2] — [1]Departamento de Física Atómica, Molecular y Nuclear, Universidad de Granada, 18071, Granada, Spain. — [2]Centro de Investigación en Tecnologías de la Información y las Comunicaciones, Universidad de Granada, 18071, Granada, Spain. — [3]Department of Physical Chemistry, University of the Basque Country UPV/EHU, Apartado 644, 48080, Bilbao, Spain. — [4]IKERBASQUE, Basque Foundation for Science, María Díaz de Haro 3, 48011, Bilbao, Spain. — [5]Department of Physics, Shanghai University, 200444 Shanghai, People's Republic of China.

A single laser-cooled ion stored in an ion trap can be used as an ultrasensitive detector of RF electric fields of diverse origin. One of the most appealing applications of such a detector considers its coupling to another oscillator. In this case, the ion can be used as a coolant for the second system, and even a quantum state transfer between them can be envisioned. In this contribution, we report on the evaluation of the sensitivity of a single Doppler-cooled ion in a Paul trap to external electric fields. We also present our progress in the implementation of a novel double trap system where two laser-cooled ions or clouds of ions can be coupled through the electric currents they induce on a common electrode.

A 3.5 Mon 11:45 K 1.016

Coulomb Coupling of Single Ions in a 2D Trap Array — •Frederick Hakelberg, Philip Kiefer, Sebastian Schnell, Matthias Wittemer, Jan-Philip Schroeder, Ulrich Warring, and Tobias Schaetz — University of Freiburg, Germany

Trapped ions present a promising system for quantum simulations [1]. Surface-electrode traps in contrast to conventional ion traps offer the advantage of scalability to larger system size and dimension while maintaining individual control: Dedicated radio-frequency electrode shapes allow the creation of two-dimensional trap arrays [2] while control electrodes allow localized manipulation of the trapping potential tuning motional frequencies and mode orientations [3,4]. The coupling between the individual ions, seen as harmonic oscillators, can be mediated via the Coulomb interaction, as has been demonstrated for one-dimensional traps [5].

In our experiment we trap Mg^+ ions in an equilateral triangle with $40\,\mu$m ion-ion distance. We present first experimental results for Coulomb coupling between ions in this two-dimensional trap array. Furthermore we investigate the effect of anharmonicities of the trap-

ping potential on the exchange of large coherent states.
[1] T. Schaetz *et al.*, New J. Phys. **15**, 085009 (2013)
[2] R. Schmied *et al.*, Phys. Rev. Lett. **102**, 233002 (2009)
[3] M. Mielenz *et al.*, Nature Communications **7**, 11839 (2016)
[4] H. Kalis *et al.*, Phys. Rev. A **94**, 023401 (2016)
[5] Brown *et al.* & Harlander *et al.*, Nature **471**, 196-203 (2011)

A 4: Ultracold Plasmas and Rydberg Systems I (joint session Q/A)

Time: Monday 10:30–12:15 Location: K 2.013

Group Report A 4.1 Mon 10:30 K 2.013
A Photon-Photon Quantum Gate Based on Rydberg Polaritons — •Steffen Schmidt-Eberle, Daniel Tiarks, Thomas Stolz, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Rydberg polaritons offer a unique way to create strong interactions for photons. We utilize these interactions to demonstrate a photon-photon quantum gate. To achieve this, a photonic control qubit is stored in a quantum memory consisting of a superposition of a ground state and a Rydberg state in an ultracold atomic gas. This qubit interacts with a photonic target qubit in the form of a propagating Rydberg polariton to generate a conditional pi phase shift, as in Ref. [1]. Finally, the control photon is retrieved. We measure two controlled-NOT truth tables and the two-photon state after an entangling-gate operation. This work is an important step toward applications in optical quantum information processing, such as deterministic photonic Bell-state detection which is crucial for quantum repeaters.

[1] D. Tiarks et al., Science Advances 2, 1600036 (2016).

A 4.2 Mon 11:00 K 2.013
Excitation blockade in highly Stark-shifted Rydberg states — •Raphael Nold, Markus Stecker, Lea Steinert, József Fortágh, and Andreas Günther — Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen

We report on the observation of excitation blockade for strongly Stark-shifted Rydberg states. Therefore, we make use of the fact that even for electric fields above the classical ionization limit, there are long-living Rydberg states with small ionization rates. We have developed a detection scheme for controlled ionization and magnified imaging of those states with high spatial and temporal resolution by adiabatic transfer to a state with a suitable ionization rate. The detector consists of a high-resolution ion microscope for ground state and Rydberg atoms with magnifications up to 1000 and a spatial resolution in the 100nm regime. The blockade effect becomes evident in the spatial $g^{(2)}$ correlation function between individual detection events. We show that the strength of the blockade effect can be sensitively adjusted by small changes in the electric field strength. This opens up new perspectives for quantum simulation techniques.

A 4.3 Mon 11:15 K 2.013
Free-Space Quantum Electrodynamics with Rydberg Superatoms — •Simon Ball[1], Christoph Tresp[1], Nina Stiesdal[1], Asaf Paris-Manodki[2], Jan Kumlin[3], Philipp Lunt[1], Christoph Braun[1], Hans Peter Büchler[3], and Sebastian Hofferberth[1] — [1]Department of Physics, Chemistry and Pharmacy, University of Southern Denmark, 5230 Odense, Denmark — [2]Instituto de Física, Universidad Nacional Autónoma de México, Mexico City 04510 Mexico — [3]Institut für Theoretische Physik III and Center for Integrated Quantum Science and Technology, Universität Stuttgart, 70569 Stuttgart, Germany

Achieving significant coupling between single photon and single atom in free space is challenging. Finding ways to increase the coupling strength has brought about cavity, circuit and more recently waveguide QED, where the electromagnetic wave is either trapped or transversely confined. We present the coherent interaction of a single Rydberg superatom interacting with a propagating, single mode, few-photon light field. Due to the collective nature of the excitation, the superatom inherits the light field's phase-relation and emits only in forward direction.[1] This property can be utilized to implement a dissipative spin chain, where the interaction between the individual spins is consecutively mediated by unidirectional travelling individual photons.

[1] A. Paris-Mandoki, C. Braun, J. Kumlin, C. Tresp, I. Mirgorodskiy, F. Christaller, H. P. Büchler, and S. Hofferberth, Phys. Rev. X 7, 41010 (2017).

A 4.4 Mon 11:30 K 2.013
On-demand single-photon source based on thermal rubidium — •Fabian Ripka, Florian Christaller, Hao Zhang, Harald Kübler, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart

Photonic quantum devices based on atomic vapors at room temperature combine the advantages of atomic vapors being intrinsically 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 effects in atomic ensembles, namely four-wave mixing (FWM) and the Rydberg blockade effect, comparable to similar realizations using cold atoms [1].

Coherent dynamics to Rydberg states [2] and sufficient Rydberg interaction strengths [3] have already been demonstrated in thermal vapors. Additionally, time-resolved probing of collective Rydberg excitation has been performed [4], revealing a lifetime long enough for effective Rydberg-Rydberg interactions.

In the current state of the experiment, the Rydberg blockade sphere is larger than the excitation volume. We report on effects on the light statistics of the emitted photons we observed in the experiment.

[1] Y. O. Dudin et al., Science 336, 6083 (2012)
[2] Huber et al., PRL 107, 243001 (2011)
[3] Baluktsian et al., PRL 110, 123001 (2013)
[4] Ripka et al., Phys. Rev. A, 053429 (2016)

A 4.5 Mon 11:45 K 2.013
Imaging nonlocal photon interactions in a cold Rydberg gas — •Annika Tebben[1], Valentin Walther[3], Renato Ferracini Alves[1], Yongchang Zhang[3], Andre Salzinger[1], Clement Hainaut[1], Nithiwadee Thaicharoen[1], Gerhard Zürn[1], Thomas Pohl[3], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Ruprecht-Karls Universität Heidelberg, Im Neuenheimer Feld 226, 69129 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China — [3]Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, DK 8000 Aarhus C, Denmark

Rydberg interactions modify the transmission of a light field through a cold atomic gas under conditions of electromagnetically induced transparency (EIT).

In this work, we develop a theory for the nonlinear, nonlocal optical response in a such a medium, without employing the adiabatic elimination of the intermediate state. We find an enhancement of this response in the vicinity of the single-photon resonance due to resonant Rydberg dressing of the atoms. Simulations show that this enhancement can be observed experimentally in the transmission of the EIT probe beam.

A 4.6 Mon 12:00 K 2.013
Emergent universal dynamics for an atomic cloud coupled to an optical waveguide — •Jan Kumlin[1], Sebastian Hofferberth[2], and Hans Peter Büchler[1] — [1]Institut für Theoretische Physik III and Center for Integrated Quantum Science and Technology, Universität Stuttgart, 70569 Stuttgart, Germany — [2]Department of Physics, Chemistry and Pharmacy, University of Southern Denmark, 5230 Odense, Denmark

Motivated by recent experiments on strong coupling of a cloud of Rydberg atoms coupled to a propagating light field [1], we study the effect of interaction-induced dephasing in an atomic cloud of atoms coupled to an optical one-dimensional waveguide. The system's dynamics can then be described by dissipative terms characterising the collective emission of photons and coherent interaction due to the virtual exchange of photons. We show that the coherent exchange interaction gives rise to universal dynamics with coherent oscillations and dephasing on a time scale that grows with the number of atoms in the cloud. Further, we discuss a possible experimental setup to decouple coherent and dissipative dynamics in order to observe the universal dynamics.

[1] A. Paris-Mandoki, C. Braun, J. Kumlin, C. Tresp, I. Mirgorodskiy, F. Christaller, H. P. Büchler, and S. Hofferberth, Phys. Rev. X 7, 41010 (2017)

A 5: Cold atoms II - interactions (joint session A/Q)

Time: Monday 10:30–12:00 Location: K 2.019

A 5.1 Mon 10:30 K 2.019

Dimensional Crossover for the Beyond-Mean-Field Corrections in the Weakly Interacting Bose Gas — •Tobias Ilg, Jan Kumlin, and Hans Peter Büchler — Institute for Theoretical Physics III, University of Stuttgart, 70569 Stuttgart, Germany

We investigate the beyond-mean-field corrections in a confined weakly interacting Bose gas at zero temperature. The system is elongated along one direction and tightly confined along the transverse directions. The confined gas can exhibit three-dimensional as well as quasi-one-dimensional behavior. We use the field-theoretic approach of Hugenholtz and Pines to include beyond-mean-field corrections. The field-theoretic treatment allows us to connect the three-dimensional regime to the quasi-one-dimensional regime and to describe a dimensional crossover of the system. We show that the inclusion of the beyond-mean-field terms leads to a correction of the coupling constant in the quasi-one-dimensional regime due to the presence of the confinement. Thus, the confinement-induced shift of the ground state energy appears naturally in our approach.

A 5.2 Mon 10:45 K 2.019

Time-dependent variational Monte Carlo method for interacting Bosons in continuous space — •Markus Holzmann — LPMMC, UMR 5493 of CNRS, Université Grenoble Alpes, F-38042 Grenoble, France

I will describe time-dependent Variational Monte Carlo method for continuous-space Bose systems based on a systematic truncation of the many-body wave function [1]. We have benchmarked the method by studing the Lieb-Liniger model of one dimensional Bosons interacting by a delta potential. We have calculated static ground state properties, as well as the unitary dynamics after a sudden quench in the interaction strength and compared to Bethe ansatz results wherever available.

[1] G. Carleo, L. Cevolani, L. Sanchez-Palencia, and M. Holzmann, Phys. Rev. X 7, 031026 (2017).

A 5.3 Mon 11:00 K 2.019

Commensurate-Incommensurate Transition in Optical Cavities — •Andreas Alexander Buchheit[1], Haggai Landa[2], Cecilia Cormick[3], Thomas Fogarty[4], Eugene Demler[5], and Giovanna Morigi[1] — [1]Saarland University, 66123 Saarbrücken — [2]IPhT, CEA Saclay, France — [3]IFEG, CONICET and Universidad Nacional de Cordoba — [4]Okinawa Institute of Science and Technology, Japan — [5]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We theoretically analyse the equilibrium configuration of an ion chain which interacts with the optical lattice of a cavity mode. We assume the lattice periodicity is almost commensurate with the interparticle distance of the ions and determine the resulting configuration as a function of their ratio. In the limit of small cooperativity, when cavity backaction is negligible, we show that this system simulates the commensurate-incommensurate phase transition. We derive a field theory for the kinks that are created in the incommensurate phase and determine the effects of the Coulomb repulsion on the phase diagram. When instead the cavity strongly couples to the ions motion we show that the commensurate-incommensurate transition becomes of first order and is associated with bistable behaviour of the cavity field. We characterize the kinks and their interactions and determine the properties of the light at the cavity output across the phase transition.

A 5.4 Mon 11:15 K 2.019

Observation of the Higgs mode in a strongly interacting fermionic superfluid — •Martin Link[1], Alexandra Behrle[1], Timothy Harrison[1], Johannes Kombe[2], Kuiyi Gao[1], Jean-Sebastien Bernier[2], Corinna Kollath[2], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [2]HISKP, University of Bonn, Nussallee 14-16, 53115 Bonn, Germany

Higgs and Goldstone modes are possible collective modes of an order parameter upon spontaneously breaking a continuous symmetry. Whereas the low-energy Goldstone (phase) mode is always stable, additional symmetries are required to prevent the Higgs (amplitude) mode from rapidly decaying into low-energy excitations. In the realm of condensed-matter physics, particle-hole symmetry can play this role and a Higgs mode has been observed in weakly-interacting superconductors. However, whether the Higgs mode is also stable for strongly-correlated superconductors in which particle-hole symmetry is not precisely fulfilled or whether this mode becomes overdamped has been subject of numerous discussions. Here, we observe the Higgs mode in a strongly-interacting superfluid Fermi gas. By inducing a periodic modulation of the amplitude of the superconducting order parameter Δ, we observe an excitation resonance at frequency $2\Delta/h$. For strong coupling, the peak width broadens and eventually the mode disappears when the Cooper pairs turn into tightly bound dimers signalling the eventual instability of the Higgs mode.

A 5.5 Mon 11:30 K 2.019

Breaking of SU(4) symmetry and interplay between strongly correlated phases in the Hubbard model — •Agnieszka Cichy[1,2] and Andrii Sotnikov[3,4] — [1]Faculty of Physics, Adam Mickiewicz University, Umultowska 85, 61-614 Poznan, Poland — [2]Umultowska 85 — [3]Institute of Solid State Physics, TU Wien, Wiedner Hauptstr. 8, 1040 Wien, Austria — [4]Akhiezer Institute for Theoretical Physics, NSC KIPT, 61108 Kharkiv, Ukraine

We study the thermodynamic properties of four-component fermionic mixtures described by the Hubbard model using the dynamical mean-field-theory approach. Special attention is given to the system with SU(4)-symmetric interactions at half filling, where we analyze equilibrium many-body phases and their coexistence regions at nonzero temperature for the case of simple cubic lattice geometry. We also determine the evolution of observables in low-temperature phases while lowering the symmetry of the Hamiltonian towards the two-band Hubbard model. This is achieved by varying interflavor interactions or by introducing the spin-flip term (Hund's coupling). We observe a strong effect of suppression of ferromagnetic order in comparison with previous studies that were usually performed by restricting to density-density interactions. By calculating the entropy for different symmetries of the model, we determine the optimal regimes for approaching the studied phases in experiments with ultracold alkali and alkaline-earth-like atoms in optical lattices.

A 5.6 Mon 11:45 K 2.019

Polaron physics with ultracold atoms and beyond — •Richard Schmidt — Department of Physics, Harvard University, Cambridge, MA 02138, USA — ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA — Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

When an impurity interacts with an environment, it changes its properties and forms a polaron. Depending on the character of the environment, various types of polarons are created. In this talk, I will review recent progress on studying the physics of polarons in cold atoms [1], and discuss related phenomena in semiconductors and the study of rotating molecules in Helium droplets [2]. Then I will show that Rydberg excitations coupled to BECs are a new, exciting playground for the study of polaronic physics. Here the impurity-bath interaction is mediated by the Rydberg electron. This gives rise to a new polaronic dressing mechanisms, where molecules of gigantic size dress the Rydberg impurity. We develop a functional determinant approach [3] which incorporates atomic and many-body theory. Using this approach we predict the appearance of a superpolaronic state, recently observed in experiments [4,5].

References: [1] R. Schmidt, et al, arXiv:1702.08587 (2017). [2] R. Schmidt, and M. Lemeshko, Phys. Rev. Lett. 114, 203001 (2015); [3] R. Schmidt, H. Sadeghpour, and E. Demler, Phys. Rev. Lett. 116, 105302 (2016). [4] F. Camargo et al., arXiv:1706.03717 (2017). [5] R. Schmidt et al., arXiv:1709.01838 (2017).

A 6: Cold atoms III - optical lattices (joint session A/Q)

Time: Monday 14:00–15:30 Location: K 0.011

A 6.1 Mon 14:00 K 0.011

Quantum simulation of lattice gauge theories using Wilson fermions — •Torsten V. Zache[1], Philipp Hauke[1,2], Fred Jendrzejewski[2], Florian Hebenstreit[3], Markus Oberthaler[2], and Jürgen Berges[1] — [1]Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg — [2]Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg — [3]Institute for Theoretical Physics, Sidlerstr. 5, CH-3012 Bern

Gauge theories play an essential role in the formulation of microscopic quantum field theories, e.g. QED or QCD. Their analytical treatment is typically limited to the perturbative regime and numerical simulations are strongly hampered by the sign problem. Recently, quantum simulators based on cold atomic gases in optical lattices have been proposed to circumvent these issues. Most proposals rely on the lattice regularization of gauge theories (LGT) via staggered fermions. Since the regularization is not unique, we propose to exploit this freedom to simplify the implementation of LGTs. We find that the choice of Wilson fermions reduces the complexity of the gauge interactions in one spatial dimension to a minimum and use this result to devise an optimized implementation of QED using a mixture of bosons and fermions in a tilted optical potential. We further perform benchmarking real-time lattice simulations with realistic experimental parameter sets, which indicate that the non-perturbative nature of electron-positron pair production due to the Schwinger mechanism can be resolved even quantitatively. We conclude that the quantum simulation of QED in the continuum limit is possible with state-of-the art technology.

A 6.2 Mon 14:15 K 0.011

Chimera patterns in conservative systems and ultracold atoms with mediated nonlocal hopping — •Hon-Wai Lau[1,2,3], Jörn Davidsen[3], and Christoph Simon[2] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, D-01187 Dresden — [2]Institute for Quantum Science and Technology and Department of Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada T2N 1N4 — [3]Complexity Science Group, Department of Physics and Astronomy, University of Calgary, Canada T2N 1N4

Chimera patterns, characterized by coexisting regions of phase coherence and incoherence, have been experimentally demonstrated in mechanical, chemical, electronic, and opto-electronic systems. The patterns have so far been studied in non-conservative systems with dissipation. Here, we show that the formation of chimera patterns can also be observed in conservative Hamiltonian systems with nonlocal hopping in which both energy and particle number are conserved. We further show the physical mechanism and the implementation in ultracold atomic systems: Nonlocal spatial hopping over up to tens of lattice sites with independently tunable hopping strength and on-site nonlinearity can be implemented in a two-component Bose-Einstein condensate with a spin-dependent optical lattice, where the untrapped component serves as the matter-wave mediating field. The present work highlights the connections between chimera patterns, nonlinear dynamics, condensed matter, and ultracold atoms.

A 6.3 Mon 14:30 K 0.011

Interorbital spin exchange in a state-dependent optical lattice — •Luis Riegger[1,2], Nelson Darkwah Oppong[1,2], Moritz Höfer[1,2], Diogo Rio Fernandes[1,2], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Ludwig-Maximilians-Universität, München

We report on the observation of tunable interorbital spin exchange in the presence of a state-dependent optical lattice for the ground state and metastable clock state of fermionic ytterbium-173. The optical lattice potential is independent of the nuclear spin and preserves the SU(N)-symmetry of the interactions, typical for alkaline-earth-like atoms. In the state-dependent lattice, excited-state and ground-state atoms act as localized and mobile magnetic moments. The large difference in the interaction strength for spin-triplet and singlet states leads to spin-exchanging dynamics between the magnetic moments mediated by exchange processes similar to those in the Anderson impurity model. Moreover, we find that the external confinement can be used to resonantly tune the exchange dynamics. This makes our system a promising platform for the study of Kondo- and Kondo-lattice-type physics.

A 6.4 Mon 14:45 K 0.011

Observation of Feshbach resonances between alkali and closed-shell atoms — •Vincent Barbé[1], Alessio Ciamei[1], Lukas Reichsöllner[1], Benjamin Pasquiou[1], Florian Schreck[1], Piotr Zuchowski[2], and Jeremy Hutson[3] — [1]University of Amsterdam, The Netherlands — [2]Nicolaus Copernicus University, Poland — [3]Durham University, United Kingdom

Magnetic Feshbach resonances are widely used to tune interactions of ultracold atoms or to magneto-associate pairs of atoms into diatomic molecules. Such resonances have been observed and used extensively for pairs of open-shell atoms, but were never detected for pairs of alkali and closed-shell atoms. Here we demonstrate experimentally the existence of such resonances in mixtures of ^{87}Sr or ^{88}Sr with ^{87}Rb [1]. Two of the coupling mechanisms involved in these Feshbach resonances were theoretically investigated in previous works [2], and in addition we discover a new form of anisotropic coupling between rotating molecular states and s-wave scattering states. This opens a route towards the magneto-association of Rb and Sr into open-shell, strongly polar molecules in an optical lattice.

[1] V. Barbé *et al.*, arXiv:1710.03093 (2017).
[2] P. Żuchowski *et al.*, Phys. Rev. Lett. 105, 153201 (2010).

A 6.5 Mon 15:00 K 0.011

Robust features of Bose-Hubbard eigenstates dressed by a cavity — •Jonas Mielke, Laurent de Forges de Parny, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany

The coherent dressing by a cavity field allows to induce long-range interactions between otherwise only locally interacting bosons in optical lattices [1]. Most studies did so far address ground state properties like long-range phase coherence and spatial ordering [2,3], while also the excitation spectrum of these systems can be expected to exhibit nontrivial structural features. We present a complete map of the system states' characteristic structural features, across the entire excitation spectrum, which generalizes standard ground state phase diagrams, for minimal system sizes. We discuss the physical mechanisms which define the smooth demarcation lines between different structural properties in parameter space, and analyse relevant scaling properties with the system size.

[1] C. Maschler, I. Mekhov, and H. Ritsch, Eur. Phys. J. D,46, 545-560 (2008);
[2] R. Landig, L. Hruby, N. Dogra, M. Landini, R. Mottl, T. Donner, and T. Esslinger, Nature 532, 476 (2016);
[3] T. Flottat, L. de Forges de Parny, F. Hébert, V.G. Rousseau, and G.G. Batrouni, Phys. Rev. B 95, 144501 (2017).

A 6.6 Mon 15:15 K 0.011

Metastability and avalanche dynamics in strongly-correlated gases with long-range interactions — •Nishant Dogra, Lorenz Hruby, Manuele Landini, Katrin Kröger, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

We experimentally study the stability of a bosonic Mott-insulator against the formation of a density wave induced by long-range interactions. The Mott-insulator is created in a quantum degenerate gas of 87-Rubidium atoms, trapped in a three-dimensional optical lattice. The gas is located inside and globally coupled to an optical cavity. This causes interactions of global range, mediated by photons dispersively scattered between a transverse lattice and the cavity. The scattering comes with an atomic density modulation, which is measured by the photon flux leaking from the cavity. We initialize the system in a Mott-insulating state and then quench the global coupling strength. We observe that the system falls into either of two distinct final states. One is characterized by low photon flux, signaling a Mott insulator, and the other is characterized by high photon flux, which we associate with a density wave. Ramping the global coupling slowly, we observe a hysteresis loop between the two states. From the increasing photon flux monitored during the switching process, we find that several thousand atoms tunnel to a neighboring site on the time scale of the single particle dynamics which can be understood as an avalanche tunnelling process in the Mott-insulating region.

A 7: Laser Development and Applications (joint session Q/A)

Time: Monday 14:00–15:45 Location: K 0.023

A 7.1 Mon 14:00 K 0.023

Pump-power scaling of a diode-pumped Alexandrite laser — •Martin Walochnik[1], Hans Huber[1], Bernd Jungbluth[2], Alexander Munk[2], Michael Strotkamp[2], Dieter Hoffmann[2], and Reinhart Poprawe[1,2] — [1]RWTH Aachen University Chair for Laser Technology LLT — [2]Fraunhofer Institute for Laser Technology ILT

The possibility of diode pumping and the tunability between 700 nm and 800 nm make Alexandrite a remarkable laser gain medium. At present the scalability of the pump power and pump brilliance as well as the temporal stability of the laser output remain challenging. We report on our progress of using a red diode laser with spatially symmetrized output for end pumping of an Alexandrite laser rod. We measured the thermal dioptric power of the pumped laser crystal and experimentally identified the induced thermal aberrations as an important limit of the applicable pump power density. We designed a laser resonator with special emphasis on fundamental mode operation for high dioptric powers. We show results of a continuously pumped Alexandrite laser with wavelengths between 740 nm and 785 nm and fundamental mode operation up to 5 W. Future work will address further development of this laser in the field of mode locking and frequency conversion to generate ultrashort pulses and operate in the UV regime, respectively.

A 7.2 Mon 14:15 K 0.023

Fourier Limited Picosecond Pulses for Laser Cooling of Relativistic Ion Beams — •Daniel Kiefer and Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schlossgartenstr. 7, 64289, Darmstadt

Laser cooling of relativistic ion beams has been shown to be a sophisticated technology [1] and white light cooling has been demonstrated in non-relativistic ion beam cooling [2]. However, the experimental realisation of white-light-cooling of relativistic beams still has to be performed. The necessary laser bandwidth shall be provided by pulsed laser light. Simulations have shown the demanding requirements for these laser pulses [3]. We present a master-oscillator-power-amplifier system supplying laser pulses of 100 to 740 ps length with a centre wavelength of 1029 nm. The system is marked by the Fourier transform limited character of the pulses, the continuously adjustable pulse length and the repetition rate between 500 kHz and 10 MHz. [1] S. Schröder et al, Phys. Rev. Lett. 64, 2901-2904, (1990). [2] S.N.Atutov et al, Phys. Rev. Lett. 80, 2129, (1998). [3] L. Eidam et al, arXiv:1709.03338 [physics.acc-ph], (2017).

A 7.3 Mon 14:30 K 0.023

Ultra Compact High-Harmonic Cavity Optical Parametric Oscillator for Optical Amplifier Seeding — •Marco Nägele[1], Florian Mörz[1], Heiko Linnenbank[1], Tobias Steinle[2], Andy Steinmann[1], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Germany — [2]ICFO, Barcelona, Spain

We present a master oscillator power amplifier (MOPA) scheme, based on a high-harmonic cavity optical parametric oscillator (OPO), emitting tunable light in the near infrared region. Different from conventional OPOs and our previous fiber-feedback OPO, the high-harmonic OPO cavity uses only a fraction of the fundamental conventional OPO cavity length, thus supporting the 15th harmonic and offering a very compact design. Additionally, low pump power values provide high suitability for post-amplification of the OPO output, since the remaining pump power is available for an optical parametric amplifier (OPA). We recorded a pump power threshold between 30-100 mW over the entire OPO tuning range from 2.3-4.1 μm. A high versatility of different pump laser sources with MHz repetition rate is suitable by using the high-harmonic cavity design and direct idler outcoupling. As the signal pulse remains inside the cavity, the ejected idler pulses match the pump laser in repetition rate, pulse duration, and shape. While we use a 450 fs pulsed solid-state pump laser at 1030 nm and 41 MHz, different repetition rate pump sources are usable by several cm cavity length adjustment in order to match a higher pump harmonic. Post amplification of the ejected idler using an (OPA) additionally generates tunable signal light between 1.4-2 μm.

A 7.4 Mon 14:45 K 0.023

Noncollinear optical parametric oscillator for Raman Spectroscopy of Microplastics — •Luise Beichert[1], Yuliya Binhammer[1], José Ricardo Andrade[1], and Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Hannoversches Zentrum für optische Technologien, Leibniz Universität Hannover, Germany

Meanwhile microplastics can be detected in an increasing rate in our enviroment as well as in our drinking water. We present a broadband and fast tunable light source to detect these particles via stimulated Raman scattering in water circulation.

Noncollinear optical parametric oscillators (NOPOs) provide a good scalability in terms of output power, repetition rate and pulse energy. The instantaneous broadband frequency conversion combined with the special phase matching geometry in the nonlinear crystal enables a fast tunability without readjustment.

We show an IR-NOPO, rapidly tunable in 1 ms from 750 to 950 nm and Ramanspectra in the range of 500-3200 cm^{-1} of different plastic particles.

A 7.5 Mon 15:00 K 0.023

Monitoring protein configurations in the fingerprint region with micro-FTIR spectroscopy using a 98 fs solid-state laser tunable from 1.33 to 8 μm at 73 MHz repetition rate — •Florian Mörz[1], Rostyslav Semenyshyn[1], Frank Neubrech[2], Tobias Steinle[3], Andy Steinmann[1], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart — [2]Kirchhoff-Institut für Physik, Universität Heidelberg — [3]ICFO-Institut de Ciencies Fotoniques, Barcelona, Spanien

Configurations of poly-L-lysine proteins using vibrational resonances at 6 μm (1667 cm-1) are monitored by employing a broadband femtosecond laser for micro-FTIR spectroscopy in combination with resonant surface-enhanced infrared absorption (SEIRA) spectroscopy, using a single gold nanoantenna. Our tabletop laser system exceeds the sensitivity of standard FTIR light sources due to an orders of magnitude higher brilliance. Absorption signals as small as 0.5% are detected without averaging, compared to 6.4% using a globar, at 10x10 μm^2 spatial resolution. By pumping a fiber-feedback optical parametric oscillator and a post-amplifier, signal and idler beams spanning from 1.33-2.0 and 2.1-4.6 μm are generated. The tuning range is extended to 8 μm by difference frequency generation between the signal and idler beams. At 7 μm a wavelength stability with fluctuations smaller than 0.1% rms over 9 hours is observed, without applying electronic stabilization. Thus our design is distinctly superior over other systems based on free-space OPOs and applications such as protein sensing using FTIR spectroscopy in combination with SEIRA are enabled.

A 7.6 Mon 15:15 K 0.023

Systematic refractive index measurements of photo-resists for three-dimensional direct laser writing — •Michael Schmid and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Femtosecond 3D printing is an important technology for manufacturing of nano- and microscopic devices and elements. Crucial for the design of such structures is the detailed knowledge of the refractive index in the visible and near-infrared spectral range and its dispersion.

We characterize different photoresists that are used with femtosecond 3D direct laser writers, namely IP-S, IP-Dip, IP-L, and OrmoComp with a modified and automized Pulfrich refractometer setup, utilizing critical angles of total internal reflection. Thereby we achieve an accuracy of $5{\cdot}10^{-4}$ and reference our values to a BK-7 glass plate. Their refractive indices are in the 1.49-1.57 range, while their Abbe numbers are in the range between 35 and 51.

Furthermore, we systematically study the effects of UV exposure duration as well as the aging process on the refractive index of the photo resists which are crucial for 3D printed functional devices, especially nano- and microscopic devices. We also deliver the first measurements of refractive index of actual 3D printed samples.

A 7.7 Mon 15:30 K 0.023

Atom Trap Trace Analysis: Pushing the volume limit for radiometric dating with applied quantum technology — •Lisa Ringena[1], Zhongyi Feng[1], Sven Ebser[1], Maximilian Schmidt[1], Arne Kersting[2], Emeline Mathouchanh[2], Philip Hopkins[2], Viola Rädle[2], Werner Aeschbach[2], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg — [2]Institut für Umweltphysik, Universität Heidelberg

Argon Trap Trace Analysis (ArTTA) applies quantum technology to establish an ultra-sensitive detection method for the radioisotope ^{39}Ar. This isotope, with a half-life of 269 years, serves as an unique tracer for dating of environmental samples. The atom of interest is distinguished from the huge background of abundant isotopes by utilizing its shift in optical resonance frequency due to differences in mass and nuclear spin. This selectivity is realized by the multitude of scattering processes in a magneto-optical trap (MOT), where single atoms are captured and detected [1]. Recently the instrument has been upgraded to operate with a minimum of 1mL STP argon gas, degassed from about 2.5L of water, drastically decreasing the effort invested in environmental studies such as ocean depth profiles, and making dating of glacier ice feasible. Paving the way towards routine operation, measures have been taken to increase the stability of the experiment, such as the setup of a new laser system. We will present systematic studies of the apparatus, which show a doubled count rate, leading to shorter measurement times and reduction of statistical errors.

[1] Ritterbusch et al., GRL 2014, DOI: 10.1002/2014GL061120

A 8: Attosecond Science II

Time: Monday 14:00–15:45 Location: K 1.011

Invited Talk A 8.1 Mon 14:00 K 1.011

Attosecond timing with spectral resolution near resonances, and new opportunities with high-repetition rate attosecond sources — •Anne Harth — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

To directly observe the ultrafast motion of electrons in atomic or molecular systems is an aspect of fundamental physics and is achievable thanks to the generation of attosecond pulses in the XUV spectral range, whereby attosecond pulse trains play by no means a less important role than single isolated attosecond pulses. A key advantage of using pulse trains is the high spectral resolution, while high temporal resolution is still retained [1]. In this talk we will provide an overview of attosecond measurements using attosecond pulse trains near resonances; the role of continuum-continuum transition in attosecond time delay measurement will be discussed within a perturbative approach.

Furthermore, we will discuss the present achievements and future steps towards high-repetition rate attosecond experiments based on optical parametric amplifier systems driving high-order harmonic generation [2]. Experiments involving e.g. double photoionisation dynamics of atoms or complex molecules, which require so-called kinematically complete measurements of all charged fragments [3], greatly benefit from high-repetition rate attosecond sources.

[1] Isinger et al. Science 358, 893 (2017)
[2] Harth et al. Journal of Optics 20, 014007 (2018)
[3] Ullrich et al. Reports on Progress in Physics 66, 1463 (2003)

Invited Talk A 8.2 Mon 14:30 K 1.011

Towards attosecond pump-probe experiments at high repetition rates — •Tobias Witting[1], Federico Furch[1], Felix Schell[1], Peter Susnjar[1], Carmen Menoni[2], Chih-Hsuan Lu[3], Andy Kung[3], Claus-Peter Schulz[1], and Marc J.J. Vrakking[1] — [1]Max-Born-Institut, Max-Born-Strasse 2A, D-12489 Berlin — [2]Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, CO 80523, USA — [3]Institute of Photonics Technologies, National Tsing Hua University, Hsincho 30013, Taiwan

Our aim is to perform attosecond pump probe experiments with coincidence detection of photoelectrons and -ions in a reaction microscope. To increase the data-rates we have recently developed a NOPA based OPCPA laser system providing 190 uJ laser pulses at 100 kHz repetition rate [1]. Here we discuss the laser system, pulse compression to near single-cycle duration, and spatio-temporal pulse characterization. We show high harmonic generation up to 50 eV driven by sub-3-cycle CEP stable laser pulses at 100 kHz. We discuss our recent progress towards a complete attosecond pump-probe beamline coupled to a reaction microsocpe (COLTRIMS).

[1] F.J. Furch, T. Witting, A. Giree, C. Luan, F. Schell, G. Arisholm, C.P. Schulz, and M.J.J. Vrakking. Optics Letters 42, no. 13 (2017)

A 8.3 Mon 15:00 K 1.011

Ultrafast CEP detection and control in real-time on an every single shot basis — •Dominik Hoff[1], Federico Furch[2], Daniel Adolph[1], Tobias Witting[2], Klaus Rühle[1], A. Max Sayler[1], Claus P. Schulz[2], Gerhard G. Paulus[1], and Marc J. J. Vrakking[2] — [1]Helmholtz-Institut Jena and Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, D-07743 Jena, Germany. — [2]Max-Born-Institute, Max-Born-Straße 2a, 12489 Berlin, Germany

With the emergence of high repetition rate few-cycle laser pulse amplifiers, e.g. for high-harmonic generation and the investigation of rare events in atomic and molecular science, the need for fast carrier-envelope phase (CEP) detection and control has arisen [1]. Here, we demonstrate an ultrafast detection and feedback scheme based on a stereo above-threshold ionization time-of-flight spectrometer (stereo ATI) capable of detecting the CEP and pulse duration at a repetition rate of up to 400 kHz [2]. It is applied to a 100 kHz, 200 μJ pulse energy NOPA laser system that is seeded by a Ti:Sa oscillator [3].

[1] Hädrich, S. et al, Opt. Lett. 41, 18, 4332 (2016)
[2] Sayler A.M. et al, Opt. Lett. Vol. 36, No. 1, 2011
[3] Furch F. et al, Opt. Lett. Vol. 42, No. 13, 2017

A 8.4 Mon 15:15 K 1.011

Tunneling exit characteristics from classical backpropagation of an ionized electron wave packet — •Hongcheng Ni, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany

We investigate tunneling ionization of a single active electron with a strong and short laser pulse, circularly polarized. With the recently proposed backpropagation method, we can compare different criteria for the tunnel exit as well as popular approximations in strong-field physics on the same footing. Thereby, we trace back discrepancies in the literature regarding the tunneling time to inconsistent tunneling exit criteria. The main source of error is the use of a static ionization potential, which is, however, time dependent for a short laser pulse. A vanishing velocity in the instantaneous field direction as tunneling exit criterion offers a consistent alternative, since it does not require the knowledge of the instantaneous binding energy. Finally, we propose a mapping technique that links observables from attoclock experiments to the intrinsic tunneling exit time.

A 8.5 Mon 15:30 K 1.011

Tunneling time in attosecond experiment, a theoretical model with a comparison for H-atom — •Ossama Kullie — University of Kassel, Fachbereich 10, Heinrichplett str. 41, 34132 Kasel

Tunneling and tunneling time are hot debated and very interesting due to their fundamental role in the quantum mechanics. The measurement of the tunneling time in today's attosecond and strong field (low-frequency) experiments, despite its controversial discussion, it offers a fruitful opportunity to understand time measurement and the time in quantum mechanics. In [1, 2] we suggested a model and derived a simple relation to calculate the real tunneling time, to calculate the real tunneling time. In this work [3] we discuss and analyze the model against an experimental result for H-atom obtained recently by Sainadh et al [4]. For H-atom the model shows a good agreement with the experimental result as previously for He-atom [1]. However there are crucial points for higher intensities, in particular where the electric field strength is higher than the atomic filed strength, we will discuss this for the case of H-atom. [1] O. Kullie, Phys. Rev. 92, 052118 (2015). [2] O. Kullie, J. Phys. B49, 095601 (2016). [3] O. Kullie, Phys. Rev. A, under review (2017). [4] U. Satya Sainadh et al arxiv:1707.05445, 2017.

A 9: Precision Spectrosocopy II - trapped ions (joint session A/Q)

Time: Monday 14:00–15:45 Location: K 1.016

Invited Talk A 9.1 Mon 14:00 K 1.016

A ppb measurement of the antiproton magnetic moment — •C. Smorra[1], S. Sellner[1], M. Borchert[1,2], J. A. Harrington[3], T. Higuchi[1,4], H. Nagahama[1], A. Mooser[1], G. Schneider[1,5], M. Bohman[1,3], K. Blaum[3], Y. Matsuda[4], C. Ospelkaus[2,6], W. Quint[7], J. Walz[5,8], Y. Yamazaki[1], and S. Ulmer[1] — [1]RIKEN, Ulmer Fundamental Symmetries Laboratory, Wako, Saitama, Japan — [2]Leibniz Universität, Hannover, Germany — [3]Max-Planck Institute für Kernphysik, Heidelberg, Germany — [4]University of Tokyo, Tokyo, Japan — [5]Johannes Gutenberg-Universität, Mainz, Germany — [6]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [7]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [8]Helmholtz-Institut Mainz, Mainz, Germany

The BASE collaboration performs high-precision measurements of the fundamental properties of protons and antiprotons in a multi Penning-trap system. Such measurements challenge the Standard Model of particle physics, since any deviation in proton and antiproton properties would hint to yet unknown CPT-odd interactions that would act differently on matter and antimatter-conjugates.

We recently reported a measurement of the antiproton magnetic moment with 1.5 ppb uncertainty (68 % C.L.) based on the frequency ratio of the Larmor frequency to the cyclotron frequency measured with two single antiprotons. We apply a novel two-particle multi-trap scheme, which enhances the data accumulation rate compared to the double trap method. In this way, we improved limits on CPT-odd interactions on antiprotons by a factor 350.

Invited Talk A 9.2 Mon 14:30 K 1.016

Towards laser cooling of atomic anions — •Alban Kellerbauer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Currently available cooling techniques for negatively charged particles allow cooling only to the temperature of the surrounding environment, typically a few kelvin. Laser cooling of atomic anions could be used to produce an ensemble of negative particles at microkelvin temperatures. These could sympathetically cool any species of negatively charged particles – from antiprotons to molecular anions – to ultracold temperatures. For this indirect cooling technique [1], a fast electronic transition is required. Until now, there are only three known atomic anions with bound–bound electric-dipole transitions. We have investigated these transitions in Os^- [2] and La^- [3] by high-resolution laser spectroscopy to test their suitability for laser cooling. The principle of the method, its potential applications, as well as recent experimental results will be presented.

[1] A. Kellerbauer & J. Walz, "A novel cooling scheme for antiprotons". New J. Phys. **8** (2006) 45. doi:10.1088/1367-2630/8/3/045.

[2] U. Warring *et al.*, "High-resolution laser spectroscopy on the negative osmium ion". Phys. Rev. Lett. **102** (2009) 043001. doi:10.1103/PhysRevLett.102.043001.

[3] E. Jordan *et al.*, "High-resolution spectroscopy on the laser-cooling candidate La^-". Phys. Rev. Lett. **115** (2015) 113001. doi:10.1103/PhysRevLett.115.113001.

A 9.3 Mon 15:00 K 1.016

Towards Sympathetic Cooling of a Single Proton in a Penning Trap for a High-Precision Measurement of the Proton Magnetic Moment — •Markus Wiesinger[1,2], Matthew Bohman[1,2], Andreas Mooser[2], Georg Schneider[2,3], Natalie Schön[2,3,4], James Harrington[1], Takashi Higuchi[2,5], Stefan Sellner[2], Christian Smorra[2,7], Klaus Blaum[1], Yasuyuki Matsuda[5], Wolfgang Quint[6], Jochen Walz[3,4], and Stefan Ulmer[2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Ulmer Fundamental Symmetries Laboratory, RIKEN, Wako, Japan — [3]Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — [4]Helmholtz-Institut Mainz, Mainz, Germany — [5]Graduate School of Arts and Sciences, University of Tokyo, Tokyo, Japan — [6]GSI-Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [7]CERN, Geneva, Switzerland

Precise comparisons of the fundamental properties of protons and antiprotons, such as magnetic moments and charge-to-mass ratios, provide stringent tests of CPT invariance, and thus, matter-antimatter symmetry. Using advanced Penning-trap methods, we have recently determined the magnetic moments of the proton and the antiproton with fractional precisions on the p.p.b. level [1,2].

Both experiments rely on sub-thermal cooling of the particle's modified cyclotron mode using feedback-cooled tuned circuits. This time-consuming process is ultimately required to identify single spin quantum transitions with high detection fidelity, which is a major prerequisite to apply multi-trap methods.

In order to advance our techniques and to drastically reduce the measurement time, we are currently implementing methods to sympathetically cool protons and antiprotons by coupling them to laser-cooled beryllium ions, using a common endcap method [3]. In this talk we present the status of our ongoing efforts to deterministically prepare single protons and antiprotons at mK-temperatures.

[1] Schneider, G. *et al.* Science **358**, 1081 (2017)

[2] Smorra, C. *et al.* Nature **550**, 371 (2017)

[3] Heinzen, D. J. & Wineland, D. J. Phys. Rev. A, **42**, 2977 (1990)

A 9.4 Mon 15:15 K 1.016

Resonant coupling of single protons and laser cooled Be ions — •Natalie Schön[1,2,7], Matthew Bohman[2,3], Andreas Mooser[2], Georg Schneider[1,2], Markus Wiesinger[2,3], James Harrington[3], Takashi Higuchi[2,4], Stefan Sellner[2], Christian Smorra[2,5], Klaus Blaum[3], Yasuyuki Matsuda[4], Wolfgang Quint[6], Jochen Walz[1,7], and Stefan Ulmer[2] — [1]University of Mainz, Germany — [2]RIKEN, Ulmer Fundamental Symmetries Laboratory, Japan — [3]MPIK Heidelberg, Germany — [4]University of Tokyo, Japan — [5]CERN, Switzerland — [6]GSI Darmstadt, Germany — [7]Helmholtz Institut Mainz, Germany

The relativistic quantum field theories of the Standard Model are invariant under the combined charge (C), parity (P) and time (T) transformation. To test this fundamental symmetry the BASE collaboration compares the g-factor and charge to mass ratio of protons and antiprotons with highest precision. Using Penning traps, we have recently performed 0.3 ppb and 1.5 ppb measurements of the proton and the antiproton g-factors, respectively. The uncertainties in the g-factor values are dominated by effects due to the energy of the trapped particle at 4 K. To overcome this limitation, we plan to resonantly couple the axial modes of laser cooled beryllium ions and of single (anti)protons. To match the axial frequencies a resonant circuit is used, which however heats the particles. Thus, after frequency matching, the resonant circuit will be decoupled from the ions by switching its resonance frequency. To this end several switches, with high isolation resistance and low insertion loss, were tested at cryogenic temperatures.

A 9.5 Mon 15:30 K 1.016

Measurements with single antiprotons in an ultra-low noise Penning trap system — •Matthias Borchert[1,2], James Harrington[3], Takashi Higuchi[2,4], Jonathan Morgner[1,2], Hiroki Nagahama[2], Stefan Sellner[2], Christian Smorra[2], Matthew Bohman[2,3], Andreas Mooser[2], Georg Schneider[2,5], Natalie Schoen[5], Markus Wiesinger[2,3], Klaus Blaum[3], Yasuyuki Matsuda[4], Christian Ospelkaus[1,6], Wolfgang Quint[7], Jochen Walz[5,8], Yasunori Yamazaki[2], and Stefan Ulmer[2] — [1]Institut für Quantenoptik, Leibniz Univerisität Hannover, Germany — [2]RIKEN, Ulmer Fundamental Symmetries Laboratory, Wako, Japan — [3]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [4]Graduate School of Arts and Sciences, University of Tokyo, Japan — [5]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [6]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [7]GSI - Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [8]Helmholtz-Institut Mainz, Germany

The observed baryon asymmetry in our Universe challenges the Standard Model of particle physics and motivates sensitive tests of CPT invariance. Inspired by that, the BASE experiment at CERN compares the fundamental properties of antiprotons and protons with high precision.

In 2014 we performed the most precise measurement of the antiproton charge-to-mass-ratio $q_{\bar{p}}/m_{\bar{p}}$ [1], with a fractional precision of 69 ppt. Very recently we reported on a 350-fold improved measurement of the antiproton magnetic moment $\mu_{\bar{p}}$ [2] using a newly-invented multi-Penning trap method. The high-precision measurement of $\mu_{\bar{p}}$ was enabled by a highly-stabilised experimental apparatus including ultra-low electric field fluctuations.

In this talk I will focus on the characterisation and optimisation of electric field noise and the interpretation of heating rates at different radial amplitudes causing axial frequency fluctuations. The optimised Penning trap heating rates measured in BASE are well below the heating rates which are usually reported in Paul traps. Furthermore, I will summarize recent experimental developments and discuss future prospects of BASE.

[1] Ulmer et al., *Nature* **524**, 196-199 (2015)
[2] Smorra et al., *Nature* **550**, 371-374 (2017)

A 10: Bose-Einstein Condensation (joint session A/Q)

Time: Monday 14:00–16:15 Location: K 2.016

A 10.1 Mon 14:00 K 2.016

Nonequilibrium Quantum Phase Transition in a Hybrid Atom-Optomechanical System — •Niklas Mann[1], M. Reza Bakhtiari[1], Axel Pelster[2], and Michael Thorwart[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [2]Physics Department and Research Center OPTIMAS, Technical University of Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

We consider a hybrid quantum many-body system formed by both a vibrational mode of a nanomembrane, which interacts optomechanically with light in a cavity, and an ultracold atom gas in the optical lattice of the out-coupled light. After integrating over the light field, an effective Hamiltonian reveals a competition between the localizing potential force and the membrane displacement force. For increasing atom-membrane interaction we find a nonequilibrium quantum phase transition from a localized non-motional phase of the atom cloud to a phase of collective motion. Near the quantum critical point, the energy of the lowest collective excitation vanishes, while the order parameter of the condensate becomes non-zero in the symmetry-broken state. The effect occurs when the atoms and the membrane are non-resonantly coupled.

A 10.2 Mon 14:15 K 2.016

Second sound across the BEC-BCS crossover — •Vijay Pal Singh[1,2,3], Daniel Kai Hoffmann[4], Thomas Paintner[4], Wolfgang Limmer[4], Johannes Hecker Denschlag[4], and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany — [4]Institut für Quantenmaterie, Universität Ulm, 89081 Ulm, Germany

We report on the first and second sound measurements across the BEC-BCS crossover and their theoretical analysis. The measurements are performed in a cigar-shaped three-dimensional cloud of ^{6}Li atoms and molecules. First sound is excited by an external potential that couples to the density, while second sound is excited by a potential modulation resulting mainly in local heating. The velocity of first and second sound is extracted from the propagation of the excited density wave. We find that the second sound velocity is reduced with decreasing cloud density and vanishes at the superfluid-thermal boundary, whereas the first sound velocity is only weakly affected by the cloud density. We compare the experiments on the BEC side of the crossover to numerical simulations and find good agreement.

A 10.3 Mon 14:30 K 2.016

Zeeman Effect in Spinor Condensates: Tuning the Mott-Superfluid transition and the Nematic Order — •Laurent de Forges de Parny[1] and Valy Rousseau[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [2]Physics Department, Loyola University New Orleans, 6363 Saint Charles Ave., LA 70118, USA

Spinor condensates, namely Bose-Einstein condensates with internal degree of freedom, allow for the investigation of quantum magnetism [1]. When loaded into an optical lattice, these systems can be described by an extended Bose-Hubbard model with spin-spin interactions [2]. Using quantum Monte Carlo simulations, we study the Zeeman effect in a system of antiferromagnetic spin-1 bosons trapped in a square lattice at zero temperature. The Zeeman effect strongly affects the Mott-superfluid transition and the magnetic properties, e.g. the singlet state and the nematic order.

[1] D. M. Stamper-Kurn and M. Ueda, Rev. Mod. Phys. 85, 1191 (2013);
[2] A. Imambekov, M. Lukin, and E. Demler, Phys. Rev. A 68, 063602 (2003).

A 10.4 Mon 14:45 K 2.016

Spatial entanglement and Einstein-Podolsky-Rosen steering in a Bose-Einstein condensate — •Tilman Zibold, Matteo Fadel, Boris Décamps, and Philipp Treutlein — Department of Physics, University of Basel, Basel, Switzerland

We investigate the spatial entanglement in a spin squeezed Bose-Einstein condensate of rubidium atoms. By letting the atomic cloud expand and using high resolution absorption imaging we are able to access the spatial spin distribution of the many-body state. The observed spin correlations between different regions go beyond classical correlations and reveal spatial non-separability. Furthermore they allow for EPR steering of a subregion of the atomic spin. By inferring measurement outcomes of non-commuting observables in one region based on measurements in a separate region we are able to seemingly beat the Heisenberg uncertainty relation, realizing the EPR paradox with an atomic system. Our findings could be relevant for future quantum enhanced measurements of spatially varying observables such as electromagnetic fields.

A 10.5 Mon 15:00 K 2.016

A coherent perfect absorber for matter waves — •Jens Benary[1], Andreas Müllers[1], Bodhaditya Santra[1], Christian Baals[1,2], Jian Jiang[1], Ralf Labouvie[1,2], Dmitry A. Zezyulin[3,4], Vladimir V. Konotop[4], and Herwig Ott[1] — [1]Department of Physics and OPTIMAS research center, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, 55128 Mainz, Germany — [3]ITMO University, St. Petersburg 197101, Russia — [4]Centro de Física teórica e Computacional and Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Lisboa 1749-016, Portugal

A coherent perfect absorber is a system in which complete absorption of incoming radiation is achieved by a spatially localized absorber embedded in a wave-guiding medium. The concept of coherent perfect absorption (CPA) was introduced [1] for light interacting with absorbing scatterers. The phenomenon is based on the destructive interference of the transmitted and reflected waves. Extending the paradigm of CPA to nonlinear matter waves we find that the conditions for CPA can be achieved easier than in the linear case. This is due to the combination of a nonlinear medium with localized absorption stabilizing the system. We experimentally demonstrate CPA for matter waves with an atomic Bose-Einstein condensate of Rb-87 in a one-dimensional periodic potential with an absorbing lattice site. This absorption is tailored via an electron beam which locally induces losses.

[1] Y. D. Chong , L. Ge, H. Cao and A. D. Stone, Coherent Perfect Absorbers: Time-Reversed Lasers. Phys. Rev. Lett. 105 053901 (2010)

A 10.6 Mon 15:15 K 2.016

Phase separation dynamics in a many-body Binary Bose-Einstein condensate — •Simeon Mistakidis[1], Garyfallia Katsimiga[1], Panagiotis Kevrekidis[2], and Peter Schmelcher[1,3] — [1]Zentrum für optische Quantentechnologien Luruper Chaussee 149 22761 Hamburg — [2]Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003-4515, USA — [3]The Hamburg Centre for Ultrafast Imaging, Universitat Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The many-body quenched dynamics of a binary mixture crossing the miscibility-immiscibility boundary and vice versa, is examine. Increasing the interspecies repulsion leads to the filamentation of the density of each component, involving shorter wavenumbers (and longer spatial scales) in the many-body approach. These filaments appear to be strongly correlated both at the one- and the two-body level, exhibiting domain-wall structures. Furthermore, following the reverse quench process dark-bright soliton trains are spontaneously generated and subsequently found to decay in the many-body scenario. We utilize single-shot images to provide a clean experimental realization of our current findings via which the filamentation process is clearly captured. To expose further the many-body nature of the observed dynamics direct measurements of the variance of single-shots are performed, verifying the presence of fragmentation but also the entanglement between the species.

A 10.7 Mon 15:30 K 2.016

Approaching Steady-State Quantum Degeneracy — •Shayne Bennetts, Chun-Chia Chen, Rodrigo Gonzalez Escudero, Benjamin Pasquiou, and Florian Schreck — Institute of Physics, University of Amsterdam

So far BECs and atom lasers have only been demonstrated as the product of a time sequential, pulsed cooling scheme. Here we will describe a steady-state system demonstrating phase-space densities (PSD) approaching degeneracy. By flowing atoms through a series of spatially separated cooling stages and employing a range of novel tricks we recently demonstrated a steady-state strontium MOT with a PSD above 10^{-3} [1], 100 times higher than previous experiments. Now we demonstrate a set of tools, compatible with steady-state operation, to continuously cool and transfer microkelvin-cold atoms from a MOT into a dipole trap reservoir. Furthermore, by combining our novel machine architecture with a lighshift engineering technique we previously demonstrated [2], we protect a BEC from the strong fluorescence of a nearby MOT. Using all these tools on our high PSD MOT, quantum degeneracy in a steady-state system seems at reach. A steady-state source of degenerate atoms offers great advantages for applications such as next generation degenerate atomic clocks, super-radiant lasers or atom-interferometers for gravitational wave detection.

[1] S. Bennetts *et al.*, Phys. Rev. Lett. 119, 223202 (2017).
[2] S. Stellmer *et al.*, Phys. Rev. Lett. 110, 263003 (2013).

A 10.8 Mon 15:45 K 2.016

Role of thermal phonon scattering for impurity dynamics in low-dimensional BEC — •Tobias Lausch, Artur Widera, and Michael Fleischhauer — TU Kaiserslautern and Forschungszentrum OPTIMAS, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany

Ultracold gases have proven powerful systems to engineer quantum systems, paving the way for quantum simulations of solid state phenomena. An intriguing focus of research lies on impurity systems, aiming on elucidating microscopic properties of thermalization or quasi-particle formation in quantum systems.

We theoretically study the immersion of single impurities into a BEC in different spatial-dimensions and solve a Boltzmann equation to analyze the non-equilibrium dynamics. We find that high order scattering processes, such as two phonon scattering, dominate the impurities cooling dynamics in low dimensional BEC even at low (experimentally accessible) finite temperatures. In fact, these two-phonon scattering processes are the microscopic mechanism reflecting the famous Mermin-Wagner-Hohenberg theorem. Our work undelines the necessity to include higher-order scattering terms in the investigation of low-dimensional impurity physics.

A 10.9 Mon 16:00 K 2.016

Prospects for studying atom-ion interaction with giant Rydberg atoms in a Bose-Einstein condensate — •Felix Engel, Kathrin Kleinbach, Thomas Dieterle, Carolin Dietrich, Robert Löw, Florian Meinert, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

Giant Rydberg atoms immersed in ultracold quantum gases realize situations where thousands of ground-state atoms reside within the Rydberg electron orbit. In our experiments, we study the interaction of a single highly excited Rydberg electron ($n \sim 200$) with a Bose-Einstein condensate (BEC). The interaction of the Rydberg electron with the condensate atoms causes a density-dependent spectral line shift and broadening of the Rydberg excitation, which reflects the underlying scattering physics.

Using a tightly focused optical microtrap we access a parameter regime for which the Rydberg electron orbit largely exceeds the spatial extent of the BEC. This reduces the contribution of electron-neutral interaction with increasing n to the observed excitation spectrum. Consequently, the interaction of the condensate atoms with the Rydberg ionic core is expected to actively shape the spectral response, which provides an appealing route to study atom-ion interaction in a BEC.

A 11: X-Ray and XUV Spectroscopy (joint session MO/A)

Time: Monday 14:00–15:45 Location: PA 2.150

Invited Talk A 11.1 Mon 14:00 PA 2.150

Theoretical soft X-ray spectroscopy of transition metal compounds: A multi-reference wave function approach — •Sergey I. Bokarev — Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18059, Rostock

To date, X-ray spectroscopy has become a routine tool that can reveal highly local and element-specific information on the electronic structure of atoms in complex environments. Here, we aim at the development of an efficient and versatile theoretical methodology for the treatment of soft X-ray spectra of transition metal compounds mainly based on the multi-configurational self-consistent field electronic structure theory combined with a perturbative LS-coupling scheme for spin-orbit coupling. A special focus is put on the L-edge photon-in/photon-out and photon-in/electron-out processes, i.e. X-ray absorption, resonant inelastic scattering, partial fluorescence yield, photoelectron and Auger spectroscopy treated on the same theoretical footing. We address the application of the X-ray metal L-edge and ligand K-edge as well as XUV spectroscopy to unraveling electronic structure and nature of chemical bonds, oxidation and spin-states, the interplay of radiative and non-radiative decay channels, fingerprints of nuclear dynamics and non-adiabatic transitions as well as ultrafast electron dynamics triggered by X-ray light. The investigated systems range from the small prototypical coordination compounds and catalysts to the aggregates of biomolecules.

A 11.2 Mon 14:30 PA 2.150

Solving the Graphene Oxide Puzzle - a TDDFT-XAS Study — •Fabian Weber, Jian Ren, Tristan Petit, and Annika Bande — Helmholtz-Zentrum Berlin

Graphene Oxide (GO) quantum dots and its derivatives have proven to be a resource efficient material for photocatalytic water splitting. Due to the amorphous nature of GO derived materials, it has however not been possible yet to fully understand what structural features are allowing the catalytic reaction.

Since X-Ray spectroscopy is a standard technique to identify neighbouring functionalities in a very selective way, we developped a time-dependent density functional theory (TDDFT) approach to probe the constitution of single specific atoms in model systems in a meaningful way. Since these localized Carbon K-edge XAS-spectra have shown to be specific up to about 3 chemical bonds, we may use a multitude of model systems of relatively small size to generate a surrounding-specific database of several unique functionalization patterns.

In this talk we show how systematic comparison of this database of several hundreds of different surrounding-specific XAS spectra with experimental data leads to a straightforward method to gain insights on structural features of amorphous materials.

A 11.3 Mon 14:45 PA 2.150

Hydrogen bond dissociation dynamics of indole-water clusters — •Melby Johny[1], Thomas Kierspel[1,2], Joss Wiese[1,2], Jolijn Onvlee[1], Helen Bieker[1,2], Terry Mullins[1,2], Andrea Trabattoni[1], Ruth Livingstone[1,2], Sebastian Trippel[1,2], Jochen Küpper[1,2,3], and and others[1,2,3] — [1]Center for Free Electron Laser Science (CFEL), Deutsches Elektronen Synchrotron (DESY), Hamburg, Germany — [2]The Hamburg Center for Ultrafast Imaging, University of Hamburg, Germany — [3]Department of Physics, University of Hamburg, Germany

The properties of atoms and molecules are strongly dependent on their local environment and hydrogen bonds are of universal importance in chemistry and biochemistry. Therefore, it is highly desirable to bridge the gap between single, isolated molecules and molecules in solvation. Photophysics of microsolvated indole is significantly relevant being strongest UV chromophore of tryptohan as well as the structure of singly hydrogen bonded indole-water cluster is known [1].

Here, we show our recent experiment performed at LCLS at SLAC for the investigation of hydrogen bond breaking dynamics of indole-water clusters via UV-pump (266 nm) and x-ray probe (2.5 nm) photoelectron-photoion-photoion-coincidence (PEPIPICO) imaging. Our preliminary analysis shows timedependent dissociation channels with distinguishable velocities for hydronium ions detected in coincidence with the photo-fragments of indole.

[1] Korter, Pratt, Küpper, J. Phys. Chem. A 1998, 102, 7211-7216

A 11.4 Mon 15:00 PA 2.150

Time-Resolved Pump-Probe Spectroscopy of XUV-induced Dynamics in Water, Ammonia and Methanol Clusters — •Rupert Michiels[1], Aaron LaForge[1], Matthias Bohlen[1], Carlo Callegari[2], Andrew Clark[3], Marcel Drabbels[3], Kevin C. Prince[2], Stefano Stranges[4], Marcello Coreno[5], Oksana Plekan[2], Veronica Oliver[3], Aaron von Conta[6], Martin Huppert[6], Hans-Jakob Wörner[6], and Frank Stienkemeier[1] — [1]Universität Freiburg, Germany — [2]Elettra-Sincrotrone Trieste, Italy — [3]Ecole Polytechnique Féderale de Lausanne, Switzerland — [4]University Sapienza, Italy — [5]ISM-CNR, Trieste, Italy — [6]ETH Zürich, Switzerland

Results for ammonia, methanol and water clusters investigating the dynamics upon XUV ionization with the FERMI free electron laser are presented. In an XUV-UV pump-probe scheme we obtain a time-resolved picture of the resulting fragments and their electronic states. Recombination and molecular dissociation lead to a great variety of electron energies and ionic fragments that give insight into the underlying dynamics. The vertical detachment energies of the electrons and masses of the ions were measured by means of a VMI velocity map imaging detector combined with a time-of-flight mass spectrometer which also allows a covariance analysis.

Invited Talk A 11.5 Mon 15:15 PA 2.150

Tracing the spatial and electronic structure of excited molecules using X-ray FEL and HHG light — •Kirsten Schnorr — Max-Planck-Institut für Kernphysik — University of California Berkeley

Free-Electron Lasers (FELs) are capable of producing intense and ultrashort X-ray pulses, which enable femtosecond time-resolved diffractive imaging experiments. This allows to initiate chemical reactions in molecules using an optical pump pulse and probing the induced changes in the nuclear structure by X-ray scattering using a delayed FEL pulse. Here, results on the strong-field induced dynamics of C_{60} molecules probed by soft and hard X-ray scattering will be presented.

A soft X-ray source based on high harmonic generation with photon energies up to 310 eV has been successfully commissioned and first time-resolved experiments carried out. Transient absorption experiments on the UV-induced dynamics of small carbon containing molecules, probed with a broadband soft X-ray pulse, will be shown.

A 12: Cold atoms IV - topological systems (joint session A/Q)

Time: Monday 16:15–17:30 Location: K 0.011

A 12.1 Mon 16:15 K 0.011

Properties of the one-particle density matrix in an interacting Chern insulator — •Andrew Hayward[1], Marie Piraud[2], and Fabian Heidrich-Meisner[2,3] — [1]LMU, Munich, Germany — [2]TU, Munich, Germany — [3]Georg-August-University Goettingen, Germany

The notion of a topological insulator is rooted in the physics of non-interacting particles but generalizes to interacting systems. Here we investigate how much the topological properties of an interacting Chern insulator are encoded in the single-particle quantities derived from the one-particle density matrix (OPDM) computed in the many-body ground state. The diagonalization of the OPDM yields the occupation spectrum and its eigenfunctions. In a concrete example we study how the occupations evolve as a function of interactions and how the eigenfunctions are deformed away from the non-interacting limit. After resolving potential ambiguities in defining OPDM eigenbands,we compute the Chern numbers for these emergent OPDM bands,which are necessarily quantized. The behavior of these quantities, occupations, OPDM eigenfunctions, and OPDM Chern numbers, across a transition into a topologically trivial phase is discussed.This research is supported by DFG Research Unit FOR2414.

A 12.2 Mon 16:30 K 0.011

Local topological invariant of an interacting, time-reversal-symmetric Hofstadter interface — •Bernhard Irsigler, Jun-hui Zheng, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main

Two-dimensional topological insulators possess conducting edge states at their boundary while being insulating in the bulk. However, the detection of edge states remains an open question in ultracold atom setups. We propose a configuration to implement a topological interface within the experimentally realizable Hofstadter model which gives rise to a topological phase boundary at the center of the system, and investigate the influence of two-body interactions in a fermionic system. The location of the boundary can in principle be detected via the spatially resolved compressibility of the system with a quantum gas microscope. Furthermore, we compute a local topological invariant through adiabatic pumping which confirms the topological phase separation.

A 12.3 Mon 16:45 K 0.011

Topological invariant for 2D open systems — •Jun-Hui Zheng and Walter Hofstetter — Goethe-Universität, 60438 Frankfurt am Main, Germany

We study the topology of 2D open systems in terms of the Green's function. The Ishikawa-Matsuyama formula for the integer topological invariant is applied in open systems and the equivalent descriptions through topological Hamiltonian and Berry curvature are developed separately. The invariant is well-defined iff all of the eigenvalues of the Green's function for imaginary frequency are finite nonzero numbers. Meanwhile, we define another topological invariant via the single particle density matrix, which works for general gapped systems and is equivalent to the former for the case of weak coupling to an environment. We also discuss two applications. For time-reversal invariant insulators, we explain the relation between the invariant for each spin-subsystem and the Z_2 index of the full system. As a second application, we consider the interference effect when an ordinary insulator is coupled to a topological insulator. The bulk-boundary correspondence of the open system shows new features.

A 12.4 Mon 17:00 K 0.011

Topological phase transition in 2D interacting disordered systems — •Jun-Hui Zheng and Walter Hofstetter — Goethe-Universität, 60438 Frankfurt am Main, Germany

We study the topological phase transition and the transport properties in two-dimensional interacting disordered systems. A generalized Ishikawa-Matsuyama formula is developed as a topological index.

Without considering the vertex correction of current operators, it corresponds to the Hall conductance of the system, within the dynamical mean-field approximation. As an example, we consider the spinful Haldane-Hubbard model. The averaged Hall conductance over different configurations of disorder is evaluated and the interaction effects are token into account by employing the dynamical mean-field theory. The finite size effects of the system are also discussed.

A 12.5 Mon 17:15 K 0.011

Hidden order and symmetry protected topological states in quantum link ladders — •Lorenzo Cardarelli[1], Sebastian Greschner[2], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Department of Quantum Matter Physics, University of Geneva , 1211 Geneva, Switzerland

We show that whereas spin-1/2 one-dimensional U(1) quantum-link models (QLMs) are topologically trivial, when implemented in ladder-like lattices these models may present an intriguing ground-state phase diagram, which includes a symmetry protected topological (SPT) phase that may be readily revealed by analyzing long-range string spin correlations along the ladder legs. We propose a simple scheme for the realization of spin-1/2 U(1) QLMs based on single-component fermions loaded in an optical lattice with *s*- and *p*-bands, showing that the SPT phase may be experimentally realized by adiabatic preparation.

A 13: Fundamentals

Time: Monday 16:15–18:00 Location: K 1.011

Invited Talk A 13.1 Mon 16:15 K 1.011

Quantum teleportation via electron-exchange collisions — •Bernd Lohmann[1,2], Karl Blum[2], and Burkhard Langer[3] — [1]The Hamburg Centre For Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Straße 9, 48149 Münster, Germany — [3]Physikalische Chemie, Freie Universität Berlin, Takustraße 3, 14195 Berlin, Germany

In recent research [1,2], we have shown that strong correlations exist in elastic electron-exchange collisions of light hydrogen-like atoms, violating Bell's inequalities significantly, which allow for generating tunable spin pairs with any desired degree of entanglement. Utilizing our tunable entanglement resource, we will discuss the possibility of performing quantum teleportation with free massive particles applying a twofold elastic electron-exchange scattering. In a first collision, an unpolarized electron will be scattered on an unpolarized atom, generating an entangled electron-atom pair. Subsequently, in a second scattering, an arbitrarily polarized electron will collide with the entangled atom thereby generating interference which allows for teleporting the degree of spin polarization onto the former unpolarized electron. We will demonstrate the feasibility of such experiments.

[1] Blum K., and Lohmann, B., Phys. Rev. Lett. 116, 033201 (2016).
[2] Lohmann, B., Blum, K., and Langer, B., Phys. Rev. A 94, 032331 (2016).

Invited Talk A 13.2 Mon 16:45 K 1.011

Probing the forces of blackbody radiation and dark energy with matter waves — •Philipp Haslinger[1], Viktoria Xu[1], Matt Jaffe[1], Osip Schwartz[1], Paul Hamilton[2], Benjamin Elder[3], Justin Khoury[3], Matthias Sonnleitner[5], Monika Ritsch-Marte[4], Helmut Ritsch[5], and Holger Müller[1] — [1]UC Berkeley, USA — [2]UC Los Angeles, USA — [3]UPenn, USA — [4]Med-Uni Innsbruck, AUT — [5]Uni Innsbruck, AUT

In this talk I will give an overview of our recent work using an optical cavity enhanced atom interferometer to sense with gravitational strength for fifths forces and for an on the first-place counter intuitive inertial property of blackbody radiation. Blackbody (thermal) radiation is emitted by objects at finite temperature with an outward energy-momentum flow, which exerts an outward radiation pressure. At room temperature e.g. a Cs atom scatters on average less than one of these photons every 10^8 years. Thus, it is generally assumed that any scattering force exerted on atoms by such radiation is negligible. However, particles also interact coherently with the thermal electromagnetic field and this leads to a surprisingly strong force acting in the opposite direction of the radiation pressure. If dark energy, which drives the accelerated expansion of the universe, consists of a screened scalar field (e.g. chameleon models) it might be detectable as a "5th force" using atom interferometric methods. By sensing the gravitational acceleration of a 0.19kg in vacuum source mass, we reach a natural bound for cosmological motivated scalar field theories and were able to place tight constraints.

A 13.3 Mon 17:15 K 1.011

New Laboratory Probes for Low-Mass Dark Matter and Dark Bosons — •Yevgeny Stadnik[1] and Victor Flambaum[2] — [1]Johannes Gutenberg University of Mainz, Germany — [2]University of New South Wales, Australia

Low-mass bosonic dark matter particles produced after the Big Bang may form an oscillating classical field, which can be sought for in a variety of low-energy laboratory experiments based on spectroscopic, interferometric and magnetometric techniques. Dark bosons can also mediate anomalous fifth forces between ordinary-matter particles that can be sought for in laboratory experiments. Recent measurements in atoms and astrophysical phenomena have already allowed us to improve on existing constraints on various non-gravitational interactions between dark bosons and ordinary-matter particles by many orders of magnitude.

References: Phys. Rev. D 89, 043522 (2014); Phys. Rev. Lett. 113, 081601 (2014); Phys. Rev. D 90, 096005 (2014); Phys. Rev. Lett. 113, 151301 (2014); Phys. Rev. Lett. 114, 161301 (2015); Phys. Rev. A 93, 063630 (2016); Phys. Rev. Lett. 115, 201301 (2015); Phys. Rev. A 94, 022111 (2016); Phys. Rev. Lett. 117, 271601 (2016); arXiv:1708.00486; arXiv:1708.06367 - Phys. Rev. X (In press); arXiv:1709.10009 - Phys. Rev. Lett. (In press).

A 13.4 Mon 17:30 K 1.011

Spin nonconservation in Compton scattering — •Sven Ahrens and Chang-Pu Sun — Beijing Computational Science Research Center Building 9, East Zone, ZPark II, No.10 East Xibeiwang Road, Haidian District, Beijing 100193, China

Spin effects of diffracted electrons in standing light waves opens the question, on whether the dynamics might be determined by selection rules based on spin conservation [1]. To answer this question, we investigate the simplest possible system (an electron interacting with a single photon field) and investigate the corresponding S-matrix for the case of 180 degree back scattering of the photon [2]. We construct a scenario with specific incoming and outgoing particle momenta, in which it becomes clear that the combined spin (intrinsic angular momentum) of the photon and electron is not conserved, when comparing before and after their interaction. We also show the angle resolved behavior of electron and photon spin and discuss the establishment of spin entanglement between the outgoing particles.

[1] D. L. Freimund and H. Batelaan, Laser Phys. 13, 892 (2003).
[2] arXiv:1708.09606 (accepted, to appear in Phys. Rev. A)

A 13.5 Mon 17:45 K 1.011

Entanglement in doubly excited states of helium — •Alejandro Gonzalez Melan and Javier Madroñero Pabon — Physics department, Universidad del Valle, Cali, Colombia

We compute the entanglement of doubly excited states of helium below the 3rd and 4th ionization thresholds. For that purpose we use a planar representation of the helium atom. The amount of the entanglement tends to increase with energy and allows us to classify series of doubly excited states. We also discuss the effect of a peridic driving by an external field on entanglement. In particular, we focus on the entanglement for two-electron nondispersive wave packets in planar helium. These are quantum objects that propagate along periodic trajectories of the classical three-body Coulomb problem and they are formed by a near-resonantly periodic driving of the Zee configuration of helium.

A 14: Precision Spectrosocopy III - trapped ions (joint session A/Q)

Time: Monday 16:15–17:45 Location: K 1.016

Invited Talk A 14.1 Mon 16:15 K 1.016

Collinear Laser Spectroscopy for High Voltage Metrology at the 1 ppm accuracy level — •Jörg Krämer[1], Kristian König[1], Christopher Geppert[2], Phillip Imgram[1], Bernhard Maass[1], Johann Meisner[3], Ernst W. Otten[4], Stephan Passon[3], Tim Ratajczyk[1], Johannes Ullmann[5], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]Institut für Kernchemie, Johannes Gutenberg Universität Mainz — [3]Physikalisch-Technische Bundesanstalt, Braunschweig — [4]Institut für Physik, Johannes Gutenberg Universität Mainz — [5]Institut für Kernphysik, Westfälische Wilhelms-Universität Münster

Voltages of the order of a few Volts can be traced back to a Josephson standard that converts a microwave frequency to a voltage by inducing a current between two superconductors. However, high voltages cannot be traced back directly, but have to be divided down by precision high voltage dividers that reach a relative accuracy of 1 ppm at best.

Similar to the Josephson effect, collinear laser spectroscopy connects the laser frequency in the laboratory frame to the high voltage used to accelerate the ions via the Doppler shift. Since this frequency can be measured with 1 Hz precision using an optical frequency comb, this technique has the potential to reach an accuracy of <1 ppm.

We will present results of laser spectroscopic high voltage measurements using a pump and probe scheme on Ca ions at the 5 ppm level, and we will elaborate on how we plan to further decrease our uncertainties by using indium ions from a liquid metal ion source and an alternative pump and probe approach.

A 14.2 Mon 16:45 K 1.016

Measuring the temperature and heating rate of a trapped single ion by imaging — •Bharath Srivathsan[1,2], Martin Fischer[1,2], Lucas Alber[1,2], Markus Weber[1,2], Markus Sondermann[1,2], and Gerd Leuchs[1,2,3] — [1]Max-Planck-Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander University Erlangen - Nürnberg (FAU), Department of Physics, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Canada

We present a technique to measure the temperature and the heating rate of a Doppler-cooled, single ion confined in a harmonic trap. In our experiment, we use a single $^{174}Yb^+$ ion trapped at the focus of a parabolic mirror covering almost 4π solid angle. The fluorescence light scattered by the ion from the cooling laser is imaged onto an EMCCD camera. We measure the size of this image while varying the power of the cooling laser. From this measurement data, we determine the heating rate by a fit to a well-known theoretical model for cooling in a trap [1]. Our method enables one to measure the heating rate directly at the Doppler limit, i.e. in a regime which is generally inaccessible to other common techniques.

[1] Stig Stenholm, Rev. Mod. Phys. 58, 699 (1986).

A 14.3 Mon 17:00 K 1.016

Optical ion traps for investigation of atom-ion interactions — •Markus Debatin, Pascal Weckesser, Fabian Thielemann, Yannick Minet, Julian Schmidt, Leon Karpa, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs Universität Freiburg, Germany

We demonstrate optical trapping of $^{138}Ba^+$ ions in absence of any rf-confinement for durations of up to 3 seconds [1] as well as optical trapping of Coulomb crystals. With the trapping probability approaching unity for durations of 100 ms and with low heating, and electronic decoherence rates, our results establish optical ion trapping as a novel and robust tool for the manipulation of cold trapped ions, e.g. in atom-ion interaction experiments [2,3]. We give an update of our experiments, which combine the Ba^+ ion with bosonic ^{87}Rb and fermionic ^{6}Li atoms in order to explore ultracold interactions.

[1] A. Lambrecht et al., Nature Photonics **11.11** 704 (2017)
[2] see e.g.: A. Grier et al., PRL **102**, 223201 (2009)
[3] M. Tomza et al. *arXiv:1708.07832 (2017)

A 14.4 Mon 17:15 K 1.016

Fock state interferometry: The single ion quantum pendulum — •Fabian Wolf[1], Chunyan Shi[1], Jan C. Heip[1], Manuel Gessner[2], Luca Pezzè[2], Augusto Smerzi[2], Marius Schulte[3], Klemens Hammerer[3], and Piet O. Schmidt[1,4] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]QSTAR, INO-CNR and LENS, Firenze, Italy — [3]Institute for Theoretical Physics, Institute for Gravitational Physics (Albert Einstein Institute), Leibniz Universität, Hannover, Germany — [4]Institut für Quantenoptik, Leibniz Universität, Hannover, Germany

The motion of a single trapped ion constitutes a physical implementation of the quantum mechanical harmonic oscillator that is controllable on the single quantum level.

We demonstrate frequency and amplitude measurements of this "quantum pendulum" with sensitivities below what is achievable with its classical counterpart.

For this purpose we prepare the ion in motional Fock states. The non-classical features of these states provide metrological gain independent of the relative phase of the ion's oscillation with respect to the local oscillator, which is a major advantage over non-classical probing schemes based on squeezing or Schrödinger cat states and allows quantum-enhanced probing of two conjugate variables with the same state. We present a metrological analysis of our probing scheme based on the Fisher information and via an Allan-deviation analysis for both a trapping frequency and an oscillation amplitude measurement.

A 14.5 Mon 17:30 K 1.016

Test of the isotropy of space with a high-precision long-term comparison of two single-ion optical clocks — •Richard Lange, Christian Sanner, Nils Huntemann, Burghard Lipphardt, Christian Tamm, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We employ two $^{171}Yb^+$ single-ion optical frequency standards that differ significantly with respect to trap geometry, control software and interrogation sequence. The clock frequency is determined by the $^2S_{1/2} \rightarrow {}^2F_{7/2}$ electric octupole (E3) transition. The relative systematic uncertainty of the clocks has been evaluated to less than 4×10^{-18} [PRL **108**, 090801 (2016)]. In a long-term comparison of the two clocks for a period of seven month with a duty cycle of up to 95 % per day, we found an agreement of the clock frequencies within the systematic uncertainty. Due to the electronic structure of the $^2F_{7/2}$ state, the E3 transition frequency is very sensitive to violations of Local Lorentz Invariance (LLI) [Nature Physics **12**, 465 (2016)]. In our experiment, this violation would manifest itself in a modulation of the clocks' frequency difference caused by the rotation of the earth in space. Analyzing our long-term data with millihertz resolution, we improve the current limits of violations of LLI in the electron sector by a factor of 100.

A 15: Ultracold Plasmas and Rydberg Systems II (joint session Q/A)

Time: Monday 16:15–17:30 Location: K 2.013

A 15.1 Mon 16:15 K 2.013

Metastable decoherence-free subspaces and electromagnetically induced transparency in interacting many-body systems — •Katarzyna Macieszczak[1,2], YanLi Zhou[3], Sebastian Hofferberth[4], Juan P. Garrahan[1,2], Weibin Li[1,2], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham NG7 2RD, United Kingdom — [3]College of Science, National University of Defense Technology, Changsha 410073, China — [4]Department of Physics, Chemistry and Pharmacy, University of Southern Denmark, Odense, Denmark

We investigate the dynamics of a generic interacting many-body system under conditions of electromagnetically induced transparency (EIT). This problem is of current relevance due to its connection to nonlinear optical media realised by Rydberg atoms. In an interacting system the structure of the dynamics and the approach to stationarity become far more complex than in the case of conventional EIT as a metastable decoherence-free subspace emerges, whose dimension for a single Rydberg excitation grows linearly in the number of atoms. We discuss the effective slow nonequilibrium dynamics, which features coherent and dissipative two-body interactions, and renders the typical assumption of fast relaxation invalid. We also show how this scenario can be utilised for the preparation of collective entangled dark states and the realisation of general unitary dynamics within the spin-wave subspace.

A 15.2 Mon 16:30 K 2.013

Realization of a XXZ-model using Rydberg atoms — •Renato Ferracini Alves[1], Miguel Ferreira Cao[1], Titus Franz[1], Martin Gärttner[2], Asier Piñeiro Orioli[3], Andre Salzinger[1], Adrien Signoles[1], Nithiwadee Thaicharoen[1], Shannon Whitlock[1,4], Gerhard Zürn[1], Jürgen Berges[3,5], and Matthias Weidemüller[1,6] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]Kirchhoff-Institut für Physik, Universität Heidelberg, Germany — [3]Institut für Theoretische Physik, Universität Heidelberg, Germany — [4]IPCMS and ISIS, University of Strasbourg and CNRS, Strasbourg, France — [5]ExtreMe Matter Institute EMMI, Darmstadt, Germany — [6]Shanghai Branch, University of Science and Technology of China, Shanghai, China

Cold Rydberg gases are a suitable platform for studying quantum many body dynamics, due to its strong and long range interactions. Questions regarding thermalization in closed quantum systems and relaxation dynamics after a quench can be addressed experimentally. This project investigates the many body dynamics of a few thousand disordered Rydberg atoms. In particular we realize a Heisenberg XXZ spin model by mapping two interacting Rydberg states to an effective spin 1/2 system. Coupling these states with a phase-controlled microwave radiation, allows us to perform arbitrary global initial state-preparation and, together with state selective ionization, a state-tomographic detection. With these techniques we extract the magnetization and study its time evolution. In this talk we will focus on recent measurements of the spin dynamics after a quench.

A 15.3 Mon 16:45 K 2.013

Quasi-particle spectra of bosonic Rydberg-dressed many-body phases — •Andreas Geissler[1], Yongqiang Li[2], Weibin Li[3], Ulf Bissbort[4], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Woalfgang Goethe-Universität, Frankfurt/Main — [2]Department of Physics, National University of Defense Technology, Changsha, China — [3]School of Physics and Astronomy, University of Nottingham — [4]SUTD, Singapore

As recent experiments have demonstrated the feasibility of Rydberg dressing [1], even in a lattice system [2], the stage is set for realizing (long predicted) exotic states of matter in ultracold gases. Our latest results (simulated in real-space bosonic dynamical mean-field theory RB-DMFT) have shown a rich diversity of crystalline and supersolid quantum phases, both close to resonant driving [3] and in the weak dressing limit [4]. While in the former case we predict a reduction of the Rydberg fraction compared to single atom dressing, we show in the latter case how a two-species mixture can make the realization of a supersolid more accessible. Based on these results we applied a quasi-particle method based on linearized Gutzwiller dynamics (Gqp), to predict various spectral functions for both cases and in an experimentally feasible regime. As RB-DMFT also predicts spectral properties, it serves as a benchmark for Gqp. We furthermore characterize the various observed gapped and ungapped quasi-particle modes.

[1] Y.-Y. Jau et al., Nat. Phys. 12, 71-74 (2016) [2] J. Zeiher et al., Nat. Phys. 12, 1095-1099 (2016) [3] A. Geißler et al., Phys. Rev. A 95, 063608 (2017) [4] Y. Li et al., arXiv:1705.01026

A 15.4 Mon 17:00 K 2.013

Localisation dynamics in a disordered Rydberg ladder — •Maike Ostmann[1,2], Jiri Minar[1,2], Matteo Marcuzzi[1,2], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham

Rydberg lattice systems are currently studied in a number of laboratories worldwide as they constitute a promising platform for quantum information processing and the quantum simulation of many-body systems out of equilibrium. We are studying the transport of excitations in Rydberg systems under the so-called facilitation condition, where the excitation of an atom to a Rydberg state is strongly enhanced by an excited neighbour. In particular we are interested in understanding the impact of disorder caused by the uncertainty of the atomic positions within the individual lattice sites. In a recent work, a connection between localisation in real space and configuration (Fock) space was established. Building on this, we are investigating the localisation phenomena in a Rydberg ladder forming a so-called Lieb lattice in configuration space. A Lieb lattice supports a macroscopically degenerate flat band which gives rise to localised eigenstates in the absence of disorder. We are exploring the influence of the disorder on these localised eigenstates. Introducing disorder to our system leads to a non-monotonic behaviour of the localisation as a function of the interaction strength. Furthermore, we are studying how different types of disorder effect the scaling of the localisation length.

A 15.5 Mon 17:15 K 2.013

Self-consistent theory of energy diffusion in ultracold Rydberg gases — •Katharina Hess, Andreas Buchleitner, and Thomas Wellens — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Herman-Herder-Straße 3, 79104 Freiburg, Deutschland

Due to their high degree of controllability, gases of ultracold Rydberg atoms are a good testbed to study fundamental questions of transport in spatially disordered quantum networks. In this talk, we will examine the transfer of a single Rydberg excitation mediated by coherent dipole-dipole interactions. We show that the dipole blockade effect can be used to change the character of transport from subdiffusive to diffusive [1]. In the latter case, we apply a self-consistent diagrammatic approach [2] in order to determine the value of the diffusion constant.

[1] T. Scholak, T. Wellens and A. Buchleitner, Phys. Rev. A 90, 063415 (2014)

[2] T. Wellens and R. A. Jalabert, Phys. Rev. B 94, 144209 (2016)

A 16: Atomic Clusters I (joint session A/MO)

Time: Monday 16:15–17:45 Location: K 2.016

Invited Talk A 16.1 Mon 16:15 K 2.016

Halo states in helium dimers/trimers — •Reinhard Doerner[1], Maksim Kunitski[1], Stefan Zeller[1], Lothar Schmidt[1], Till Jahnke[1], Markus Schöffler[1], Dörte Blume[2], Jörg Voitsberger[1], Florian Trinter[1], and Anton Kalinin[1] — [1]Goethe Universität Frankfurt Germany — [2]Washington State University USA

We will show experimental imaging the Helium dimer, trimer and the Efimov state of He3. We will also show movies of the rotational response of halo states to a nonresonant short laser pulse.

A 16.2 Mon 16:45 K 2.016

Rotating rotationless: nonadiabatic alignment of the helium dimer — •Maksim Kunitski[1], Qingze Guan[2], Stefan Zeller[1], Dörte Blume[2], and Reinhard Dörner[1] — [1]Institut für Kernphysik, Goethe-Universität Frankfurt am Main — [2]Department of Physics and Astronomy, University of Oklahoma

Quantum mechanically rotational and vibrational dynamics in molecules is time evolution of corresponding wave packets. Such dynamics can be periodic, as well-known rotational and vibrational revivals with wave packets consisting of many coherently prepared bound states. How the rotational and vibrational dynamics would look like in a molecular system with a single bound state? One of such extreme quantum system is the helium dimer, where the two-body potential supports only one state.

We applied the nonadiabatic "kick" to the helium dimer by a femtosecond laser pulse (pump) and watched evolution of the system by Coulomb explosion imaging, which was initiated by the second much more intense delayed probe pulse. The observed time-dependent alignment of the helium dimer, as well as time evolution of the rovibronic wave packet, is going to be discussed.

A 16.3 Mon 17:00 K 2.016

Evidence of angulon quasiparticles formation in superfluid ^{4}He nanodroplets — •Igor Cherepanov, Giacomo Bighin, and Mikhail Lemeshko — IST Austria (Institute of Science and Technology Austria), Am Campus 1, 3400, Klosterneuburg, Austria

Quasiparticles are a core concept in many-body physics widely used for solving quantum impurity problems [1]. Models based on quasiparticles serve as an alternative to theories implying extensive numerical calculations. Moreover, they provide a more straightforward and intuitive understanding of complex phenomena taking place in many-body systems. Here we present the evidence for the formation of angulon quasiparticles [2] in experiments on trapping molecules in superfluid ^{4}He nanodroplets. The angulon consists of a rotating impurity (such as a molecule) dressed by a field of surrounding bath excitations (phonons, rotons etc.). Anisotropic interactions of the impurity with helium give rise to a number of many-body effects, such as angulon instabilities – resonant transfer of a small amount of angular momentum from the molecule to the superfluid. We demonstrate that broadening and splitting of spectral lines as well as a violation of rotational selection rules can be explained by means of angulon instabilities [3]. Furthermore, the dynamical emergence of angulon instabilities affects the time evolution of a rotational wavepacket and therefore may be detected in experiments on impulsive molecular alignment in ^{4}He droplets.

[1] M. Lemeshko, Phys. Rev. Lett. **118**, 095301 (2017)
[2] R. Schmidt, M. Lemeshko, Phys. Rev. Lett. **114**, 203001 (2015)
[3] I. Cherepanov, M. Lemeshko, Phys, Rev. Materials **1**, 035602 (2017)

A 16.4 Mon 17:15 K 2.016

Decoherence in the dissociation of the alkali-helium droplet system — •Marcel Binz, Lukas Bruder, Ulrich Bangert, Daniel Uhl, and Frank Stienkemeier — Institute of Physics, University of Freiburg, Germany

The intriguing properties of the alkali (Ak)-helium droplet system have been extensively studied in the past by several groups. The broadened Ak absorption lines were successfully explained by a pseudo-diatomic molecule model, and the dissociation of this pseudo molecular system was studied in detail with fs pump probe experiments. As an intriguing aspect of the dissociation, we have in a recent study investigated the temporal evolution of an electronic coherence induced in the parent system and follow this evolution in the desorbing Ak atom. For this purpose, we have applied coherent nonlinear spectroscopy to our helium droplet machine. Our scheme is particularly sensitive to the time evolution of coherences and allows us to follow the dissociation with high spectro-temporal resolution.

A 16.5 Mon 17:30 K 2.016

Resonante Ionisation dotierter Heliumtropfen — •Michael Kelbg[1], Lev Kazak[1], Michael Zabel[1], Andreas Heidenreich[2], Josef Tiggesbäumker[1] und Karl-Heinz Meiwes-Broer[1] — [1]Universität Rostock, Inst. f. Physik, Rostock, Germany — [2]Ikerbasque, Basque Foundation for Science, Bilbao, Spain

Heliumtropfen sind für NIR-Laserpulse transparent und können erst bei hohen Intensitäten durch Feldionisation ionisiert werden. Durch eine Dotierung des Tropfens mit Metallen oder anderen Edelgasen als Ionisationskeim ist es jedoch bereits für deutlich niedrigere Intensitäten möglich den gesamten Heliumtropfen lawinenartig zu ionisieren. Besonders effektiv wird dieser Prozess durch Anregung mittels zwei getrennter Pulse, wobei der erste Puls ein Plasma erzeugt, und der zweite Puls dann durch Erreichen der Bedingungen für die Mie-Resosanz einen optimalen Energietransfer ermöglicht.

Eine Dotierung mit Xenon führt zu einem leicht zu ionisierendem Cluster im Zentrum des Heliumtropfens. Die Effektivität einer resonanten Anregung äußert sich hier durch die Erzeugung von sehr hohen Ladungszuständen des Xenons bis zu Xe23+. Ein völlig anderes Bild zeigt sich bei Dotierung mit Magnesium. Dieses bildet zunächst einen sogenannten Magnesiumschaum, bei dem die einzelnen Magnesiumatome im Abstand von 10 Å voneinander in einem metastabilen Zustand verharren. Durch Anregung des Magnesiums unterhalb der Ionisationsenergie lässt sich ein Kollaps des Magsiumschaums induzieren.

Zuletzt wird die Elektronenemission aus dem Tropfen bei unterschiedlicher Dotierung und Anregung untersucht.

A 17: Atoms in external fields

Time: Monday 16:15–17:45 Location: K 2.019

A 17.1 Mon 16:15 K 2.019

Observation of the motional Stark effect in low magnetic fields — •Manuel Kaiser[1], Jens Grimmel[1], Lara Torralbo-Campo[1], Florian Karlewski[1], Nils Schopohl[2], and József Fortágh[1] — [1]Center for Quantum Science, Physikalisches Institut, Universität Tübingen, Germany — [2]Center for Quantum Science, Institut für Theoretische Physik, Universität Tübingen, Germany

The motional Stark effect (MSE) originates from a Lorentz force acting in opposite directions on the ionic core and the electrons of an atom moving in a magnetic field. This introduces a coupling between the internal dynamics and the center-of-mass motion of the atom which is therefore no longer a constant of motion. Approximately the MSE can be seen as a Stark effect resulting from an electric field in the frame of a moving atom. We measured this motional Stark shift on ^{87}Rb Rydberg atoms moving in low magnetic fields employing a velocity selective spectroscopy method in a vapor cell. For an atom velocity of 400 m/s, a principal quantum number of n = 100, and a magnetic field of 100 G the shifts are on the order of 10 MHz. Our experimental results are supported by numerical calculations based on a diagonalization of the effective Hamiltonian governing the valence electron of ^{87}Rb in the presence of crossed electric and magnetic fields. Furthermore we present our investigations on the velocity associated with the pseudomomentum as a constant of motion, that is supported by our experimental findings.

A 17.2 Mon 16:30 K 2.019

Excitonic Spectra of Giant-Dipole States in Cuprous Oxide — Markus Kurz and •Stefan Scheel — Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23, D-18059 Rostock

Excitons are the quanta of the fundamental optical excitation in semiconductors. Recently, the discovery of highly excited Rydberg excitons in Cuprous Oxide (Cu_2O) and their exposure to external fields have shown a plethora of complex physical phenomena [1]. In atomic physics an exotic species of Rydberg atoms in crossed electric and magnetic fields, so-called giant-dipole atoms, have been predicted for two decades [2]. These exotic objects are characterized by an electron-ionic core separation in the range of several micrometers.

In this work we present the eigenspectra of a novel species of excitons when exposed to crossed electric and magnetic fields. In particular, we present the eigenenergies of giant-dipole excitons in Cu_20 in crossed fields [3]. We calculate the excitonic spectra within several theoretical approaches. We verify that stable bound excitonic giant-dipole states are only possible in the case of strong magnetic fields, as this is the only regime providing sufficiently deep potential wells for their existence. Comparing both analytic as well as numerical calculations we obtain excitonic giant-dipole spectra with level spacings up to 100 μeV.

[1]T. Kazimierczuk *et al.*, Nature (London) **514**, 343 (2014)
[2]O. Dippel, *et al.*, Phys. Rev. A **49**, 4415 (1993)
[3]M. Kurz, *et al.*, Phys. Rev. B **95**, 245205 (2017)

A 17.3 Mon 16:45 K 2.019

Analytic model of a multi-electron atom — •Oleg D Skoromnik[1], Ilya D Feranchuk[2,3,4], Alexander U Leonau[4], and Christoph H Keitel[1] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Atomic Molecular and Optical Physics Research Group, Ton Duc Thang University, 19 Nguyen Huu Tho Str., Tan Phong Ward, District 7, Ho Chi Minh City, Vietnam — [3]Faculty of Applied Sciences, Ton Duc Thang University, 19 Nguyen Huu Tho Str., Tan Phong Ward, District 7, Ho Chi Minh City, Vietnam — [4]Belarusian State University, 4 Nezavisimosty Ave., 220030, Minsk, Belarus

We put forward a fully analytical approximation for the observable characteristics of many-electron atoms, which is obtained via a complete and orthonormal hydrogen-like basis. The basis contains a single-effective charge parameter that is identical for all electrons of a given atom. The completeness of the basis allows us to employ the secondary-quantized representation for the construction of regular perturbation theory, which includes correlation effects and converges fast. The hydrogen-like basis set provides a possibility to perform all summations over intermediate states in closed form, including both the discrete and continuous spectra. We demonstrate that our fully analytical zeroth-order approximation describes the whole spectrum of the system and provides accuracy, which is independent of the number of electrons. Moreover, the second-order perturbation theory results become comparable with those via a multi-configuration Hartree-Fock approach. [1] J. Phys. B 50 245007 (2017) https://doi.org/10.1088/1361-6455/aa92e6

A 17.4 Mon 17:00 K 2.019

Two-electron nondispersive wave packets — •Alejandro Gonzalez Melan and Javier Madroñero Pabon — Physics department, Universidad del Valle, Cali, Colombia

We provide a full characterization of nondispersive two-electron wave packets (NDWP) found in the Floquet spectrum of driven helium. First evidence for the existence of these quantum objects which propagate along periodic trajectories of the classical three-body Coulomb problem without dispersion where provided by large numerical calculations within one- [1] and two-dimensional [2] models. We are able to identify the resonance states that play the fundamental role in the formation of these NDWP which allows us to perform an efficient treatment of the problem in the full three dimensional system.

[1] P. Schlagheck and A. Buchleitner, Eur. Phys. J. D **22**, 401 (2003)
[2] J. Madroñero and A. Buchleitner, Phys. Rev. A **77**, 053402 (2008)

A 17.5 Mon 17:15 K 2.019

Atomic systems in curved spacetime and non-geodesic motion — •Sebastian Ulbricht[1,2], Robert A. Müller[1,2], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Germany — [2]Technische Universität Braunschweig, Germany

It is well known, that any kind of external energy density leads to a curvature of spacetime. Due to an increasing number of high precision experiments, the effects of spacetime curvature on quantum systems are widely discussed in modern physics. Spacetime curvature as well as acceleration (non-geodesic motion) are described in the framework of General Relativity. Both of them may influence the properties of extended quantum objects like electron distribution. Treated as a small perturbation these effects lead, for example, to energy level shifts in atomic systems.

In this contribution we discuss the case of an relativistic hydrogen atom placed in the spacetime of homogeneous acceleration g (Rindler spacetime). Up to now, this model has been mostly described using perturbation theory. We present a more general approach for this scenario, going beyond perturbative methods. The energy level shifts for ground state and exited states are investigated. We analyze them for typical values of acceleration, for instance on the surface of the Earth and in the vicinity of a neutron star.

A 17.6 Mon 17:30 K 2.019

Hydrogen Analogs in an anisotropic crystal in magnetic fields — •Javier Madroñero and Victor Loaiza — Physics Department, Universidad del Valle, Cali

An artificial hydrogen atom with an anisotropic effective mass can be realized in some anisotropic crystals, e.g., silicon crystals with low-concentration phosphorus impurities. Here, we use an ab-initio quantum approach for the description of the anisotropic diamagnetic Kepler problem which combines a representation in a Sturmian basis with the method of complex rotation to identify the auto-ionization resonances from which experimental photothermal ionization spectrum can be obtained. We study the fluctuations of the spectrum and explore the possibility of controlling it by the magnetic field.

A 18: Ultrafast Spectroscopy with XUV (joint session MO/A)

Time: Monday 16:15–17:45 Location: PA 2.150

Invited Talk A 18.1 Mon 16:15 PA 2.150

Measurement of femtosecond dynamics in HCL molecules with THz streaking — Katharina Wenig[1], Marek Wieland[1], Sophie Walther[1], Arne Baumann[1], Anastasios Dimitriou[1], Mark Prandolini[1], Oliver Schepp[1], Ivette Bermundez Maciias[2], Malte Sumfleth[1], Nikola Stojanovic[2], Stefan Düsterer[2], Juliane Röntsch-Schulenburg[2], Markus Drescher[1], and •Ulrike Frühling[1] — [1]Institut für Experimentalphysik, Universität Hamburg, Deutschland — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Deutschland

We have studied the ultrafast electronic decay of core excited HCL molecules directly in the time domain. In the experiment we used femtosecond XUV pulses form the free-electron laser in Hamburg (FLASH) to resonantly excite $2p_{3/2}$ core electrons to the antibonding σ^* orbital. After the excitation the molecules dissociate and the electronic excitation relaxes via the emission of an Auger-electron. In order to follow the evolution of this coupled electronic and nuclear dynamics we have collinearly superimposed the exciting XUV pulses with intense THz pulses from the FLASH THz undulator. Electrons emitted from the molecules are accelerated (streaked) by the THz electric field whereby the resulting momentum change depends on the THz phase at the ionization time. Thus the ionization dynamics can be studied by measuring the streaked electron spectra. In the talk the experimental technique and first experimental results will be presented.

A 18.2 Mon 16:45 PA 2.150

A chemical understanding of the lack of site-specificity in molecular inner-shell photofragmentation — •Ludger Inhester[1,2], Bart Oostenrijk[3], Sang-Kil Son[1,2], Robin Santra[1,2,4], Linda Young[5], and Stacey L. Sorensen[3] — [1]Center for Free-Electron Laser Science, DESY — [2]The Hamburg Centre for Ultrafast Imaging — [3]Department of Physics, Lund University — [4]Department of Physics, University of Hamburg — [5]Argonne National Laboratory

In many cases fragmentation of molecules upon inner-shell ionization is very unspecific with respect to the initially localized ionization site. Often this finding is interpreted in terms of an equilibration of internal energy into vibrational degrees of freedom after Auger decay. Here we investigate the x-ray photofragmentation of ethyl trifluoroacetate upon core electron ionization at environmentally distinct carbon sites using photoelectron-photoion-photoion coincidence measurements and ab-initio electronic structure calculations. For all the 4 carbon ionization sites, the Auger decay weakens the same bonds and transfers the two charges to opposite ends of the molecule, which leads to a rapid dissociation into 3 fragments followed by further fragmentation steps. The lack of site-specificity is attributed to the character of the dicationic electronic states after Auger decay, instead of a fast equilibration of internal energy.

A 18.3 Mon 17:00 PA 2.150

Electron-ion coincidence spectroscopy on small quantum systems — •Lena Worbs[1], Andreas Przystawik[1], David Schwickert[1], Sergey Usenko[1,2], and Tim Laarmann[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, Hamburg 22607, Germany — [2]The Hamburg Centre for Ultrafast Imaging CUI, Luruper Chaussee 149, Hamburg 22761, Germany

Relative phase control with sub-cycle precision of extreme-ultraviolet (XUV) pulses from a free-electron laser has been demonstrated by using a Michelson-type all reflective interferometric autocorrelator to trace the light-wave oscillation with a period of 129 as [1]. Novel applications using these phase controlled pulses in an electron-ion coincidence experiment will be discussed in the present contribution.

For this purpose a double-sided electron-ion coincidence spectrometer with delay-line detectors has been developed to detect electrons and ions generated in the same ionization event. The spectrometer detects ions and electrons with position-sensitivity providing angular-resolved information. The use of delay-line detectors enhances the information content of the electron spectra due to additional time-of-flight information on the ion side and thus the selection of wanted coincidence events, i.e. the selection of particularly charged ions as counterparts. First results on Xe atoms and C_{60} molecules will be discussed.

[1] Usenko, S. et al. Attosecond interferometry with self-amplified spontaneous emission of a free electron laser. Nat. Commun. 8, 15626 doi: 10.1038/ncomms15626 (2017)

A 18.4 Mon 17:15 PA 2.150

Molecular Light-Induced Couplings Revealed by Attosecond Transient Absorption Spectroscopy — •Lorenz Drescher, Geert Reitsma, Tobias Witting, Serguei Patchkovskii, Marc Vrakking, and Jochen Mikosch — Max-Born-Institut, Berlin, Deutschland

Attosecond transient absorption spectroscopy (ATAS) is the study of the modulation of absorption of short attosecond XUV pulses in matter by a phase-locked strong IR pulse. In recent years, ATAS has been used to study the light-induced coupling of nearby states in atoms [1] and homonuclear molecules.

Here we present results from our experimental and theoretical study of ATAS of a polyatomic molecule (CH_3I) in the core-to-valence and core-to-Rydberg transition region. Core-excited states are an interesting target for transient absorption because element specific transitions give a local view into the molecular valence [2]. For ATAS they are additionally intriguing because the short coherence time (due to fast Auger decay of the core-hole) enhances the sub-cycle dependence on the probing IR field.

Our results show the sub-cycle dependent light-induced coupling of states due to the AC Stark effect. It shows that the coupling of the core-to-Rydberg states is much stronger than the coupling of the core-to-valence states.

[1] C. Ott, et al., Nature 516, 374-378 (2014).
[2] L. Drescher et al., JCP 145, 011101 (2016).

A 18.5 Mon 17:30 PA 2.150

Electron spectra of a water molecule irradiated by an x-ray free-electron laser pulse — •Julia M. Schäfer[1,2], Ludger Inhester[1,3], Sang-Kil Son[1], Reinhold F. Fink[2], and Robin Santra[1,3,4] — [1]Center for Free-Electron Laser Science, DESY, Hamburg — [2]Institut für Physikalische und Theoretische Chemie, Universität Tübingen — [3]The Hamburg Center for Ultrafast Imaging, Hamburg — [4]Fachbereich Physik, Universität Hamburg

With the high intensity X-ray light that is generated by X-ray free-electron lasers (XFELs) molecular samples can be ionized many times. We investigate the spectrum of electrons emitted from molecules exposed to these intense X-ray pulses. Calculated photoelectron and Auger electron spectra are presented for a single water molecule that reaches through repeated ionization steps many electronic hole configurations. The rich details in the spectra depend in a non-intuitive way on X-ray pulse parameters. We discuss how the observed trends can be explained by the competition of microscopic electronic processes. A detailed comparison between spectra calculated for independent atoms and spectra calculated for molecules is made. Our results demonstrate how multiple X-ray ionization related effects like Charge-Rearrangement-Enhanced X-ray Ionization in Molecules (CREXIM) and frustrated absorption manifest themselves in the electron spectra.

A 19: Cold atoms V - optical lattices (joint session A/Q)

Time: Tuesday 14:00–15:30 Location: K 0.011

A 19.1 Tue 14:00 K 0.011

Two- and four-body spin-exchange interactions in optical lattices — •Bing Yang[1,2], Han-ning Dai[1,2], Andreas Reingruber[1], Hui Sun[1,2], Yu-ao Chen[2], Zhen-Sheng Yuan[2,1], and Jian-Wei Pan[2,1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Ultracold atoms in optical lattices represent an ideal platform for modeling elementary spin interactions. Here we report on the observations of two- and four-body spin-exchange interactions in an optical superlattice. Using a spin-dependent superlattice, atomic spins can be coherently addressed and manipulated. Bell states are generated via spin superexchange process and their quantum correlations are detected. A minimum toric code Hamiltonian in which the four-body ring-exchange interaction is the dominant term, is implemented by engineering a Hubbard Hamiltonian in disconnected plaquette arrays. Our work represents an essential step towards studying topological matters with many-body systems and the applications in quantum computation and simulation.

A 19.2 Tue 14:15 K 0.011

Multimode Bose-Hubbard model for quantum dipolar gases in confined geometries — Florian Cartarius[1], •Rebecca Kraus[1], Ferdinand Tschirsich[2], Simone Montangero[1,2], Anna Minguzzi[3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Institute for Complex Quantum systems, Universität Ulm, D-89069 Ulm, Germany — [3]Université Grenoble-Alpes, CNRS, Laboratoire de Physique et Modélisation des Milieux Condensés, F-38000 Grenoble, France

We theoretically consider ultracold polar bosonic molecules in a wave guide. The particles experience a periodic potential due to an optical lattice oriented along the wave guide and are polarized by an electric field orthogonal to the guide axis. The array is mechanically unstable by opening the transverse confinement in the direction orthogonal to the polarizing electric field and can undergo a transition to a double-chain (zigzag) structure. For this geometry we derive a multimode generalized Bose-Hubbard model for determining the quantum phases of the gas at the mechanical instability, taking into account the quantum fluctuations in all directions of space. We determine the phase diagrams using exact diagonalization and an imaginary time-evolving block decimation program, where we also investigate the emergence of a Haldane insulating phase. We find that, even for tight transverse confinement, the aspect ratio between the two transverse trap frequencies controls not only the classical but also the quantum properties of the ground state in a nontrivial way.

A 19.3 Tue 14:30 K 0.011

Ground state cooling of Cs atoms in state-dependent optical lattices — •Richard Winkelmann, Gautam Ramol, Stefan Brakhane, Goel Moon, Peng Du, Max Werninghaus, Wolgang Alt, Dieter Meschede, and Andrea Alberti — Institute of Applied Physics, Bonn, Germany

We report on experimental realization of ground state cooling of neutral Cs atoms in state dependent optical lattices, which are realized by fast optical polarization synthesis [1]. Two-dimensional polarization-synthesized optical lattices allow us to employ microwave radiation to couple different motional states in both x- and y-directions; by driving microwave sideband transitions, we succeed to cool atoms into the motional ground state in the xy-plane. A pair of Raman lasers is used to cool atoms in the third dimension, along which atoms are convined by a state-independent optical lattice. We expect to prepare >99% population in the ground state population for each dimension.

Ground state cooling enables both long coherence times and indistinguishability of atoms, which are prerequisites for discrete time quantum walks, the preparation low entropy states via atom sorting [2] and direct measurement of the exchange phase for identical quantum particles [3].

[1] C. Robens et al.,Fast, high-precision optical polarization synthesizer for ultracold-atom experiments., arXiv, 2017. [2] C. Robens et al., Low-entropy states of neutral atoms in polarization-synthesized optical lattices. PRL, 2017. [3] C. F. Roos et al., Revealing quantum statistics with a pair of distant atoms. PRL, 2017.

A 19.4 Tue 14:45 K 0.011

Coupling a finite thermal bath to a many-body localized system — •Antonio Rubio-Abadal[1], Jae-yoon Choi[1], Johannes Zeiher[1], Simon Hollerith[1], Jun Rui[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für

Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München,

The thermalization of an isolated quantum system can fail in the presence of quenched disorder, even with interactions. This phenomenon, known as many-body localization (MBL), has been recently the focus of much theoretical work, though many open questions still remain regarding its existence in higher dimensions or its robustness to a finite bath coupling. Ultracold atoms in optical lattices have emerged as an extremely suitable platform for the study of MBL, and promise to shed light into some of its properties.

In our experiment, we use a quantum-gas microscope with projected disorder to study the dynamics of a quenched state of bosons in two dimensions, where we observe a remaining memory of the initially prepared state by measuring the evolution of its imbalance. By introducing a second bosonic species unaffected by the disorder potential, a thermal component has been added to the system, and we have measured its effect on the disordered component, which in the presence of a big enough thermal component ultimately loses its imbalance.

A 19.5 Tue 15:00 K 0.011

Exploring the doped Fermi-Hubbard model in low dimensions — •Joannis Koepsell[1], Guillaume Salomon[1], Timon Hilker[1], Jayadev Vijayan[1], Michael Höse[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Univsersität, München

We use ultracold fermionic lithium atoms to realize synthetic one dimensional Fermi-Hubbard chains. With our quantum gas microscope we study emerging antiferromagnetic correlations as a function of doping and magnetization. The local spin and density resolution allows us to observe the change of the wave vector of the spin correlations as a function of density and magnetization. In a quantitative comparison we show that our results can be well described by Luttinger-liquid theory. Finally we report on ongoing studies of the system in the crossover from one to two dimensions.

A 19.6 Tue 15:15 K 0.011

Progress in the cooling of molecules using a magnetic decelerator — Yair Segev, Michael Karpov, •Martin Pitzer, Nitzan Akerman, Julia Narevicius, and Edvardas Narevicius — Department of Chemical & Biological Physics, Weizmann Institute of Science, Rehovot, Israel

Ultracold and dense ensembles of molecules can complement their atomic counterparts in the investigation of various fundamental questions, e.g. in cold chemistry, precision measurements or many-body physics [1].

However, many cooling schemes - especially optical cooling - are much more difficult to implement for molecules than they are for atoms. We report here our recent progress in a different approach, a magnetic decelerator for paramagnetic species [2,3].

A pulsed supersonic expansion provides a cold (around 300 mK) and extremely dense jet of oxygen molecules that are slowed down by a co-moving magnetic trap. After catching these molecules in a superconducting magnetic trap, several cooling schemes such as evaporative or sympathetic cooling can be performed. Due to the high initial particle density of 10^{10}cm^{-3}, we expect to observe collisions of molecules in the rovibrational ground state and study the elastic and inelastic cross sections relevant for cooling towards quantum degeneracy.

[1] Carr, et al., New J. Phys. 11, 055049 (2009)
[2] Akerman, et al., New J. Phys. 17, 065015 (2015)
[3] Akerman, et al., Phys. Rev. Lett. 119, 073204 (2017)

A 20: Attosecond Science III

Time: Tuesday 14:00–15:45 Location: K 1.011

Invited Talk A 20.1 Tue 14:00 K 1.011

Attosecond Streaking in Dielectrics — •L. Seiffert[1], Q. Liu[2,3], S. Zherebtsov[2,3], A. Trabattoni[4,5], P. Rupp[2,3], M. C. Castrovilli[6], M. Galli[4,6], F. Süssmann[2,3], K. Wintersperger[2], J. Stierle[2], G. Sansone[4,6], L. Poletto[6], F. Frassetto[6], I. Halfpap[7], V. Mondes[7], C. Graf[7], E. Rühl[7], F. Krausz[2,3], M. Nisoli[4,6], T. Fennel[1,8], F. Calegari[5,6,9], and M. Kling[2,3] — [1]Universität Rostock — [2]MPQ Garching — [3]LMU München — [4]Politecnico di Milano — [5]Center for Free-Electron Laser Science, DESY — [6]National Research Council of Italy — [7]FU Berlin — [8]MBI Berlin — [9]University of Hamburg

Scattering of electrons in dielectrics is at the heart of laser nanomachining, light-driven electronics, and radiation damage. Accurate theoretical predictions of the underlying dynamics require precise knowledge of the low-energy electron transport involving elastic and - even more important - inelastic collisions. Here, we demonstrate real-time access to electron scattering in isolated SiO_2 nanoparticles via attosecond streaking [1]. Utilizing semiclassical Monte-Carlo trajectory simulations [2,3] we identify that the presence of the field inside the dielectric cancels the influence of elastic scattering, enabling selective characterization of the inelastic scattering time [4].

[1] R. Kienberger et al., Nature 427, 817-821 (2004)
[2] F. Süßmann et al., Nat. Commun. 6, 7944 (2015)
[3] L. Seiffert et al., Appl. Phys. B 122, 1-9 (2016)
[4] L. Seiffert et al., Nat. Phys. 13, 766-770 (2017)

Invited Talk A 20.2 Tue 14:30 K 1.011

Controlling the refraction of ultrashort XUV pulses — Lorenz Drescher, Oleg Kornilov, Tobias Witting, Geert Reitsma, Jochen Mikosch, Marc Vrakking, and •Bernd Schütte — Max-Born-Institut, Berlin

Refraction is widely found in nature and is important for many applications. For instance, refractive lenses and prisms are indispensable tools that are extensively used to control the properties of light beams at visible, infrared and ultraviolet wavelengths. The lack of refractive lenses and prisms in the XUV range is due to the large absorption and the low capability of bending light in this spectral region.

Here we demonstrate control over the refraction of ultrashort XUV pulses by applying a gas density gradient across the XUV beam profile that leads to spectral dispersion and refraction of the beam. The deflection of XUV radiation is particularly large for spectral components close to atomic and molecular resonances, and the experimental results are well reproduced by simulations. Control of the sign and the strength of refraction in different spectral regions is demonstrated by varying the gas pressure, the gas jet position and its composition. The gas jet thereby acts as a deformable prism in the XUV range. We further show temporal control and characterization of the refracted XUV radiation by applying a moderately intense NIR laser pulse.

In the future, our concept may be exploited to measure transient refractive index changes in the XUV region. Furthermore, our results may be the first step towards the design of an XUV refractive lens, which would provide novel opportunities in ultrafast XUV science.

A 20.3 Tue 15:00 K 1.011

Topological effects in high-harmonic generation by linear chains — •Helena Drüeke[1], Kenneth Hansen[2], and Dieter Bauer[1] — [1]Institute of Physics, University of Rostock, 18051 Rostock, Germany — [2]Department of Physics and Astronomy, Aarhus University, DK-8000, Denmark

High-harmonic generation (HHG) in the two topological phases of a finite, one-dimensional, periodic structure is investigated using a self-consistent time-dependent density functional theory (TDDFT) approach [1,2]. For harmonic photon energies smaller than the band gap, the harmonic yield is found to differ up to fourteen orders of magnitude for the two topological phases. This giant topological effect is explained by the degree of destructive interference in the harmonic emission of all valence-band electrons, which strongly depends on whether topological edge states are present or not.

[1] Kenneth K. Hansen, Tobias Deffge, Dieter Bauer, *High-order harmonic generation in solid slabs beyond the single-active-electron approximation*, Phys. Rev. A 96, 053418 (2017).
[2] Dieter Bauer, Kenneth K. Hansen, *High-harmonic generation in solids with and without topological edge states*, (submitted) arXiv:1711.05783.

A 20.4 Tue 15:15 K 1.011

Finite system effects on high harmonic generation: from atoms to solids — •Kenneth Hansen[1], Dieter Bauer[2], and Lars Bojer Madsen[1] — [1]Department of Physics and Astronomy, Aarhus University, DK-8000, Denmark — [2]Institute of Physics, University of Rostock, 18051 Rostock, Germany

Using time-dependent density field theory (TDDFT)[1] high harmonic generation (HHG) has been studied in one-dimensional structures of intermediate sizes from a single nucleus upto hundreds of nuclei. The well known HHG cutoff for atomic systems is observed to extent linearly with system size and is found to converge into previously observed cutoffs for bulk solids only for large systems. The change from atomic HHG to solid state HHG is observed from system sizes of 6-8 nuclei and is first fully converged at system sizes of 60 nuclei. The systems size dependence of the observed HHG cutoffs is found to follow the limitations of movement of classical electron-hole pairs in the band structure. Because of the correlation between recombination energy and electron-hole propagation length high energy recombination events are not possible in small systems, but become available for larger systems resulting in the change of the cutoff energies with system size. When varying the field intensity we observe that the cutoffs move linearly with the intensity even for small systems that are far from a true bulk solid.

[1] Kenneth K. Hansen, Tobias Deffge, Dieter Bauer, *High-order harmonic generation in solid slabs beyond the single-active-electron approximation*, Phys. Rev. A 96, 053418 (2017).

A 20.5 Tue 15:30 K 1.011

Simulation of Brunel harmonics from laser-driven dielectric solids — •Benjamin Liewehr[1], Björn Kruse[1], Christian Peltz[1], Peter Jürgens[2], Anton Husakou[2], Mikhail Ivanov[2], Marc Vrakking[2], Alexandre Mermillod-Blondin[2], and Thomas Fennel[1,2] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23, D-18051 Rostock — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Str. 2A, D-12489 Berlin

The onset of ultrafast structural modification of dielectric materials is accompanied by a wealth of non-linear phenomena, ranging from rapid ionization over local plasma formation, to high-harmonic generation (HHG)[1]. Brunel harmonics [2], being one of the possible nonlinear wave-mixing processes, are a promising optical probe for quantitative plasma diagnostics on the femtosecond time scale as they encode the ultrafast evolution of the plasma density due to sub-cycle ionization dynamics.

Using a simplified rate-equation-based ionization-radiation model we investigate optimal conditions for generating Brunel harmonics and study the qualitative signatures in the harmonic signal. The predictions from the continuum model are further compared with results from three-dimensional, microscopic particle-in-cell (MicPIC) simulations [3]. The emerging similarities and differences will be discussed.

[1] H. Liu et al., Nature Phys. 13, 262 (2017)
[2] F. Brunel, J. Opt. Soc. Am. B 4, 521 (1990)
[3] Ch. Peltz et al., New J. Phys. 14, 065011 (2012)

A 21: Precision Spectroscopy IV - highly charged ions (joint session A/Q)

Time: Tuesday 14:00–15:45 Location: K 1.016

Invited Talk A 21.1 Tue 14:00 K 1.016

High precision hyperfine measurements in bismuth challenge bound-state strong field QED — •Rodolfo Sánchez — GSI, Darmstadt, Germany

High-resolution laser spectroscopy on the ground-state hyperfine splitting of hydrogen-like and lithium-like bismuth ions ($Bi^{82+,80+}$) has been carried out at the "Experimentier Speicherring" (ESR) at the GSI Helmholtz-Center for Heavy Ion Research in Darmstadt. The accuracy of the hyperfine splitting determination was improved by more than an order of magnitude compared to previous measurements and sufficient to test bound-state strong-field QED in the so-called specific difference between the two hyperfine splitting energies for the first time. We found a surprising discrepancy from the atomic theory predictions by more than 7σ. I will report on these measurements, possible explanations for this "hyperfine puzzle" of strong-field QED and on further activities that have been started to resolve this issue.

A 21.2 Tue 14:30 K 1.016

X-Ray Spectroscopy of the KLL-Dielectronic Recombination Resonances with a Heidelberg Compact EBIT — •Peter Micke[1,2], Steffen Kühn[1], Jannik Dierks[2], Thomas Pfeifer[1], Piet O. Schmidt[2,3], Sven Bernitt[1,4], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Leibniz Universität Hannover, Germany — [4]Friedrich-Schiller-Universität Jena, Germany

The study of highly charged ions is of great interest for atomic, plasma and astrophysics, as well as fusion research. Moreover, their electronic levels include strongly enhanced contributions of special relativity and quantum electrodynamics. We have carried out high-resolution x-ray spectroscopy of the KLL dielectronic recombination resonances of highly charged argon and iron in one of the novel 0.86 T Heidelberg Compact Electron Beam Ion Traps (HC-EBIT). In this resonant process a free electron out of the EBIT's mono-energetic electron beam is captured into the L-shell of a trapped ion, promoting a second, bound K-shell electron into the L-shell. The excited intermediate state releases a K_α photon during decay, recorded by a high-purity Ge detector. We achieved an excellent electron-energy resolving power of more than 860 together with high relative accuracy for the resonance positions on the order of 50 to 100 meV by using a PTB calibrated high-precision voltage divider. By comparing our results with theoretical values, accurate absolute resonance energies can be deduced and atomic structure theory benchmarked.

A 21.3 Tue 14:45 K 1.016

Identifications of optical transitions in highly charged ions for metrology and searches of variation of the fine-structure constant — •Hendrik Bekker[1], Julian Berengut[2], Anastasia Borschevsky[3], Nicky Potters[1], Julian Rauch[1], Alexander Windberger[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Insitüt für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]School of Physics, The University of New South Wales, Sydney NSW 2052 — [3]Van Swinderen Institute, Universiteit Groningen, Nijenborgh 4, 9747 AG Groningen

Compared to the neutral and singly charged ions that are used in current optical clocks, level-shifts due to external perturbations are greatly suppressed in highly charged ions (HCI). Furthermore, increased relativistic effects in HCI lead to a strong sensitivity to variation of the fine-structure constant α. Many HCI are predicted to have optical transitions suitable for laser spectroscopy due to level crossings. However, for these HCI, theory is not capable of predicting the energy level structures to the required precision. To address this issue, we investigated several of the proposed HCI, which we produced, trapped, and collisionally excited in the Heidelberg electron beam ion trap (HD-EBIT). The wavelengths of subsequent fluorescence light were determined at the ppm-level using a grating spectrometer. We present our latest results for $Ir^{16+,17+,18+}$ and $Pr^{9+,10+}$ which are used to benchmark state-of-the-art atomic theory calculations and to provide a deeper insight into the suitability of the proposed HCI for metrology purposes. This is a necessary step towards future laser spectroscopy.

A 21.4 Tue 15:00 K 1.016

Electron-gun development for electron-ion crossed-beams experiments — •B. Michel Döhring[1], Alexander Borovik Jr.[1], Benjamin Ebinger[1], Kurt Huber[1], Tobias Molkentin[1], Alfred Müller[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

Reliable atomic data for electron impact ionisation of atoms are of crucial importance for the modelling of ionised-matter environments and other plasma related applications. To achieve a greater range of accessible electron energies and densities a new electron gun [1,2,3] that delivers a ribbon-shaped beam has been integrated into the experimental crossed-beams setup in Giessen. This gun is designed for electron energies from 10 to 3500 eV with high electron currents at all energies. Ten different electrodes provide a high degree of flexibility for choosing a number of operation modes. Here, we present the latest developments and the commissioning status of the high-power electron gun. In particular, we focus on the challenges associated with fast energy scan measurements.

[1] W. Shi et al., NIMB 205 (2003) 201-206.
[2] A. Borovik Jr. et al., J. Phys.: Conf. Ser. 488 (2014) 142007.
[3] B. Ebinger et al., NIMB 408 (2017) 317-322.

A 21.5 Tue 15:15 K 1.016

Two-loop corrections to the bound-electron *g*-factor — •Bastian Sikora[1], Natalia S. Oreshkina[1], Halil Cakir[1], Vladimir A. Yerokhin[2], Christoph H. Keitel[1], and Zoltán Harman[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia

The *g*-factor of electrons bound in H-like ions can be measured and calculated with high accuracy. Comparisons between the theoretical and experimental values of the *g*-factor allow precision tests of QED and the determination of fundamental constants such as the electron mass or the fine-structure constant α [1].

In order to achieve high accuracy in theoretical predictions in heavy ions, the interaction with the nuclear potential needs to be taken into account to all orders in $Z\alpha$. Currently, the largest theoretical uncertainty arises from the two-loop self-energy corrections. We present all-order evaluations of the loop-after-loop self-energy contributions, and partial results for other diagrams, in which we treat the Coulomb interaction in intermediate states to zero and first order. – [1] V. A. Yerokhin, E. Berseneva, Z. Harman *et al.*, Phys. Rev. Lett. **116** 100801 (2016).

A 21.6 Tue 15:30 K 1.016

Precision theory of the *g* factor of highly charged ions — •Zoltán Harman[1], Bastian Sikora[1], Halil Cakir[1], Vladimir A. Yerokhin[1,2], Natalia S. Oreshkina[1], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Center for Advanced Studies, Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia

Quantum electrodynamic (QED) contributions to the electron *g* factor in strong binding fields have been tested to high precision in Penning trap measurements: an experiment with $^{28}Si^{13+}$ allowed to benchmark certain higher-order QED corrections for the first time [1]. Recently, the uncertainty of the electron mass has been largely decreased via measurements on the $^{12}C^{5+}$ ion [2], and by using the theoretical value of the *g* factor. In order to reduce theoretical uncertainties, we calculate further higher-order corrections.

An independent and improved determination of the fine-structure constant α may also be possible in near future employing a weighted difference of the *g* factors of the H- and Li-like ions of the same element. This weighted difference in chosen to maximize the cancellation of detrimental nuclear effects between the two charge states. It is shown that this method can be used to extract a value for α from bound-electron *g*-factor experiments with an accuracy competitive with or better than the present literature value [3]. – [1] S. Sturm *et al.*, Phys. Rev. Lett. **107** 023002 (2011); [2] S. Sturm *et al.*, Nature **506** 467 (2014); [3] V. A. Yerokhin *et al.*, Phys. Rev. Lett. **116** 100801 (2016).

A 22: Atomic Clusters II (joint session A/MO)

Time: Tuesday 14:00–16:00 Location: K 2.016

A 22.1 Tue 14:00 K 2.016

X-ray coherent diffractive imaging of quantum vortices in single helium droplets — •Rico Mayro Tanyag[1], Charles Bernando[1], Curtis Jones[1], Luis Gomez[1], Andrey Vilesov[1], Camila Bacellar[2], James Cryan[2], Oliver Gessner[2], Ken Ferguson[3], Sebastian Schorb[3], Christoph Bostedt[3,4], Daniel Rolles[5], and Artem Rudenko[5] — [1]University of Southern California, Los Angeles, California USA — [2]Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California USA — [3]SLAC National Accelerator Laboratory, Menlo Park, California USA — [4]Argonne National Laboratory, Lemont, Illinois USA — [5]Kansas State University, Manhattan, Kansas USA

Free, single, rotating superfluid 4He nanodroplets (diameter D = 200-2000 nm, temperature T = 0.4 K) containing a number of quantum vortices have been studied via ultrafast X-ray coherent diffraction imaging using a free electron laser. The droplets were doped with Xe atoms, which collect on the vortex cores and serve as a contrast agent. In order to obtain the instantaneous positions and shapes of the vortices from the diffraction images, a phase retrieval algorithm has been developed, which utilizes the droplet boundary as a physical support. The algorithm also uses the droplet's scattering phase as an input for the iterative phase reconstruction. The obtained reconstructions reveal a plethora of transient vortex configurations within the droplet. The details of the algorithm and the possible origin of the observed vortex configuration will be discussed.

A 22.2 Tue 14:15 K 2.016

Imaging the equilibrium shapes of spinning superfluid quantum droplets — •B. Langbehn[1], K. Sander[2], Y. Ovcharenko[1,3], C. Peltz[3], A. Clark[4], M. Coreno[5], R. Cucini[5], P. Finetti[5], M. Di Fraia[5], L. Giannessi[5], C. Grazioli[5], D. Iablonskyi[6], A. C. LaForge[7], T. Nishiyama[8], V. Oliver Álvarez de Lara[4], P. Piseri[9], O. Plekan[5], K. Ueda[6], K. C. Prince[5], F. Stienkemeier[7], C. Callegari[5], T. Fennel[3,10], D. Rupp[1,10], and T. Möller[1] — [1]TU Berlin — [2]Univ. Rostock — [3]European XFEL — [4]EPFL, Lausanne — [5]Elettra-Sincrotrone Trieste — [6]Tohoku Univ. Sendai — [7]Univ. Freiburg — [8]Kyoto Univ. — [9]Univ. di Milano — [10]MBI, Berlin

With the intense short-wavelength femtosecond light pulses from free-electron lasers (FELs) it is now possible to study the structure of unsupported nanoparticles, including superfluid helium nanodroplets. When produced by a free-jet expansion from the liquid phase, these droplets can gain angular momentum. As superfluid droplets cannot rotate in the classical hydrodynamic sense, quantized vortices accommodating the angular momentum are formed inside the droplets. These alter the equilibrium shapes known for normal liquid droplets. In an experiment at the FERMI FEL, we recorded wide-angle scattering images of individual helium nanodroplets. From the diffraction patterns, we reconstructed the full three-dimensional droplet shapes, enabling a comparison to a theoretical model of rotating normal liquid droplets. Surprisingly, the observed shapes of the superfluid droplets match their classical counterparts.

A 22.3 Tue 14:30 K 2.016

Two-color diffraction imaging of helium nanodroplets — •L. Hecht[1], B. Langbehn[1], Y. Ovcharenko[1,2], M. Sauppe[1], J. Zimmermann[1], B. Kruse[3], C. Peltz[3], K. Sander[3], A. Colombo[4], P. Piseri[4], A. D' Elia[5], M. di Fraia[6], L. Giannessi[6], O. Plekan[6], K. Prince[6,7], M. Zangrando[6], C. Callegari[6], T. Möller[1], T. Fennel[3,8], and D. Rupp[1,8] — [1]IOAP, TU Berlin — [2]XFEL@DESY — [3]Univ. Rostock — [4]Univ. Milano — [5]Univ. Trieste — [6]FERMI@Elettra — [7]IOM, Trieste — [8]MBI, Berlin

Extremely intense femtosecond pulses produced by short-wavelength free-electron lasers open up the possibility to image non-depositable nanostructures like superfluid helium nanodroplets in a single shot [Gomez *et al.* Science **345** (2014)] and to follow the transient formation [Bostedt *et al.* PRL **108** (2012)] and disintegration [Gorkhover *et al.* Nat. Phot. **10** (2016)] of laser-excited matter. At the FERMI facility a two-color XUV beam [Ferrari *et al.* Nat. Comm. **7** (2016)] can be used to perform time-resolved imaging with the goal to investigate ultrafast excitation and plasma dynamics.

Two diffraction images, each generated by one color, of the same He droplet can be separated through filter foils in front of the scattering detector. A pulsed cryogenic cluster source produces these at a size of several hundred nanometers. A combination of around 21 and 42 eV is scanned for a resonant scattering response, as the singly (*1s2p*) and doubly (*2p3p*) excited states of atomic He lie close to these energies, and thereby spatially resolve the excitation profile of the nanodroplets. The experimental setup and first results will be presented.

A 22.4 Tue 14:45 K 2.016

Coherent diffraction images of isolated helium nanodroplets obtained with a high harmonic source — N. Monserud[1], B.

Langbehn[2], P. Nuñez von Voigt[2], M. Sauppe[2], A. Spanier[2], J. Zimmermann[1,2], Y. Ovcharenko[2,3], T. Möller[2], F. Frassetto[4], L. Poletto[4], A. Trabattoni[5], F. Calegari[5,6], M. Nisoli[6,7], K. Sander[8], C. Peltz[8], T. Fennel[1,8], B. Schütte[1], M.J.J. Vrakking[1], A. Rouzée[1], and •D. Rupp[1,2] — [1]Max-Born-Institut Berlin — [2]TU Berlin — [3]European XFEL — [4]CNR Padova — [5]CFEL@DESY — [6]CNR Milano — [7]Politecnico di Milano — [8]Universität Rostock

We recently demonstrated single-shot coherent diffractive imaging of individual gas-phase nanoparticles with a table-top light source (Nat. Comm. 8, 493 (2017)). In the present work, superfluid helium nanodroplets were irradiated by intense extreme ultraviolet (XUV) pulses from high-order harmonic generation (HHG). The single-shot XUV spectra of the multicolor pulses were measured in coincidence. From the diffraction images, a majority of spherical droplets and a small fraction of rotationally distorted prolate shapes could be identified. Further, the spherical diffraction images were analyzed via multicolor Mie fits and the refractive indices at the harmonic wavelengths were extracted. They are a sensitive measure of changes in the electronic structure and thus can serve as a handle for tracking ultrafast excitation and ionization dynamics in the droplets in time-resolved imaging approaches - ultimately with intense attosecond pulses, that are currently under development at HHG sources and free-electron lasers.

A 22.5 Tue 15:00 K 2.016

Machine-Learning assisted classification of diffraction images — •J. Zimmermann[1], M. Sauppe[2], B. Langbehn[2], Y. Ovcharenko[2,4], LDM Collaboration[3], T. Fennel[1,5], T. Möller[2], and D. Rupp[1] — [1]MBI Berlin — [2]IOAP, TU Berlin — [3]FERMI@Elettra — [4]XFEL, Hamburg — [5]Univ. Rostock

Short wavelength Free-Electron-Laser (FEL) enable diffractive imaging of individual nano-sized objects with a single x-ray laser shot. Due to the high repetition rates, large data sets with up to several million diffraction patterns are typically obtained in FEL particle diffraction experiments, representing a severe problem for data analysis. Assuming a dataset of N diffraction patterns with M x K pixels, a high dimensional space (N x M x K) has to be analyzed. Thus feature selection is crucial as it reduces the dimensionality. This is typically achieved via custom-made algorithms that do not generalize well, e.g. feature extraction methods applicable to spherically shaped patterns but not to arbitrary shapes. This work exploits the possibility to utilize a neural network (NN) as a feature extractor. A workflow scheme is proposed based on a Residual Convolutional NN, that drastically reduces the amount of work needed for the classification of large diffraction datasets, only a fraction of the data has to be manually classified. As a next step a generalized and fully unsupervised approach is envisioned (no manual classification needed) using an auto-encoder NN. First performance evaluations are done using data obtained from an experiment on helium nanodroplets conducted at the LDM endstation of the FERMI free-electron laser in Trieste.

A 22.6 Tue 15:15 K 2.016

Holography combined with iterative phase retrieval: advances in coherent diffractive imaging of single nanoparticles — •Felix Zimmermann[1], Tais Gorkhover[2], Daniela Rupp[1,3], Thomas Möller[1], and Anatoli Ulmer[1] — [1]TU Berlin — [2]LCLS@SLAC — [3]MBI Berlin

Free-Electron-Lasers open the door to high-resolution images of noncristallin nanoparticles such as viruses via coherent diffraction of single X-ray pulses. The phase loss problem impedes the extraction of high resolution structural information from the recorded diffraction patterns. Two major approaches address this problem. First, one can recover the phase during post processing using iterative algorithms. Second, one can directly encode the phase into the image using reference scatterers as common in holography. The limitations and advantages of iterative and holographic methods differ significantly: iterative algorithms can reconstruct the sample from its diffraction patterns alone, but require a priori constraints and rely on human input. Usually, a number of independent reconstructions using different starting values have to be performed. The final result is based on the average of these reconstructions. In holography, a unique reconstruction without prior knowledge can be performed via simple calculations based on the Fourier transformation, but the result is degraded by the transfer function given by the reference. This talk will discuss whether a combination of both approaches might be advantageous regarding stability, computational complexity and achievable fidelity.

A 22.7 Tue 15:30 K 2.016

Optical focusing of isolated particles for diffractive imaging experiments — •Salah Awel[1,4], Daniel Horke[1,4], Rick Kirian[2], Xiaoyan Sun[1], Andrei Rode[3], Jochen Küpper[1,4,5], and Henry Chapman[1,4,5] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Arizona State University, Tempe, AZ, USA — [3]Laser Physics Centre, Australian National University, Canberra, Australia — [4]Center for Ultrafast Imaging, Universität Hamburg, Germany — [5]Department of Physics, Universität Hamburg, Germany

Single-particle imaging (SPI) is emerging as a new techniques at x-ray free-electron lasers (XFELs) that consists of directing a stream of randomly oriented bioparticles across the focus of the XFEL beam aiming to construct high-resolution 3D structure from diffraction patterns of multiple identical particles. Presently, the difficulty of efficiently delivering isolated bioparticles to the sub-micrometer x-ray focus is the limiting factor in the development of SPI. In order to mitigate this problem, we have developed a technique for guiding aerosolized nanoparticles to the x-ray focus using spatially shaped optical laser beam [1]. Our current experiments aim at transversely confining streams of aerosolized particles as they exit an aerosol injector with a counter-propagating "hollow-core" quasi-Bessel beam. Through radiation pressure and thermal (photophoretic) forces that arise from the interaction of the particle with the surrounding gas molecules, the particles confine within the low-intensity core of the laser beam [2].

[1] Eckerskorn et al., *Opt. Exp.* **21**, 30492-30499 (2013).
[2] Eckerskorn et al., *Phys. Rev. Applied* **4**, 064001 (2015).

A 22.8 Tue 15:45 K 2.016

Signatures of Rabi cycling and excited state population dynamics in single-shot coherent diffractive imaging — •Björn Kruse[1], Christian Peltz[1], and Thomas Fennel[1,2] — [1]University of Rostock, Albert-Einstein-Straße 23, D-18059 Rostock, Germany — [2]Max-Born-Institute, Max-Born-Straße 2A, D-12489 Berlin, Germany

Only recently, coherent single-shot diffractive imaging (CDI) of individual free nanoparticles has been demonstrated with a laser-based source using high harmonic generation [1], promising new applications and unprecedented insights into the ultrafast dynamics induced or probed via the single-shot scattering process. So far, CDI experiments have been analyzed via an effective classical linear response description, e.g. to reconstruct the shape and orientation of nanoparticles [2]. For strong laser fields and in particular for resonant excitations, both the linear and the classical description may no longer be valid as population depletion and stimulated emission become important. To what extent such processes may influence CDI scattering images is currently largely unknown. In our theoretical analysis, we describe the quantum-mechanical few-level bound state dynamics using a density matrix formalism and incorporate this into a 3D Maxwell solver based on the finite-difference time-domain method (FDTD). We discuss how and to which extend the spatio-temporal population dynamics influences the scattering images and analyze the observed trends.

[1] D. Rupp et al., Nat. Commun. **8**, 493 (2017)
[2] I. Barke et al., Nat. Commun. **6**, 6187 (2015)

A 23: Strong laser fields - I (joint session A/MO)

Time: Tuesday 14:00–15:45 Location: K 2.019

Invited Talk A 23.1 Tue 14:00 K 2.019

Multiphoton Ionization of Chiral Molecules — •Thomas Baumert — Institut fuer Physik der Universitaet Kassel, Germany

Molecular chirality is widely recognized for its relevance to the building blocks of life and its vital role for medicine and health. Chiral recognition in the gas phase using electromagnetic radiation is an emerging research field and promising for fundamental research as well as for applications due to the non-interacting nature of molecules in the gas phase. Photoelectron angular distributions after one photon or multiphoton ionization turned out to be especially sensitive to that end and are usually measured by velocity map imaging (VMI) techniques. The corresponding circular dichroism is termed photoelectron circular dichroism (PECD). Based on electric dipole interaction, its magnitude of up to a few ten percent typically surpasses that of other chiroptical techniques and can be turned into a highly sensitive analytic tool with respect to investigation of enantiomeric excess. Resonance-enhanced multi-photon ionization (REMPI) gives access to electronic intermediates and, with the help of femtosecond laser excitation and ionization, PECD has been demonstrated on bicyclic ketones. As more angular momentum can be transferred in a multiphoton process in comparison to single photon ionization, higher order nodal structures were observed. An exploration of the nuclear and electron dynamics of the intermediate resonance may stimulate the development of laser driven purification schemes. In this talk I will present the field and our experiments. References are compiled for example in our latest publication: Kastner et al. JCP 2017, Vol. 147, 013926 (9 pp)

A 23.2 Tue 14:30 K 2.019

Non-linear dichroism in atomic ionization — •Jiri Hofbrucker[1,2], Andrey V. Volotka[1], and Stephan Fritzsche[1,2] — [1]Helmholtz Institute, Jena, Germany — [2]Friedrich-Schiller University Jena

Dichroic behavior is usually associated with an interaction of polarized atomic or chiral molecular target and circularly polarized light. However, in a non-linear interaction regime, elliptically polarized light ionizing symmetric target also produces a dichroic photoelectron angular distributions. The fundamental origin of this asymmetry explains why is the elliptical dichroism strictly a feature of multi-photon processes only, and why it is never observed in the single photon ionization process. Being energy and system specific, this phenomena give us an opportunity to study many-electron effects as well as fundamentals of non-linear light-matter interaction. Observation of this phenomena in two-photon ionization of an inner-shell shell electron of a rare gas atom is proposed.

A 23.3 Tue 14:45 K 2.019

Spin polarization and spin filtering of free electrons in bichromatic laser fields — Matthias M. Dellweg and •Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Coherent electron scattering from intense laser fields of high frequency is studied theoretically. By solving the time-dependent Dirac equation it is shown that the combination of a fundamental laser mode with a counterpropagating second harmonic may act as a spin filter for free electrons, provided the field polarizations are chosen properly [1]. Besides, a spin-polarizing interferometric electron beam splitter is presented which relies on an arrangement of three pairs of counterpropagating laser waves [2]. The proposed laser field configuration is shown to exert the same effect on free electrons as an ordinary Stern-Gerlach magnet does on atoms.

[1] M. M. Dellweg and C. Müller, Phys. Rev. A 95, 042124 (2017)
[2] M. M. Dellweg and C. Müller, Phys. Rev. Lett. 118, 070403 (2017)

A 23.4 Tue 15:00 K 2.019

Deterministic control with sequences of intense pulses — •Stefano M. Cavaletto, Zoltan Harman, Thomas Pfeifer, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Coherent-control methods and pulse-shaping technology have revolutionized our access to the quantum properties of matter. However, with widely used measurement-driven techniques, such as adaptive feedback control, the complex reaction pathways followed by an optimally controlled system often remain concealed. With intense time-dependent pulses dressing the atomic level structure, only a limited number of effective pulse-shaping strategies have been identified. Here, we put forward a deterministic scheme to fully reconstruct the action of an intense pulse on a quantum system from absorption-spectroscopy measurements, including the dependence upon possibly unknown pulse properties and atomic structures [S. M. Cavaletto *et al.*, *Phys. Rev. A* **95**, 043413 (2017)]. An optimal pulse sequence based on this extracted information can then be designed, facilitating manipulation and interpretation of the chosen control strategy. The scheme may be implemented also at x-ray energies with intense pulses from free-electron lasers, representing an effective route to x-ray quantum control.

A 23.5 Tue 15:15 K 2.019

Isotopic shifts measured via strong-field laser-atom interaction — •Nicolas Camus, Sofia Botsi, Lutz Fechner, Jose Crespo López-Urrutia, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

High-precision measurements of isotopic shifts in the energy levels of atoms can provide sensitive tests of our understanding of relativistic and QED effects [1]. We present a novel spectroscopic method to measure small isotopic shifts utilizing the coherent population of different states arising from strong-field ionization. We experimentally measure the isotope shift between ^{36}Ar, ^{38}Ar and ^{40}Ar for the $3s^23p^5$ ($^2P_{3/2} \rightarrow {}^2P_{1/2}$) transition in singly charged argon ions. We measure it by implementing a Ramsey-like scheme using two ultrashort (6 fs) laser pulses. The first laser pulse excites the system into a coherent superposition of the aforementioned states by removing an electron from the atomic p-shell of the neutral atom. This superposition leads to a spin-orbit wave packet (SOWP) oscillating with a period of T = 23.3 fs that lasts for long times (tens of ns). The second delayed pulse probes, after ∼170.000 cycles, the wavepacket dynamics of the system by further ionization, allowing for a precision determination of the spin-orbit frequency at the $\Delta E/E \sim 10^{-7}$ level . The detection of the different argon isotopes is made by a time-of-flight spectrometer. [1]. I. I. Tupitsyn et al., PRA 68, 022511 (2003)

A 23.6 Tue 15:30 K 2.019

Two pulse characterization by interferometric imaging of self-diffraction — •Christoph Leithold[1], Jan Reislöhner[1], Holger Gies[2,3], and Adrian N. Pfeiffer[1] — [1]Institute of Optics and Quantum Electronics, Abbe Center of Photonics, Friedrich Schiller University Jena, Germany — [2]Theoretisch-Physikalisches Institut, Abbe Center of Photonics, Friedrich Schiller University Jena, Germany — [3]Helmholtz-Institut Jena, Germany

A pulse characterization scheme based on interferometric, spectrally resolved imaging of self-diffraction [1] is presented. Similar to interferometric FROG [2] and MEFISTO [3], interferograms of the nonlinear signal are recorded for different pulse delays. Due to the noncollinear nature of the setup, it can be applied to over octave spanning waveforms by separating signals on the spatial frequency axis. Additionally to the temporal waveform the method also resolves one spatial dimension and is therefore not limited by geometrical effects like beam smearing [4], known from other noncollinear schemes. In fact, both fundamental pulses can be recovered from the same measurement. The retrieval of the pulses is carried out solely in the (temporal) frequency domain and can be done analytically as well as iterative numerically which is more robust when dealing with noisy data. [1] C. Leithold, J. Reislöhner, H. Gies and A.N. Pfeiffer Opt. Lett. 42, No. 23 in press. [2] G. Stibenz and G. Steinmeyer, Opt. Express 13, 2617 (2005). [3] Amat-Roldan, I. G. Cormack, P. Loza-Alvarez, and D. Artigas, Opt. Lett. 30, 1063 (2005). [4] A. C. Tien, S. Kane, J. Squier, B. Kohler, and K. Wilson, J. Opt. Soc. Am. B 13, 1160 (1996).

A 24: Cold Molecules and Reactions (joint session MO/A)

Time: Tuesday 14:00–15:45 Location: PA 2.150

Invited Talk A 24.1 Tue 14:00 PA 2.150

Towards the study of quantum-state-selected Penning reactions — Jonas Grzesiak, Simon Hofsäss, Vivien Behrendt, Frank Stienkemeier, Marcel Mudrich, and •Katrin Dulitz — Institute of Physics, University of Freiburg, Hermann-Herder-Str.3, 79104 Freiburg i.Br., Germany

Our goal is to study quantum-state-controlled Penning collisions between lithium atoms and metastable helium atoms at low collision energies, e.g., to study the influence of electron-spin polarization on the reaction rate and to observe quantum resonance effects. For this, we use an experimental apparatus which consists of a discharge source for the production of metastable helium atomic beams and a magneto-optical trap (MOT) for ultracold lithium atoms. Using a novel multi-pulse detection scheme, we are able to mass-selectively probe the ionic reaction products at improved energy resolution. In this contribution, I will give an overview of the current state of these experiments. I will also present our progress towards achieving quantum-state selectivity of the reaction partners, which includes optical quenching of the metastable He(2^1S_0) state and magnetic-hexapole focusing of the metastable He(2^3S_1, $M_J = 1$) state into the MOT target.

A 24.2 Tue 14:30 PA 2.150

Reactive scattering between metastable helium atoms and ultracold lithium atoms — •Jonas Grzesiak[1], Vivien Behrendt[1], Frank Stienkemeier[1], Marcel Mudrich[2], and Katrin Dulitz[1] — [1]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str.3, 79104 Freiburg i.Br. — [2]Department of Physics and Astronomy, Ny Munkegade 120, 8000 Aarhus C, DK

The experimental observation of quantum effects in Penning ionization reactions has recently attracted a lot of attention [1]. Our goal is to study such processes in a quantum-state-controlled manner at low collision energies, e.g., to study the influence of electron-spin polarization on the reaction rate. For this, we use an experimental setup which is composed of a magneto-optical trap for ultracold lithium atoms and a discharge source for the production of supersonic beams of metastable helium atoms. In this contribution, we will present a novel detection scheme which allows for the mass-selected detection of the ionic reaction products at improved energy resolution and we will discuss the influence of elastic collisions on the reaction rate measurements.

[1] A. B. Henson, S. Gersten, Y. Shagam, J. Narevicius, E. Narevicius, Science 338, 234 (2012).

A 24.3 Tue 14:45 PA 2.150

Blackbody-Induced Radiative Dissociation of van der Waals Clusters at the Cryogenic Storage Ring — •Felix Nuesslein[1], Klaus Blaum[1], Sebastian George[1], Jürgen Göck[1], Florian Grussie[1], Robert von Hahn[1], Matthias Klein[2], Thomas Kolling[2], Holger Kreckel[1], Michael Lembach[2], Christian Meyer[1], Preeti Manjari Mishra[1], Gereon Niedner-Schatteburg[2], Viviane Schmidt[1], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, D-69117 Heidelberg — [2]Technische Universität Kaiserslautern, D-67663 Kaiserslautern

Recently, blackbody-induced dissociation of van der Waals clusters was studied for $(SF_6)_N^-$ in a room temperature electrostatic ion beam trap [1]. However, the ground state stability of the various cluster sizes and the temperature-dependent dynamics of the infrared-active molecular clusters have not yet been investigated. For these, the Heidelberg electrostatic Cryogenic Storage Ring (CSR) provides ideal conditions. It was recently used to measure the rotational relaxation of infrared-active molecules in a ~15 K effective radiation field [2]. Low residual gas density (<140 cm^{-3}) enables storage of fast ion beams in the CSR for times up to hours [3]. Currently, we assemble a laser vaporization source to produce $(SF_6)_N^-$ and $SF_5^+(SF_6)_{N-1}$ clusters. We aim at studying their heating dynamics inside the CSR at various temperatures via the two main infrared bands of SF_6 at 10.6 μm and 16 μm.

[1] I. Rahinov et al., Eur. Phys. J. D 70 (2016) 260.
[2] C. Meyer et al., Phys. Rev. Lett. 119 (2017) 023202.
[3] R. von Hahn et al., Rev. Sci. Instrum. 87 (2016) 063115.

A 24.4 Tue 15:00 PA 2.150

Molecular conformer-selection by matter-wave diffraction at narrow-band optical phase gratings — •Christian Brand[1], Benjamin A. Stickler[2], Christian Knobloch[1], Armin Shayeghi[1], Klaus Hornberger[2], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria — [2]Faculty of Physics, University of Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

Molecular conformations are of utmost importance in molecular recognition processes and recent collision studies have demonstrated the strong influence of molecular conformation on bimolecular reaction rates [1]. It is therefore of great interest to develop methods that are capable of separating single structures even from a congested conformational space. Here propose a new method that can separate conformers independently of their molecular dipole moment [2]. By diffraction the matter-wave at a near-resonant ultraviolet optical grating, individual conformers of complex molecules can be spatially isolated in a selected diffraction order. We illustrate the principle and discuss how to prepare a conformer-pure molecular beam of the neurotransmitter 2-phenylethylamine. The technique thus paves the way for structure-sensitive experiments with hydrocarbons and biomolecules, such as neurotransmitters and hormones, which evaded conformer-pure isolation so far. The applications range from environmental research, biomolecular physics to astrophysics.

[1] Chang et al., Science 342 98 (2013)
[2] C. Brand et al., ArXiv 1710.01035 (2017)

A 24.5 Tue 15:15 PA 2.150

Separation of water dimer — •Helen Bieker[1,2], Melby Johny[1], Thomas Kierspel[1], Boris Sartakov[3], Andrey Yachemenev[1], Sebastian Trippel[1,3], Daniel A. Horke[1,2], and Jochen Küpper[1,2,4] — [1]Center for Free-Electron Laser Science, DESY — [2]The Hamburg Center for Ultrafast Imaging, University Hamburg — [3]General Physics Institute, Russian Academy of Sciences — [4]Department of Physics, University of Hamburg

To unravel the microscopic details of intermolecular interactions in water, we prepare controlled samples of size- and isomer-selected water clusters. Inhomogeneous electric fields allow us to create pure samples of individual structural isomers or of size-selected molecular clusters and to disperse molecules in a beam according to their quantum states [1].

Here, we aim to develop an understanding of the structures of water clusters containing a few monomer units. We present our first results on the production of size-selected samples using supersonic expansions, subsequent separation of water dimer in strong electric fields, extending previous studies [2].

Future experiments aim at utilizing x-ray and electron diffractive imaging to study the structures and ultrafast dissociation dynamics of these polymolecular systems.

[1] Y.P. Chang, D. A. Horke, S. Trippel and J. Küpper, *Int. Rev. Phys Chem.* **34**, 557-590 (2015)
[2] R. Moro, R. Rabinovitch, C. Xia, and V.V. Kresin, *Phys. Rev. Lett.* **97**, 123401 (2006)

A 24.6 Tue 15:30 PA 2.150

A Molecular Zeeman slowing scheme — •Maurice Petzold, Paul Kaebert, Philipp Gersema, Mirco Siercke, and Silke Ospelkaus — Institut für Quantenoptik, Leibniz Universität Hannover

We present our results on implementing a novel technique for slowing molecules to velocities trappable by magneto-optical traps. The scheme relies on the decoupling of angular momenta at high magnetic fields and is capable of continuously slowing and compressing the 1D velocity distribution. Detailed Monte-Carlo simulations show a significant increase in flux of slow molecules compared to current slowing techniques. To underline our theoretical efforts, we perform an experiment on an atomic test bed with similar level structure, showing good agreement between experimental and theoretical results. The advantages and implementation of our scheme closely resemble those of atomic Zeeman slowing, and implementation of our idea in a molecular system could be the missing link for realizing a large, ultra-cold ensemble of directly cooled molecules.

A 25: Poster Session I

Time: Tuesday 16:15–18:15 Location: Redoutensaal

A 25.1 Tue 16:15 Redoutensaal

The tunneling time, a theoretical model for real tunneling time and the attosecond experimental results. — •Ossama Kullie — University of Kassel, Fachbereich 10, Heinrichplett str. 41, 34132 Kassel

In this work we discuss our theoretical tunnelings model for real tunneling time [1, 2, 3], with a comparison to the results of attosecond experiments for He-atom and H-atom, where good agreements with the experiments are found. However, although the tunneling time is hot debated with a controversial discussions, it offers a fruitful op-

portunity to understand time measurement and the time in quantum mechanics. In our model a real tunneling time is suggested and is compared with other model including time-dependent Schroedinger equation, and Feynman bath integral or the statistical approach of the tunneling time. In addition, we will see that there are crucial points for higher intensities, in particular where the electric filed strength is higher than the atomic filed strength, this opens some questions on the experimental side.
[1] O. Kullie, Phys. Rev. **92**, 052118 (2015). [2] O. Kullie, J. Phys. B **49**, 095601 (2016). [3] O. Kullie, (2017), Ann. of Phys. (2017), under review. arXiv:1701.05012.

A 25.2 Tue 16:15 Redoutensaal

Near L-edge single and multiple photoionization of singly charged iron ions — •Stefan Schippers[1], Michael Martins[2], Randolf Beerwerth[3], Sadia Bari[4], Kristof Holste[1], Kaja Schubert[4], Jens Viefhaus[4,5], Daniel Wolf Savin[6], Stephan Fritzsche[3], and Alfred Müller[1] — [1]Univ. Gießen — [2]Univ. Hamburg — [3]Univ. Jena and HI Jena — [4]DESY — [5]HZB — [6]Columbia Astrophysics Laboratory, New York, USA

Absolute cross sections for m-fold photoionization ($m = 1, \dots, 6$) of Fe^+ by a single photon were measured employing the photon-ion merged-beams setup PIPE at the PETRA III synchrotron light source, operated by DESY in Hamburg, Germany. Photon energies were in the range 680–920 eV which covers the photoionization resonances associated with $2p$ and $2s$ excitation to higher atomic shells as well as the thresholds for $2p$ and $2s$ ionization. Supporting semi-relativistic and fully relativistic atomic-structure calculations are in good agreement with each other and with the experimental results. In particular, the complex deexcitation cascades after the creation of inner-shell holes in the Fe^+ ion have been tracked on the atomic fine-structure level. The resulting theoretical product charge-state distributions are in much better agreement with the experimental data than previously published charge-state distributions from a configuration-average approach. The present experimental and theoretical results [1] are valuable for opacity calculations and are expected to pave the way to a more accurate determination of the iron abundance in the interstellar medium.
[1] S. Schippers et al., Astrophys. J. 849 (2017) 5.

A 25.3 Tue 16:15 Redoutensaal

Condensation effects and interatomic processes in noble gases investigated by cathodoluminescence — •Catmarna Küstner-Wetekam, Andreas Hans, Xaver Holzapfel, Philipp Schmidt, Christian Ozga, Gregor Hartmann, Arno Ehresmann, and André Knie — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

The condensation behaviour and properties of electronic decay processes of noble gases sensitively depend on their atomic number. The grade of condensation strongly impacts the radiative properties of these systems such as line width and spectral shapes. Therefore the luminescence spectra acts as a fingerprint of these systems. Here, we present luminescence spectra from helium, neon, and argon jets produced by supersonic expansion from a cryogenic cluster source after electron impact excitation. As an outlook, we compare them with emission after site-selective photo-excitation and suggest the investigation of various interatomic processes by cathodoluminescence. Finally, we envision our method to be of importance for many schemes, in which electrons are emitted by any means in large clusters, because they can subsequently induce emissions comparable to direct cathodoluminescence.

A 25.4 Tue 16:15 Redoutensaal

A grazing-incidence 4-quadrant split-mirror setup for multidimensional spectroscopy experiments in the XUV — •Carina da Costa Castanheira, Marc Rebholz, Thomas Ding, Lennart Aufleger, Patrick Rupprecht, Paul Birk, Christian Ott, and Thomas Pfeifer — Max-Planck Institut für Kernphysik, Heidelberg, Germany

In this work the home-built four-quadrant split-mirror dedicated for grazing-incidence multidimensional spectroscopy experiments in the near infrared (NIR) and extreme ultraviolet (XUV) is characterized by an interferometric measurement. For this purpose the stability was investigated with a HeNe laser and the temporal overlap between the mirrors themselves was determined using a femtosecond Ti:Sa laser system. Beginning with analyzing stability issues and finding temporal overlap between the mirrors, this work continued with first measurements on NIR-NIR-XUV four-wave-mixing in neon in the extreme ultraviolet (XUV) spectral region. Furthermore, first nonlinear XUV-only proof-of-principle experiments were carried out with this setup at the free-electron laser facility FLASH in Hamburg (Germany). These experiments can be seen as a working proof of the four-quadrant split-mirror setup which serves as a basis for future progress in four-wave-mixing experiments with our setup at both mixed NIR/XUV as well as XUV-only spectral regions.

A 25.5 Tue 16:15 Redoutensaal

Attosecond Time Delays in Photoionization of Noble Gas and Halogen Atoms — •Liang-Wen Pi and Alexandra S. Landsman — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany

Ultrafast processes are now accessible on the attosecond time scale due to the availability of ultrashort XUV laser pulses. Noble gas and halogen atoms remain interesting targets due to their giant dipole resonance and Cooper minimum. We have calculated photoionization cross section, asymmetry parameter and Wigner time delay using the time-dependent local-density approximation (TDLDA), which includes electron correlation effects and generates qualitatively good agreement with experimental data and other theoretical calculations. The asymmetry parameter provides additional information on the electron phase in the photoionization process. We find that halogen atoms bear a strong resemblance on cross section, asymmetry parameter and time delay to their noble gas neighbors. Our predicted time delay can be tested in future attosecond experiments on these atoms and related molecules.

A 25.6 Tue 16:15 Redoutensaal

Strong-field assisted VUV amplification in doped helium droplets — •Andreas Rubisch, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

High harmonic generation in intense laser pulses is a valuable tool to obtain radiation in the UV and x-ray regime. In order to overcome the typically low conversion efficiency, it was proposed to assist the emission of high harmonics in single atoms or molecules by an intense near-infrared (NIR) driving pulse [1].

Such a mechanism could be powerful in atomic clusters as well. There the NIR pulse generates a nano-plasma, which, however, is highly unstable upon evaporation. Here we study helium droplets doped with a handful of xenon atoms, where by means of dopant-induced ignition a lower-temperature nano-plasma is formed [2,3].

We perform classical molecular-dynamics calculations for the NIR-driven cluster system. The interaction with a weak VUV pulse is treated perturbatively and we investigate the trade-off between absorption and emission of VUV light from the irradiated nano-plasma.

[1] T. Bredtmann et al., PRA 93, 021402(R) (2016)

[2] A. Mikaberidze et al., PRA 77, 041201(R) (2008); PRL 102, 128102 (2009)

[3] S.R. Krishnan et al. PRL 107, 173402 (2011)

A 25.7 Tue 16:15 Redoutensaal

Tracing the molecular potential energy landscape on rovibronic emission maps of molecular hydrogen — •Philipp Schmidt, Andreas Hans, Christian Ozga, Arno Ehresmann, and André Knie — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

The band spectra of molecular systems in absorption or emission are an integral part in the history and development of spectroscopic observations. While generally assumed to be well understood and a case for textbooks, there are still transitions between bound and unbound states in even the simplest molecules such as hydrogen that require extensive theoretical treatment to explain or exhibit an intertwined system of lines hard to identify. By examining the photon and ion emissions of such systems in dependance of their internal energy, the full process from excitation to final deexcitation can be monitored. When performed over the complete set of accessible states at once, the resulting map disentangles not only the individual processes from each other, but also gives a unique view on their interaction at the respective boundaries. Here we present such a treatment for molecular hydrogen and its isotopes through comparing experimental results after selective excitation by synchrotron radiation and theoretical models in the entire regime of singly excited states.

A 25.8 Tue 16:15 Redoutensaal

Design of a Thomson Ion Streak Spectrometer for the European-XFEL — Burkhard Langer, Felix Gerke, Egill Antonsson, and •Eckart Rühl — Physikalische Chemie, Freie Universität Berlin, Takustr. 3, 14195 Berlin

When clusters or nanoparticles are exposed to free-electron-laser (FEL) radiation, Coulomb explosion produces ions that can have kinetic energies of several hundred electron volts. In a conventional time-of-flight mass spectrometer the ion spectrum is smeared out since the flight time blends the charge-to-mass ratio with the kinetic energy of the ions. In our novel design of a Thomson type spectrometer the simultaneous application of a magnetic and an electric field is used to disentangle these properties. Ions of the same charge-to-mass ratio are focused on specific parabolas on the detection screen and the positions along these parabolas depend upon their kinetic energy. For experiments at FEL facilities, such as FLASH and the European-XFEL in Hamburg, that offer an X-ray beam with micro-bunches it is possible to use a fast, stepwise varying extraction field to imprint the micro-bunch time structure to the kinetic energy of the ions. This increases the detection efficiency by using several of the micro-bunches, particularly when the novel spectrometer is used in combination with other time resolved devices.

A 25.9 Tue 16:15 Redoutensaal

Electronic bridge for the x-ray Mössbauer transition in ^{57}Fe — •Pavlo Bilous and Adriana Pálffy — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, D-69117 Heidelberg, Germany

The 14.4 keV transition coupling the first excited state to the ground state in the isotope ^{57}Fe is widely used for Mössbauer absorption spectroscopy. The commissioning of the first x-ray free electron laser (XFEL) sources render possible both direct excitation of this transition [1] but also alternative ways involving two-photon transitions. Here we investigate the excitation of the nuclear 14.4 keV state with two x-ray beams at approximately equal energies at an x-ray laser facility such as SACLA or LCLS. Apart from the process of direct absorption of two photons by the nucleus we investigate excitation of the nuclear state via the electronic bridge process in the atomic shell. Our results show that the direct two-photon excitation of the ^{57}Fe nucleus is highly unlikely whereas the excitation via electronic bridge may reach measurable rates.

[1] A. I. Chumakov *el.*, Nature Phys. in press (2017)

A 25.10 Tue 16:15 Redoutensaal

Angular-resolved photoelectron spectroscopy of xenon doped helium droplets — •Michael Zabel, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universität Rostock, Institut für Physik, Albert-Einstein-Strasse 23, 18059 Rostock

Angular resolved photoelectron emission of xenon doped helium droplets ionized with a 810 nm femtosecond laserpuls is studied. The signal of the direct and rescattered electrons was investigated for different laser intensities and doping conditions.

A 25.11 Tue 16:15 Redoutensaal

Direct two-electron ejection from F$^-$ by a single photon — •Alfred Müller[1], Alexander Borovik Jr.[1], Sadia Bari[2], Ticia Buhr[1], Kristof Holste[1], Michael Martins[3], Alexander Perry-Sassmannshausen[1], Ronald Phaneuf[4], Simon Reinwardt[3], Sandor Ricz[5], Kaja Schubert[2], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]DESY Hamburg — [3]Universität Hamburg — [4]University of Nevada, Reno, USA — [5]ATOMKI Debrecen, Hungary

Double and triple detachment of the F$^-(1s^2 2s^2 2p^6)$ negative ion by a single photon have been investigated in the photon energy range 660 to 1000 eV [1]. The experimental data provide unambiguous evidence for the dominant role of direct photo-double-detachment with a subsequent single-Auger process in the reaction channel leading to F^{2+} product ions. Absolute cross sections were determined for the direct removal of a $(1s + 2p)$ pair of electrons from F$^-$ by the absorption of a single photon.

[1] A. Müller *et al.*, (submitted).

A 25.12 Tue 16:15 Redoutensaal

A non-linear mapping from photo-electron spectra to pulse shape — •Sajal Kumar Giri, Ulf Saalmann, and Jan-Michael Rost — Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany

Strong field quantum dynamics are very sensitive to the shape of the interacting field. Finding a suitable pulse shape to reach a predefined target lies in the heart of quantum control. The forward nonlinear mapping between the interacting pulse and the objective (photoelectron spectra(PES)) can be achieved by solving the time-dependent Schrödinger equation. However, the non-linear inverse mapping i.e. a mapping from the PES to the pulse shape is not straightforward. In this work, we have explored the non-linear inverse mapping using the artificial neural network. As a test system, we have studied quasi-resonant two-photon ionization of a helium atom for the interaction with different pulse shapes of the same energy and same frequency content. For this process, the photo-electron spectra are very different for different pulses and contain all the detailed information of the pulses. The sensitivity of each input to the output is also investigated in this work. This method can be extended for the measurement of free electron laser pulse shape from the knowledge of PES.

A 25.13 Tue 16:15 Redoutensaal

Transitions above (and near) the ionisation threshold — •Anne Harth, Robert Moshammer, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

Photoionization is a fundamental and still extensively discussed process, where an electron is removed from e.g. an atom by a high-energy photon. Recently, it was possible to measure a photoionization phase shift between a single electron coming from the 2s or 2p state in a neon atom [1,2]. Such a phase shift can be interpreted as a time delay that is on the order of only a few attoseconds.

However, the kinetic energy of such a released electron depends on the photon energy and the ionisation potential. A slow electron, which is still in the influence of its mother ion, can absorb additional photons. The dipole matrix element, which describes the additional photoabsorption in the continuum, is often either neglected or calculated [4] and was not experimentally studied so far, but plays an important role e.g. in the above mentioned photoionization experiment in Neon [2,3].

We propose and discuss a multi-color electron wave packet interferometer to experimentally study the near ionisation threshold continuum including continuum-continuum dipole transitions matrix elements.

[1] Schultze et al. Science 328, 1658 (2010)
[2] Isinger et al. Science 358 , 893 (2017)
[3] Véniard et al. Phys. Rev. A 54, 721 (1996)
[4] Dahlström et al. Chemical Physics 414, 53 (2013)

A 25.14 Tue 16:15 Redoutensaal

Disentangling the photodissociation pathways of small lead clusters by time-resolved monitoring of their delayed decays: The case of Pb$_{31}^+$ — •Markus Wolfram, Stephan König, Steffi Bandelow, Paul Fischer, Alexander Jankowski, Gerrit Marx, and Lutz Schweikhard — Ernst-Moritz-Arndt Universität, Greifswald, Deutschland

Lead clusters Pb$_n^{(+/-)}$ in the size range between about $n = 15$ and 40 have recently shown to exhibit complex dissociation spectra due to sequential and competing decays [1]. In order to disentangle the pathways, the exemplary Pb$_{31}^+$ clusters have been stored and size selected in a Penning trap at the ClusterTrap setup [2] and irradiated by nanosecond laser pulses.

We present time-resolved measurements of the decay behavior at time scales from several tens of microseconds to several hundreds of milliseconds. The study results in strong evidence that Pb$_{31}^+$ decays not only by neutral monomer evaporation but also by neutral heptamer breaking off [3].

[1] S. König et al., J. Phys. Chem. C 121 (2017) 10858
[2] F. Martinez et al., Int. J. Mass Spectrom. 365-366 (2014) 266
[3] M. Wolfram et al., J. of Phys. B: Atomic, Molecular and Optical Physics, in print

A 25.15 Tue 16:15 Redoutensaal

Laser-nucleus interactions with nucleon emission — •Sergei Kobzak, Hans Weidenmüller, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Recent experimental developments in laser physics and laser-driven acceleration promise to deliver coherent photon beams with energies ranging up to several MeV. The utilization of a laser beam with photon energies comparable to typical nuclear excitation energies will shed light on a number of questions and will open new unexplored avenues for nuclear physics [1,2].

In this work we investigate theoretically the interaction between coherent gamma-ray laser pulses and medium-weight or heavy nuclei in the case of sudden regime. In this regime the compound nucleus statistical equilibration rate is slower than the average photon absorption rate. Consequently, nucleons are excited independently and are expelled from the common average potential. Multiple photon absorptions may lead to complete evaporation of the nucleus if the duration of the laser pulse of several MeV per photon is long enough. The time evolution of such processes is studied with help of master equations which take into account neutron decay and feeding, dipole absorption and emission and the nucleon-nucleon interaction.

[1] A. Pálffy and H. A. Weidenmüller, Phys. Rev. Lett. 112, 192502 (2014).
[2] A. Pálffy, O. Buss, A. Hoefer and H. A. Weidenmüller, Phys. Rev. C 92, 044619 (2015).

A 25.16 Tue 16:15 Redoutensaal

Attosecond streaking with twisted X waves — •Birger Böning[1], Willi Paufler[1], and Stephan Fritzsche[1,2] — [1]Friedrich-Schiller-Universität, Jena, Germany — [2]Helmholtz-Institut Jena, Germany

Attosecond streaking is an established technique to measure timing information in the interaction of ultrashort laser pulses with atoms or molecules. This technique is based on the photoionization by an attosecond laser pulse in the presence of a strong linearly polarized near infrared (NIR) laser pulse. We investigate the attosecond streaking with an X wave pulse carrying orbital angular momentum and a strong linearly polarized near infrared (NIR) laser pulse. In contrast to plane wave pulses, X waves have a spatially dependent temporal profile, which modifies the ionization process. In this contribution we theoretically explore the influence of this complex pulse structure on the streaking of photoelectrons for both localized and macroscopically extended targets. On the basis of the strong-field approximation (SFA), we find that the streaking spectra of localized targets sensitively depend on the opening angle of the X wave and the position of the atomic target relative to the beam axis. For macroscopically extended targets, we find that the streaking spectra do not depend on the parameters characterizing the twist of the X wave.

[1]: B. Böning et al., Phys. Rev. A 96, 043423 (2017)

A 25.17 Tue 16:15 Redoutensaal

Radical increase of the parametric X-ray intensity under condition of extremely asymmetric diffraction — •Oleg D Skoromnik[1], Vladimir G Baryshevsky[2], Alexander P Ulyanenkov[3], and Ilya D Feranchuk[4,5,6] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institute for Nuclear Problems, Belarusian State University, 4 Nezavisimosty Ave., 220030 Minsk, Belarus — [3]Atomicus GmbH, Schoemperlen Str. 12a, 76185 Karlsruhe, Germany — [4]Atomic Molecular and Optical Physics Research Group, Ton Duc Thang University, 19 Nguyen Huu Tho Str., Tan Phong Ward, District 7, Ho Chi Minh City, Vietnam — [5]Faculty of Applied Sciences, Ton Duc Thang University, 19 Nguyen Huu Tho Str., Tan Phong Ward, District 7, Ho Chi Minh City, Vietnam — [6]Belarusian State University, 4 Nezavisimosty Ave., 220030, Minsk, Belarus

A dynamical theory of diffraction is employed for the description of the parametric X-ray radiation (PXR) from relativistic electrons which move in a crystal along the crystal-vacuum interface. In this geometry the emission of photons is happening in the regime of extremely asymmetric diffraction (EAD). In the EAD case the whole crystal length contributes to the formation of X-ray radiation opposed to Laue and Bragg geometries, where the emission intensity is defined by the X-ray absorption length. We predict a radical increase of two order of magnitude in the PXR intensity in comparison with the conventional experimental geometries of PXR. [1] Nucl. Instr. Meth. B 412 (2017) 86-92.

A 25.18 Tue 16:15 Redoutensaal

Correlation method for velocity map imaging and time of flight techniques for electrons and ions in helium nanodroplets. — •cristian medina[1], dominik schomas[1], nicolas rendler[1], robert moshammer[2], thomas pfeifer[2], and marcel mudrich[3] — [1]Albert Ludwigs University of Freiburg, Freiburg, Germany — [2]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [3]Aarhus University, Aarhus, Denmark

Velocity map imaging (VMI) and time of flight (TOF) are techniques that have been used separately to study molecules and clusters. Using a combined VMI-TOF setup, doped helium nanodroplets are irradiated by near-infrared femtosecond laser pulses creating a nanoplasma state by strong-field ionization. The occurring electrons couple very efficiently to the laser field and acquire high energy, resulting in an avalanche of impact ionizations. The large number of charged particles allows us to collect complete spectra for both, VMI and TOF, from a single hit. We present a computational method for the data acquisition and correlation in real time for the VMI-TOF experiment by linking the CCD-camera from the VMI to a data acquisition card of the TOF. This allows us to identify a single event in each technique making possible to link each other and study the complete spectra for a single nanoplasma. The program runs on the LabVIEW real-time platform in a rate of 3μs per loop and includes identification of events that analyses and save only single events data discarding non relevant information.

A 25.19 Tue 16:15 Redoutensaal

The role of laser dressed bands in the strong field dynamics of dielectrics — •Lukas Medišauskas, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Since the discovery of high harmonic generation (HHG) in solid state materials, the dependence of HHG spectra on the generating medium as well as on the chosen geometry and characteristics of the generating radiation were actively investigated.

However, a strong electromagnetic field applied to a material not only drives the electronic dynamics, but also modifies the electronic states via the AC Stark effect, thus modifying the effective band structure.

We investigate such laser “dressing” of the bands of a solid by solving the time-dependent Schrödinger equation for a model dielectric exposed to a strong and low frequency field. Using an expansion into photon-number states, we identify the dominating multi-photon channels and reveal their connection to the field dressed bands. Finally, we demonstrate that the HHG process in solids can be traced to the field dressed band structure.

A 25.20 Tue 16:15 Redoutensaal

K-shell photoionoization of Silicon ions — •Ticia Buhr[1], Alexander Perry-Sassmannshausen[1], Simon Reinwardt[2], Sandor Ricz[3], Michael Martins[2], Alfred Müller[4], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Germany — [2]Institut für Experimentalphysik, Universität Hamburg, Germany — [3]Institute for Nuclear Research, Hungarian Academy of Sciences, Debrecen, Hungary — [4]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen, Germany

Absolute cross sections for single and multiple photoionization of low charged atomic silicon ions at the silicon K-edge have been experimentally determined. Such data are of immediate interest for x-ray astrophysics [1] and benchmark theoretical calculations. The measurements were carried out at the PIPE setup [2] at the beam line P04 on the synchrotron light source PETRA III (Hamburg, Germany) employing the photon-ion merged-beams technique. Precise K-shell ionization resonance parameters (positions, widths,...) for these ions and branching ratios for the production of the various product-ion charge states are provided.

[1] T. Holczer *et al.*, Astrophys. J. **708**, 981 (2010).
[2] S. Schippers *et al.*, J. Phys. B **47**, 115602 (2014).

A 25.21 Tue 16:15 Redoutensaal

Multiple ionization of Ne^+ ions by photoabsorption near the K edge — Alfred Müller[1], Dietrich Bernhardt[1], Alexander Borovik Jr.[1], •Ticia Buhr[1], Jonas Hellhund[1], Kristof Holste[1], A. L. David Kilcoyne[2], Stephan Klumpp[3,4], Michael Martins[3], Sandor Ricz[5], Jörn Seltmann[4], Jens Viefhaus[4,6], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]ALS, Berkeley, USA — [3]Universität Hamburg — [4]DESY, Hamburg — [5]Atomki, Debrecen, Hungary — [6]HZB, Berlin

Single, double and triple photoionization of Ne^+ ions by single photons have been investigated at PETRA III in Hamburg [1]. Absolute cross sections were measured using the photon-ion merged-beams technique [2]. Photon energies were between 840 and 930 eV, covering the range from the lowest-energy resonances associated with the excitation of one single K-shell electron up to double excitations involving one K- and one L-shell electron, well beyond the K-shell ionization threshold. Photoionization of neutral Ne was also studied just below the K edge. The photon energy bandwidths were between 32 and 500 meV, facilitating the determination of natural line widths. For comparison with theoretical calculations, astrophysically relevant photoabsorption cross sections were inferred by summing the measured partial ionization channels. The observed resonances in the final ionization channels reveals the presence of complex Auger-decay mechanisms.

[1] A. Müller *et al.*, Astrophys. J. **836**, 166 (2017).
[2] S. Schippers *et al.*, J. Phys. B **47**, 115602 (2014).

A 25.22 Tue 16:15 Redoutensaal

Imaging Charge Distribution in Time with XUV photoelectrons — •Abraham Camacho Garibay, Hyunwook Park, and Louis DiMauro — The Ohio State University, Columbus, OH, USA

Recent experiments with XFELs have shown the usefulness of photoelectron energy measurements in order to understand the electronic properties of the targets. These experiments usually require extreme intensities and very short pulses. Here we show that the same basic idea can be applied in principle with less demanding conditions, by utilizing a table-top IR laser as a pump, and a short delayed XUV probe in order to obtain information about the expansion dynamics of the target.

A 25.23 Tue 16:15 Redoutensaal

Time-resolved X-ray Imaging of Anisotropic Nanoplasma Expansion — •Christian Peltz[1], Christoph Bostedt[2], Mathias Kling[3], Thomas Brabec[4], 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. This process 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]. Here we present the first successful high resolution reconstruction of corresponding experimental results, obtained at the LCLS facility with SiO2 nanoparticles (D=120 nm), and compare them to the theoretical predictions.

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

A 25.24 Tue 16:15 Redoutensaal

Strong field ionization with Bessel pulses — •Willi Paufler[1], Birger Böning[1], and Stephan Fritzsche[1,2] — [1]Friedrich-Schiller Universität, Jena, Germany — [2]Helmholtz-Institut, Jena, Germany

Since twisted light beams draw interest in many parts of physics, it is also desired to understand their interaction with atoms and molecules. We apply a Quantum Trajectory Monte Carlo model (QTMC) to describe strong field ionization of atoms by twisted beams (Bessel beams) and calculate photoelectron momentum distributions (PEMD). Bessel beams are an infinite superposition of circularly polarized plane waves with the same helicity, whose wave vectors lie on a cone. Thus, we compare the obtained PEMD to those of strong field ionization by circularly polarized pulses. We focus on the momentum distributions in propagation direction of the pulse and show how to these momentum distributions depend on experimental parameters, such as the opening angle of the beam or the impact parameter of the atom with regard to the beam axis.

A 25.25 Tue 16:15 Redoutensaal

Attosecond time-resolved photoelectron holography — Gil Porat[1], Gideon Alon[2], Shaked Rozen[2], Oren Pedatzur[2], •Michael Krüger[2], Adi Natan[3], Barry D. Bruner[2], Marc J. J. Vrakking[4], and Nirit Dudovich[2] — [1]JILA, NIST and University of Boulder, Colorado, USA — [2]Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel — [3]Stanford PULSE Institute, SLAC, Menlo Park, California, USA — [4]Max-Born-Institut, 12489 Berlin, Germany

Ultrafast strong-field physics provides insight into quantum phenomena that evolve on an attosecond time scale, the most fundamental of which is quantum tunneling. In this work we apply attosecond photoelectron holography [1] as a new method to resolve the temporal properties of the tunneling process. Adding a weak second harmonic (SH) field to a strong fundamental laser field enables us to reconstruct the ionization times of photoelectrons that play a role in the formation of a photoelectron hologram with attosecond precision. We decouple the contributions of the two arms of the hologram and resolve the subtle differences in their ionization times, separated by only a few tens of attoseconds.

[1] Y. Huismans et al., Science 331, 61 (2011).

A 25.26 Tue 16:15 Redoutensaal

Accurate modeling of Auger cascades and its applications — •Sebastian Stock[1,2], Randolf Beerwerth[1,2], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

Inner-shell excitation or ionization of atoms and ions usually leads to a cascade of autoionization processes. In the past decade, advances in experimental techniques such as modern UV and X-ray sources as well as ultrafast time-resolved spectroscopy have fueled considerable interest in the study of complex decay cascades. Our approach to an accurate description of these decay cascades is based on extensive multiconfiguration Dirac–Fock calculations on a fine-structure level. In order to achieve good results within the limits of todays computational power, we employ models of varying sophistication, including important electron correlation effects and higher-order effects such as shake processes [1, 2]. Apart from showing our theoretical modeling in general, we here present our recent results on Auger cascades in singly-charged silicon and neutral krypton [3] which have been conducted in collaboration with different experimental groups.

[1] S. Schippers *et al.*, *Phys. Rev. A* **94**, 041401 (2016).
[2] S. Stock, R. Beerwerth, and S. Fritzsche, *Phys. Rev. A* **95**, 053407 (2017).
[3] K. Hütten *et al.*, submitted 2017.

A 25.27 Tue 16:15 Redoutensaal

A source for helium droplets and liquid jets for time-resolved diffractive imaging experiments with high-harmonic pulses — •Katharina Kolatzki[1,2], Nils Monserud[1], Arnaud Rouzée[1], Mario Sauppe[1,2], Bernd Schütte[1], Julian Zimmermann[1,2], Thomas Möller[2], Marc J.J. Vrakking[1], and Daniela Rupp[1,2] — [1]MBI, Germany — [2]IOAP TU Berlin, Germany

Our recent demonstration of single-particle coherent diffractive imaging (CDI) with a femtosecond high-harmonics generation (HHG) source [D. Rupp et al., Nat. Comm. 8, 493 (2017)] opens the door to the investigation of excitation and ionization dynamics in extended matter. These processes take place in the attosecond time domain. In principle, attosecond pulses can be generated by HHG sources, but the achievable intensities are too low for single-shot CDI. For a diffractive imaging approach, it is necessary to average over multiple single shot diffraction images, which requires a constant target. To make this procedure feasible, we intend to build a source for extremely large helium droplets and liquid jets, which will serve as a reproducible target. Key ideas and design parameters will be discussed.

A 25.28 Tue 16:15 Redoutensaal

Manipulating single photon propagation through alkali vapour cells — •Lea Kopf[1], Hüseyin Vural[2], Simone Luca Portalupi[2], Julian Maisch[2], Simon Kern[2], Jonas Weber[2], Michael Jetter[2], Ilja Gerhardt[3,4], Peter Michler[2], and Robert Löw[1] — [1]5. Physikalisches Institut and IQST, University of Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, IQST and SCoPE, University of Stuttgart, Allmandring 3, D-70569 Stuttgart, Germany — [3]3. Physikalisches Institut and IQST, University of Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany — [4]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

A crucial component of future quantum network technologies are quantum memories, in which single photons are stored and read-out. Single photons generated in quantum dots provide on-demand emission and a high photon indistinguishability. The broadband capabilities and room temperature operation of quantum memory schemes in alkali vapour cells are a suitable storage medium. By tuning quantum dot photons to a 'transparency window' between the hyperfine lines we have realized a temperature dependent time delay. In a next step we want to employ an EIT/Autler-Townes scheme to achieve optical control on the single photon propagation. An important aspect for storing single photons is excellent control over the read/write pulses, optical pumping and the manufacturing of optimized vapour cells.

A 25.29 Tue 16:15 Redoutensaal

Modular He nanodroplet source for the SQS end station at the European XFEL — •Fabian Seel[1], Anatoli Ulmer[1], Bruno Langbehn[1], Daniela Rupp[1], Yevheniy Ovcharenko[2], and Thomas Möller[1] — [1]IOAP, Technische Universität Berlin, Germany — [2]European XFEL, Hamburg, Germany

Because of their unique properties, ultra-cold superfluid helium nanodroplets are considered to be perfect matrices for high resolution spectroscopy [Angew. Chem. Int. Ed. 2004, 43, 2622 - 2648] and can be doped with virtually any atomic or molecular sample. Diffraction patterns of such single free nanoparticles can be recorded using the ultrashort and bright X-ray pulses generated by X-Ray Free-Electron Lasers (XFEL). From those diffraction patterns, the structure of an embedded sample can be reconstructed quickly and reliably with the novel technique of Droplet Coherent Diffractive Imaging (DCDI) [Struct. Dyn. 2, 051102 (2015)]. To exploit valuable beamtime at the new European XFEL, we set up a new source for helium droplets, matching the XFEL's pulse structure with a pulse train length of $600\,\mu s$ at a repetition rate of 10 Hz. At operating temperatures as low as 5 K, large droplets with $N \geq 10^8$ atoms can be produced in an expansion through a conical nozzle. To provide a source for different conditions, we have developed a modular source head that is able to operate with either a pulsed Even-Lavie Valve or a commercial Parker Series 99 Pulsed Valve. First characterization measurements taken in the laboratory will be presented and discussed.

A 25.30 Tue 16:15 Redoutensaal

Transient absorption spectroscopy of the ionization continuum of argon — •Paul Birk, Veit Stooss, Maximilian Hartmann, Alexander Blättermann, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Attosecond transient absorption spectroscopy opens a way to study ultrafast dynamics in excited electronic states of atoms and molecules. The spectral line shapes and their NIR laser-induced changes measured by these experiments carry information about the studied quantum system and originate from the dipole response of bound states. Here, we investigate the response of the ionization continuum. With our all-optical approach, we observed signatures of strong NIR laser-induced coupling between the ionization continuum of argon with its dipole-forbidden excited states. These signatures are compared with the optical response calculated by a numerical multi-level model simulation. This approach enables direct access into the laser-driven strong-field dynamics involving the ionization continuum and spectral dark states.

A 25.31 Tue 16:15 Redoutensaal

Single shot velocity map imaging of electrons from dopand-induced helium nanoplasmas in strong near-infrared laser pulses. — •Nicolas Rendler[1], Dominik Schomas[1], Cristian Medina[1], Robert Moshammer[2], Thomas Pfeifer[2], Andreas Heidenreich[3,4], and Marcel Mudrich[5] — [1]Albert Ludwigs University of Freiburg, Freiburg, Germany — [2]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [3]Faculty of Chemistry, University of the Basque Country (UPV/EHU) and Donostia International Physics Center (DIPC), Donostia, Spain — [4]IKERBASQUE, Basque Foundation for Science, Bilbao, Spain — [5]Aarhus University, Aarhus, Denmark

A doped helium nanodroplet irradiated by intense near-infrared (NIR) laser pulses forms a highly ionized nanoplasma even at laser intensities where the helium is not directly ionized. The dopant atoms provide first seed electrons which start the electron impact ionization avalanche of the whole droplet. The dynamics of ignition and explosion of the nanoplasma depends not only on the number and the kind of dopants but also on the droplet size and laser intensity. We present single shot velocity map imaging (VMI) measurements of electrons produced by irradiation of xenon doped helium nanodroplets with intense NIR femtosecond laser pulses at various laser intensities for different helium and dopant cluster sizes. The salient structures of the electron spectra are discussed and compared to molecular dynamics simulations. Additionally ion time of flight (TOF) spectra can be recorded in parallel to the electron VMI.

A 25.32 Tue 16:15 Redoutensaal

Electron dynamics in Helium and Neon driven by intense XUV radiation — •Alexander Magunia[1], Lennart Aufleger[1], T. Ding[1], M. Rebholz[1], M. Hartmann[1], V. Stooss[1], P. Rupprecht[1], D. Wachs[1], C. da Costa Castanheira[1], Z. H. Loh[2], A. Attar[3], S. Düsterer[4], G. Brenner[4], R. Treusch[4], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]Nanyang Technological University Singapore, Singapore — [3]University of California, Berkeley, USA — [4](DESY), Hamburg, Germany

The measurement of laser-induced dynamics in few-electron systems provides a way to investigate the correlated response of multiple electrons in atoms and molecules when driven by strong and short electric fields. Using a lab-based high-harmonic source we have formerly studied such dynamics via their imprint on the XUV absorption line shape in response to strong fields in the near infrared and visible spectral region. [C. Ott et al., Science 340, 716 (2013)].
Here we present an extension of this scheme to the XUV-only spectral region, using intense and partially coherent light of a Free-Electron Laser (FEL, FLASH@DESY) to investigate the line shape modifications across the 2s2p autoionizing resonance in Helium. The XUV-pulse intensity is in the range from 10^{12} Wcm^{-2} to 10^{14} Wcm^{-2}. These first results are supported by a few-level simulation for which the time-dependent Schrödinger equation is solved numerically, addressing also the statistical SASE-FEL pulse-structure. Furthermore a first view into the strong-field behavior of the multi-electron system Neon is given.

A 25.33 Tue 16:15 Redoutensaal

Diffractive imaging of a xenon nanoplasma with pnCCDs — •Timo Dörries[1], Daniela Rupp[2], Thomas Möller[1], Mario Sauppe[1], Maria Müller[1], Anatoli Ulmer[1], Bruno Langbehn[1], Jan Philippe Müller[1], Yevheniy Ovcharenko[1], Benjamin Erk[3], Jonathan Correa[4], and Robert Hartmann[5] — [1]Technische Universität Berlin, Germany — [2]Max-Born-Institut, Berlin, Germany — [3]FLASH at DESY, Hamburg, Germany — [4]XFEL at DESY, Hamburg, Germany — [5]pnSensors, Munich, Germany

We have studied the interplay of intense coherent XUV pulses from the free-electron laser FLASH in Hamburg with single xenon clusters. They serve as ideal model systems for light matter interaction as they are easy to produce, size scalable, free flying particles that often have spherical symmetry. The used photon energies close to $90\,eV$ are resonant to transitions in xenon atoms and ions; consequently a nanoplasma is formed with an altered scattering response and the emission of fluorescence light. Both the elastically scattered and fluorescence photons are detected using a single-photon sensitive large area detector (pnCCDs) with high dynamic range. Different detector coatings allow for identification of the fluorescence signal. Via Mie simulations, optical properties and thus information about the electronic structure of the clusters can be extracted.

A 25.34 Tue 16:15 Redoutensaal

Time resolved coincidence measurements of interatomic Coulombic decays — •Sophie Walther[1], Anastasios Dimitriou[1], Till Jahnke[2], Markus Pfau[1], Martin Ranke[1], and Ulrike Frühling[1] — [1]Universität Hamburg — [2]Goethe-Universität, Frankfurt

Presentation of the experimental setup for the THz-streaking experiments to measure ICD in Neon-Dimers using a Cold Target Recoil Ion Momentum Spectroscopy (COLTRIMS) detector. In the experiment XUV pulses will be superimposed with THz pulses to perform the time resolved experiments.

A 25.35 Tue 16:15 Redoutensaal

Ionisation dynamics of mixed Xe/Kr clusters in intense laser pulses — •Thomas Menz[1], Bruno Langbehn[1], Patrick Behrens[1], Linos Hecht[1], Anatoli Ulmer[1], Benjamin Erk[2], Laurent Mercadier[3], Daniela Rupp[1,4], and Thomas Möller[1] — [1]IOAP, TU Berlin — [2]DESY Hamburg — [3]European XFEL, Hamburg — [4]MBI Berlin

Atomic clusters can be used for precise light-matter interaction studies. Rare gas clusters for example can serve as ideal model systems with a simple geometric and electronic structure. In particular, mixed clusters can be utilised to disentangle and analyse the dynamics of surface and bulk in a core-shell system. Using a picosecond laser with a wavelength of 263 nm, Xe/Kr clusters were ionised and measured via time-of-flight spectroscopy. Different mixtures of Xe and Kr and varying cluster sizes are compared and implications for the structure and properties of Xe/Kr clusters in intense light pulses are discussed.

A 25.36 Tue 16:15 Redoutensaal

Investigations of Kramers-Henneberger atoms in alkali metals via tailored light fields — •Christoph Jusko[1], Slawomir Skruszewicz[2], Danilo Zille[2], Gerhard G. Paulus[2], and Milutin Kovacev[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

Theoretical studies predict a stabilizing interaction of atoms with high-intense light fields in the over-the-barrier ionization regime. We present an experimental approach to detect these stabilized atoms, called Kramers-Henneberger atoms, with tailored intense light fields in alkali metals via velocity map imaging.

A 25.37 Tue 16:15 Redoutensaal

Coulomb rescattering and the ionization enhancement around the twice pondermotive energy — •P. L. He[1,2], K. Z. Hatsagortsyan[1], and C. H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Shanghai Jiao Tong University, Shanghai 200240, China

In this work, we proposed a method to regularize the Coulomb divergence in the Improved Strong Field Approximation, which takes into account the Coulomb interaction via the Born approximation within the framework of Strong Field Approximation. With this method, the ionization enhancement around twice the ponderomotive energy of the ejected electron is analyzed. By comparing the relevant classical trajectories and the quantum orbits, insights into the enhancement and ionization mechanisms are gained.

A 25.38 Tue 16:15 Redoutensaal

Automated re-establishment of the spatial overlap in XUV/XUV pump-probe experiments in the focus of CAMP at FLASH — •Nils Bernhardt[1], Mario Sauppe[1], Cédric Bomme[2], Stefan Düsterer[2], Benjamin Erk[2], Torsten Feigl[3], Erland Müller[2], Jan P. Müller[1], Christopher Passow[2], Daniel Ramm[2], Daniel Rolles[2,4], Dimitrios Rompotis[2], Rolf Treusch[2], Holger Weigelt[2], Jannis Zimbalski[1], Thomas Möller[1], and Daniela Rupp[1,5] — [1]TU Berlin — [2]DESY — [3]optikX fab — [4]Kansas State University, USA — [5]MBI Berlin

Double pulse experiments with high intensity short-wavelength free-electron lasers enable unprecedented insight into the light induced dynamics of matter on the nanoscale. The recently installed multilayer based split-and-delay unit for the multi-purpose end-station CAMP at FLASH provides sub-femtosecond resolution and long delays up to 650 picoseconds. For time-resolved experiments the two pulses have to be overlapped in the focus, but actuator inaccuracies lead to a slight variation of the beam angle for different delays and subsequently to a misalignment that needs to be corrected. In this work, we develop a routine that tracks the inaccuracies and automatically overlaps the double pulses within the focus plane.

A 25.39 Tue 16:15 Redoutensaal

Characterizing the structure of pulsed rare gas cluster and helium nanodroplet sources — •Patrick Behrens[1], Bruno Langbehn[1], Fabian Seel[1], Anatoli Ulmer[1], Daniela Rupp[1,2], and Thomas Möller[1] — [1]IOAP, Technische Universität Berlin — [2]Max-Born-Institut Berlin

With XUV and X-ray free-electron lasers (FEL) delivering ultrashort intense light pulses, a detailed insight into the structure of nanoparticles such as viruses and macromolecules has become feasible. In this context, atomic clusters and helium nanodroplets enable novel experimental opportunities for fundamental research and imaging of nanospecimen [Tanyag et al., 2015, Struct. Dyn. 2],[Gorkhover et al., 2017, arXiv:1707.09424]. In particular, superfluid helium nanodroplets can serve as an ideal cooling matrix for spectroscopy.

The specific cluster source properties, e.g. stagnation pressure, temperature, valve opening time and distance between source and interaction region, play a crucial role in FEL spectroscopy as they directly determine the size, shape, distribution and density of the cluster beam.

In this presentation, we will discuss available methods to characterize these beam properties for different cluster sources.

A 25.40 Tue 16:15 Redoutensaal

X-ray and XUV Fourier holography of free-flying nanoparticles — •A Ulmer[1], J Bielecki[2], L Flückiger[3], A Al Haddad[4], F Benzi[2], J Correa[5], T Ekeberg[5], B Erk[5], L Hecht[1], A Heilrath[1], M Hantke[2], O Kulyk[6], B Langbehn[1], D Larsson[2], I Lundholm[2], T Osipov[7], C Passow[5], D Rompotis[5], D Rupp[1], J Sellberg[8], G van der Schot[2], P Walter[7], L Young[4], F Zimmermann[1], F Maia[2], J Hajdu[2], T Möller[1], C Bostedt[4], and T Gorkhover[1,7,9] — [1]TU Berlin — [2]Uppsala Univ. — [3]La Trobe Univ. — [4]Argonne Nat. Lab. — [5]Desy — [6]ELI Beamlines — [7]SLAC — [8]KTH Stockholm — [9]Stanford

The advance of XUV/X-ray Free Electron Lasers (FEL) enable unprecedented insights into processes in individual non-crystalline nanoparticles with high spatial and temporal resolution. While in X-ray imaging of solid state targets Fourier transform holography was used for a long time as an elegant solution to the phase problem [Eisebitt et al., *Nature* **432**, 885-888], it was only recently realized for unsupported nanospecimen, using a X-ray FEL facility [Gorkhover et al., 2017, arXiv:1707.09424]. Here atomic gas phase clusters were used as a holographic reference scatterer to image nanometer scale bio specimen – both injected by two different sources. Using a new approach, it becomes possible to overcome problems with alignment and overlap of two particle beams by using only one injector. This simplifies the experimental setup vastly, while increasing the holographic hit rate at the same time. First results of the proof of concept experiment as well as a framework to evaluate gas phase holograms will be presented.

A 25.41 Tue 16:15 Redoutensaal

Laser Infrastructure for Multi-Dimensional Spectroscopy from XUV to Mid-IR — •Patrick Rupprecht, Lennart Aufleger, Thomas Ding, Marc Rebholz, Carina da Costa Castanheira, Stephan Goerttler, Alexander Magunia, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Two-Dimensional Femtosecond Spectroscopy (2DFS) has developed into an indispensable tool to investigate vibrational and electronic couplings in molecular dynamics [Jonas, Annu. Rev. Phys. Chem. 2003]. The presented setup at MPI for Nuclear Physics, Heidelberg, will extend conventional 2DFS schemes towards multi-dimensional, multicolor transient spectroscopy. Based on a 20 mJ pulse energy, 1 kHz repetition-rate Titanium:Sapphire laser system, the optical setup will provide attosecond pulses in the XUV (with maximum photon energies beyond 150 eV), few-cycle pulses in the visible to near infrared spectral region, as well as multi-mJ, femtosecond tunable-wavelength pulses from 1.1 μm to 2.6 μm from an OPA. In combination with the already existing four-quadrant split mirror, this setup targets electron correlation dynamics in atomic and molecular systems. Of particular interest is also the metrology of absorption line shape changes to quantify the influence of strong laser fields from fundamental to complex systems [Ott et al., Science 2013].

A 25.42 Tue 16:15 Redoutensaal

Grazing-Incidence XUV Split-Delay Unit for the FLASH2 Reaction Microscope — •Florian Trost[1], Kirsten Schnorr[1], Sven Augustin[1], Georg Schmid[1], Severin Meister[1], Hannes Lindenblatt[1], Yifan Liu[1], Thomas Wodzinski[2], Barbara Keitel[2], Elke Ploenjes-Palm[2], Markus Braune[2], Marion Kuhlmann[2], Stefan Düsterer[2], Rolf Treusch[2], Thomas Pfeifer[1], Claus Dieter Schröter[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]DESY, Hamburg

In order to perform XUV pump-probe experiments on small quantum systems such as atomic targets or small molecules and clusters, a new direct-focussing XUV split-and-delay optics was designed, installed and commissioned as part of the permanent reaction microscope user endstation at FLASH2. A planar mirror, which is divided into two halves geometrically, splits an incoming XUV pulse into two parts and introduces a variable temporal delay between them. An off-axis ellipsoidal mirror then focuses the XUV pulses into the gas target of the reaction microscope.

The focus position and the optical aberrations of the FEL beam were measured using a wavefront sensor. We identified the influence of position and rotation of the mirrors on the different aberrations. A

focus size of 3 micrometer in diameter was obtained. The new direct-focussing XUV optics decreases background from scattered light compared to our previous back-reflecting geometry due to single passage through the interaction region and because of the smaller focus size.

A 25.43 Tue 16:15 Redoutensaal

Strong Field Ionization of the H atom in bi-circular fields — •Philipp M. Stammer[1,2], Felipe Morales[1], Olga Smirnova[1,2], and Misha Ivanov[1,3,4] — [1]Max-Born-Institute for Nonlinear Optics and Short Pulse Spectroscopy, Germany — [2]Technical University Berlin, Germany — [3]Imperial College London, United Kingdom — [4]Humboldt-University Berlin, Germany

Interaction of a strong laser field with an atom or a molecule is often described in a simple three-step picture: an electron is ionized, then it is accelerated away from the core, to be finally driven back to the parent ion, driven by the laser field. The recollision or the rescattering with the parent ion is at the heart of strong-field phenomena, i.e. High Harmonic Generation (HHG) and Above Threshold Ionization (ATI).

While a circularly polarized laser field does not allow for recollision, a bi-circular field (consisting of two co-planar, counter-rotating, circularly polarized laser fields) does. Bi-circular HHG has been studied both experimentally and theoretically, whereas research on ATI spectra in these fields has been mostly limited to analytical studies.

In this work we present ATI spectra calculated via direct solution of the Time Depending Schrödinger Equation for the Hydrogen atom, exposed to an intense bi-circular field. These calculations are computationally demanding, and will help to understand the underlying physics, and confirm the analytical predictions.

The emitted photo-electrons exhibit the same three-leaf structure as the electric field, but also deflections and structure due to the interaction with the Coulomb potential will be discussed.

A 25.44 Tue 16:15 Redoutensaal

Reaction Microscope Endstation at FLASH2 — •Hannes Lindenblatt[1], Kirsten Schnorr[1], Sven Augustin[1], Georg Schmid[1], Severin Meister[1], Florian Trost[1], Yifan Liu[1], Markus Braune[2], Rolf Treusch[2], Claus-Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]DESY, Hamburg

Our group has recently installed a Reaction Microscope as permanent endstation at FLASH2. During the last year, first experiments and several upgrades where performed. Most notably, a gracing incidence mirror for focussing and split-and-delay was installed. In the near future, our target delivery system will be upgraded to ease usage of different gas-phase targets. Furthermore, an IR Laser as well as a HHG source will become available for the beamline. These will allow for a multitude of pump-probe schemes. The poster will provide an overview of the setup including beam geometry, target preparation, diagnostics and data acquisition, as well as first results.

A 25.45 Tue 16:15 Redoutensaal

Two photon double ionization in Neon — •Severin Meister[1], Kirsten Schnorr[1], Sven Augustin[1], Georg Schmid[1], Hannes Lindenblatt[1], Florian Trost[1], Markus Braune[2], Robert Moshammer[1], and Thomas Pfeifer2[1] — [1]MPIK Heidelberg — [2]DESY

The presented experiment unveils the angular correlation of emitted electrons in sequential two-photon double ionization of neon (in a time-resolved manner). In sequential ionization electrons are removed via intermediate ionic states. Even though the atom is first singly ionized and in the following, independent step further ionized by absorbing a second photon, measurements and theory find both electrons to be correlated. The angular distribution of the "first" electron is predicted to depend on the detection angle of the "second" one, which stands in contrast to the simple picture of sequential ionization. This can be quantified by the β_4 anisotropy-parameter which is non-zero for the first electron, under the condition that the second electron was emitted.

A 25.46 Tue 16:15 Redoutensaal

Fragmentation Dynamics of Argon Dimers and Multi-Photon Ionization of Atomic Argon Studied by XUV-IR Experiments at FLASH — •Georg Schmid[1], Kirsten Schnorr[1], Sven Augustin[1], Hannes Lindenblatt[1], Severin Meister[1], Thomas Ding[1], Yifan Liu[1], Kamal P. Singh[2], Mathieu Gisselbrecht[3], Harald Redlin[4], Stefan Düsterer[4], Rolf Treusch[4], Claus-Dieter Schröter[1], Thomas Pfeifer[1], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]IISER, Mohali, India — [3]Lund University, Sweden — [4]DESY, Hamburg

Different XUV multi-photon ionization pathways of Ar_2 dimers such as interatomic coulombic decay (ICD) and charge transfer at a curve crossing (CT-CC) were identified by measuring the kinetic-energy release of the Coulomb-exploded dimer fragments using a reaction microscope. By applying an intense IR probe pulse, we were able to follow the dynamics of these fragmentation pathways in real time. Amongst other things, we have deduced an average lifetime for the charge transfer channel $\mathrm{Ar}^{2+}(3\mathrm{p}^{-3}nl)-\mathrm{Ar} \rightarrow \mathrm{Ar}^{+}(3\mathrm{p}^{-2}n'l')+\mathrm{Ar}^{+}(3\mathrm{p}^{-1})$, which agrees with theoretical calculations.

Furthermore, we investigated XUV multi-photon ionization of atomic Ar at FEL intensities of $I \sim 5 \times 10^{13}$ W/cm^2 and measured charge states up to Ar^{5+}. An IR probe pulse enabled to distinguish between sequential and non-sequential ionization routes and revealed intermediate resonances.

A 25.47 Tue 16:15 Redoutensaal

Strong-field induced nuclear dynamics in C_{60} traced via time-resolved X-ray scattering at LCLS — •Sven Augustin[1], Kirsten Schnorr[1], Georg Schmid[1], Hannes Lindenblatt[1], Robert Moshammer[1], Arnaud Rouzée[2], Marc Vrakking[2], Claus-Peter Schulz[2], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Max-Born-Institut, Berlin

Time-resolved X-ray scattering images and time-of-flight spectra of NIR (800 nm) laser-excited C_{60} molecules have been recorded employing the LAMP instrument at AMO/LCLS. Using a pnCCD detector, in average 100 photons scattered off C_{60} have been detected per 1.8 keV X-ray pulse.

Different dynamics have been observed as the NIR laser intensity was varied: For higher intensities, the scattering signal vanishes within less than 100 femtoseconds indicating complete disintegration (i.e., Coulomb explosion) of the fullerenes. In addition, a fast symmetric shrinking of the circular scattering patterns has been found, from which the time scale of the molecular expansion can be determined to be roughly 100 femtoseconds. For lower intensities, more complex variations of the size of the scattering pattern on longer time scales (up to picoseconds) have been observed.

A 25.48 Tue 16:15 Redoutensaal

The signature of electron correlation in HHG spectra from a He atom — •Julius Rapp and Dieter Bauer — Universität Rostock

We present high-harmonic generation (HHG) spectra from He obtained by numerical simulations which fully treat electron correlation. As expected, the major part of the spectrum is exactly reproduced by single-active-electron modeling. However, beyond the first plateau's cutoff at $3.17\,U_\mathrm{p}+1.3\,I_\mathrm{p}^\mathrm{He}$ we find a second plateau with orders of magnitude less HHG yield. Interestingly, the characteristics of those additional HHG features significantly differ from the singly charged ion's HHG signature. We illustrate the disentanglement of several possible explanations by time-frequency analyses and extended simple-man's modeling based on the strong-field approximation.

A 25.49 Tue 16:15 Redoutensaal

Determination of the mean cluster size and evolution of excitonic valence states by fluorescence from homogenous Ne, Ar and Kr clusters — •Xaver Holzapfel, Andreas Hans, Gregor Hartmann, Christian Ozga, Philipp Schmidt, Philipp Reiss, Arno Ehresmann, and André Knie — Institut für Physik und CINSaT, HeinrichPlett-Str. 40, D-34132 Kassel, Germany

Finite aggregates like clusters are used to study microscopic phenomena, in the range between molecular and condensed matter physics. The average size of clusters is their most important quantity for fundamental investigations. For clusters produced by supersonic expansion, the average cluster size is usually estimated indirectly by an empirical law involving the expansion parameters. Here we present a direct method to measure the mean cluster size by resonant excitation of outer valence electrons and the subsequent emission of fluorescence photons from homogenous Ne, Ar and Kr clusters. This method has been compared to the average cluster size determination by the empirical law. The collected data reveals new excitonic valence states and enables additional and more precise insights into the evolution of cluster states by scaling the mean size from the molecular to condensed matter regions.

A 25.50 Tue 16:15 Redoutensaal

A molecular movie of Interatomic Coulombic Decay in NeKr
— •Florian Trinter[1], Tsveta Miteva[2], Miriam Weller[1], Sebastian Albrecht[1], Alexander Hartung[1], Martin Richter[1], Joshua Williams[1], Averell Gatton[3], Bishwanath Gaire[3], Thorsten Weber[3], James Sartor[4], Allen Landers[4], Ben Berry[5], Vasili Stumpf[2], Kirill Gokhberg[2], Reinhard Dörner[1], and Till Jahnke[1] — [1]Institut für Kernphysik, Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, 69120 Heidelberg, Germany — [3]Lawrence Berkeley National Laboratory, Chemical Sciences Division, Berkeley, California 94720, USA — [4]Department of Physics, Auburn University, Auburn, Alabama 36849, USA — [5]J. R. MacDonald Laboratory, Department of Physics, Kansas State University, Manhattan, Kansas 66506, USA

During the last 15 years a novel decay mechanims of excited atoms has been discovered and investigated. This so called "Interatomic Coulombic Decay" (ICD) involves the chemical environment of the electronically excited atom or molecule: the excitation energy is transferred to a neighbor of the initially excited particle usually ionizing that neighbor. It turned out that ICD is a very common decay route in nature as it occurs across van der Waals and hydrogen bonds. The time evolution of ICD is predicted to be highly complex, as its efficiency strongly depends on the distance of the atoms involved and this distance typically changes during the decay. Here we present a direct measurement of the temporal evolution of ICD using a novel experimental approach.

A 26: Ultracold Plasmas and Rydberg systems (joint session A/Q)

Time: Wednesday 14:00–15:45 Location: K 0.011

A 26.1 Wed 14:00 K 0.011

Van der Waals interaction potential between Rydberg atoms near surfaces
— •Johannes Block and Stefan Scheel — Institut für Physik, Universität Rostock, D-18059 Rostock, Germany

Rydberg atoms experience strong van der Waals interactions due to their large transition dipole moments. As these interactions are mediated by photons, they can be altered by dielectric surroundings. As a model system for atoms near a superconducting stripline cavity, we show the effect of a mirror on the van der Waals interaction of Rydberg atoms by direct diagonalization of the interaction Hamiltonian including terms up to electric quadrupole-quadrupole interaction [1,2]. We find that the presence of the mirror strongly modifies the interactions leading to a significant change in the Rydberg blockade [3].

[1] J.S. Cabral *et al.*, J. Phys. B: At. Mol. Opt. Phys. **44**, 184007 (2011).
[2] J. Stanovevic *et al.*, Phys. Rev. A **78**, 082709 (2008).
[3] J. Block and S. Scheel, arXiv:1710.08965

A 26.2 Wed 14:15 K 0.011

An optogalvanic flux sensor for trace gases
— •Johannes Schmidt[1,2,5], Markus Fiedler[1,5], Ralf Albrecht[1,5], Denis Djekic[3,5], Patrick Schalberger[2,5], Holger Baur[2,5], Robert Löw[1,5], Tilman Pfau[1,5], Jens Anders[3,5], Norbert Frühauf[2,5], Edward Grant[4], and Harald Kübler[1,5] — [1]5th Institute of Physics — [2]Institute for Large Area Microelectronics — [3]Institute for Theory of Electrical Engineering — [4]Department of Chemistry, University of British Columbia — [5]University of Stuttgart, Center for Integrated Quantum Science and Technology (IQST)

We demonstrate the applicability of a new kind of gas sensor based on Rydberg excitations. From an arbitrary probe gas the molecule in question is excited to a Rydberg state, by succeeding collisions with all other gas components this molecule gets ionized and the emerging electron and ion can then be measured as a current, which is the clear signature of the presence of this particular molecule. As a first test we excite Alkali Rydberg atoms in an electrically contacted vapor cell [1,2] and demonstrate sensitivities down to 100 ppb on a background of N_2. We investigate different amplification circuits, ranging from solid state devices on the cell to thin film technology based transimpedance amplifiers inside the cell [3]. For a real life application, we employ our gas sensing scheme to the detection of nitric oxide in a background gas at thermal temperatures and atmospheric pressure.

[1] D. Barredo, et al., *Phys. Rev. Lett.* **110**, 123002 (2013)
[2] R. Daschner, et al., *Opt. Lett.* **37**, 2271 (2012)
[3] J. Schmidt, et al., *AMFPD* **24**, 296-298 (2017)

A 26.3 Wed 14:30 K 0.011

Rydberg molecules for ion-atom scattering in the ultracold regime
— •Thomas Schmid[1], Christian Veit[1], Nicolas Zuber[1], Thomas Dieterle[1], Christian Tomschitz[1], Robert Löw[1], Michal Tarana[2], Michal Tomza[3], and Tilman Pfau[1] — [1]5. Physikalisches Institut & Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany — [2]J. Heyrovskzý Institute of Physical Chemistry of the ASCR, Prague, Czech Republic — [3]Centre of New Technologies & Faculty of Physics, University of Warsaw, Poland

We propose a novel experimental method to extend the investigation of ion-atom collisions from the so far studied cold regime to the unexplored ultracold regime [1]. Key aspect of this method is the use of Rydberg molecules to initialize the ultracold ion-atom scattering event. We exemplify the proposed method with the lithium ion-atom system, for which we present simulations of how the initial Rydberg molecule wavefunction, freed by photoionization, evolves in the presence of the ion-atom scattering potential. We predict bounds for the ion-atom scattering length from *ab initio* calculations of the interaction potential. We demonstrate how the scattering length can be experimentally determined from the scattered wavepacket. Finally, we present our ultracold Rb-Li Rydberg setup containing an ion microscope and a delay-line detector to allow for the temporally and spatially resolved detection of the scattered ion-atom wavepacket.

[1] T. Schmid et al.; *arXiv* 1709.10488 (2017).

A 26.4 Wed 14:45 K 0.011

Epidemic dynamics in open quantum spin systems
— Carlos Perez-Espigares[1], •Matteo Marcuzzi[1], Ricardo Gutierrez[1,2], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK — [2]Complex Systems Group, Universidad Rey Juan Carlos, 28933 Móstoles, Madrid, Spain

We derive a simple epidemic spreading process to describe the nonequilibrium dynamics of an open many-body system, motivated by recent experiments realised with strongly-interacting gases of highly-excited (Rydberg) atoms, in which the facilitated excitation of Rydberg states competes with radiative decay in a three-level structure. This is approximately mapped onto a population dynamics model where individuals can be either healthy, infected or immunised, and which displays a continuous phase transition from a regime where the epidemic stops to one where instead it can continue spreading indefinitely. The study of the strongly-dephased (classical) regime displays signatures of this continuous phase transition, whereas a preliminary analysis of the weakly-dephased (quantum) regime suggests a shift to a sequence of discontinuous jumps. We discuss the limitations of our modelling imposed by a more realistic setting of laser-driven Rydberg atoms, with a particular focus on the role of the long-range tails of the interactions.

A 26.5 Wed 15:00 K 0.011

Multi-excitons in flexible Rydberg aggregates
— •Ghassan Abumwis[1,2] and Sebastian Wüster[1,2,3] — [1]mpipks, Dresden, Germany — [2]Bilkent University, Ankara, Turkey — [3]IISER, Bhopal, India

Flexible Rydberg aggregates are ensembles of Rydberg atoms that are allowed to move, they provide a platform to investigate quantum phenomena like energy transport and conical intersections. This can be achieved by doping the aggregate with an excitation, an excited state that is energetically higher but close to the primary Rydberg state, leading to the resonant dipole-dipole interaction becoming dominant. Consequently, the excitation is delocalized throughout the aggregate creating excitons.

We follow up on previous results and add a second excitation to the aggregate. We demonstrate that products of excitons can be used to express biexciton states for a chain with a dislocation at one end, a one-dimensional aggregate with equal spacing between atoms except for the last two. Moreover, we show that non-adiabatic effects can be made prominent in flexible Rydberg chains. Finally, we analyze the interaction between two excitation pulses based on the initial biexciton state and the presence of a dislocation. Our findings further enlarge the pool of Born-Oppenheimer surfaces for quantum transport that can be engineered in flexible Rydberg aggregates.

A 26.6 Wed 15:15 K 0.011

Experimental realization of an Optical Feshbach resonance using ultra-long range Rydberg molecules — •Oliver Thomas[1,2], Carsten Lippe[1], Tanita Eichert[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

Over the last decades Feshbach resonances in ultra cold atomic gases have lead to some of the most important advances in atomic physics. Not only did they enable ground breaking work in the BEC-BCS crossover regime, but they are also a widely used tool for the association of ultra cold molecules. Leading to the observation of the first molecular Bose-Einstein Condensates and the emergence of ultra cold dipolar molecular systems. We show the experimental realization of optical Feshbach resonances using ultra-long range Rydberg molecules and demonstrate their practical use by tuning the revival time of a quantum many-body system quenched into a deep optical lattice. We believe this opens up a complete new field of Feshbach resonances as ultra-long range Rydberg molecules have a plenitude of available resonances for nearly all atomic species.

A 26.7 Wed 15:30 K 0.011

Pendular states of butterfly Rydberg molecules — •Carsten Lippe[1], Oliver Thomas[1,2], Tanita Eichert[1], and Herwig Ott[1] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz

Butterfly Rydberg molecules are a special class of Rydberg molecular states arising from a shape resonance in the p-wave scattering channel of a ground state atom and a Rydberg electron. They owe their name to the shape of the electronic wavefunction which resembles the shape of a butterfly.

We have performed high resolution photoassociation spectroscopy of uv-excited deeply bound butterfly Rydberg molecules of ^{87}Rb. We find states bound up to -50GHz from the $25\mathrm{P}_{1/2}, F = 1$ and $25\mathrm{P}_{1/2}, F = 2$ state, corresponding to bond lengths of $50\,a_0$ to $500\,a_0$.

Due to strong admixture of high angular momentum states the butterfly Rydberg molecules feature giant permanent electric dipole moments of hundreds of Debye which allow us to resolve the rotational structure of the Rydberg molecules and observe pendular states. This enables an unprecedented degree of control over the orientation of dipolar molecules even in weak electric fields.

Furthermore, the identification of different structures of pendular state spectra which can be attributed to different total angular momentum projections helps to map the detected molecular bound states to the corresponding potential energy curves.

A 27: XUV/X-ray Science

Time: Wednesday 14:00–16:15 Location: K 1.011

A 27.1 Wed 14:00 K 1.011

XUV-Pump/XUV-Probe Strong-field Transient Absorption of Neon at FLASH — •Thomas Ding[1], Marc Rebholz[1], Lennart Aufleger[1], Maximilian Hartmann[1], Kristina Meyer[1], Alexander Magunia[1], David Wachs[1], Veit Stooss[1], Paul Birk[1], Gergana Borisova[1], Andrew Attar[2], Thomas Gaumnitz[3], Zhi Heng Loh[4], Sebastian Roling[5], Marco Butz[5], Helmut Zacharias[5], Stefan Düsterer[6], Rolf Treusch[6], Stefano Cavaletto[1], Zoltán Harman[1], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck Institut für Kernphysik, Heidelberg, Germany — [2]University of California Berkeley, Berkeley, USA — [3]Eidgenössische Technische Hochschule Zürich, Zürich, Switzerland — [4]Nanyang Technological University Singapore, Singapore — [5]Westfälische Wilhelms-Universität Münster, Münster, Germany — [6]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

We present first transient-absorption spectroscopy experiments with extreme ultraviolet (XUV) pump and probe pulses delivered by the free-electron laser FLASH. Applying our pump-probe scheme at photon energies around 50 eV, pulse durations of about 50 fs and intensities up to 10^{14} Wcm^{-2} to neon, we traced the sequential two-photon ionization plus the excitation of one-photon bound-bound transitions within the doubly charged Ne^{2+} ion. Analyzing the nonlinear absorption spectra as a function of the pulse delay and the intensity reveals resonant XUV strong-field coupling of those transitions and allows to retrieve the FLASH coherence time from transient absorption spectra.

A 27.2 Wed 14:15 K 1.011

Angle-resolved observation of X-ray second harmonic generation in diamond — •Björn Senfftleben[1], Priyanka Chakraborti[1], Brendan Kettle[1,2], Dilling Zhu[3], Takahiro Sato[3], Silke Nelson[3], Samuel Teitelbaum[4], Phillip H. Bucksbaum[4], Jerome B. Hastings[4], Sharon Shwartz[5], David A. Reis[4], and Matthias Fuchs[1,4] — [1]University of Nebraska-Lincoln, Lincoln, NE, USA — [2]Imperial College, London, UK — [3]Linac Coherent Light Source, Menlo Park, CA, USA — [4]Stanford Pulse Institute, Menlo Park, CA, USA — [5]Bar-Ilan University, Ramat Gan, Israel

For a long time, the limited X-ray intensity of classical light sources have restricted experimental investigations of non-linear effects in the X-ray regime. With the advent of X-ray free-electron lasers (XFELs), it has become possible to explore new parameter spaces and to study X-ray matter interactions in the nonlinear regime. First experiments have tested the limits of current theoretical models.

Here we report the observation of angularly-resolved X-ray second harmonic generation (XSHG) in diamond at several phase-matching geometries. The quadratic dependence of the number of generated second harmonic photons on the incident pulse energy was verified. Further, the angular dependence of the efficiency and the rocking curve widths of the process were investigated. A good agreement with the theory has been found.

A 27.3 Wed 14:30 K 1.011

Measuring sub-Ångström translations by time-domain interferometry — •Stephan Goerttler[1], Andreas Kaldun[1], Christian Ott[1], Kilian Heeg[1], Patrick Reiser[1], Cornelius Strohm[2], Johann Haber[2], Rajagopalan Subramanian[1], Rudolf Rüffer[3], Ralf Röhlsberger[2], Jörg Evers[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Germany — [3]ESRF-European Synchrotron, CS40220, 38043 Grenoble Cedex 9, France

The temporal phase of a coherently emitted pulse is inextricably linked to the translation of the emitter in space. We use interferometry in the time domain and a direct analytical phase-reconstruction algorithm to retrieve the temporal phase imprinted onto the 14.4-keV emission line of ^{57}Fe. As the wavelength of this transition is very small ($\lambda = 0.82$Å) we can determine the motion of the emitter on sub-Ångström length and nanosecond time scale.

A 27.4 Wed 14:45 K 1.011

Controlling Excitation Dynamics of Mössbauer Nuclei — •Kilian P. Heeg[1], Andreas Kaldun[1], Cornelius Strohm[2], Patrick Reiser[1], Christian Ott[1], Rajagopalan Subramanian[1], Dominik Lentrodt[1], Johann Haber[2], Hans-Christian Wille[2], Stephan Goerttler[1], 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

Mössbauer nuclei with transitions in the hard x-ray regime are usually probed by single x-ray pulses only, such that advanced concepts in light-matter interaction which, e.g., require control fields, cannot be realized straightforwardly. Here, we generalize a recent method to spectrally amplify x-ray pulses [1] to generate a sequence of two pulses with controlled relative phase. Such tailored x-rays are employed in a two-step interaction scheme: preparation and subsequent control of the excitation dynamics in a resonant target of ^{57}Fe Mössbauer nuclei. Our experimental results confirm that the collective nuclear dipole response can indeed be manipulated and we find clear signatures of

fundamental processes in light-matter interaction such as stimulated emission and absorption.
[1] K. P. Heeg *et al.*, Science 357, 375 (2017).

A 27.5 Wed 15:00 K 1.011

Rabi oscillations of x-ray radiation between two nuclear ensembles — Xiangjin Kong[1], Johann Haber[2], Ralf Röhlsberger[2], and •Adriana Pálffy[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg

The realization of the strong coupling regime between a single cavity mode and an electromagnetic resonance is one of the centerpieces of quantum optics. In this regime, the reversible exchange of a photon between the two components of the system leads to so-called Rabi oscillations [1]. Strong coupling was used in the optical and infrared regimes to produce non-classical states of light, enhance optical nonlinearities, and control quantum states for computing purposes.

Here, we report from the theory side on the first observation of Rabi oscillations of an x-ray photon between two resonant ^{57}Fe-layers embedded in two coupled cavities [2]. The theoretical predictions for the observed oscillation are based on an effective Hamiltonian for the system, in which the two layers couple strongly. A sinusoidal beating in the system's temporal evolution as signature of the Rabi oscillations, as well as the splitting of the nuclear resonances in the reflected light spectrum have been confirmed by experiment. These observations significantly advance the development of the new field of x-ray quantum optics.

[1] M. Brune *et al.*, Phys. Rev. Lett. 76, 1800 (1996).
[2] J. Haber *et al.*, Nature Photonics 11, 720 (2017).

A 27.6 Wed 15:15 K 1.011

Ion-source Development for Inner-Shell Photodetachment of Negative Ions — •Alexander Perry-Sassmannshausen[1], Paul Willamowski[1], Ticia Buhr[1], Alfred Müller[2], and Stefan Schippers[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

A research plan has been devised for studying inner-shell photoionization of negative atomic ions at the PIPE end station of beam line P04 of PETRA III at DESY in Hamburg. First results have already been obtained for double and triple photodetachment of O^- [1] and F^- [2] ions resulting from K-shell ionization or excitation. In the future, also heavier ions will be investigated. To this end, a new Cs-sputter ion source is currently commissioned in Giessen. Results from performance tests of the new ion source will be presented.

[1] S. Schippers *et al.*, Phys. Rev. A **94**, 041401(R) (2016).
[2] A. Müller *et al.*, (submitted).

A 27.7 Wed 15:30 K 1.011

Auger cascade calculations for astrophysically relevant ions — •Randolf Beerwerth[1,2], Sebastian Stock[1,2], Stefan Schippers[3], and Stephan Fritzsche[1,2] — [1]Helmholtz Institut Jena, 07743 Jena — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena — [3]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen

We performed Auger cascade calculations to model the deexcitation pathways that follow upon direct ionization or resonant excitation of inner shell electrons. By building the complete deexcitation trees, we can compute cross sections and ion yields that are useful for e.g. plasma modeling in astrophysical applications. Of special importance for these applications are several isotopes of iron, which are the target of experimental campaigns with the photon-ion merged-beams setup PIPE [1]. We present our calculations for the multiple ionization of Fe^{1+} and Fe^{3+}, where experimental data is available [1, 2] as well as for Fe^{2+}, where an experimental campaign is planned.

Previous configuration average calculations are not in good agreement with the experimental results, which is resolved by our model at fine structure level. For higher charge states, several three electron Auger processes become crucial where an additional shake down transition provides a sufficient gain in energy for an additional Auger decay. Including such transitions drastically modifies the computed ion yields and leads to a good agreement with experimental results.

[1] S. Schippers et al., Astrophys. J. 849 (2017) 5.
[2] R. Beerwerth et al., submitted

A 27.8 Wed 15:45 K 1.011

Comprehensive study of nondipole effects in photoionization of the He 1*s* and Ne 2*s* shells — •Ticia Buhr[1], Levente Abrok[2], Akos Köver[2], Beatrix Pollakowski-Herrmann[3], Jan Weser[3], Jan Dreismann[1], David Nagy[2], Daniel Paul[1], Dezso Varga[2], Alfred Müller[1], Burkhard Beckhoff[3], Stefan Schippers[1], and Sandor Ricz[2] — [1]Justus-Liebig-Universität Gießen, Gießen — [2]Institute for Nuclear Research, Hungarian Academy of Sciences, Debrecen, Hungary — [3]Physikalisch-Technische Bundesanstalt, Berlin

Nondipole effects strongly modify the polar and azimuth angle dependence of the double differential cross section of the photoelectron emission [1]. In order to study these effects in detail, angular distributions of He 1*s* and Ne 2*s* photoelectrons were measured over wide ranges of the polar and azimuth angles covering a solid angle of about 2π. The experiments were carried out at the beam line PTB-XRS of BESSY II using linearly polarized photons. The photoelectrons were detected with an ESA-22-type electrostatic electron spectrometer [2] in in-plane as well as in off-plane geometry determined by the photon momentum and polarization vectors. The observed disagreement between the experimental and theoretical angular distributions might be explained with the neglected terms in the calculations [1].

[1] A. Derevianko *et al.*, At. Data Nucl. Data Tables **73**, 153 (1999).
[2] L. Ábrók *et al.*, Nucl. Instrum. Methods B **369**, 24 (2016).

A 27.9 Wed 16:00 K 1.011

Rayleigh scattering of twisted light by hydrogenlike ions — •Anton Peshkov[1], Andrey Volotka[1], Andrey Surzhykov[2,3], and Stephan Fritzsche[1,4] — [1]Helmholtz-Institut Jena, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Technische Universität Braunschweig, Germany — [4]Friedrich-Schiller-Universität Jena, Germany

The elastic scattering of photons by bound electrons of atoms, commonly known as Rayleigh scattering, has attracted much interest in experiment and theory as one of the simplest second-order quantum electrodynamical process. In particular, the measurement of the linear polarization of the elastically scattered plane-wave radiation has been recently performed at the PETRA III synchrotron at DESY [1]. Until the present, however, very little is known about the scattering of twisted light. When compared to plane-wave photons, such twisted photons carry a well-defined projection of the orbital angular momentum [2]. Here we analyze theoretically the behavior of the polarization Stokes parameters of scattered photons for the elastic scattering of twisted Bessel light by means of the Dirac's relativistic equation. Special attention was paid to the scattering on three different atomic targets: a single atom, a mesoscopic (atoms in a trap) and a macroscopic (foil) targets. Our calculations indicate that the Stokes parameters of the scattered twisted light may significantly differ from their behaviour for an incident plane-wave radiation.

[1] K.-H. Blumenhagen *et al.*, New J. Phys. 18, 103034 (2016).
[2] A. A. Peshkov *et al.*, Phys. Rev. A 96, 023407 (2017).

A 28: Precision Spectroscopy V - highly charged ions (joint session A/Q)

Time: Wednesday 14:00–15:45 Location: K 1.016

A 28.1 Wed 14:00 K 1.016

Ion sources and beamline of the ALPHATRAP *g*-factor experiment — •Tim Sailer[1,2], Ioanna Arapoglou[1,2], José R. Crespo López-Urrutia[1], Alexander Egl[1,2], Martin Höcker[1], Sandro Kraemer[1,2], Andreas Weigel[1,2], Robert Wolf[1,3], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik — [2]Fakultät für Physik und Astronomie, Universität Heidelberg — [3]ARC Centre of Excellence for Engineered Quantum Systems, School of Physics, The University of Sydney, NSW Australia

The Penning-trap experiment ALPHATRAP, located at the Max-Planck-Institut für Kernphysik in Heidelberg, aims to measure the *g* factor of bound electrons in highly charged ions (HCI) up to hydrogen-like $^{208}Pb^{81+}$. In the electrical field of the nucleus with a strength of the order of 10^{16} V/cm bound-state quantum electrodynamics can be tested with highest precision in extreme conditions. To enable measurements beyond the current thermal limits, laser-cooling will be implemented. To this end, a Laser Ion Source (LIS) based on a Nd:YAG laser is used to produce $^{9}Be^{+}$ ions, which will subsequently be laser cooled inside the trap using a 313nm laser system. HCI, which cannot be directly addressed by the laser, will be sympathetically cooled by the beryllium ions. The LIS is attached to the existing beamline, which allows an external production and injection of the $^{9}Be^{+}$ ions. Additionally, a table-top electron beam ion source has been used successfully to produce and inject ions up to $^{40}Ar^{13+}$ into the trap. Finally, the HD-EBIT will be connected to the experiment in the near future to enable the transfer and subsequent measurement of heavy HCI.

A 28.2 Wed 14:15 K 1.016

SIM-X: Silicon Microcalorimeters for X-ray Spectroscopy at Storage Rings - Status and Perspectives — •Pascal Andree Scholz[1], Victor Andrianov[2], Artur Echler[3,4], Peter Egelhof[3,4], Oleg Kiselev[3], Saskia Kraft-Bermuth[1], and Damian Müll[1] — [1]Justus Liebig University Giessen, Germany — [2]Lomonosov Moscow State University, Russia — [3]GSI Helmholtz Center, Germany — [4]Johannes Gutenberg University Mainz, Germany

High-precision X-ray spectroscopy of highly-charged heavy ions provides a sensitive test of quantum electrodynamics in very strong Coulomb fields. However, one limitation of the current accuracy of such experiments is the energy resolution of available X-ray detectors. Due to their excellent energy resolution for X-ray energies around 100 keV, silicon microcalorimeters, based on silicon thermistors and tin absorbers, have already demonstrated their potential in previous experiments at the Experimental Storage Ring (ESR) of the GSI Helmholtz Center for Heavy Ion Research. Based on these experiments, a larger detector array with three times the active detector area in a cryogen-free cryostat equipped with a pulse tube cooler is currently in preparation. After a successful test experiment in june 2016 at the ESR with SIM-X, efforts in optimization and characterization concerning the thermal design and performance were made in order to improve the overall energy resolution and performance. In this presentation, we will present the current status of developments and perspectives in particular with respect to the next FAIR Phase 0 experiments.

A 28.3 Wed 14:30 K 1.016

Commissioning of the ALPHATRAP double Penning-trap system — •Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], 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 Institute for Nuclear Physics, Heidelberg — [2]Faculty of Physics and Astronomy, University of Heidelberg

The ALPHATRAP experiment is a state-of-the-art Penning-trap setup aiming for high-precision g-factor measurements on heavy highly charged ions (HCI), such as hydrogen-like $^{208}Pb^{81+}$. That way the most stringent test of bound-state quantum electrodynamics (BS-QED) can be carried out. The storage and manipulation of the ions is achieved using a double Penning-trap system in which the electron's g-factor is deduced from measuring the magnetic moment of the bound electron. The setup includes several ion creation possibilities for offline ion production, additional to the online injection of heavy HCI from the Heidelberg Electron Beam Ion Trap. The latter will deliver the ions of interest via an ion beam-line to the cryogenic double Penning-trap system, which is currently at the commissioning stage. Presently, proof-of-principle measurements are taking place in preparation for the first g-factor measurement. Among other things, necessary requirements for such a measurement will be the optimisation of the trapping potential, effective ion cooling, adiabatic ion transport as well as accurate knowledge of field inhomogeneities within the trapping region. These results and the current status of the experiment will be discussed.

A 28.4 Wed 14:45 K 1.016

Progress of the MEDeGUN commissioning and extension of the TwinEBIS test bench — •Hannes Pahl[1,2], Martin Breitenfeldt[1], Alexander Pikin[1,3], Johanna Pitters[1], and Fredrik Wenander[1] — [1]CERN, 1211 Geneva 23, Switzerland — [2]Universität Heidelberg, 69120 Heidelberg, Germany — [3]Brookhaven National Laboratory, Upton 11973, USA

We report on recent results related to the commissioning of a Brillouin-type electron gun (MEDeGUN) at TwinEBIS, a test bench for the development of Electron Beam Ion Sources (EBIS) at CERN. MEDeGUN is developed for both nuclear research and medical applications. It combines a strong electrostatic compression of the electron beam inside the magnetically shielded gun with the conventional magnetic compression into the ionisation region, providing high current-density electron beams for rapid charge breeding. During the commissioning, a 10 keV electron beam of more than 1 A was successfully injected into a 2 T solenoid field with negligible losses.

In order to measure the charge breeding efficiency, an upgrade of the existing setup is required. Hence, the TwinEBIS setup will be extended with a low-energy ion beam line that allows for external ion injection and extraction. A number of diagnostic devices for the extracted ion bunches will be installed, and a gas feed will be added to enable neutral gas injection directly into the EBIS ionisation region. Here, we present the design of the beam line and modifications to MEDeGUN intended to be implemented for the next commissioning run.

A 28.5 Wed 15:00 K 1.016

Electronic transitions in highly charged ions as X-ray wavelength standards — •Sven Bernitt[1,2], Steffen Kühn[2], René Steinbrügge[3], Hans-Christian Wille[3], Thomas Stöhlker[1,4], and José R. Crespo López-Urrutia[2] — [1]IOQ, Friedrich-Schiller-Universität, Jena, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Deutsches Elektronen-Synchrotron, Hamburg, Germany — [4]Helmholtz-Institut Jena, Germany

The newest generations of synchrotron and free-electron laser light sources combined with high resolution monochromators offer high X-ray photon fluxes over narrow bandwidths. This allows for a wide range of new applications, among others in material science, biophysics, laboratory astrophysics, and fundamental atomic physics. However, currently most experiments have to rely on crystallographic standards or absorption edges measured in macroscopic samples for the calibration of X-ray wavelengths, which limits the achievable accuracies. Electronic transitions in few-electron highly charged ions can serve as reliable high-precision alternative X-ray wavelength standards. We have developed PolarX-EBIT, a compact electron beam ion trap with a novel off-axis electron gun. It allows to measure resonantly excited fluorescence of highly charged ions interacting with X-rays without blocking the photon beam, therefore allowing wavelength calibration simultaneous with arbitrary downstream experiments. We present the new trap as well as the results of an experiment where it was used to provide an accurate calibration of the photoabsorption of various gases relevant for the interpretation of astropysical X-ray spectra.

A 28.6 Wed 15:15 K 1.016

Recent laser cooling and laser spectroscopy experiments at the ESR — •Danyal Winters[1], Oliver Boine-Frankenheim[1,2], Axel Buss[3], Christian Egelkamp[3], Lewin Eidam[2], Volker Hannen[3], Zhongkui Huang[4], Daniel Kiefer[2], Sebastian Klammes[1,2], Thomas Kühl[1,5], Markus Löser[6,7], Xinwen Ma[4], Peter Spiller[1], Wilfried Nörtershäuser[2], Rodolfo Sanchez Alarcon[1], Ulrich Schramm[6,7], Mathias Siebold[6], Markus Steck[1], Thomas Stöhlker[1,5,8], Johannes Ullmann[3], Thomas Walther[2], Hanbing Wang[4], Weiqiang Wen[4], Christian Weinheimer[3], Daniel Winzen[3], and Michael Bussmann[6] — [1]GSI Darmstadt — [2]TU-Darmstadt — [3]Uni Münster — [4]IMP Lanzhou — [5]HI-Jena — [6]HZDR Dresden — [7]TU-Dresden — [8]Uni-Jena

One of the most promising techniques for ion beam cooling at relativistic energies, is laser cooling. The fluorescence emitted after laser excitation can be used for both optical beam diagnostics and precision spectroscopy. We present results on experiments with $^{12}C^{3+}$ beams (122 MeV/u) stored in the experimental storage ring (ESR) in Darmstadt, Germany. The cooling transition in the ions was excited using a pulsed laser system with a high repetition rate, and a wide-scanning cw laser system. A novel XUV detector system, installed inside the vacuum of the ESR, was used to detect the fluorescence from the ions. We will present the experimental setup and preliminary data, and give an outlook on future experiments at FAIR in Germany and HIAF in China.

A 28.7 Wed 15:30 K 1.016

Commissioning of a detection system for forward emitted XUV photons at the ESR — M. Bussmann[1], A. Buss[2], C. Egelkamp[2], L. Eidam[3], V. Hannen[2], Z. Huang[4], D. Kiefer[5], S. Klammes[5], Th. Kühl[6,7,8], M. Loeser[1], X. Ma[4],

W. Nörtershäuser[9], H.-W. Ortjohann[2], R. Sánchez[6,9], M. Siebold[1], Th. Stöhlker[6,7,10], J. Ullmann[7,9,10], J. Vollbrecht[2], Th. Walther[5], H. Wang[4], Ch. Weinheimer[2], D. Winters[6], and •D. Winzen[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Institut für Kernphysik, WWU Münster — [3]Institut für Theorie Elektromagnetischer Felder, TU Darmstadt — [4]Institute of Modern Physics, CAS Lanzhou — [5]Institut für Angewandte Physik, TU Darmstadt — [6]GSI, Darmstadt — [7]Helmholtz-Institut Jena — [8]Institut für Physik, Uni Mainz — [9]Institut für Kernphysik, TU Darmstadt — [10]Institut für Optik und Quantenelektronik, Uni Jena

The Institut für Kernphysik in Münster developed an XUV-photon detection system for laser spectroscopy measurements at the ESR. In a test beam time for laser cooling with $^{12}C^{3+}$-ions at $\beta \approx 0.47$, the $^2S_{1/2} - {}^2P_{1/2}$ and the $^2S_{1/2} - {}^2P_{3/2}$ transitions were investigated to commission the system. The detector features a movable cathode plate which is brought into the vicinity of the beam to collect forward emitted Doppler shifted photons ($\lambda_{lab} \approx 93$ nm). The photons produce mostly low energetic (<3 eV) secondary electrons which are electromagnetically guided onto an MCP detector. Preliminary results of the beam time will be presented. This work is supported by BMBF under contract number 05P15PMFAA.

A 29: Precision Measurements and Metrology (Atom Interferometry) (joint session Q/A)

Time: Wednesday 14:00–15:30 Location: K 2.013

Group Report A 29.1 Wed 14:00 K 2.013

Probing the forces of blackbody radiation and dark energy with matter waves — •Philipp Haslinger[1], Vitkoria Xu[1], Matt Jaffe[1], Osip Schwartz[1], Paul Hamilton[2], Benjamin Elder[3], Justin Khoury[3], Matthias Sonnleitner[5], Monika Ritsch-Marte[4], Helmut Ritsch[5], and Holger Müller[1] — [1]UC Berkeley, USA — [2]UC Los Angeles, USA — [3]UPenn, USA — [4]Med-Uni Innsbruck, AUT — [5]Uni Innsbruck, AUT

In this talk I will give an overview of our recent work using an optical cavity enhanced atom interferometer to sense with gravitational strength for fifths forces and for an on the first-place counterintuitive inertial property of blackbody radiation. Blackbody (thermal) radiation is emitted by objects at finite temperature with an outward energy-momentum flow, which exerts an outward radiation pressure. At room temperature e.g. a Cs atom scatters on average less than one of these photons every 10^8 years. Thus, it is generally assumed that any scattering force exerted on atoms by such radiation is negligible. However, particles also interact coherently with the thermal electromagnetic field and this leads to a surprisingly strong force acting in the opposite direction of the radiation pressure.

If dark energy, which drives the accelerated expansion of the universe, consists of a screened scalar field (e.g. chameleon models) it might be detectable as a "5th force" using atom interferometric methods. By sensing the gravitational acceleration of a 0.19kg in vacuum source mass, we reach a natural bound for cosmological motivated scalar field theories and were able to place tight constraints.

A 29.2 Wed 14:30 K 2.013

Matter waves optics with a space-borne Bose-Einstein condensate experiment — •Dennis Becker[1], Ernst M. Rasel[1], Wolfgang Ertmer[1], and the QUANTUS Team[1,2,3,4,5,6,7,8] — [1]IQ, Leibniz Universität Hannover — [2]HU Berlin — [3]JGU Mainz — [4]FBH Berlin — [5]U Ulm — [6]ZARM Bremen — [7]DLR — [8]TU Darmstadt

Atom interferometers are reaching an exquisite performance and expected to be sensitive probes of fundamental interactions. Thanks to the clean environment and long observation times possible, space promises to unfold the full potential of such sensors. In this contribution, we report on the first realization of a cold atom experiment in space achieved by the sounding rocket mission MAIUS-1. Within 6 min of micro-g and 81 experiments, the chip-based BEC machine demonstrated a high degree of stability and a good agreement with quantum gases models. These results are a key milestone towards BEC-based space missions aiming for gravimetry, gradiometry, tests of fundamental physics laws or the detection of gravitational waves.

QUANTUS & MAIUS are supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR 50WM 1131-1137.

A 29.3 Wed 14:45 K 2.013

New developments with the Gravimetric Atom Interferometer GAIN — •Bastian Leykauf[1], Anne Stiekel[1], Vladimir Schkolnik[1], Christian Freier[1], Hartmut Wziontek[2], Axel Rülke[2], Markus Krutzik[1], and Achim Peters[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Bundesamt für Karthographie und Geodäsie (BKG)

GAIN uses the interference of cold atoms to precisely and accurately measure temporal changes in the gravitational acceleration [1].

In cooperation with the German Federal Agency for Cartography and Geodesy (Bundesamt für Karthographie und Geodäsie, BKG), we conducted a measurement campaign at the geodetic observatory in Wettzell. We will report on the results of this measurement campaign, including the study of active and passive vibration isolation strategies as well as common-mode noise suppression by differential gravity measurements using two atomic samples. We will furthermore discuss systematic effects in the measured gravity value caused by residual magnetic fields [2] and higher order light-shifts.

[1] Freier et al. *Mobile quantum gravity sensor with unprecedented stability*, Journal of Physics: Conference Series **723** (2016)
[2] Hu et al. *Mapping the absolute magnetic field and evaluating the quadratic Zeeman-effect-induced systematic error in an atom interferometer gravimeter*, Physical Review A **96**, 033414 (2017)

A 29.4 Wed 15:00 K 2.013

Large momentum transfer in a dual lattice configuration — •Matthias Gersemann[1], Sven Abend[1], Christian Schubert[1], Martina Gebbe[2], Ernst M. Rasel[1], and the QUANTUS team[1,2,3,4,5,6] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU zu Berlin — [4]Institut für Quantenphysik, Uni Ulm — [5]Institut für Angewandte Physik, TU Darmstadt — [6]Institut für Physik, JGU Mainz

Bose-Einstein condensates (BEC) in combination with large momentum transfer beam splitters are a key component for future infrasound atomic gravitational wave detectors. For this reason we developed a new method for symmetric scalable large momentum separation using the combination of double Bragg diffraction and Bloch oscillations in a dual-lattice configuration. The basic principle consists of an initial splitting via Double Bragg diffraction and a subsequent acceleration by Bloch oscillations. This sequence enables the transfer of up to $1008\,\hbar k$ in a single beam splitter and $408\,\hbar k$ when implemented in an atom interferometer, limited by technical constraints. Further perspectives and limits are investigated and already show that this technique is also applicable for sensitivity enhancements of devices with smaller scales.

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 number DLR 50WM1552-1557 (QUANTUS-IV-Fallturm), the Deutsche Forschungsgemeinschaft (DFG) in the scope of the SFB 1128 geo-Q and "Niedersächsisches Vorab" through QUANOMET.

A 29.5 Wed 15:15 K 2.013

The linear potential and the cubic phase — •Matthias Zimmermann[1], Maxim A. Efremov[1], Albert Roura[1], Wolfgang P. Schleich[1], Arvind Srinivasan[2], Jon P. Davis[3], Frank A. Narducci[4], Sam A. Werner[5], and Ernst M. Rasel[6] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, Germany — [2]Naval Air Systems Command, EO Sensors Division, Patuxent River, USA — [3]AMPAC, North Wales, USA — [4]Naval Postgraduate School, Monterey, USA — [5]Physics Laboratory, NIST, Gaithersburg, USA — [6]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany

The quantum mechanical propagator of a massive particle in a linear gravitational potential is well-known to contain a phase φ_g scaling with the third power of propagation time T. This phase has the remarkable feature of being proportional to the ratio m_g^2/m_i, where m_g

and m_i denote the gravitational and the inertial mass of the particle, respectively.

We propose an experiment to observe this phase using an atom interferometer [1]. For this purpose, we prepare two different accelerations g_g and g_e for the ground and excited state of the atom. In this way the atom accumulates two different phases $\varphi_g^{(g,e)}$ depending on its internal state and the total interferometer phase scales as T^3.

[1] M. Zimmermann et al., *Appl. Phys. B* **123**:102 (2017)

A 30: Atomic Clusters III (joint session A/MO)

Time: Wednesday 14:00–15:30 Location: K 2.016

A 30.1 Wed 14:00 K 2.016

Single-shot electron imaging of helium nanoplasmas — •Dominik Schomas[1], Nicolas Rendler[1], Andreas Heidenreich[2,3], Thomas Pfeifer[4], Robert Mosshammer[4], and Marcel Mudrich[5] — [1]Physikalisches Institut, Albert-Ludwigs-University, Freiburg — [2]Kimika Fakultatea, Euskal Herriko Unibertsitatea (UPV/EHU) and Donostia International Physics Center (DIPC) — [3]IKERBASQUE, Basque Foundation for Science — [4]Max Planck Institute for Nuclear Physics, Heidelberg — [5]stronomDepartment of Physics and Ay, Aarhus University

Strong femtosecond laserfields can turn a helium nanodroplet into a highly charged nanoplasma. The initial ignition just needs a few electrons provided by tunnel ionization of helium or a dopant particle to start an avalanche of ionizations. The cluster is then completely within a few femtoseconds. Repulsion between ions leads to Coulomb explosion of the cluster and highly energetic ions and electrons are produced. We use the velocity map imaging (VMI) technique to measure the energy and angular distribution of the electrons, and a time-of-flight (TOF) spectrometer to collect the ions. One helium droplet produces enough signal to measure VMI and TOF spectra for individual helium droplets hit by single laser pulses. With pump-probe measurements we investigate the time evolution of the system.

A 30.2 Wed 14:15 K 2.016

Highly Charged Rydberg Ions from the Coulomb Explosion of Clusters — •Dzmitry Komar, Lev Kazak, Mohammed Almassarani, Karl-Heinz Meiwes-Broer, and Josef Tiggesbäumker — Institut für Physik, Universität Rostock, 18059 Rostock, Germany

Ion emission from a nanoplasma produced in the interaction of intense optical laser pulses with argon clusters is studied resolving simultaneously charge states and recoil energies. By applying appropriate static electric fields we observe that a significant fraction of the ions Ar^{q+} (q=1-7) have electrons with binding energies lower than 150 meV, i.e. n_{Ryd} => 15 levels are populated. Charge state changes observed on a microsecond time scale can be attributed to electron emission due to autoionizing Rydberg states, indicating that high-l Rydberg levels are populated as well. The experiments support theoretical predictions that a substantial fraction of delocalized electrons, which are bound with hundreds of eV to the nanoplasma after the laser exposure, fill up only meV bound ion states in the adiabatic expansion. We expect the process to be relevant for the long-term evolution of expanding laser-induced dense plasmas in general.

A 30.3 Wed 14:30 K 2.016

Size Dependent Ion Yields from NaCl Nanoarticles Ionized by Intense Femtosecond Laser Pulses — •Egill Antonsson, Felix Gerke, Lucia Merkel, Ina Halfpap, Burkhard Langer, and Eckart Rühl — Physical Chemistry, Freie Universität Berlin, D-14195 Berlin, Germany

Ionization of size selected nanoparticles by intense femtosecond laser pulses is studied by time-of-flight mass spectrometry. For NaCl nanoparticles (d=100-600 nm), a size dependent modulation in the ratio of the yields of Na^+ and Cl^+ ions is observed, although the stoichiometry of the nanoparticles is constant irrespective of size. The observed size dependent ion yields are interpreted in terms of a model, where the intense laser pulses create a nanoplasma and the ion yields of the constituent elemental ions in the nanoparticles are determined by the plasma temperature and the ionization potentials of the elements.

A 30.4 Wed 14:45 K 2.016

Size-dependent angular anisotropy in ion and electron emission of free NaCl nanoparticles excited by intense femtosecond laser pulses studied by Velocity Map Imaging spectroscopy — •Felix Gerke, Lucia Merkel, Egill Antonsson, and Eckart Rühl — Physikalische Chemie, Freie Universität Berlin, Takustr. 3, 14195 Berlin

We present results regarding the angular distribution of ions and electrons emitted from NaCl nanoparticles (d = 100-500 nm) during photoionization by intense femtosecond laser pulses obtained from Velocity Map Imaging (VMI) spectroscopy. The beam of a pulsed Ti:Sapphire laser (λ = 800 nm, E = 1.55 eV) is crossed in vacuum with a beam of free NaCl nanoparticles, that is focused by an aerodynamic lens, leading to ionization of the nanoparticles. Electrons and ions emitted from the nanoparticles are recorded by a VMI spectrometer. A size-dependent asymmetry in the electron and ion emission with respect to the propagation direction of the laser beam is observed. Here, more electron and ion emission is observed in the propagation direction of the laser pulses than in opposite direction. A comparison of electron and ion emission from nanoparticles of different size reveals the angular anisotropy, which is increasing with nanoparticle size. Furthermore, a comparison to model calculations simulating the internal electric field of the nanoparticles by means of the discrete dipole approximation is used to attribute the experimentally observed angular anisotropy to size-dependent non-isotropic internal electric fields in the nanoparticles.

A 30.5 Wed 15:00 K 2.016

Lasersheet nanoparticle imaging — •Lena Worbs[1,2], Amit Samanta[1], Daniel Horke[1,2], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Center for Ultrafast Imaging, Universität Hamburg, Germany — [3]Department of Physics, Universität Hamburg, Germany

For coherent diffractive imaging of nanoparticles at free-electron lasers, sample delivery techniques and appropriate diagnostics have to be developed.

To characterize nanoparticle beams from aerodynamic cooling elements, e.g., aerodynamic lenses or buffer-gas cooling cells, a sheet of light is generated, and the scattered light of nanoparticles passing through the sheet is imaged with a microscope. Lasersheet imaging enables a full reconstruction of the transverse profile of the nanoparticle beam. Furthermore, it offers the opportunity to image the nanoparticle beam density without an additional setup, allowing the optimization of sample delivery methods.

A 30.6 Wed 15:15 K 2.016

Cold and controlled nanoparticle beams for single particle diffractive imaging — •Nils Roth[1], Salah Awel[1,2], Amit Samanta[1], Armando Estillore[1], Lena Worbs[1,2], Muhamed Amin[1], Karol Dlugolecki[1], Nicolai Pohlmann[1], Daniel Horke[1,2], and Jochen Küpper[1,2,3,4] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Center for Ultrafast Imaging, Universität Hamburg, Germany — [3]Department of Physics, Universität Hamburg, Germany — [4]Department of Chemistry, Universität Hamburg, Germany

Coherent diffractive imaging at free-electron lasers promises to allow the reconstruction of the three-dimensional molecular structures of isolated particles at atomic resolution [1]. However, because of the typical low signal to noice ratio, this requires the collection of a large amount of diffraction patterns. Since every intercepted particle is destroyed by the intense x-ray pulse, a new and preferably identical sample particle has to be delivered into every pulse. Currently the inefficient delivery of particles and the correspondingly low number of strong diffraction patterns collected during typical beam times is one of the major limiting factors. With the aid of numerical simulations we developed new aerodynamic devices, such as aerodynamic lenses and buffer-gas cells, to produce cold and high-density beams of nanoparticles, *e.g.*, viruses. We benchmark developed injectors in our aerosol beam characterisation setup, using novel laser-based particle detection schemes.

[1] M. M. Seibert, et al, *Nature* **470**, 78 (2011).

A 31: Strong laser fields - II

Time: Wednesday 14:00–16:00 Location: K 2.019

Invited Talk A 31.1 Wed 14:00 K 2.019

H_2^+ and HeH^+: Two fundamentally important molecules in strong laser fields — Philipp Wustelt[1], Max Möller[1], A. Max Sayler[1,2], and •Gerhard G. Paulus[1,2] — [1]Friedrich Schiller University, Jena, Germany — [2]Helmholtz Institute Jena, Germany

Ion beam experiments studying the fragmentation of HeH^+ and H_2^+ are performed and compared. The two molecules represent extreme instances of polar and non-polar molecules. Therefore, the behavior of most chemical bonds in strong fields can be expected to lie in between these extremes.

In the experiment, the fragments generated through the interaction with femtosecond laser pulses of wavelengths from 400 to 2400 nm and intensities up to 10^{17} W/cm^2 are recorded on a position- and time-sensitive detector such that the momenta of the fragments can be fully reconstructed.

The excitation and ionization dynamics in H_2^+ and HeH^+ is very different, particularly at low intensities. In the former, dissociation is strong and the molecule stretches due to coupling of electronic states before ionization. HeH^+, in contrast, can directly be vibrationally excited for sufficiently long wavelengths. Dissociation, on the other hand, is almost negligible for short wavelengths.

A 31.2 Wed 14:30 K 2.019

Two-color laser pulses and "the phase of the phase" — •Mohammad Adel Almajid and Dieter Bauer — Institute of Physics, University of Rostock, 18051 Rostock, Germany

Phase of the phase (PoP) spectroscopy using two-color colinearly polarized laser pulses has been introduced and applied to the tunneling regime of strong-field ionization [1]. PoP spectra represent concisely how much and with which phase lag the photoelectron yield changes as a function of the relative phase between the two colors.

In the multiphoton regime, we find an alternating PoP along the above-threshold ionization rings, generating a characteristic checkerboard pattern in the PoP spectra, which can analytically be described within the strong-field approximation [2].

In the case of counter-circularly polarized ω-2ω laser pulses a three-fold symmetry in the PoP spectra is obtained, and there is a jump in the PoP signature at a particular radial photoelectron momentum, which can analytically be described using the saddle point equation.

[1] S. Skruszewicz *et al.*, *Two-Color Strong-Field Photoelectron Spectroscopy and the Phase of the Phase*, Phys. Rev. Lett. 115, 043001 (2015).
[2] M. A. Almajid *et al.*, *Two-color phase-of-the-phase spectroscopy in the multiphoton regime*, J. Phys. B: At. Mol. Opt. Phys. 50, 194001 (2017).

A 31.3 Wed 14:45 K 2.019

Towards phase-of-the-phase spectroscopy on atomic hydrogen — •Bennet Krebs, Dzmitry Komar, Konstantin Gröner, Michael Zabel, Lev Kazak, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Universitaet Rostock, Institut fuer Physik, Albert-Einstein-Str. 24, D-18059 Rostock

A hot capillary thermal atomic hydrogen source is used in order to extract angular resolved photoelectron signal from H_1. Near infrared laser light ($\lambda = 800$ nm, $\tau = 130$ fs, $I_f \approx 10^{14}$ W/cm^2) is used to ionize hydrogen in the tunneling regime. A serious problem with respect to strong field photoemission from atomic hydrogen is the background signal caused by the low efficiency in standard H_1-sources. Directional focused H_1 sources interact with the perpendicular aligned laser-field only within their cross section, while residual or recombined H_2 may be ionized over the whole laser volume. At high gas loads the H_2 signal may be orders of magnitude higher than the desired atomic signal. VMI spectra of H_1 are presented and compared to spectra of molecular hydrogen. By expanding the laser setup to $\omega/2\omega$ fields we plan conduct $\mathcal{PoP}$ Spectroscopy [1] on the simplest atomic system in order to contribute benchmark data for theory.

[1] S. Skruszewicz, et al. Phys. Rev. Lett. 115, 043001 (2015)

A 31.4 Wed 15:00 K 2.019

Strong field ionization dynamics of photoelectrons in parallel mid infrared two color laser fields — •Daniel Würzler[1,2], Slawomir Skruszewicz[1,2], Max Sayler[1,2], Danilo Zille[1,2], Yinyu Zhang[1,2], Daniel Adolph[1,2], Philipp Wustelt[1,2], Max Möller[1,2], Stephan Fritzsche[1,3], Josef Tiggesbäumker[4], Dieter Bauer[4], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantum-Electronics, Max-Wien-Platz 1, D-07743 Jena, Germany — [2]Helmholtz Institute Jena, Fröbelstieg 3, D-07743 Jena, Germany — [3]Institute of Theoretical Physics, Max-Wien-Platz 1, D-07743 Jena, Germany — [4]Institute of Physics, Albert-Einstein-Str. 24, D-18059 Rostock, Germany

Due to the nonlinearity of strong-field ionization processes, even small modifications of the ionizing laser field (ω) can have a significant impact on the resulting dynamics. Such modifications can be realized with subcycle precision by coherently superimposing the ionizing laser field with its second harmonic (2ω) [1-2]. Here, we apply this technique to the mid-IR wavelength regime ($\lambda_\omega = 1800$nm and $\lambda_{2\omega} = 900$nm) in parallel field configuration. By tuning the relative phase, φ_{rel}, of the two fields, we investigate phase-dependent photoelectron momenta spectra of Xe. Using the 'phase of the phase' [3] of the spectra, we discuss various contributions to forward scattering from trajectories revisiting the ion several times during ionization [4].

[1] C. Figueira de Morisson Faria et al. Phys. Rev. A 61, 063415 [2] D. Shafir et al. Nature 485, 343-346 [3] S. Skruszewicz et al. Phys. Rev. Lett. 115, 043001 [4] M. Möller et al. Phys. Rev. A 90, 023412

A 31.5 Wed 15:15 K 2.019

Phase resolved measurements of strong field photoionization in alkali metal vapor — •Philipp Kellner[1], Daniel Adolph[2], Yinyu Zhang[1,2], Danillo Zille[1], Philipp Wustelt[1], Max Moeller[1], A. Maxwell Sayler[1,2], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantumelectronics, Max-Wien-Platz 1, 07743 Jena — [2]Helmholtz-Institute, Fröbelstieg 3, 07743 Jena

The carrier-envelope phase (CEP) is a crucial parameter for experiments where ultrashort strong pulses of laserlight interact with matter such as high harmonic and attosecond-pulse generation or above-threshold ionization. The talk will present phase-resolved measurements of strong-field photoionization from alkali metal vapor induced by few-cycle pulses at 800 nm and 1800 nm center wavelength. These measurements pave the way towards single-shot CEP- and pulse duration measurements in the mid-IR-wavelength range. Unlike well established techniques of CEP-measurement e.g. f-2f interferometers or the xenon-based CE phasemeter, the alkali-phasemeter should allow precise, single-shot phase characterization with high repetition rates and low pulse energies. The key to reducing the pulse energy lies in the usage of materials with low ionization potential. Lower ionization potentials allow for longer wavelength and smaller intensities by staying in the tunneling-ionization-regime. The CE phasemeter based on alkali metalls can make pulse reconstruction in the shortwave IR-Regime possible and might also be an alternative for pulse duration measurements with FROG.

A 31.6 Wed 15:30 K 2.019

CEP-asymmetries from bichromatic multi-photon ionization of Xenon atoms — •Stefanie Kerbstadt, Dominik Pengel, Lars Englert, Tim-Daniel Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg, Institut für Physik, Carl-von-Ossietzky-Straße 9-11, 26129 Oldenburg

Recently, we introduced a novel approach to the generation of polarization-tailored bichromatic fields, based on ultrafast pulse shaping of an octave-spanning Carrier Envelope Phase (CEP)-stable white light supercontinuum [1-2]. The bichromatic shaping scheme opens up an entirely new class of polarization-tailored optical waveforms for various applications including multi-pathway coherent control of ultrafast dynamics, high-order harmonics generation and the design of polarization-sensitive two-color pump-probe experiments with phase-locked CEP-stable laser pulses at a broad range of excitation wavelengths [3]. In this contribution, bichromatic pulse shaping is applied to study CEP-sensitive lateral asymmetries in the photoelectron angular distribution from 7- vs. 8-photon ionization of Xenon atoms. The physical mechanism is discussed in terms of the interference of states with opposite parity, addressed by the corresponding quantum pathways. In addition, we vary the polarization state of both colors from linear to circular, generating a CEP-sensitive 3D-photoelectron wave packets with 1-arm-vortex shape.

[1] S. Kerbstadt et al., J. Mod. Opt. 64 (2017) 1010.
[2] S. Kerbstadt et al., Opt. Expr. 25 (2017) 12518.
[3] S. Kerbstadt et al., New J. Phys. 19 (2017) 103017.

A 31.7 Wed 15:45 K 2.019

Strong-field photoemission from a one-dimensional nanometric blade structure — •Timo Paschen[1], Ryan Roussel[2], James Rosenzweig[2], and Peter Hommelhoff[1,3] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]UCLA Physics and Astronomy, Los Angeles, CA 90095-1547 — [3]Max-Planck Institut für die Physik des Lichts, 91058 Erlangen

We present femtosecond laser-induced electron emission from a nanometric one-dimensional blade structure. Due to the unique combination of silicon-based production technology and optical near-field properties well known from nanotip research [1,2] confined laser-induced electron emission can be achieved. By tightly focusing μJ-level few-cycle laser pulses onto the sample and harnessing local field enhancement at the structure the optical-field strength can reach up to 60 V/nm, turning the electron emission mechanism into strong-field photoemission. We will discuss energy-resolved electron spectra showing clear signs of strong-field effects such as the high-energy plateau and the intensity-dependent cut-off shift. The high total emitted charge of several thousand electrons per laser pulse and maximum achieved electron energies of more than 1 keV render the presented structure an excellent candidate as a line electron source for dielectric laser acceleration (DLA) [3], for example.

[1] M. Schenk et al., Phys. Rev. Lett., 105, 257601 (2010).
[2] M. Krüger et al., Nature 475, 78 (2011).
[3] J. Breuer et al., Phys. Rev. Lett., 111, 134803 (2013).

A 32: Molecules in Intense Laser Fields (joint session MO/A)

Time: Wednesday 14:00–15:45 Location: PA 2.150

Invited Talk A 32.1 Wed 14:00 PA 2.150

Strong-field ionization of laser-aligned molecules — •Jochen Küpper — Center for Free-Electron Laser Science, DESY, Hamburg — Center for Ultrafast Imaging, Universität Hamburg — Department of Physics and Department of Chemistry, Universität Hamburg

The interaction of strong laser fields with matter intrinsically enables the imaging of transient dynamics with extremely high spatiotemporal resolution. This paradigm of photophysics has grown into new emerging research areas, ranging from attosecond science to laser-induced electron diffraction, providing new insight into atoms, molecules and, more recently, condensed matter. Also, the earliest moments of strong-field interactions have attracted attention for capturing the intrinsic nature of strong-field physics. While pioneering attosecond science experiments and molecular-frame measurements revealed non-trivial spatiotemporal features in electron tunneling, these initial conditions are generally considered a weak perturbation. We investigated strong-field ionization in the molecular frame. Cabornyl sulfide (OCS) molecules were quantum-state selected, strongly laser aligned, and ionized using short near-infrared laser pulses. We analyzed the dynamics of the electron and discuss the obtained molecular-frame photoelectron-angular distributions. Our findings have strong impact in the interpretation of laser induced electron diffraction, where the photoelectron momentum distribution is used to retrieve molecular structures. Furthermore, the encoding of the time-energy relation in the photoelectron momenta provides new ways of probing electron tunneling and the molecular potential with sub-femtosecond resolution.

A 32.2 Wed 14:30 PA 2.150

Intermolecular vibration in $(NO_2)_2$ molecules studied with few-cycle laser pulses — Katrin Reininger, Jingming Long, Federico Furch, Marc J.J. Vrakking, •Claus P. Schulz, and Jochen Mikosch — Max-Born-Institut, Max-Born-Str. 2a, 12489 Berlin, Germany

The intermolecular vibration of the NO_2 dimer molecule is an interesting object of study for high-harmonic generation and strong-field ionization probes of molecular dynamics [1]. The vibration can be conveniently excited by impulsive stimulated Raman scattering (ISRS).

Here we measure the amplitude of the intramolecular motion using photofragment kinetic energy spectroscopy. We employ a newly developed high repetition rate Optical Parametric Chirped-Pulse Amplification (OPCPA) laser system delivering sub-7 fs duration pulses [2] in combination with a novel velocity map imaging (VMI) spectrometer based on an in-vacuum pixel detector [3].

Following ISRS, the molecule is strong-field ionized to the $(NO_2)_2^+$ A_g state and undergoes dissociation. We observe an oscillation in the kinetic energy release of NO_2^+ with pump-probe delay on the 130fs time-scale of the O_2N–NO_2 vibration. From the kinetic energy spectrum and the calculated potential surfaces, we determine the amplitude of the vibrational motion in the $(NO_2)_2$ ground state.

[1] W. Li, *et al.*, Science 322, 1207 (2008).
[2] F. J. Furch, *et al.*, Opt. Express 24, 19293 (2016).
[3] J. M. Long, *et. al.*, J. Chem. Phys. 147, 10, 013919 (2017).

A 32.3 Wed 14:45 PA 2.150

Intensity dependence of Photon Energy Sharing in H_2 Multiphoton Ionization — •Patrick Fross, Denhi Martinez, Nicolas Camus, Thomas Pfeifer, and Robert Moshammer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

When ionizing molecules with strong laser fields, the dynamics of photofragmentation determines how the photon energy is shared between the resulting fragments. Understanding this photon energy sharing helps to understand and eventually control the fragmentation process in intense laser fields. Recently Joint-Energy-Spectra (JES) have been observed for dissociative and double ionization of H_2 in order to investigate photon-number-resolved ionization dynamics at laser intensities of $5 \cdot 10^{13}$-$1 \cdot 10^{14}$ W/cm^2. We present measurements of full 3D photon-number-resolved momentum distributions in H_2 dissociative and double ionization for different intensities using 35fs laser pulses with a central wavelength of 395nm and recording the reaction fragments with a Reaction Microscope. The JES clearly shows that for high laser intensities events involving different numbers of photons cannot be distinguished anymore.

A 32.4 Wed 15:00 PA 2.150

Fragmentation dynamics of HeH^+ in intense ultrashort laser pulses — •Philipp Wustelt[1,2], Florian Oppermann[3], Lun Yue[4], Max Möller[1,2], A. Max Sayler[1,2], Manfred Lein[3], Stefanie Gräfe[4], and Gerhard G. Paulus[1,2] — [1]Institute of Optics and Quantum Electronics, Friedrich-Schiller-University Jena, D-07743 Jena, Germany — [2]Helmholtz Institute Jena, D-07743 Jena, Germany — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover — [4]Institute of Physical Chemistry, Friedrich-Schiller University-Jena, Helmholtzweg 4, D-07743 Jena, Germany

The helium hydride molecular ion, HeH^+, is the simplest heteronuclear polar molecule and serves as a benchmark system for the investigation of multi-electron molecules and molecules with a permanent dipole. We specifically address the question: How does the permanent dipole of HeH^+ affect the fragmentation dynamics in intense ultrashort laser pulses? We study the laser induced laser-induced fragmentation; including non-ionizing dissociation, single ionization and double ionization; of an ion beam of helium hydride and an isotopologue at various wavelengths and intensities. These results are interpreted using reduced dimensionality solutions to the time-dependent Schrödinger equation and with simulations based on Dressed surface hopping.

A 32.5 Wed 15:15 PA 2.150

Electron-Nuclear Coupling through Autoionizing Rydberg States after Strong-field Excitation of Molecules — •Yonghao Mi, Nicolas Camu, Lutz Fechner, Martin Laux, Robert Moshammer, and Thomas Pfeifer — Max-Planck-Institute for Nuclear Physics

Channel-selective electron emission from strong-field photo-ionization of H_2 molecules is experimentally investigated by using ultrashort laser pulses and a Reaction Microscope. The electron momenta and energy spectra in coincidence with bound and dissociative ionization channels are compared. Surprisingly, we observed an enhancement of the photoelectron yield in the low-energy region for the bound (H_2^+) ionization channel. By further investigation of asymmetrical electron emission using two-color laser pulses, this enhancement is understood as the population of the autoionizing states of neutral H_2 molecules in which vibrational energy is transferred to electronic energy. This general mechanism, provides access to the excited-state population of molecular ions produced in a strong-field interaction.

A 32.6 Wed 15:30 PA 2.150

Probing electronic structure *via* molecular-frame photoelectron imaging — •Joss Wiese[1], Sebastian Trippel[1], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Hamburg — [2]The Hamburg Center for Ultrafast Imaging, Hamburg — [3]Department of Physics, University of Hamburg

Chemical function arises from the interplay of valence electrons and a view at the evolution of the highest occupied molecular orbitals (HOMOs) during a chemical reaction promises direct insight into the fundamentals of chemistry. For this purpose we employ tomographic photoelectron imaging [1] of spatially confined ensembles of indole strong-field ionized by intense near-infrared laser pulses. Reconstructed static three-dimensional photoelectron distributions in molecular-frame momentum space (MF-ARPES) will be presented. These exhibit distinct manifestations of tunneling as well as multiphoton ionization, which allow for the mapping of the molecule's electronic structure. The technique yields experimental access to properties of the HOMO potential energy surface that are commonly only approachable through quantum chemistry. Based on the measured photoelectron distributions the importance of resonant electronic states for the tunneling ionization pathway will be enquired and the validity of molecular strong-field ionization models will be tested.

[1] Maurer, Dimitrovski, Christensen, Madsen, Stapelfeldt, *Phys. Rev. Lett.* ***109***, 123001 (2012)

A 33: Poster Session II

Time: Wednesday 16:15–18:15 Location: Redoutensaal

A 33.1 Wed 16:15 Redoutensaal

Laser spectroscopy of the 1001 nm transition in atomic dysprosium — •Lena Maske, Dominik Studer, Niels Petersen, Florian Mühlbauer, Klaus Wendt, and Patrick Windpassinger — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

High precision spectroscopy of ultra-narrow transitions in cold quantum gases is a promising tool for tests of fundamental physics [1]. Furthermore, ultra-narrow transitions in atoms and molecules are extremely useful for applications in quantum simulation and quantum state manipulation. When considering magnetic quantum gases or very complex electronic systems, a good candidate for an ultra-narrow resonance is the 1001 nm $4f^{10}6s^2\ {}^5I_8 \rightarrow 4f^9\,({}^6H^0)\,5d6s^2\ {}^7I_9^0$ ground state transition in atomic dysprosium. Theoretical calculations predicted the exceptionally small linewidth of 53 Hz [2].

We present the first laser spectroscopy of the possibly ultra-narrow 1001 nm line in atomic dysprosium. Using resonance ionization spectroscopy with pulsed Ti:sapphire lasers at a hot cavity laser ion source, we were able to observe the transition and confirm the level energy listed in the NIST database. In addition, we show our progress towards precision spectroscopy of the 1001 nm transition with a continuous wave ECDL in cold dysprosium atoms to measure the linewidth and the isotope shift.

[1] V.A. Dzuba et al., Physical Review A81, 052515 (2010)
[2] C. Delaunay et al., Physical Review D96, 093001 (2017)

A 33.2 Wed 16:15 Redoutensaal

Observation of the motional Stark effect in low magnetic fields — •Manuel Kaiser[1], Jens Grimmel[1], Lara Torralbo-Campo[1], Florian Karlewski[1], Nils Schopohl[2], and József Fortágh[1] — [1]Center for Quantum Science, Physikalisches Institut, Universität Tübingen, Germany — [2]Center for Quantum Science, Institut für Theoretische Physik, Universität Tübingen, Germany

The motional Stark effect (MSE) originates from a Lorentz force acting in opposite directions on the ionic core and the electrons of an atom moving in a magnetic field. This introduces a coupling between the internal dynamics and the center-of-mass motion of the atom which is therefore no longer a constant of motion. Approximately the MSE can be seen as a Stark effect resulting from an electric field in the frame of a moving atom. We measured this motional Stark shift on ^{87}Rb Rydberg atoms moving in low magnetic fields employing a velocity selective spectroscopy method in a vapor cell. For an atom velocity of 400 m/s, a principal quantum number of n = 100, and a magnetic field of 100 G the shifts are on the order of 10 MHz. Our experimental results are supported by numerical calculations based on a diagonalization of the effective Hamiltonian governing the valence electron of ^{87}Rb in the presence of crossed electric and magnetic fields. Furthermore we present our investigations on the velocity associated with the pseudomomentum as a constant of motion, that is supported by our experimental findings.

A 33.3 Wed 16:15 Redoutensaal

Two-loop corrections to the bound electron g factor: contribution of light-by-light scattering — •Vincent Debierre, Bastian Sikora, Halil Cakir, Natalia S. Oreshkina, Zoltán Harman, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg

We report on the computation of a specific set of two-loop corrections to the bound-electron g factor. Diagrams belonging to this set involve the scattering of the external magnetic field in the Coulomb field of the ionic nucleus, which represents the lowest nonvanishing order of the so-called magnetic loop. We have looked at the electric loop (EL)+magnetic loop (ML) diagram and the self-energy(SE)+magnetic loop diagrams. We restrict ourselves to the $1S$ ground state, and our approach, which treats the binding of the electron to the nucleus at all orders, is hence valid for highly charged, high-Z ions.

We announce full results on the EL-ML diagram, and partial results on the vertex (analytical and subsequent numerical results for the zero-potential term) and the non-vertex (full contribution from the energy-type (or reducible) correction) SE-ML diagrams. The numerical values obtained so far indicate corrections to the g factor of order up to 10^{-8} for the largest contribution (electric loop+magnetic loop), in the case of $_{82}$Pb, values that could be observed in principle in upcoming experiments such as ALPHATRAP and HITRAP.

A 33.4 Wed 16:15 Redoutensaal

Accurate theoretical lifetimes data in the prospects of high precision experiments — •Moazzam Bilal[1,2], Andrey Volotka[1], Randolf Beerwerth[1,2], and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Friedrich-Schiller-Universität, Jena, Germany

We present a detailed investigation of the magnetic dipole (M1) line strengths between the fine-structure levels of the ground configurations in B-, F-, Al- and Cl-like Ar, Fe, Mo and W ions. Systematically improved (enlarged) multiconfiguration Dirac-Hartree-Fock (MCDHF) wave functions are employed for the evaluations of the Coulomb type inter-electronic interactions. Relativistic configuration interaction method is used to evaluate the Breit type inter-electronic interactions. The QED corrections are incorporated by correcting the transition operator of the atomic magnetic moment for the anomalous magnetic moment of the electron (EAMM). One electron QED correction going beyond EAMM approximation is also implemented. The M1 transition rates are reported using the calculated line strengths and available accurate transition energies. Finally, the lifetimes in millisecond to picoseconds range are calculated including the contributions from the transition rate from the E2 transition channel. The discrepancy with available experiments is discussed and a benchmark dataset of theoretical lifetimes is provided in the prospects of future experiments. [1] A. Lapierre et al 2005 *Phys. Rev. Lett.* **95**, 183001. [2] G. Brenner et al 2007 *Phys. Rev. A* **75**, 032504. [3] P. Jönsson, et al 2013 *Comput. Phys. Commun.* **184** 2197.

A 33.5 Wed 16:15 Redoutensaal

Experimental setup for quantum logic inspired cooling and readout techniques for a single (anti-)proton —

•Johannes Mielke[1], Teresa Meiners[1], Malte Niemann[1], Juan M. Cornejo[1], Anna-Greta Paschke[1,2], Matthias Borchert[1,3], Jonathan Morgner[1], Amado Bautista-Salvador[1,2], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch Technische Bundesanstalt, Braunschweig — [3]Ulmer Fundamental Symmetries Laboratory, RIKEN

We discuss techniques tailored for quantum logic inspired cooling and manipulation of a single (anti-)proton in a Penning trap system. Inside the trap a double-well potential is engineered for co-trapping a beryllium ion, which enables for the use of quantum logic spectroscopy inspired sympathetic cooling and readout techniques [1, 2]. These should allow for preparation at sub-Doppler temperatures and a readout of the (anti-)proton's spin-state in less than a second. Within the BASE collaboration [3] these methods could be applied to precision measurements of the (anti-)proton's g-factor, thus contributing to a precise test of CPT invariance with baryons.

Here, we present recent progress made in the setup of the Penning trap apparatus, laser systems, and imaging optics for cooling, manipulation, and detection of the trapped beryllium ion.

[1] D. J. Heinzen *et al.*, PRA **42**, 2977 (1990)
[2] D. J. Wineland *et al.*, J. Res. NIST **103**, 259-328 (1998)
[3] C. Smorra *et al.*, EPJ-ST **224**, 3055 (2015)

A 33.6 Wed 16:15 Redoutensaal

Molecular Beam for Quantum Logic Spectroscopy of Single Molecular Ions — •Jan C. Heip[1], Fabian Wolf[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]IQO, Leibniz Universität, Hannover, Germany

The internal structure of molecules offers rich possibilities for tests of fundamental physics. For example, transitions involving vibrational levels are sensitive to possible variations in the electron-to-proton mass ratio. The additional degrees of freedom (rotational and vibrational) cause obstacles in controlling the quantum states of molecules required for precision spectroscopy. Recent developments in state detection of molecular ions using state-dependent optical dipole forces [1] and state preparation via Raman transitions induced by far-detuned, infrared lasers [2] or frequency combs implements a toolbox which brings high precision optical spectroscopy for molecules within reach. An interesting candidate for a test of possible m_e/m_p variations is $^{16}O_2^+$ [3]. We are currently setting up a new experimental apparatus consisting of a RF Paul trap and a molecular beam to perform experiments on O_2^+. A Multi-channel plate equipped with a phosphor screen is used to characterize the spatial and temporal properties of the gas pulses from the molecular beam. First studies on the photo-ionization spectrum of $^{16}O_2^+$ using a pulsed dye laser are carried out and progress towards quantum logic spectroscopy of these molecular ions will be presented.

[1] Wolf et. al., Nature 530, 457 (2016)
[2] Chou et. al., Nature 545, 203 (2017)
[3] Kajita, Phys. Rev. A 95, 023418 (2017)

A 33.7 Wed 16:15 Redoutensaal

Optical quenching of metastable helium atoms via the 4^1P state — •Vivien Behrendt, Jonas Grzesiak, Simon Hofsäss, Frank Stienkemeier, and Katrin Dulitz — Albert-Ludwigs-Universität Freiburg

Our experiments are aimed at studying quantum-state-selected reactive Penning collisions between metastable helium atoms and ultracold lithium atoms. As a first step towards this goal, it is necessary to distinguish between the contributions of the He(2^1S) and the He(2^3S) state to the reaction. In this contribution, we will present a novel scheme for the quenching of the metastable singlet state using optical pumping to the 4^1P state at 397 nm and subsequent decay to the electronic ground state. We will present the experimental setup and preliminary results which illustrate that this scheme offers several experimental advantages compared to previous approaches.

A 33.8 Wed 16:15 Redoutensaal

Extrapolation of spectral lines of highly charged technetium ions in the EUV range — Leticia Täubert[1], Julia I. Jäger[1], •Chintan Shah[1], Klaus Werner[2], and José Ramón Crespo López-Urrutia[1] — [1]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [2]Eberhard Karls Universität, Tübingen, Germany

Astronomical observations of elements heavier than iron in stars give insights into their stellar evolution. To interpret spectroscopic observations, accurate atomic data of highly charged trans-iron ions are required. The trans-iron element technetium (Z=43) is of special interest since it is the lightest element with no stable isotopes. The spectroscopic measurement of such element poses a technical challenge due to its radioactive nature. Here, we examined its neighboring elements ruthenium (Z=44) and molybdenum (Z=42) on the premise that their atomic structures are same as of technetium. We produced Ru^{14+} and Ru^{15+} using an electron beam ion trap and measured the extreme ultraviolet spectra using flat-field grazing incidence spectrometer. We then identified spectral lines using the Flexible Atomic Code [3]. The NIST spectral line database was used to acquire the corresponding molybdenum spectra. These data enabled the extrapolation of the spectral lines of highly charged technetium.

[1] K. Werner et al., ApJL, 753, L7 (2012)
[2] K. Werner et al., A&A, 574, A29 (2015)
[3] M. Gu, CJP, 86, 5 (2008).

A 33.9 Wed 16:15 Redoutensaal

Evaluating the performance of cascaded atomic clocks — •Marius Schulte[1], Piet O. Schmidt[2,3], and Klemens Hammerer[1] — [1]Institut für theoretische Physik und Institut für Gravitationsphysik (Albert Einstein Institut), Leibniz Universität Hannover, Appelstrasse 2, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

A fundamental challenge for optical clocks is given by the noise properties of their local oscillator. Increasing the interaction time with the atomic reference allows to make more precise estimates on the frequency error and better corrections in the clock operation, however this is only true as long as the phase between local oscillator and reference can be uniquely measured. In this way atomic clocks with e.g. Ramsey interrogation have maximal interrogation times which are set by the noise strength of the local oscillator and limit their long term stability [1]. Cascaded clocks with multiple atomic ensembles were proposed to overcome this limitation [2]. Here we perform numerical analysis of such protocols, finding optimised servo controllers as well as reviewing the maximal interrogation times and long term stability.

[1] Leroux, I. D., et al., On-line estimation of local oscillator noise and optimisation of servo parameters in atomic clocks, Metrologia 54.3 (2017) [2] Borregaard, J. and Sørensen, A. S., Efficient atomic clocks operated with several atomic ensembles, Phys. Rev. Lett. 111, 090802 (2013)

A 33.10 Wed 16:15 Redoutensaal

Hyperfine structure in heavy muonic atoms — •Niklas Michel, Natalia S. Oreshkina, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

We consider bound states between an atomic nucleus and a muon, so called muonic atoms. Especially for high charge numbers, the surrounding atomic electrons do not influence the muon and the system is essentially hydrogenlike. Just as in normal atoms, there is fine and hyperfine splitting, but the significance of the various contributions differs dramatically. In particular, nuclear structure effects are much bigger, and vacuum polarization effects are very important. We calculate the level structure in heavy muonic atoms, taking several QED and nuclear structure effects into account in first-order perturbation theory and beyond. Thereby, precise values of the hyperfine structure of muonic atoms are obtained [1] and the dependence of transition energies in muonic atoms on nuclear parameters is investigated.

[1]: Phys. Rev. A 96, 032510 (2017)

A 33.11 Wed 16:15 Redoutensaal

Towards Quantum Logic Spectroscopy of Highly Charged Ar^{13+} — •Peter Micke[1,2], Steven A. King[1], Tobias Leopold[1], Lisa Schmöger[1,2], Maria Schwarz[1,2], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]QUEST-Institut, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Leibniz Universität Hannover, Germany

Precision spectroscopy of electric dipole-forbidden optical transitions in highly charged ions (HCIs) has applications in the study of fundamental physics and the development of new optical atomic clocks with extremely low systematic uncertainties. However, precision spectroscopy on HCIs is challenging since they are usually produced at megakelvin temperatures and do not offer strong cycling transitions for laser cooling. We are currently commissioning an experiment aiming at high-precision quantum logic spectroscopy (QLS) on HCIs, using

Ar^{13+} as the first test species. Produced in the PTB electron beam ion trap (EBIT), one of the novel 0.86 T Heidelberg Compact EBITs, the HCIs will be extracted and decelerated through a beamline, injected into a linear Paul trap and sympathetically cooled by laser-cooled Be^{+} ions. A cryogenic system is operated with a pulse-tube cryocooler, mechanically decoupled from the Paul trap and located in a separate room together with the PTB-EBIT, and provides a trap temperature of below 5 K for long-term storage of HCIs. Ground state cooling of the logic ion Be^{+} has been achieved as a prerequisite for state preparation and readout via QLS.

A 33.12 Wed 16:15 Redoutensaal

The *g*-factor of highly charged ions — •Halil Cakir, Bastian Sikora, Vincent Debierre, Natalia S. Oreshkina, Jan S. Breidenbach, Christoph H. Keitel, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The determination of the *g*-factor of highly charged ions allows us to test QED effects in strong fields. There are already very precise measurements of the *g*-factor of light ions [1] and measurements for heavy highly charged ions are on the way [2]. However, in many cases, theoretical calculations of the *g*-factor of ions are not on the same level of precision yet. For heavier ions in particular, expansions in the nuclear coupling strength $Z\alpha$ are not feasible.

A combination of experimental and theoretical values of the *g*-factor of ions recently allowed a significant improvement of the electron mass [3]. A similar interplay of experiment and theory for very heavy ions is expected to improve the value of the fine-structure constant [4]. In this context, we present recent theoretical calculations of the *g*-factor for H- and Li-like ions. – [1] A. Wagner *et al.*, Phys. Rev. Lett. **110**, 033003 (2013); [2] S. Sturm *et al.*, Atoms **5**, 4 (2017); [3] S. Sturm *et al.*, Nature **506**, 467 (2014); [4] V. M. Shabaev et al., Phys. Rev. Lett. **96**, 253002 (2006).

A 33.13 Wed 16:15 Redoutensaal

The ALPHATRAP *g*-Factor Experiment — •Ioanna Arapoglou[1,2], Alexander Egl[1,2], Martin Höcker[1], 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 Institute for Nuclear Physics, Heidelberg — [2]Faculty of Physics and Astronomy, University of Heidelberg

ALPHATRAP is a high-precision Penning-trap experiment which aims for the most stringent test of bound-state quantum electrodynamics (BS-QED) in the strong field regime. These fields are provided by heavy highly charged ions (HCI), such as hydrogen-like $^{208}Pb^{81+}$, where the electron is exposed to the strong binding potential of the nucleus. The heavy HCI are externally produced and delivered via a beamline to the cryogenic double Penning-trap system, which enables a measurement of the bound electron's *g*-factor. For the external ion production, the setup is equipped with an external non-cryogenic compact room temperature Electron Beam Ion Trap (EBIT) and a laser ionization source. Additionally, part of the beamline will be connecting the Heidelberg-EBIT to the Penning-trap setup. Currently, experiments are performed at ALPHATRAP with $^{40}Ar^{13+}$ ion, in preparation for the first *g*-factor measurement. For further reduction of energy related systematic shifts, sympathetic laser cooling using $^{9}Be^{+}$ will be implemented which is expected to improve the precision of the measurement besides permitting two-ion Coulomb crystallization. The ALPHATRAP setup as well as the current status of the experiment and the first results with trapped highly charged ions will be discussed.

A 33.14 Wed 16:15 Redoutensaal

Electronic level structure investigations in Th^{+} and nuclear properties of ^{229m}Th — •David-Marcel Meier, Johannes Thielking, Przemyslaw Glowacki, Maksim V. Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

The ^{229}Th isotope possesses a unique, low-energy nuclear isomeric state at about 7.8(5) eV. This fact has stimulated the development of novel ideas in the borderland between atomic and nuclear physics, for example the use as an optical nuclear clock. Since the required precise information on the isomer energy is not yet available, it is intensely searched for using different experimental approaches. For the excitation of the nuclear isomer via electronic bridge or NEET processes, we investigate two-photon laser excitation of high-lying electronic levels in Th^{+}. We recently expanded our search range to higher energies and measured more than 100 previously unknown energy levels with $J = 1/2$, $3/2$ and $5/2$ in the range from 7.8 eV to 9.8 eV. We also present the recent progress of the hyperfine structure measurement of $^{229m}Th^{2+}$ ions and the determination of ^{229m}Th nuclear properties.

A 33.15 Wed 16:15 Redoutensaal

Towards an excition scheme for giant dipole states of Rydberg excitons in Cu2O — •Thomas Stielow, Markus Kurz, and Stefan Scheel — Universität Rostock, Institut für Physik, Albert-Einstein-Straße 23, 18059 Rostock, Germany

An exotic species of Rydberg atoms in crossed eletric and magnetic fields are so-called giant-dipole atoms [1]. They are characterized by an electron-ionic core separation in the range of several micrometers, leading to huge permanent dipole moments of several hundred thousand Debye. So far, these states stay out of reach for observation. Recently, the possible formation of giant dipole states by Rydberg excitons in Cu_2O has been proposed [2]. Excitons observe much stronger couplings to external fields, bringing giant dipole states into the reach of current experiments performed on Cu_2O. We discuss different possible excitation paths leading to giant dipole excitons based on the latest descriptions of excitonic giant dipole states.

[1] O. Dippel, P. Schmelcher, and L. S. Cederbaum, Phys. Rev. A, **49**, 4415 (1994).

[2] M. Kurz, P. Grünwald, and S. Scheel, Phys. Rev. B **95**,245205 (2017).

A 33.16 Wed 16:15 Redoutensaal

Networks of Atomic Spectra — •Julian Heiss[1], David Wellnitz[1], Armin Kekić[1,2], Sebastian Lackner[3], Andreas Spitz[3], Michael Gertz[3], and Matthias Weidemüller[1,4] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]École Normale Supérieure, Paris, France — [3]Institut für Informatik, Im Neuenheimer Feld 205, 69120 Heidelberg, Germany — [4]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

We demonstrate a network-inspired approach for treating atomic spectroscopy data of hydrogen, helium and iron. Nodes of the network represent states, while links represent transitions between them. We find that the node community structure coincides with state labels derived from the quantum mechanical treatment of atoms. Using state-of-the-art methods for link prediction we are able to predict unknown atomic transitions.

A 33.17 Wed 16:15 Redoutensaal

On the status of experiments with hydrogen-like ions at the Heidelberg electron beam ion trap — •Hendrik Bekker and José R. Crespo López-Urrutia — Max-Planck-Insitüt für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The strong enhancement of bound-state quantum-electrodynamic (QED) and relativistic effects combined with the relatively simple structure of heavy hydrogen-like ions make them highly suitable for studies of fundamental physics. For example, the value of fundamental constants can be extracted from *g*-factor measurements [1]. Also, the ground-state hyperfine splitting (HFS) can be within laser range, allowing for precision spectroscopic studies of variation of fundamental constants [2]. By also investigating the HFS in Li-like systems, QED can be tested in the strongest electric field available at present for experimental study [3]. At the Heidelberg electron beam ion trap (HD-EBIT), preparations for high energy operation are underway. Planned measurements include investigations of the HFS of Pr^{58+}. Furthermore, the HD-EBIT will function as an ion source for the Penning trap experiments PENTATRAP and ALPHATRAP.

[1] S. Sturm, *et al.* "High-precision measurement of the atomic mass of the electron." Nature 506.7489 (2014): 467-470

[2] S. Schiller, "Hydrogenlike HCI for tests of the time independence of fundamental constants." Phys. Rev. Lett. **98**, 180801 (2007)

[3] V. M. Shabaev, *et al.* "Towards a test of QED in investigations of the hyperfine splitting in heavy ions." Phys. Rev. Lett. **86**, 3959 (2001)

A 33.18 Wed 16:15 Redoutensaal

Analytical evaluation of energy levels for multi-electron atoms with Hartree-Fock accuracy — •Kamil D Dzikowski, Oleg D Skoromnik, Natalia S Oreshkina, and Christoph H Keitel — Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

We employ a complete hydrogen-like basis with an effective charge parameter to find fully analytic expressions for energy levels of multi-electron ions and atoms. The completeness of such basis allows us to write a secondary quantized representation of the exact Hamiltonian for construction of perturbation theory. To increase the convergence rate, we isolate contributions from states with closely spaced energies, by forming suitable linear combinations of the corresponding state vectors. We then use them to diagonalize the system's Hamiltonian, effectively accounting for all orders of perturbation theory within a corresponding finite basis subset. The accuracy of calculated characteristics is comparable with the one obtained via advanced numerical solutions of Hartree-Fock equations. [1] J. Phys. B 50 245007 (2017) https://doi.org/10.1088/1361-6455/aa92e6

A 33.19 Wed 16:15 Redoutensaal

Radiation pressure on a two-level atom: an exact analytical approach — •Lionel Podlecki[1], Rohan Glover[1,2], John Martin[1], and Thierry Bastin[1] — [1]Institut de Physique Nucléaire, Atomique et de Spectroscopie, CESAM, University of Liege, Bât. B15, Sart Tilman, Liège 4000, Belgium — [2]Centre for Quantum Dynamics, Griffith University, Nathan, QLD 4111, Australia

The mechanical action of light on atoms is nowadays a tool used ubiquitously in cold atom physics. In the semiclassical regime where the atomic motion is treated classically, the computation of the mean force acting on a two-level atom requires in the most general case numerical approaches. Here we show [1] that this problem can be tackled in a pure analytical way. We provide an analytical yet simple expression of the mean force that holds in the most general case where the atom is simultaneously exposed to an arbitrary number of lasers with arbitrary intensities, wave vectors, and phases. This yields a novel tool for engineering the mechanical action of light on single atoms.

[1] L. Podlecki, R. Glover, J. Martin, and T. Bastin, Radiation pressure on a two-level atom: an exact analytical approach, J. Opt. Soc. Am. B (in press); arXiv:1702.05410, (2017).

A 33.20 Wed 16:15 Redoutensaal

A new calibration standard for X-ray light sources — •Steffen Kühn[1], Sven Bernitt[2], Peter Micke[3], René Steinbrügge[4], and José Ramon Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, 07743 Jena, Germany — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [4]Deutsches Elektronen-Synchrotron, Notkestrasse 85, 22607 Hamburg, Germany

In the last decade X-ray laser spectroscopy has been proven to be a reliable technique to investigate atomic transitions of highly charged ions with highest precision by measuring the fluorescence of an ion cloud following the resonant excitation by a brilliant, monoenergetic photon beam provided by synchrotrons or free-electron lasers. We developed a new setup in which the highly charged ions are produced and stored in an electron beam ion trap (EBIT) that employs a novel off-axis electron gun with optical access along the beam axis. This allows an in-situ usage of the ion cloud to resonantly photoexcite well-known inner-shell atomic transitions and thus calibrate the photon beam energy with highest accuracy. Here we present first results of a calibration of the U49-2_PGM beam line at BESSY II in Berlin. The calibrated photon beam was used to investigate the absorption spectra of different molecular gases, which are crucial for the interpretation of X-ray satellite observations.

A 33.21 Wed 16:15 Redoutensaal

UV laser systems for sympathetic cooling of highly charged ions using ^{9}Be$^+$ — •Lukas Spiess[1], Lisa Schmöger[2], Julian Stark[1], Janko Nauta[1] und José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institut für Experimentalphysik, Universität Innsbruck, Austria

Precisely measuring the spectrum of cold, highly charged ions (HCIs) is of particular interest for metrology and measuring a possible variation of the fine structure constant. Since HCIs in general lack suitable optical transitions for laser cooling, at CryPTEx [1][2] HCIs are sympathetically cooled by a second laser-cooled ion species. For this purpose $^9Be^+$ is chosen because it can be trapped alongside various HCIs in a linear Paul trap. The photoionization laser for creation of $^9Be^+$ is based on [3]. It consists of a 940 nm diode laser which is twice frequency doubled: firstly using a PPKTP crystal and secondly a BBO crystal. The produced light at 235 nm interacts with the $2s^1S_0$ - $2p^1P_1$ transition for resonance-enhanced two photon ionization. The produced ions are then Doppler-cooled via the $^2S_{1/2}$ - $^2P_{3/2}$ transition at 313 nm. The required laser is based on [4] and is generated from fiber lasers at 1051 nm and 1550 nm. In a first stage, 626 nm light is produced by sum frequency generation in a PPLN crystal, followed by second harmonic generation in a BBO crystal to generate the needed 313 nm light.

[1] M. Schwarz et al., Rev. Sci. Instr. 83
[2] L. Schmöger et al., Science 347
[3] H.-Y. Lo et al., Appl. Phys. B 114
[4] A. C. Wilson et al., Appl. Phys. B 105

A 33.22 Wed 16:15 Redoutensaal

A cryogenic Paul trap experiment for long-time storage of highly-charged ions — •Julian Stark[1], Peter Micke[1,2], Lisa Schmöger[3], Janko Nauta[1], Steffen Kühn[1], Lukas Spiess[1], Tobias Leopold[2], Steven King[2], Piet O. Schmidt[2], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Institut für Experimentalphysik ,Universität Innsbruck, Austria

Forbidden transitions in highly charged ions (HCIs) are particularly interesting candidates for novel optical frequency standards and searches for physics beyond the Standard Model, such as possible drifts in the value of the fine structure constant α. For the purpose of these high precision experiments the HCIs are sympathetically cooled by simultaneously trapped Be^+ ions in a cryogenic linear radio-frequency Paul trap [1,2,3]. We present the design of a cryogenic Paul trap setup which is based on CryPTEx [1] but focusses on long storage times of HCIs at extremely stable trapping conditions by isolating mechanical vibrations. Furthermore, a novel superconducting Paul trap resonator will enable precise localization of HCIs in low-noise trapping potentials which is needed for high precision laser spectroscopy.

[1] M. Schwarz et al., Rev. Sci. Instrum. 83, 083115 (2012)
[2] L. Schmöger et al., Rev. Sci. Instrum. 86, 103111 (2015)
[3] L. Schmöger et al., Science 347, 6227 (2015)

A 33.23 Wed 16:15 Redoutensaal

Laboratory measurement of "Dark Matter" decay 3.5 keV X-ray line — •Chintan Shah[1], Stepan Dobrodey[1], Sven Bernitt[1,2], René Steinbrügge[1], Liyi Gu[3], Jelle Kaastra[3], and José Ramón Crespo López-Urrutia[1] — [1]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [2]Friedrich-Schiller-Universität Jena, Jena, Germany — [3]SRON Netherlands Institute for Space Research, Utrecht, Netherlands

Speculations about a possible dark matter origin of observed unidentified x-ray line feature at ∼3.5 keV from galaxy clusters have sparked an incredible interest in the scientific community and given rise to a tide of publications attempting to explain the possible cause for this line [1, 2]. Motivated by this, we have measured the K-shell X-ray spectra of highly ionized bare sulfur ions following charge exchange with gaseous molecules in an electron beam ion trap, as a source of or a contributor to this X-ray line. We produced S^{16+} and S^{15+} ions and let them capture electrons in collision with those molecules with the electron beam turned off while recording X-ray spectra. We observed a charge-exchange-induced X-ray feature at the Lyman series limit (3.47 ± 0.06 keV). The inferred X-ray energy is in full agreement with the reported astrophysical observations and supports the proposed novel scenario by Gu [2, 3].

[1] E. Bulbul et al., ApJ, 13, 789 (2014)
[2] L. Gu et al., A & A, L11, 584 (2015)
[3] C. Shah et al., ApJ, 833, 52 (2016).

A 33.24 Wed 16:15 Redoutensaal

Polarization of resonanly excited X-ray line — •Chintan Shah[1], Pedro Amaro[2], René Steinbrügge[1], Sven Bernitt[1,3], Stephan Fritzsche[3], Andrey Surzhykov[4], José Ramón Crespo López-Urrutia[1], and Stanislav Tashenov[2] — [1]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisches Institut, Heidelberg, Germany — [3]Friedrich-Schiller-Universität Jena, Jena, Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

X-ray polarization and anisotropy due to resonant recombination were experimentally studied using an electron beam ion trap. The electron-ion collision energy was scanned over the KLL dielectronic, trielectronic and quadruelectronic recombination resonances of $Fe^{18+..24+}$ and $Kr^{28+..34+}$ with an excellent resolution of ∼ 6 eV. The x-ray asymmetries were measured by two detectors along and perpendicular to the beam axis. Direct polarization was also measured using Compton polarimetry [1]. We observed that most of the x-ray transitions lead to polarization including higher-order resonances. These channels influence not only the charge balance but also the polarization of the dominant K_α x-ray line emitted by hot plasmas [2]. We conclude that the careful inclusion of relativistic Breit interaction [3] and hitherto neglected higher-order channels [2] is necessary to construct reliable plasma models diagnostics.

[1] C. Shah et al., PRA 92, 042702 (2015)
[2] C. Shah et al., PRE 93, 061201(R) (2016)
[3] P. Amaro et al., PRA 95, 0227012 (2017).

A 33.25 Wed 16:15 Redoutensaal

Dielectronic recombination of MNN in highly charged tungsten with open *f*-shells — •Chintan Shah[1], Pedro Amaro[2], José Paulo Santos[2], and José Ramón Crespo López-Urrutia[1] — [1]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [2]LIBPhys-UNL, FCT-UNL, P-2829-516, Caparica, Portugal

Tungsten is selected as the coating material for tokamaks Due to its high-resistance to thermal loads. Sputtering leads to contamination of highly-charged W ions in such plasmas where it provides unwanted cooling that can prevent an effective fusion ignition. Thus, an accurate recombination rates are require to predict ionization balance of such plasma [1, 2]. By using an electron beam ion trap (EBIT), we performed measurements of dielectronic recombination following MNN mechanisms in highly charged W in the energy region of multielectronic compound resonances with many *f*-holes. In order to probe MNN dielectronic resonances with energies below the ionization threshold of ions with open *f*-shells, as well as maintaining an ion abundance constant, the electron beam energy was scanned over the resonances with times of tens of milliseconds. Preliminary calculations based on Flexible Atomic Code are reported in order to determine the main MNN resonance channels, ion abundances as well as recombination processes via multi-electron excitations. The present results can be used to provide the experimental benchmark for the theoretical predictions and plasma models [2].

[1] Pütterich et al., Nucl. Fusion 50, 025012 (2010)
[2] S. Preval et al., Phys. Rev. A 93, 0420307(2016).

A 33.26 Wed 16:15 Redoutensaal

VUV spectroscopy of highly charged ruthenium ions of astrophysical interest — Julia I. Jäger[1], Leticia Täubert[1], •Chintan Shah[1], Lisa Loebling[2], Klaus Werner[2], and José Ramón Crespo López-Urrutia[1] — [1]Max-Plank-Institut für Kernphysik, Heidelberg, Germany — [2]Eberhard Karls Universität, Tübingen, Germany

The discovery of technetium in the atmospheres of red giants constituted convincing proof that *s*-process nucleosynthesis is indeed occurring in evolved stars. The presence of Tc in the immediate progenitor stars can be an outstanding indicator for recent nucleosynthesis. However, the main obstacle for using Tc as an indicator is the lack of experimental as well as theoretical atomic data for high ionization stages [1, 2]. Since radioactive nature of Tc imposes a technical challenge in our experiment for now, as a first step, we decided to investigate the neighboring Ru (Z=44) ions assuming their atomic structures are the same. Using electron beam ion trap, we generated $Ru^{4+..6+}$ ions and emitted vacuum ultraviolet fluorescence was measured with 3-meter normal-incidence-monochromator. Some of the VUV lines are identified by the use of Flexible Atomic Code [3]. We further plan to implement these data in non-LTE model-atmosphere simulations computing stellar spectra that can finally be compared to ultraviolet observations obtained with space-based UV telescopes.

[1] K. Werner et al., ApJL, 753, L7 (2012)
[2] K. Werner et al., A&A, 574, A29 (2015)
[3] M. Gu, CJP, 86, 5 (2008).

A 33.27 Wed 16:15 Redoutensaal

Integration of photonic structures and thermal atomic vapors — •Artur Skljarow[1], Ralf Ritter[1], Nico Gruhler[2,3], Wolfram H.P. Pernice[2,3], Harald Kübler[1], Tilman Pfau[1], and Robert Löw[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany — [2]Institute of Nanotechnology, Karlsruhe Institute of Technology, D-76344 Eggenstein-Leopoldshafen, Germany — [3]Institute of Physics, University of Münster, Heisenbergstr. 11, D-48149 Münster, Germany

The usage of atomic vapors in technological applications has become increasingly relevant over the past few years. They are utilized e.g. in atomic clocks, magnetometers, as frequency reference or to slow down and store light. Integrated devices which combine photonic structures and thermal atomic vapors on a chip could be an ideal basis for such purposes, as they provide efficient atom-light coupling on a miniaturized scale well beyond the diffraction limit.

After having investigated various types of waveguides on the D_1 line in Rubidium, now we want to use a three level ladder scheme featuring optical access to telecom photons. By this, we are able to use Si as waveguide material instead of Si_3N_4.

[1] R. Ritter, et al., *Appl. Phys. Lett.* **107**, 041101 (2015)
[2] R. Ritter et al., *New Journal of Physics* **18**, 103031 (2016)

A 33.28 Wed 16:15 Redoutensaal

Development of a HHG frequency comb for XUV metrology of Highly Charged Ions — •Janko Nauta[1], Alexander Ackermann[1], Julian Stark[1], Steffen Kühn[1], Andrii Borodin[1], Peter Micke[2], Lisa Schmöger[3], Thomas Pfeifer[1], and José Crespo López Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Institut für Experimentalphysik ,Universität Innsbruck, Austria

Recent theoretical studies have shown that forbidden optical transitions in highly charged ions (HCI) are the most sensitive systems for probing the variation of the fine structure constant α [1]. Moreover, they have been proposed as novel frequency standards due to their low polarizability and insensitivity to black body radiation [2].

We plan to perform high resolution spectroscopy of cold HCI [2] in the extreme ultraviolet region (XUV), where transitions, from dipole-allowed (E1) to highly forbidden, also take place. To this end, we are developing an enhancement cavity to amplify femtosecond pulses from a phase-stabilized infrared frequency comb at 100 MHz. High-order harmonics will be generated in the tight focus of the cavity, and can be used for direct frequency comb spectroscopy of HCI to determine absolute transition energies.

[1] J. Berengut et al., Phys. Rev. Lett. 109, 070802 (2012)
[2] A. Derevianko et al., Phys. Rev. Lett. 109, 180801 (2012)
[3] L. Schmöger et al., Science 347, 6227 (2015)

A 33.29 Wed 16:15 Redoutensaal

Ionenfalle mit transparenten Elektroden — •Kai Krimmel[1,2], Sebastian Wolf[2], Johannes Heinrich[3], Ron Folman[4], Mark Keil[4], Dmitry Budker[1,2,5,6] und Ferdinand Schmidt-Kaler[1,2] — [1]Helmholtz-Institut Mainz, Mainz 55128, Germany — [2]QUANTUM, Institut für Physik, JGU Mainz, Mainz 55128, Germany — [3]Laboratoire Kastler Brossel, UPMC-Sorbonne Universites, CNRS, ENS-PSL Research University, College de France — [4]Department of Physics, Ben-Gurion University of the Negev, Be'er Sheva 84105, Israel — [5]Department of Physics, University of California at Berkeley, Berkeley, CA 94720, USA — [6]Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

Wir präsentieren eine lineare segmentierte Ionenfalle aus transparenten Chips, die eine Beobachtung von Fluoreszenzlicht durch die Falle erlauben. Die Falle ist aus einem Quartzglas-Substrat mit ITO und goldbeschichteten Elektroden hergestellt und soll für die Speicherung großer Kristalle aus Be+-Ionen und eine sympathetische Kühlung von zusätzlichen eingeschossenen Fremdionen dienen. Wir stellen den Aufbau und erste Messungen zur Charakterisierung der Falle dar und diskutieren zukünftige Anwendungsfälle wie z.B. die Kühlung von Anti-Wasserstoff-Ionen (P. Pérez et al., "The GBAR antimatter gravity experiment") oder eine Speicherung und Kühlung von geladenen Teilchen sehr unterschiedlicher Ladungs-zu-Masse-Verhältnissen (N. Leefer et al., "Investigation of two-frequency Paul traps for antihydrogen production").

A 33.30 Wed 16:15 Redoutensaal

Gamma spectroscopy to measure the ^{229}Th isomer energy using a 2-dimensional array of metallic magnetic microcalorimeters — •J. Geist[1], D. Hengstler[1], M. Krantz[1], R. Pons[1], P. Schneider[1], C. Schötz[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], G.A. Kazakov[2], S.P. Stellmer[2], T. Schumm[2], and J. Bussmann[1] — [1]Heidelberg University — [2]Vienna University of Technology

The isotope ^{229}Th has a nuclear isomer state with the lowest presently known excitation energy, which possibly allows to connect the fields of nuclear and atomic physic with a potential application in a nuclear clock. In order to verify and improve the accuracy of the currently most accepted energy value, (7.8 ± 0.5) eV, we want to resolve the 29.18 keV doublet in the γ-spectrum following the α-decay of ^{233}U, corresponding to the decay into the ground and isomer state, to measure the isomer transition energy without additional theoretical input parameters.

We developed the detector array maXs-30 consisting of 8x8 metallic magnetic calorimeters with an expected energy resolution below 6 eV, providing a large detection area of 16 mm^2 to face the low rate of the 29.18 keV transitions.

In first measurements we observed the 29.18 keV transitions as a single peak with an instrumental resolution of 33 eV.A strong background contribution due to β-radiation from accumulated decay products in the ^{233}U-source was discovered. We present results of the latest measurements with an adjusted maXs-30 detector, new generation SQUIDs and an updated setup in the cryostat.

A 33.31 Wed 16:15 Redoutensaal

Modelling high-harmonic generation in solids beyond the single active electron — •Helena Drüeke and Dieter Bauer — Institute of Physics, University of Rostock, 18051 Rostock, Germany

Laser-driven electrons in linear chains of ions constitute the simplest models for the study of high-harmonic generation (HHG) in solids. The importance of band structure, finite-size or surface effects, and electron-electron interaction can be systematically investigated using such models.

On the poster, we illustrate our implementation of a time-dependent Kohn-Sham solver for the study of solid slabs in intense laser fields. In particular, we present HHG spectra, discuss their cut-offs, and analyze the role of electron-electron interaction and topological surface effects [1,2].

[1] Kenneth K. Hansen, Tobias Deffge, Dieter Bauer, *High-order harmonic generation in solid slabs beyond the single-active-electron approximation*, Phys. Rev. A 96, 053418 (2017).
[2] Dieter Bauer, Kenneth K. Hansen, *High-harmonic generation in solids with and without topological edge states*, (submitted) arXiv:1711.05783.

A 33.32 Wed 16:15 Redoutensaal

The Electron Capture in ^{163}Ho experiment — •Clemens Hassel and THE ECHo COLLABORATION — Kirchhoff-Institute of Physics, Heidelberg University, Germany.

Direct determination of the electron neutrino (m_{ν_e}) and anti-neutrino mass ($m_{\bar{\nu}_e}$) can be obtained by the analysis of electron capture and beta spectra respectively. In the last years experiments analysing the ^{3}H beta spectrum reached a limit on $m_{\bar{\nu}_e}$ of 2 eV. The upper limit on m_{ν_e} is still two orders of magnitudes higher at about 225 eV. The Electron Capture in ^{163}Ho experiment, ECHo, is designed to investigate m_{ν_e} in the sub-eV region and reach the same sensitivity as foreseen for $m_{\bar{\nu}_e}$ in new ^{3}H-based experiments. In ECHo, high sensitivity on a finite m_{ν_e} will be reached by the analysis of the endpoint region in high statistics and high resolution calorimetrically measured ^{163}Ho spectra. To perform this experiment, high purity ^{163}Ho source will be enclosed in a large number of low temperature metallic magnetic micro-calorimeters which are readout using the microwave multiplexing technique. This approach allows for a very good energy resolution of below $\Delta E_{\mathrm{FWHM}} < 5$ eV and for a fast time resolution well below 1 μs. Thanks to the modular approach, the ECHo experiment is designed to be stepwise up-graded. The first on-going phase, ECHo-1k, is characterized by a ^{163}Ho activity of about 1 kBq enclosed in about 100 pixels. The statistics of 10^{10} events in the ^{163}Ho spectrum will allow to improve the limit on m_{ν_e} by more than one order of magnitude. In this talk, the present status of the ECHo-1k experiment will be discussed as well as the plans for the next phase, ECHo-100k.

A 33.33 Wed 16:15 Redoutensaal

Towards High Precision Spectroscopy of μLi and μBe — •Marcel Willig, Jan Haack, Julian Krauth, Stefan Schmidt, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA, Mainz, Germany

Laser spectroscopy of muonic atoms proved to be a useful tool for measuring the rms charge radii of the lightest nuclei. The values gained with this method are orders of magnitude more precise than by electron scattering alone. This increased precision gave rise to the proton radius puzzle, a 5.6σ difference between the rms charge radius of muonic hydrogen and the respective CODATA value [1].

Further measurements have been performed on Deuterium [2], ^{3}He and ^{4}He. The next logical steps are muonic Li and Be. Spectroscopy of these atoms will improve the radii by an order of magnitude, only limited by the current accuracy of the calculated nuclear polarizability.

We summarize the results on H, D, He and present our ideas towards high precision spectroscopy of μLi and μBe. In addition we have performed a first study of the feasibility of stopping muons in a large Be ion crystal, which will also be presented.

[1] R. Pohl et al., Nature 466.7303, 213-216 (2010)
[2] R. Pohl et al., Science 353.6300, 669-673 (2016)

A 33.34 Wed 16:15 Redoutensaal

Commissioning of a new electron beam ion source as charge breeder for rare isotope beams — •Christian Warnecke[1], Michael Blessenohl[1], Stepan Dobrodey[1], Karl M. Rosner[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

Canada's national particle accelerator Centre TRIUMF is currently upgrading its facilities with the Advanced Rare IsotopE Laboratory (ARIEL) to deliver two additional rare isotope beams simultaneously to TRIUMF's user end stations. A new electron beam ion source (EBIS) is included in the ARIEL facility to boost the charge states of the short-lived rare isotopes to charge-to-mass ratios of $4 < A/q < 6$. For rare isotopes with half-lives down to 65 milliseconds and low abundancies of down to 10^6 per bunch, the whole process of injection, charge breeding and extraction has to be as efficient as possible. Furthermore the bunch repetition rates of around 100 Hz need a highly optimized setup. We present first injection-extraction measurements within the commissioning phase including characteristics of the electron gun with electron beam currents up to 1 A.

A 33.35 Wed 16:15 Redoutensaal

Towards laser spectroscopy of atomic tritium — •Jan Haack, Julian Krauth, Stefan Schmidt, Marcel Willig, Rishi Horn, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik und Exzellenzcluster PRISMA, Mainz, Germany

We are currently setting up a new experiment for trapping of atomic tritium in a magnetic bottle and perform laser spectroscopy on it. This is compelling because with precise measurement of the 1S-2S transition the uncertainty of the triton charge radius can be improved by a factor of 400, making it comparable with its mirror nucleus ^{3}He who's charge radius has been improved recently using muonic helium. Comparison will e.g. allow high precision studies of 3-nucleon-forces. In our experiment tritium is trapped by using a magnetic octupole guide as a velocity selector, a ^{6}Li-MOT as a cold buffer gas and a magnetic bottle as storage. In a first stage the setup will be tested using atomic hydrogen. Additionally the planned setup can be used as a general storage device for hydrogen-like atoms in the future. We will present the design and concept of our upcoming experiment.

A 33.36 Wed 16:15 Redoutensaal

Excitation of hydrogen-like ions by twisted light: The effect of multipole mixing on the alignment of excited states — •Sabrina A.-L. Schulz[1,2], Robert A. Müller[1,2], Anton Preshkov[3], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Technische Universität Braunschweig, Germany — [3]Helmholtz-Institut Jena, Germany

During the last years twisted or vortex light beams have attracted considerable attention both in experiment and theory. These beams carry a non-zero projection of orbital angular momentum (OAM) onto their propagation direction and have a helical phase front [1]. Owing to these specific features the interaction of twisted light with ions and atoms may lead to a modification of the conventional (plane-wave) selection rules of radiative transitions. Such OAM-modified selection rules were recently observed experimentally by Schmiegelow and colleagues [2]. In this contribution, we theoretically investigate how these OAM-modified selection rules affect the magnetic sublevel population of photoexcited hydrogen-like ions. Particular emphasis is paid to radiative transitions, which can occur via several multipole channels. For example, we discuss the $1s_{1/2} \to 2p_{3/2}$ transition, which can proceed via the electric dipole (E1) and magnetic quadrupole (M2) channels. We show how the relative strength of these multipole transitions can be influenced by twisted light and how this can be seen in the magnetic sublevel population.

[1] H. M. Scholz-Marggraf, *et al.* Phys. Rev. A 90, 013425 (2014)
[2] C. T. Schmiegelow, *et al.* Nature Communications 7 12998 (2016)

A 33.37 Wed 16:15 Redoutensaal

Integrated and Time-Resolved Measurements of Collisional Energy Transfer in Rubidium P-States — •Ralf Albrecht[1], Johannes Schmidt[1,2], Robert Löw[1], and Harald Kübler[1] — [1]Integrated Quantum Science and Technology, Universität Stuttgart, 5. Physikalisches Institut — [2]Institut für Großflächige Mikroelektronik

Buffer gases are often used as collisional partners in spectroscopy gases e.g. to effectively average out the Doppler effect by redistributing velocity classes and therefore extend the time of light-matter interactions. We want to determine collisional cross-sections of excited 5P-states in rubidium. Thus, fluorescence spectra are acquired to observe quenching collisions by evaluating fluorescence intensities of different optical transitions. In addition, measurements at various atomic densities and thermal velocities are taken to extract information of the temperature dependence of collisional decay rates. Furthermore, a setup for pulsed saturation spectroscopy was built to measure time-resolved decay rates of optically excited rubidium. This allow us to measure quenching collisions with nanosecond resolution. The results are compared with that from our fluorescence measurements.

A 33.38 Wed 16:15 Redoutensaal

Laserspectroscopy experiments at CRYRING@ESR — •Konstantin Mohr[1], Aineah Barasa[1], Tim Ratajzyk[1], Wilfried Nörtershäuser[1], Zoran Andelkovic[2], Rodolfo Sanchez[2], Volker Hannen[3], Axel Buss[3], and Christian Weinheimer[3] — [1]Institut für Kernphysik, TU Darmstadt — [2]GSI Helmholtzzentrum — [3]Institut für Kernphysik, WWU Münster

CRYRING is a storage ring at the GSI Helmholtzzentrum that provides ion-beams with energies in range of 300keV/u up to 14MeV/u for the heaviest ion-species like $^{238}U^{92+}$. In 2017 a first ion-beam of H_2^+-ions was established. During the beam-time in November 2017 cooling, acceleration and bunching was successfully tested. In October 2018, first experiments on stored ion-beams are scheduled.

In one of these experiments, Mg will be evaporated in a standard oven and subsequently ionized in a Nielsen-type ion source. After mass separation and injection into CRYRING, $^{24}Mg^+$ ions will be used for testing whether it is possible to polarize ion-beams in a storage ring by optical pumping. Therefore a cw dye-laser drives the $3s\,^2S_{1/2} \rightarrow 3p\,^2P_{1/2}$ transition of Mg at 280,35 nm. Usage of circular polarized σ^+-light will lead to an occupation of the m_s-substate with the maximum quantum-number $m_s = 1/2$. In this case, a previously observed fluorescence signal should vanish. To prove the polarization, σ^- or π polarized light can be used for repumping. This poster will present the status of CRYRING for laser spectroscopy experiments.

This work is supported by BMBF under contract numbers 05P15RDFAA and 05P15PMFAA.

A 33.39 Wed 16:15 Redoutensaal

Transverse free-electron target for CRYRING@ESR — •B. Michel Döhring[1], Carsten Brandau[1,2], Alexander Borovik Jr[1], Benjamin Ebinger[1], Christophor Kozhuharov[2], Tobias Molkentin[1], Alfred Müller[1], and Stefan Schippers[1] — [1]Justus-Liebig-Universität Gießen — [2]GSI

The storage ring CRYRING@ESR [1] will be one of the first operational devices at the anti-proton and heavy-ion accelerator facility, FAIR, which is currently under construction in Darmstadt. A transverse free-electron target for crossed-beams in-ring experiments is currently under development. Such an electron-ion crossed-beams arrangement has never been realised at a heavy-ion-storage ring before. The electron target is based on an earlier development in Gießen [2] and consists of a multi-electrode assembly to control beam size, electron density and electron energy. According to the electron-optical simulations that we performed during the design phase of the target, the electron density will reach up to 10^9 cm^{-3} at electron energies up to 12.5 keV. The present status of the project will be presented.

[1] M. Lestinsky et al., 2016 Eur. Phys. J. ST 225 797.
[2] B. Ebinger et al., 2017 Nucl. Instrum. Meth. B 408 317.

A 33.40 Wed 16:15 Redoutensaal

Fluorescence based measurement of nuclear polarization in atomic beams. — •Abhilash Javaji[1], Mark Bissell[2], Robert Harding[3,4], Marcus Jankowski[1], Magdalena Kowalska[4], Walter Neu[1], and Philipp Wagenknecht[1] — [1]Dept. of Physics, University of Oldenburg, Oldenburg, Germany — [2]School of Physics and Astronomy, Manchester University, Manchester, United Kingdom — [3]Dept. of Physics, University of York, York, United Kingdom — [4]EP-Dept., CERN, Geneva, Switzerland

The new laser-polarization setup at ISOLDE, CERN is dedicated to versatile studies involving β-decay asymmetry and β-NMR studies with spin-polarized radioactive ion beams. The spin-polarization is achieved via the optical pumping of atomic levels with circularly polarized laser light propagating collinearly with the ion/atom beam, which is subsequently transferred to the nuclear spin through the hyperfine interaction. Finally, the spins are decoupled in a strong magnetic field and β-decay asymmetry or its destruction can be observed. The latest venture has been the development of a fluorescence based polarization checker to be used with stable isotopes. For this purpose a 2nd laser perpendicular to the magnetic field is used to probe the sub-states of the spin polarized stable nuclei (e.g.^{85}Rb) to determine the degree of polarization. At stronger fields, Zeeman splitting separates the magnetic sub-levels enough to be probed individually, producing fluorescence whose intensity is proportional to the population of each sub-state, thus determining the degree of nuclear polarization. The development of the setup and scheduled tests will be presented.

A 33.41 Wed 16:15 Redoutensaal

Stellar Laboratories: High-precision Atomic Physics with STIS — •Conny Glaser, Thomas Rauch, and Klaus Werner — Institut für Astronomie und Astrophysik, Eberhard Karls Universität Tübingen, Sand 1, D-72076 Tübingen, Germany

Stellar atmospheres are prime laboratories to determine atomic properties of highly ionized species. Since reliable opacities are crucial ingredients of many astrophysical simulations and a detailed comparison of iron-group oscillator strengths is still outstanding, we used the Space Telescope Imaging Spectrograph (STIS) to measure high-resolution spectra of three hot subdwarf stars that exhibit extremely high iron-group abundances. These allow us to identify even very weak spectral lines. The predicted relative strengths of the identified lines are compared with the observations to judge the quality of Kurucz's line data and to determine correction factors for abundance determinations of the respective elements.

A 33.42 Wed 16:15 Redoutensaal

He buffered Laser Ablation Ion Source for Collinear Laser Spectroscopy — •Tim Ratajczyk[1], Victor Varentsov[2,3], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt — [2]Facility for Antiproton and Ion Research in Europe (FAIR GmbH), Darmstadt — [3]Institute for Theoretical and Experimental Physics, Moscow, Russia

In the field of laser spectroscopy the laser systems have evolved to highly precise measurement devices, covering the wavelength range from infrared to ultra violet. The ion beams from non-volatile substances on the other hand are often produced by surface ionization devices, which mostly allow for the ion beams from alkali and earth alkali metals and inhibit the study of other interesting elements (e.g. refractory elements). Conventional laser ablation ion sources expand the region of available elements, but their ion beams have large emittances. We present the current status of a combined He buffered laser ablation ion source with an electrode funnel for spatial confinement and the He gas for transportation and cooling of the ions. This ion source will combine the high variability of target materials from laser ablation with a small emittance ion beam and the possibility of bunching due to the funnel system.

A 33.43 Wed 16:15 Redoutensaal

Polarisation Dynamics of Many-body Systems Dynamically Polarised via the Cross Effect — •Federica Raimondi, Daniel Wisniewski, Alexander Karabanov, Walter Kockenberger, Igor Lesanovsky, and Juan Garrahan — University of Nottingham

Dynamic Nuclear Polarisation (DNP) provides significant signal enhancement compared to conventional thermal polarisation techniques used in typical nuclear magnetic resonance applications. Of the possible DNP mechanisms, the cross effect (CE), involving triple spin-flips between two interacting electrons and a nucleus, is most efficient at low temperatures and microwave irradiation amplitude of the first electron. In order to examine the dependence of CE polarisation dynamics on the system geometry, large-scale simulations must be carried out. This becomes impracticable using the full Liouville-von-Neumann description of the system. We have developed a new formalism that separates the dynamics of the system into fast and slow, allowing projection onto the Zeeman subspace, thereby greatly reducing the state-space of the system. Under given conditions, it is then possible to simulate the Zeeman Projected polarisation dynamics using classical kinetic Monte Carlo methods. With this approach, a system of 118 proton spins has been simulated.

A 33.44 Wed 16:15 Redoutensaal

A Detection System for Laser Spectroscopy Experiments at CRYRING@ESR — •Axel Buss[1], Volker Hannen[1], Christian Huhmann[1], Dominik Thomas[1], and Zoran Andelkovic[2] — [1]Institut für Kernphysik, Universität Münster — [2]GSI Helmholtzzentrum für Schwerionenforschung

In order to enable laser spectroscopy experiments at CRYRING, a new general purpose fluorescence detector has been developed at the University of Münster. The design allows detection from ultraviolet wavelengths to the near infrared regime. Thus, the detector can be used to observe a large variety of atomic transitions. Among others Mg- (at 280 nm) and Ca+ (at 854 nm/866 nm) ions have transitions in the wavelength regime covered by the detector.

Geant4 simulations have been performed in order to optimize the detection efficiency of fluorescence photons, while * at the same time * suppressing the detection of background photons. This is realized by an elliptical detector geometry, which selectively focuses fluorescence photons from the beam axis onto PMTs outside of the vacuum. In order to achieve a high sensitivity over the complete wavelength range, two sets of interchangable PMTs will be used, one for the UV range and one for the long wavelength part. By the time of the DPG spring meeting, construction of the detection system and integration into the CRYRING facility should be complete. The poster will present the design, construction, and status of the instrument.

This project is funded by BMBF under contract number 05P15PMFAA.

A 34: Cold atoms VI - traps (joint session A/Q)

Time: Thursday 10:30–12:15 Location: K 0.011

A 34.1 Thu 10:30 K 0.011

Dipole trapping in the absence of gravity — •Christian Vogt[1], Marian Woltmann[1], Sven Herrmann[1], Claus Lämmerzahl[1], and The PRIMUS-Team[1,2] — [1]University of Bremen, Center of Applied Space Technology and Microgravity (ZARM), 28359 Bremen — [2]Institut für Quantenoptik, LU Hannover

Cold atoms have proven to be a useful toolbox with wide applications in testing the fundamentals of physics, e.g the weak equivalence principle which provides the cornerstone of Einstein's general relativity theory [1]. In the recent years great effort has been made to take advantage of these techniques in weightlessness. For example the first BEC in space was created and effective temperatures down to the pK regime were demonstrated in the drop tower in Bremen [2]. So far all of these result from atoms held in magnetic traps on atom chips. This talk will be about the first realization of a dipole trap in weightlessness. Proven its worth on ground , dipole traps have never before been operated in microgravity, although they can produce high number BECs and have unique advantages like the ability to apply feshbach resonances. Our experiment, the PRIMUS project, uses the drop tower in Bremen witch offers up to 4.7s of microgravity time in drop mode. The talk will focus on the dimension of evaporation and the reduction of evaporation time. The PRIMUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 1642. [1] D. Schlippert et al., Phys. Rev. Lett. 112, 203002 (2014) [2] Jan Rudolph,(PhD Thesis), Leibniz University Hannover, 2016.

A 34.2 Thu 10:45 K 0.011

A high repetition deterministic ion source — •Cihan Sahin, Philipp Geppert, Adreas Müllers, and Herwig Ott — Technische Universität Kaiserslautern

An ion source with minimal energy spread and deterministic operability has many possible applications in basic research and technical applications including surface spectroscopy, ion microscopy, ion implantation or milling. Key requirements for these applications include among others a high degree of control of ion trajectories and high rates.

We developed an ion source capable of delivering ions on demand with high fidelity. The basis of our ion source is a magneto-optical trap (MOT) of ^{87}Rb atoms. The atoms are photoionized by a three photon process within a small volume inside the MOT. A symmetric detector setup for electrons and ions allows to detect the ionization fragments.

We can classify the operation of the source in three modes. In the single ion operation mode the electron is used to switch for a short time a gating electrode on and so let the corresponding ion pass. With an additional external trigger deterministic operation mode is enabled and single ions are provided on demand with high fidelity around a rate of $10\,000\,\mathrm{s}^{-1}$. The source can also be used in the continuous operation mode delivering ions with a rate of $1 \times 10^6\,\mathrm{s}^{-1}$.

A 34.3 Thu 11:00 K 0.011

Time-dependent custom tailored optical potentials — •Lukas Palm, Marvin Holten, Philipp M. Preiss, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Engineering quantum states of ultracold atoms requires precise control over the confining potentials. Spatial light modulators displaying computer generated holograms are readily employed to spatially shape such optical potentials in a wide variety of geometries. However, their capabilities in the time domain are severely restricted by the refresh rate of the device.

We utilize multiple optical modes with a relative detuning to realize time-dependent potentials where RF control of the optical frequencies allows a wide range of modulation rates. This allows the creation of rapidly rotating traps where high angular momenta and strongly correlated states are accessible. Therewith we want to realize quantum Hall physics in a few fermion system.

A 34.4 Thu 11:15 K 0.011

Thermodynamics of a non-equilibrium single-atom system — •Daniel Mayer[1], Daniel Adam[1], Quentin Bouton[1], Steve Haupt[1], Tobias Lausch[1], Felix Schmidt[1], and Artur Widera[1,2] — [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 investigation of phase space dynamics of individual atoms, quenched out of equilibrium by a Raman cooling pulse. We numerically model our findings by using an effective two-temperature approach, yielding excellent agreement with the experimental data. For application of multiple pulses, we observe the approach of a thermal state with a new temperature.

Experimentally, we prepare a few atom sample of laser cooled Cs atoms in a crossed, optical dipole trap. We apply a pulse of degenerate Raman sideband cooling, thereby quenching the phase space distribution of the sample. The dynamics emerging after the quench is observed by two distinct methods: we extract information about the radial momentum distribution by a release-recapture experiment while in axial direction we use fluorescence imaging in a 1D optical lattice to observe the atomic position distribution.

A 34.5 Thu 11:30 K 0.011

Precision measurement of the dynamical polarizability of dysprosium at 1064nm — Cornelis Ravensbergen[1,2], •Vincent Corre[1,2], Elisa Soave[2], Marian Kreyer[1,2], Slava Tzanova[1,2], Emil Kirilov[2], and Rudolf Grimm[1,2] — [1]Institut für Quanten Optik und Quanten Information, Innsbruck — [2]Institut für Experimental Physik, Universität Innsbruck

The field of ultracold dipolar gases has grown vastly in the last years, motivated by the new phases made accessible by the long-range anisotropic dipole-dipole interaction. Among dipolar systems, atomic gases of lanthanides - erbium and dysprosium - have been cooled down to the degenerate regime and have demonstrated striking dipolar effects. But while the geometry of the trapping potential is known to have a critical influence on the behavior of these gases, questions remain about the value of the dynamical polarizability of dysprosium, as a large discrepancy still exists between theoretical calculations and experimental measurements. We report on a new measurement of the dynamical polarizability of dysprosium at 1064 nm with unprecedented precision. We take advantage of our dual-species experimental set-up and use potassium as a reference species. By calibrating the polarizability of dysprosium on the one of potassium, which is well known, we free ourselves from the main sources of systematic error that are the trapping laser waist and aberrations, and anharmonicity effects. We check that other possible error sources have negligible effect. Eventually we obtain values for the scalar and tensor parts of the polarizability with a relative error of 2%, that are close to the theoretical predictions.

A 34.6 Thu 11:45 K 0.011

Tuning collective dipole-dipole interactions via cavities — •Helge Dobbertin and Stefan Scheel — Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23, 18059 Rostock, Germany

When resonant atoms are confined inside a volume smaller than the transition wavelength λ cubed, they couple via strong dipole-dipole interactions and show a collective response to near-resonant light. Recent studies [1] found that the resulting line shifts of cold atomic gases substantially differ from the textbook Lorentz-Lorenz effect. At finite temperature [2] an additional density dependent shift occurs due to collisions.

Here, we discuss possibilities to tune the dipole-dipole interactions by means of macroscopic cavity geometries. This may offer a new handle to separate collisional and dipole-dipole induced shifts and to study the microscopic basis of local-field corrections in cold and thermal atomic ensembles [3].

[1] J. Pellegrino et al., Phys. Rev. Lett. **113**, 133602 (2014).
[2] J. Keaveney et al., Phys. Rev. Lett. **108**, 173601 (2012).
[3] J. Javanainen et al., Phys. Rev. A **96**, 033835 (2017).

A 34.7 Thu 12:00 K 0.011

Dipolar quantum droplets and striped states — •Fabian Böttcher, Matthias Wenzel, Jan-Niklas Schmidt, Michael Eisenmann, Tim Langen, Igor Ferrier-Barbut, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

The dipolar interaction allows for self-organized structure formation similar to the Rosensweig instability in classical ferrofluids. In our experiments with quantum gases of Dysprosium atoms, we observe a phase-transition between a gas and a liquid, characterized by the formation of self-bound droplets. In contrast to theoretical mean field predictions the superfluid droplets did not collapse. We confirmed experimentally that this unexpected stability is due to beyond mean field quantum corrections of the Lee-Huang-Yang type. These droplets are 100 million times less dense than liquid helium droplets and open new perspectives as a truly isolated quantum system.

Under strong confinement in one dimension, we observe the formation of an array of stripes. We also study striped ground states theoretically and outline prospects to reach a phase coherent supersolid ground state.

In a further ongoing experiment we rotate the droplets by a spinning magnetic field and observe that they can be rotated faster than the transverse trapping frequency due to a surface tension counteracting the centrifugal force. We also observe the excitation of a scissors mode of the droplets.

A 35: Ultracold Atoms I (joint session Q/A)

Time: Thursday 10:30–12:15 Location: K 1.022

A 35.1 Thu 10:30 K 1.022

Multi-mode double-bright EIT cooling (theory) — Nils Scharnhorst[1,2], •Javier Cerrillo[3], Johannes Kramer[1], Ian D. Leroux[1], Jannes B. Wübbena[1], Alex Retzker[4], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — [3]Institut für Theoretische Physik, Technische Universität Berlin, 10623 Berlin, Germany — [4]Racah Institute of Physics, Hebrew University of Jerusalem, 91904 Jerusalem, Israel

We developed a multi-mode ground state cooling technique based on electromagnetically-induced transparency (EIT) [1]. By involving an additional ground and excited state, two individually adjustable bright states together with a dark state are created. While the dark state suppresses carrier scattering, the two bright states are brought into resonance with spectrally separated motional red sidebands. The approach is scalable to more than two bright states and several dark states by introducing additional laser couplings. For large laser intensities, the Lamb-Dicke theory becomes unsuitable and a description based in a generalized fluctuation-dissipation theorem for non-linear response [2] is presented.

[1] Scharnhorst et al., arXiv:1711.00738, arXiv:1711.00732, (2017).
[2] Cerrillo et al., PRB 94, 214308 (2016).

A 35.2 Thu 10:45 K 1.022

Multi-mode double-bright EIT cooling (Experiment) — •Nils Scharnhost[1,2], Javier Cerrillo[3], Johannes Kramer[1], Ian D. Leroux[1], Jannes B. Wübbena[1], Alex Retzker[4], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — [3]Institut für Theoretische Physik, Technische Universität Berlin, 10623 Berlin, Germany — [4]Racah Institute of Physics, Hebrew University of Jerusalem, 91904 Jerusalem, Israel

Ground-state cooling (GSC) of ions and atoms is an essential prerequisite for many experiments in quantum optics, e.g. atomic clocks. Sideband cooling and cooling via electromagnetically induced transparency (EIT) are common techniques to achieve GSC. Due to their narrow cooling resonance, both techniques restrict cooling to a narrow frequency range. The desire to scale up the number of ions in quantum systems and to control all relevant (motional) degrees of freedom in such large atomic ensembles demands for novel cooling approaches, such as the capability to simultaneously cool several motional modes.

We developed double-bright EIT (D-EIT) cooling [1] as a novel scalable approach to standard EIT cooling by extending its level scheme by one additional ground and one excited state. D-EIT allows simultaneous GSC of modes around two separated frequencies and we experimentally demonstrate for the first time GSC of all three motional degrees of freedom of a trapped ion within a single, short cooling pulse.

[1] Scharnhorst et al., arXiv: 1711.00732v2 (2017)

A 35.3 Thu 11:00 K 1.022

Ground state cooling of atoms 300 nm away from a hot surface — •Yijian Meng, Alexandre Dareau, Philipp Schneeweiss, and Arno Rauschenbeutel — VCQ, TU Wien – Atominstitut, Stadionallee 2, 1020 Wien, Austria

Cold atoms coupled to light guided in nanophotonic structures constitute a powerful research platform, e.g., for probing surface forces, the study of light-induced self-organization, as well as quantum networking. The strong spatial confinement of the optical trapping fields in nanophotonic systems gives rise to significant fictitious magnetic field gradients. These can be used to perform degenerate Raman cooling (DRC), which has been pioneered in optical lattices [1].

Here, we implement DRC of atoms in a nanofiber-based optical trap [2]. Remarkably, this scheme only requires a single fiber-guided light field, which provides three-dimensional cooling. We show that continuously applying such cooling extends the lifetime of atoms in the trap by one order of magnitude. Using fluorescence spectroscopy [3], we precisely measure the temperature of the atoms. We find that they can be cooled close to the motional ground state despite the atoms being less than 300 nm away from the hot fiber surface. This achievement sets an excellent starting point for further experiments, for example, the investigation of heat transfer at the nanoscale using quantum probes.

[1] S. E. Hamann et al., Phys. Rev. Lett. 80, 4149 (1998).
[2] E. Vetsch *et al.*, Phys. Rev. Lett. **104**, 203603 (2010).
[3] P. S. Jessen et al., Phys. Rev. Lett. 39, 49 (1992).

A 35.4 Thu 11:15 K 1.022

Radio-frequency sideband cooling and sympathetic cool-

ing of trapped ions in a static magnetic field gradient — Theeraphot Sriarunothai[1], •Gouri Shankar Giri[1], Sabine Wölk[1,2], and Christof Wunderlich[1] — [1]Department Physik, Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany — [2]Institute for Theoretical Physics, University of Innsbruck, Technikerstraße 21a, 6020 Innsbruck, Austria

We report a detailed investigation on near-ground state cooling of one and two trapped atomic ions [1]. We introduce a simple RF sideband cooling method for confined atoms and ions, using RF radiation applied to bare ionic states in a static magnetic field gradient, and demonstrate its application to ions confined at secular trap frequencies, $\omega_z \approx 2\pi \times 117$kHz. For a single $^{171}Yb^+$ ion, the sideband cooling cycle reduces the average phonon number, $\langle n \rangle$ from the Doppler limit to $\langle n \rangle = 0.30(12)$. This is in agreement with the theoretically estimated lowest achievable phonon number in this experiment. We extend this method of RF sideband cooling to a system of two $^{171}Yb^+$ ions, resulting in a phonon number of $\langle n \rangle = 1.1(7)$ in the center-of-mass mode. Furthermore, we demonstrate the first realisation of sympathetic RF sideband cooling of an ion crystal consisting of two individually addressable identical isotopes of the same species.

[1] Th. Sriarunothai et al., arXiv: 1710.09241 (2017)

A 35.5 Thu 11:30 K 1.022

Synchronization-assisted cooling of atomic ensembles — •Simon B. Jäger[1], Minghui Xu[2,3], Stefan Schütz[4], John Cooper[2,3], Murray Holland[2,3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]JILA, National Institute of Standards and Technology and Department of Physics, University of Colorado, Boulder, Colorado 80309-0440, USA — [3]Center for Theory of Quantum Matter, University of Colorado, Boulder, Colorado 80309, USA — [4]icFRC, IPCMS (UMR 7504), ISIS (UMR 7006), Université de Strasbourg and CNRS, 67000 Strasbourg, France

We analyze the dynamics leading to radiative cooling of an atomic ensemble inside an optical cavity when the atomic dipolar transitions are incoherently pumped. Our study is performed in the regime where the cavity decay is the largest rate in the system. Using a semiclassical approximation we identify three stages of cooling. At first hot atoms are cooled by the cavity friction forces. After this stage, the atoms' center-of-mass motion is further cooled by the coupling to the internal degrees of freedom while the dipoles synchronize. In the latest stage dipole-dipole correlations are stationary and the center-of-mass motion is determined by the interplay between friction and dispersive forces due to the coupling with the collective dipole. For this final stage we derive a mean-field model that is valid on a timescale where particle-particle correlations build up slowly. On this timescale we observe that the system can reach momentum widths below the recoil limit. Beside this we find limit cycles and chaotic dynamics.

A 35.6 Thu 11:45 K 1.022

Dissipative cooling of quasi-condensate excitations — •Carsten Henkel[1] and Isabelle Bouchoule[2] — [1]Universität Potsdam — [2]Institut d'Optique, Palaiseau

The elementary excitations of a Bose condensate are described by the celebrated Bogoliubov dispersion. Their spectrum is discrete for a trapped system. We discuss the theory of these excitations in experiments where atoms leave the trap in a controlled way. One observes a stationary non-equilibrium situation where temperature measurements give different results, either from the density profile or from density fluctuations [1]. We develop a simple stochastic theory based on quantum projection noise and find that the limiting temperature is slightly below the chemical potential. The calculations need accurate Bogoliubov mode functions that interpolate smoothly between the dense (Thomas-Fermi) region and the low-density wings [2, 3], a region where mean-field theories fail [4, 5].

[1] A. Johnson, S. Szigeti, M. Schemmer, and I. Bouchoule, Phys. Rev. A 96 (2017) 013623
[2] A. L. Fetter and D. L. Feder, Phys. Rev. A 58 (1998) 3185
[3] A. Diallo and C. Henkel, J. Phys. B 48 (2015) 165302
[4] L. Pitaevskii and S. Stringari, Phys. Rev. Lett. 81 (1998) 4541
[5] C. Henkel, T.-O. Sauer, and N. P. Proukakis, J. Phys. B 50 (2017) 114002

A 35.7 Thu 12:00 K 1.022

Semiclassical Laser Cooling in Standing Wave Configurations — •Thorsten Haase and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, Germany

Laser cooling is a widely used technique in experiments in quantum optics and quantum information science. For most purposes of cooling above the Doppler limit laser fields are used which can be modelled by plane running waves. In this regime, the interaction between the radiation field and particles, modelled by two-level systems, is well explained by the semiclassical theory of Doppler cooling. Standing waves exhibit a different behaviour with analogies to blue detuned laser cooling at higher intensities [Ci92]. We present a semiclassical model for the interaction of a two-level system with arbitrary field modes, which includes standing and strongly focused waves. Our model exactly reproduces the theory of Doppler cooling for running plane waves. Additionally, it gives rise to different cooling properties inside standing laser fields. Our results are consistent with a special case investigated in [Ci92]. We simulate the interaction of a trapped two-level ion in the particular field configuration relevant for the 4Pi-Pac experiment in Erlangen [Al17], where the ion is trapped around the focus of a parabolic mirror to achieve almost perfect atom-photon coupling.

[Ci92] Cirac et. al, Phys. Rev. A, Vol. 46, No. 5, Sep 1992, 2668-2681 [Al17] Alber et. al, J. Europ. Opt. Soc. Rap. Public. 13, 14 (2017)

A 36: Precision Measurements and Metrology (Gravity and Miscellaneous) (joint session Q/A)

Time: Thursday 10:30–12:00 Location: K 2.013

A 36.1 Thu 10:30 K 2.013

A high-flux BEC source for the transportable Quantum Gravimeter QG-1 — •Jonas Matthias, Nina Grove, Maral Sahelgozin, Jan Philipp Barbey, Sven Abend, Waldemar Herr, and Ernst M. Rasel — Inst. f. Quantenoptik, LU Hannover

Absolute inertial sensors based on atom interferometry will benefit in two ways from using Bose-Einstein condensates (BEC). First, their low expansion rate reduces the leading order systematic uncertainties of current generation sensors. Second, the per-shot sensitivity will be increased by a higher interferometer contrast and by implementing higher-order Bragg diffraction compared to Raman diffraction used with thermal ensembles. However, formerly the application of BECs was hindered by the size and repition rate of typical BEC experiments, which usually fill a laboratory and have a repetition rate on the order of several ten seconds.

These limitations have been overcome by atom-chip-based BEC sources, which allow compact apparatuses and achieve a high flux at the same time. The source for the transportable Quantum Gravimeter QG-1 consists of a $2D^+$ MOT and a mirror MOT on a three-layer atom chip as published by Rudolph et al, 2015. The atoms will be evaporatively cooled to quantum degeneracy in a magnetic trap and released from the trap for atom interferometry in free fall. In this talk we will present the current progress on atom cooling and Bose-Einstein condensation.

This work is supported by the Deutsche Forschungsgemeinschaft (DFG) as part of project A01 within the SFB 1128 geo-Q.

A 36.2 Thu 10:45 K 2.013

Pre-stabilized laser system for future gravitational-wave detectors at a wavelength of 1550nm — •Fabian Thies, Nico Koper, and Benno Willke — Max Planck Institute for Gravitational Physics, Hannover, Germany

To reduce thermal noise in future gravitational-wave detectors(GWDs)[1] and in updated current detectors[2] the use of cryogenic test masses is proposed. Silicon is a promising material for these test masses, because of its high mechanical quality factor and the good thermal conductivity at cryogenic temperatures. The use of silicon requires a laser source at a wavelength of 1550nm or longer.

Currently commercial available laser systems do not fulfill the demanding requirements concerning the laser power, frequency and intensity noise and the spatial beam profile of future GWDs.

We will use a low noise laser at the wavelength of 1550nm as a seed for erbium-ytterbium fiber amplifiers, to get into the range of the proposed laser power levels. To reach the demanded noise levels active stabilizations are necessary in such a laser system for GWDs.

Here we present the results of the characterization of several possible seed lasers and of a fiber ring cavity as an in-fiber frequency sensor.

[1]ET Science Team, ET conceptual design document ET-0106C-10, http://www.et-gw.eu/index.php/etdsdocument

[2]LIGO Scientic Collaboration, Instrument Science White Paper, https://dcc.ligo.org/public/0113/T1400316/004/T1400316-v5.pdf

A 36.3 Thu 11:00 K 2.013

Sensor noise measurements for an improved active seismic isolation of the AEI 10m-Prototype — •Robin Kirchhoff — Albert-Einstein / Max-Planck Institut für Gravitationsphysik Hannover, Callinstraße 38, 30167 Hannover

Large scale, ground based interferometric gravitational wave detectors use a combination of passive isolation and active control loops to reduce the coupling of seismic motion into the Michelson interferometer. The active isolation is limited by the self-noise of the in-loop sensors and a precise characterization of this noise is needed to optimize the control loops. In the Albert-Einstein-Institute in Hannover, the Sub-SQL (standard quantum limit) interferometer is under construction, which is a 10 m Michelson interferometer designed to be limited by quantum noise for prototyping techniques to surpass the SQL. To reach the quantum noise limit, all classical and technical noise sources, including seismic noise, must be suppressed below quantum noise levels. The seismic attenuation system (AEI-SAS) provides the required seismic pre-isolation of an optical platform using both passive and active techniques. Several huddle tests were performed using these seismically isolated platforms to precisely measure the noise of different inertial sensors and their amplifier electronics. The initially installed Sercel L-22D geophones were measured to have a higher self-noise compared to Sercel L-4C geophones. The geophones were therefore exchanged and the resulting improvement of the active isolation performance of the AEI-SAS was verified.

A 36.4 Thu 11:15 K 2.013

Fabrication Process Control of Wire Grid Polarizers for the Deep Ultraviolet- by Transmission Spectroscopy in the Visible Spectral Range — •Walter Dickmann[1], Thomas Siefke[2], Johannes Dickmann[3], Carol Bibiana Rojas Hurtado[3], and Stefanie Kroker[1,2] — [1]Technische Universität Braunschweig, LENA Laboratory for Emerging Nanometrology — [2]Friedrich-Schiller-Universität Jena, Institute of Applied Physics — [3]Physikalisch-Technische Bundesanstalt Braunschweig

Wire grid polarizers (WGPs) are periodic nano-optical metasurfaces which act as polarizing elements. In the deep ultraviolet (DUV) region the performance of metallic WGPs is poor whereas wide bandgap semiconductors are promising materials for this spectral range. RCWA calculations provide extinction ratios (ERs) of up to 10^4. However, so far fabricated titanium dioxide WGPs achieved only ERs which are almost two orders of magnitude smaller than the simulated values. This is mainly due to surface roughness and deterministic structural deviations resulting from the fabrication process and approaching the size range of the structural features for short application wavelengths. In this contribution we present a method to characterize deterministic structural deviations of DUV polarizers at the nanometer scale by transmission spectroscopy in the visible spectral range. The achieved results lay the foundation for an in situ fabrication process control.

This research is supported by the DFG within research training group 'Metrology for Complex Nanosystems' (GrK 1952/1) and within project 'PolEx' (KR4768/1-1).

A 36.5 Thu 11:30 K 2.013

Thickness uniformity measurements of crystalline AlGaAs mirror coatings — •Philip Koch — MPI für Gravitationsphysik, Hannover, Deutschland

Beside quantum noise, the sensitivity of the current generation of gravitational wave detectors is limited by coating Brownian noise of the interferometer mirrors. This arises from thermal fluctuations of the molecules in the coating itself. Coating Brownian noise is dependent on the mechanical loss angle of the coating materials. AlGaAs mirror coatings are crystalline dielectric coatings which have higher Q factors (lower loss) and thus a ten-fold reduction of coating Brownian noise compared to the commonly used amorphous silica-tantala coatings. A homogenous surface figure is needed in the high precision interferometry to avoid optical losses. A method to measure the surface homogeneity of mirror coatings will be presented with an accuracy of below 0.05 nm. This method was used to measure a 0.5 nm RMS thickness homogeneity across a 5 cm diameter AlGaAs coating provided by Crystalline Mirror Solutions.

A 36.6 Thu 11:45 K 2.013

Feasibility and Possibility of Testing Non-Classical Features of Gravity in a Double-slit-Type Experiment — •Sahar Sahebdivan — Atominstitut, TU Wien, Stadionallee 2, 1020 Wien

In this presentation, we are exploring the feasibility of observing non-classical features of gravity in a low-energy regime in a quantum optics experiment.

If gravity has an underlying quantum nature, it should hold the most fundamental quantum characteristics such as superposition principle and entanglement. Despite the weakness of gravity, in principle there is a chance, to observe such a quantum signature of the gravity by exploiting the quantum optical techniques, without direct observation of graviton.

We are investigating a new dynamical scheme called, gravitational quantum regime, in which the source of gravity is a quantum particle, and its centre of mass is subject to the spatial superposition. In a Gedankenexperiment, a test particle is gravitationally interacting with a quantum nanoparticle in a double-slit setup. Possible entanglement or superposition of the fields is investigated.

We are looking for the corresponding deviation of the classical description of gravity despite being far from Planck scale. Any experimental interrogation which reveals that gravitational field obeys the quantum superposition principle would be the first recognition of quantumness of gravity. This study will show how feasible it is to search for a non-classical feature of gravity in such regime of motion.

A 37: Clusters IV (joint session MO/A)

Time: Thursday 10:30–12:15 Location: PA 2.150

Invited Talk A 37.1 Thu 10:30 PA 2.150

Untersuchungen zur Coulomb-Wechselwirkung bei polyanionischen Metallclustern — Madlen Müller[1], •Franklin Martinez[2], Norman Iwe[2], Klara Raspe[2], Steffi Bandelow[1], Josef Tiggesbäumker[2], Lutz Schweikhard[1] und Karl-Heinz Meiwes-Broer[2] — [1]Institut für Physik, E.-M.-A.-Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald — [2]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18059 Rostock

Der Ladungszustand ist ein wichtiger Parameter beim Studium der elektronischen Eigenschaften freier, nanoskopischer Teilchen. Im Falle mehrfach negativ geladener Metallcluster beeinflusst vor allem die Coulomb-Wechselwirkung zwischen den Valenzelektronen die Clustereigenschaften. So spielt bei den hier betrachteten Polyanionen der Coulombwall eine wichtige Rolle, sowohl bei der Aufladung, d.h. der Elektronenanlagerung, als auch bei der Elektronenemission. Die Eigenschaften dieses Coulombwalls sind jedoch noch weitgehend ungeklärt und stehen vermutlich in komplexen Abhängigkeiten von beispielsweise der Clusterform oder von elektronischen Korrelationen. In diesem Beitrag werden Untersuchungen zur Coulomb-Wechselwirkung anhand erstmalig gemessener Photoelektronenspektren von polyanionischen Metallclustern vorgestellt. Dabei bietet insbesondere der Verlauf der gemessenen Energieverteilungen einen Zugang zur Clustergrößen- und Ladungszustandsabhängigkeit des Coulombwalls. Die experimentellen Beobachtungen werden mit Abschätzungen aus dem Metallkugel- und dem Jellium-Modell verglichen.

A 37.2 Thu 11:00 PA 2.150

Elektronenaffinitäten von polyanionischen Metallclustern — •Madlen Müller[1], Franklin Martinez[2], Steffi Bandelow[1], Norman Iwe[2], Klara Raspe[2], Josef Tiggesbäumker[2], Lutz Schweikhard[1] und Karl-Heinz Meiwes-Broer[2] — [1]Institut für Physik, E.-M.-A.-Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald, Deutschland — [2]Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18059 Rostock, Deutschland

Die Photoelektronenspektroskopie von Metallclustern, bislang vorrangig an einfach negativ geladenen Systemen durchgeführt, gibt Aufschluss über Elektronenaffinitäten (EA) und die elektronische Struktur. Im Bezug auf polyanionische Systeme sollte sich die EA mit zunehmendem Ladungszustand erheblich ändern, da in einem einfachen Bild die Coulombenergie das Jelliumpotenzial anhebt, unter Umständen, bis über das Vakuumniveau hinaus.

Erstmals werden massenselektierte Metallcluster mit bis zu 800 Atomen und sieben zusätzlichen Elektronen in einer linearen Paulfalle produziert. Von diesen polyanionischen Systemen werden Photoelektronenspektren aufgenommen und Schwellenwerte d.h. Elektronenaffinitäten der negativen Ladungszustände bestimmt. Insbesondere werden dabei metastabil gebundene Elektronen über ihre negative Bindungsenergie nachgewiesen. Das Verhalten der Schwellenwerte in Abhängigkeit von Clustergröße und Ladungszustand wird vorgestellt und diskutiert. Das Projekt wurde durch den Sonderforschungsbereich 652 der DFG unterstützt.

A 37.3 Thu 11:15 PA 2.150

Magnetic-quantum-state-selected metastable helium atoms for Penning reaction studies — •Simon Hofsäss, Jonas Grzesiak, Frank Stienkemeier, and Katrin Dulitz — University of Freiburg

Our experiments are aimed at studying the influence of electron-spin polarization on the Penning reaction rate between supersonically expanded metastable helium atoms and ultracold lithium atoms confined in a magneto-optical trap (MOT). In our experiments, we plan to selectively focus the He(2^3S_1, $M_J = 1$) state into the stationary MOT target using magnetic hexapoles in a Halbach configuration. We present first experimental results which clearly show that a beam of metastable helium atoms can be steered using magnetic hexapole focusing, and we compare these results to the outcome of particle trajectory simulations.

A 37.4 Thu 11:30 PA 2.150

Optical properties of small cationic aluminium clusters and (Al_7)-(1-adamantanethiol)$^+$ hybrid systems — •Andre Knecht[1], Polina Lisinetskaya[2], Tobias Bischoff[1], Andrea Merli[1], Thomas Möller[1], Tobias Lau[3], Bernd von Issendorff[4], Roland Mitric[2], and Torbjörn Rander[1] — [1]IOAP, Technische Universität Berlin — [2]Institut für physikalische und theoretische Chemie, Universität Würzburg — [3]Helmholtz Zentrum Berlin — [4]Physikalisches Institut, Universität Freiburg

Radiative processes, such as fluorescence or Raman-scattering can be modified by the presence of a nearby metal[1]. While on the macroscopic such processes are well understood, our knowledge on the molecular level is sparse. Here we present results on hybrids consisting of a small metal cluster, Al_7^+, and an anorganic cluster, a thiolized diamondoid. Diamondoids, sp^3-hybridized, hydrogen passivated subnanometer-sized carbon-cages serve as a UV absorbent and fluorescent species in the hybrid system. Mass selectable aluminium cluster cations act as the UV plasmonic host with size-dependent band energies. To attach adamantane, the smallest diamondoid, to the metal cluster a molecular linker (SH) was used. This combination was choosen, because the plasmon resonance of the Al cluster energetically overlaps with the stray absorption bands of 1-adamantanethiol. The monodisperse clusters were generated and investigated in the gas phase using partial ion yield spectroscopy. We show first results, as well as a TD-DFT analysis of the data.

[1]Tam et al., Nano letters 7.2 (2007):496-501

A 37.5 Thu 11:45 PA 2.150

Velocity Map Imaging of the Photo-induced Dissociation of Mass-selected Cation Complexes — •Daniel Leicht, Brandon M. Rittgers, and Michael A. Duncan — University of Georgia, Athens, USA

We employ a velocity map imaging mass spectrometer to study the photo-induced dissociation of mass-selected ionic molecular complexes. Ions are produced in a molecular beam and pulse extracted in a linear time-of-flight mass spectrometer. After mass selection, the ions are intersected with a laser beam, leading to dissociation. The fragments are then detected with spatial resolution by multichannel plates and a phosphor screen. From the spatial distribution of fragments we can extract the kinetic energy release of the dissociation process.

Excitation of Ag^+-benzene and Ag^+-toluene with 355 nm leads to the exclusive formation of benzene$^+$ and toluene$^+$ fragments, respectively. This is indicative of a dissociative charge transfer process. On the other hand, irradiation of Zn^+-acetylene with 266 nm leads to the formation of both, Zn^+ and acetylene$^+$ fragments. Apparently, two different photo-initiated dissociation pathways take place in this system.

The observed kinetic energy release in all of these systems can provide information about the binding energy and, given sufficient resolution, the population of quantum states in the fragment ions.

A 37.6 Thu 12:00 PA 2.150

Nanodroplet production and characterization — •Amine Gourram[1], Armando Estillore[1], Daniel Horke[1,3], and Jochen Kuepper[1,2,3] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, Universität Hamburg, Hamburg, Germany — [3]The Hamburg Center for Ultrafast Imaging, Universität Hamburg, Hamburg, Germany

X-ray diffractive imaging of single molecules or nanoparticles at free-electron lasers allows the extraction of structural information at subnanometer resolution [1]. However, this requires the efficient production and delivery of isolated samples into the x-ray beam. We present our proposed aerosol source for the efficient production of a high-density aerosol of sub-100 nm nanoparticles, based on electrospray aerosolisation. The produced aerosol source will be characterized regarding its efficiency and density for different nanoparticle types and sizes using optical light scattering measurement [2] and differential particle mobility analysers.

[1] Seibert et al., Nature **470**, 78-81 (2011)

[2] Awel et al., Opt. Expr. **24**, 6507-6521 (2016)

A 38: Annual General Meeting of the Atomic Physics division

Time: Thursday 12:45–13:45 Location: K 0.011

Duration 60 minutes

A 39: Precision Spectroscopy VI - neutrals and ions (joint session A/Q)

Time: Thursday 14:00–16:00 Location: K 1.016

Invited Talk A 39.1 Thu 14:00 K 1.016

News from the "Proton Radius Puzzle" — •Randolf Pohl — Johannes Gutenberg Universität Mainz

The *Proton Radius Puzzle* [1] is the 5 sigma discrepancy between the charge radius measured in muonic hydrogen [2] on the one hand, and in regular hydrogen and elastic electron scattering on the other [3]. I will report on several new measurements in muonic and electronic atoms, which have recently started to shed light on the discrepancy. These include measurements in muonic deuterium [4], helium-3 and helium-4, as well as a new measurement in regular hydrogen [5]. In the outlook, I will present ongoing and planned measurements of the CREMA Collaboration targeting the (magnetic) Zemach radius of the proton [6], and the charge radii of other light nuclei.

[1] J.C. Bernauer, R. Pohl, Spektrum der Wiss., April 2014
[2] A. Antognini et al., (CREMA Collab.), Science 339, 417 (2013)
[3] P. Mohr et al. (CODATA-2014), Rev. Mod. Phys. 88, 035009 (2016)
[4] R. Pohl et al., (CREMA Collab.), Science 353, 669 (2016)
[5] A. Beyer et al., Science 358, 79 (2017)
[6] R. Pohl et al., J. Phys. Soc. Japan Conf. Proc. 18, 011021 (2017)

A 39.2 Thu 14:30 K 1.016

A Network Approach to Atomic Spectra — •David Wellnitz[1], Julian Heiss[1], Armin Kekić[1,2], Sebastian Lackner[3], Andreas Spitz[3], Michael Gertz[3], and Matthias Weidemüller[1,4] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]École Normale Supérieure, Paris, Frankreich — [3]Institut für Informatik, Im Neuenheimer Feld 205, 69120 Heidelberg, Germany — [4]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

We demonstrate a network-inspired approach for treating atomic spectroscopy data. Nodes of the network represent states, while links represent transitions between them. We find that such spectroscopic networks exhibit an anti-community structure, microscopically characterized by equal quantum numbers of the electronic angular momentum. Using state-of-the-art methods for link prediction, transitions missing in the data can be identified without having to rely upon a microscopic model of the atom. We apply our methods to spectroscopic networks of hydrogen, helium and iron. Implications of our network approach for understanding complex atomic structure are discussed.

A 39.3 Thu 14:45 K 1.016

Analytical methods for the extraction of an ionization potential from dense atomic spectra — •Pascal Naubereit, Reinhard Heinke, Dominik Studer, Marcel Trümper, and Klaus Wendt — Institut für Physik, Johannes Gutenberg-Universität Mainz, D-55128 Mainz, Germany

Complex atomic structures can exhibit intrinsic quantum chaotical behavior. Correspondingly, this prevents a clear identification and assignment of energy levels. However, for the determination of the ionization potential applying e.g. resonance ionization spectroscopy, the convergence of Rydberg series is the most precise direct measurement method. If the possibility to directly allocate and identify a series of Rydberg levels amongst hundreds of other resonances is not available, one may rely on more comprehensive analytical investigation methods for these atomic spectra. In this presentation, several approaches to extract a value for an unknown ionization potential from highly dense atomic spectra are compared. In addition, the applicability of the methods to atomic systems of increasing complexity, namely sodium, holmium, promethium and protactinium, is examined.

A 39.4 Thu 15:00 K 1.016

Laser spectroscopy on the radioactive element promethium — •Dominik Studer[1], Holger Dorrer[2], Carlos Guerrero[3], Stephan Heinitz[4], Reinhard Heinke[1], Pascal Naubereit[1], Sebastian Raeder[5], Dorothea Schumann[4], and Klaus Wendt[1] — [1]Institut für Physik, JGU Mainz, Germany — [2]Institut für Kernchemie, JGU Mainz, Germany — [3]Universidad de Sevilla, Spain — [4]PSI, Villigen, Switzerland — [5]Helmholtz Institut Mainz, Germany

Promethium ($Z = 61$) is an exclusively radioactive element with short half-lives of up to 17 years. Consequently, Pm sample amounts that can be safely handled in laboratories are small and data on atomic transitions is scarce. Apart from the heavy actinides and transactinides, Pm is the last element where the first ionization potential (IP) has not been directly measured until now.

Here we present the results from resonance ionization spectroscopy of ^{147}Pm ($t_{1/2} = 2.6$ y) in a hot cavity laser ion source. More than 1000 new optical transitions were recorded in the spectral ranges from 415 - 470 nm and 800 - 910 nm using pulsed Ti:sapphire lasers. Although a straightforward analysis of Rydberg convergences was prevented by complex spectra for high excitation energies, the IP could be determined with a precision of better than 1 cm^{-1} by measuring the electric field ionization threshold for several weakly bound states. Finally the hyperfine structure of two subsequent transitions in a newly developed RIS scheme was measured with experimental linewidths of ≈ 120 MHz as preparation for the extraction of nuclear structure parameters in on-line spectroscopy experiments on short-lived Pm isotopes.

A 39.5 Thu 15:15 K 1.016

Spectroscopy of the $6S_{1/2} \to 5D_{5/2}$ electric quadrupole transition of atomic cesium — •Sebastian Pucher, Alexandre Dareau, Philipp Schneeweiss, and Arno Rauschenbeutel — VCQ, TU Wien – Atominstitut, Stadionallee 2, 1020 Wien, Austria

The $6S_{1/2} \to 5D_{5/2}$ electric quadrupole transition of cesium is studied experimentally via Doppler-free spectroscopy in hot vapor. The hyperfine structure of this transition is resolved, and the line intensities and optical pumping dynamics are analyzed. In an additional experiment, the lifetime of the $5D_{5/2}$ state is determined by recording the fluorescence light associated to the decay of atoms from the intermediate $6P_{3/2}$ state to the electronic ground state, in excellent agreement with literature values. Based on these results, we plan future experiments with laser-cooled atoms close to surfaces, e.g., in order to enhance the quadrupole coupling.

A 39.6 Thu 15:30 K 1.016

Absolute Quantum Gravimeter: an autonomous and mobile atom interferometer operating at the 1E-10 level of stability over months to support Geosciences — •Jean Lautier Gaud, Vincent Ménoret, Pierre Vermeulen, and Bruno Desruelle — Muquans, Talence, France

This paper reports recent remarkable achievements of cold-atom technologies and related operational devices in the area of Quantum Sensing and Metrology which occurred at Muquans in 2017. We will present in detail the status of the Absolute Quantum Gravimeter (AQG) that has left the laboratory for geophysical studies. The AQG is an industry-grade commercial gravity sensor which today meets the objective to provide a gravimeter based on atom interferometry with laser-cooled atoms as a mobile turn-key device. We report on an operational stability of the absolute measurements of g at the 1E-10 level in various types of environment during month-long continuous acquisition periods. The first unit of the AQG has traveled more than 7000 km, so we will comment on the last measurement campaigns and comparisons performed by the AQG. These have in particular validated the repeatability of the measurements at the 1E-9 level, the ease of use and the robustness of such technology. This paper will also be the occasion to describe in more details the high degree of maturity of several key enabling technologies such as intelligent integrated laser systems that can help Quantum Technologies with cold atoms taking-off for a wider range of applications in Quantum Computing, Quantum Simulation and Quantum Communication.

A 39.7 Thu 15:45 K 1.016

Ba^+ Isotope shift studies in preparation of atomic parity violation measurement — •Nivedya Valappol[1], Elwin Dijck[1], Aswin Hofsteenge[1], Olivier Grasdijk[1], Amita Mohanty[2], Mayerlin Portela[3], Lorenz Willmann[1], and Klaus Jungmann[1] — [1]Van Swinderen Institute, FSE, University of Groningen, The Netherlands — [2]NISER, Bhubaneswar, India — [3]Laboratorio de Òptica Cuàntica, Universidad de los Andes, Bogotà D.C., Colombia

The Ba^+ ion, has a structure of spectral lines similar to heavy single valence electron alkali atoms. It is precisely studied by laser spectroscopy in presence of several light fields in order to prepare for a measurement of atomic parity violation (APV). Measurements in heavy alkali earth ions (e.g. Ba^+ and Ra^+) permit the precise determination of the weak mixing (Weinberg) angle $\sin^2\theta_W$ with improvement over the previous best measurement in neutral Cs by a factor of 5 in a week of actual measurement time. The transition frequencies for the $6s^2S_{1/2}$ - $6p^2P_{1/2}$, $6p^2P_{1/2}$ - $5d^2D_{3/2}$ and $6s^2S_{1/2}$ - $5d^2D_{3/2}$ transitions in $^{138}Ba^+$ have been measured to 10^{-10} relative accuracy employing a line shape model for single ions in a radio frequency Paul trap [1]. These measurements have been extended to $^{134,136}Ba^+$. Together with a determination of the lifetime of the excited $5d^2D_{5/2}$ state these measurements provide for a stringent test of calculations, the accuracy of which is pivotal for a determination of $\sin^2\theta_W$. The observed lifetime is 25.8(5)s. Being about 5s shorter than previous measurements and calculations agreeing with them, it provides for a puzzle.

[1] E. A. Dijck et al., Phy. Rev. A 91, 060501(R)(2015)

A 40: Strong laser fields - III

Time: Thursday 14:00–16:00 Location: K 2.019

Invited Talk A 40.1 Thu 14:00 K 2.019

Electron vortices — Dominik Pengel, Stefanie Kerbstadt, Lars Englert, Tim Bayer, and •Matthias Wollenhaupt — Carl von Ossietzky Universität, Oldenburg, Germany

Recently, the emergence of vortex structures in the momentum distribution of free electron wave packets from photoionization of atoms with sequences of two time-delayed counterrotating circularly polarized (CRCP) ultrashort laser pulses was predicted [1] and demonstrated experimentally [2]. Electron vortices arise from the superposition of two time-delayed free electron wave packets with different magnetic quantum numbers. In our experiment three-dimensional electron vortices are generated by multiphoton ionization of potassium atoms using CRCP femtosecond laser pulses from a polarization-shaped supercontinuum source [3] and reconstructed tomographically from velocity map imaging (VMI) measurements [4]. Absorption of another photon in the continuum changes the c_6 azimuthal symmetry of the threshold vortex into c_8 for above threshold ionization (ATI) [5]. Electron vortices from non-perturbative excitation show c_4 azimuthal symmetry and a π-phase jump in the polar direction. Currently, we study electron vortices generated by bichromatic polarization-shaped CEP-stable supercontinua [3].

[1]J. M. Ngoko Djiokap *et al.*, Phys. Rev. Lett. **115**, 113004 (2015).
[2]D. Pengel *et al.*, Phys. Rev. Lett. **118**, 053003 (2017).
[3]S. Kerbstadt *et al.*, Opt. Express **25**, 12518 (2017).
[4]S. Kerbstadt *et al.*, New J. Phys. **19**, 103017 (2017).
[5]D. Pengel *et al.*, Phys. Rev. A **96**, 043426 (2017).

Invited Talk A 40.2 Thu 14:30 K 2.019

Magnetic Quantum Number in Strong Field Ionizaton — •Sebastian Eckart[1], Maksim Kunitski[1], Martin Richter[1], Alexander Hartung[1], Jonas Rist[1], Florian Trinter[1], Kilian Fehre[1], Nikolai Schlott[1], Kevin Henrichs[1], Lothar Ph. H. Schmidt[1], Till Jahnke[1], Markus Schöffler[1], Kunlong Liu[2], Ingo Barth[2], Jivesh Kaushal[3], Felipe Morales[3], Misha Ivanov[3], Olga Smirnova[3], and Reinhard Dörner[1] — [1]Goethe-Universität, Frankfurt am Main, Germany — [2]Max Planck Institute of Microstructure Physics, Halle (Saale), Germany — [3]Max Born Institute, Berlin, Germany

Our experiment shows that elliptically polarized laser pulses selectively tunnel-ionize electrons with defined sign of the magnetic quantum number (m) leaving behind an ion with defined ring current confirming theoretic predictions. Further we find that the initial momentum distributions upon tunnel-ionization depends on m as well. This leads to a shifted energy dependent yield for ionization from m-prepared states. Finally we show how to demerge angular offsets for different m-states allowing for the preparation and detection of ring currents with sub-cycle temporal precision. The three-dimensional electron momenta have been measured in coincidence with their ionic cores using cold-target recoil-ion momentum spectroscopy (COLTRIMS).

A 40.3 Thu 15:00 K 2.019

Space-time-resolved UV-photoionization of rare gases — •Arne Baumann[1,2], Oliver Schepp[1,2], Dimitrios Rompotis[4], Marek Wieland[1,2,3], and Markus Drescher[1,2,3] — [1]Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany — [2]Hamburg Centre for Ultrafast Imaging - CUI, Hamburg, Germany — [3]Center for Free-Electron-Laser Science - CFEL, Hamburg, Germany — [4]Deutsches Elektronensynchrotron - DESY, Hamburg, Germany

The photoionization of Kr and Xe is studied in the presence of a strong UV-field, where multi-photon and tunneling ionization lead to the formation of high charge states.

The experimental scheme is based on wave-front splitting of intense Ti:Sa third harmonic pulses at 268 nm and a colliding pulse geometry. Individual pulses are focused antiparallely into a gas target and ions created are imaged onto a position-sensitive detector, thus retrieving the spatial distribution of charged particles and mapping the temporal delay between both pulses onto a spatial coordinate.

In the case of Kr, high-lying Rydberg states, which are affected by strong AC-Stark shifts, are excited through 3-photon absorption, and interrogated by UV and IR pulses. By these means, different time-domain superpositions of the present fields are imaged simultaneously. The extracted durations of UV and IR pulses are in good agreement with values expected from the perturbative model.

A 40.4 Thu 15:15 K 2.019

Reconstructing real-time quantum dynamics in strong and short laser fields — •Veit Stooss[1], Stefano M. Cavaletto[1], Stefan Donsa[2], Alexander Blättermann[1], Paul Birk[1], Christoph H. Keitel[1], Iva Brezinová[2], Joachim Burgdörfer[2], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany, EU — [2]Institute for Theoretical Physics, Vienna University of Technology, Wiedner Hauptstraße 8, 1040 Vienna, Austria, EU

Recent results [1, 2, 3] suggest a link between the shape of spectral lines and strong-field-induced amplitude and phase shifts of the response function of the system. Here, we present a method which allows the retrieval of the entire holographic (amplitude and phase) time-resolved response function recording the transient absorption spectrum of an ultrashort probe signal. This still holds for the case of coherently excited systems which exhibit complex time dependence due to the interaction with strong fields. This finding is applied to a time-domain observation of Rabi cycling between doubly-excited atomic states in the few-femtosecond regime. The principle is shown to be viable also in much more complex systems and unlocks the real-time-resolved observation of theresponse function for non-equilibrium states of matter with a single-shot measurement.

[1] C. Ott et.al, Science 340, 716-720 (2013) [2] A. Kaldun, Phys. Rev. Lett. 112, 103001 (2014) [3] H. Mashiko et al., Nat. Comm. 5, 5599 (2014)

A 40.5 Thu 15:30 K 2.019

Suppression of strong-field effects in photoionization of ultracold alkali atoms — •Tobias Kroker[1,2], Philipp Wessels[1,2], Bernhard Ruff[1,2], Klaus Sengstock[1,2], Markus Drescher[1,2], and Juliette Simonet[1,2] — [1]Zentrum für Optische Quantentechnologien (ZOQ), Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging (CUI), Luruper Chaussee 149, 22761 Hamburg

We investigate experimentally the ionization of genuine single active electron atoms in strong light fields accessing a regime where the Keldysh parameter is close to unity and nominally all transition scenarios of multiphoton-, tunnel-, and over-the-barrier ionization can take place. Surprisingly, we observe a clear dominance of multiphoton ionization even at high peak intensities exceeding the over-the-barrier-ionization threshold.

Our fully quantitative approach relies on exposing trapped ultracold ^{87}Rb atoms to intense femtosecond laser pulses. Such targets indeed allow for the exact determination of atom numbers and densities and thus the atomic loss fraction can be directly measured.

This novel methodology enables the extraction of absolute ionization probabilities and cross-sections for testing the validity of theoretical models under debate in the so-called transitional non-adiabatic tunneling regime.

A 40.6 Thu 15:45 K 2.019

Coulomb-focusing in strong-field ionization and its effect in non-dipole interaction regime: analytical approach — •Jiří Daněk, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Strong field ionization with mid-infrared lasers offers new possibilities, such as time-resolved photoelectron holography[1], for atomic/molecular imaging. New discoveries, in particular the counterintuitive features of the photoelectron momentum distribution in the non-dipole regime[2], have shown that detailed understanding of the role of the Coulomb field of the atomic core on the underlying dynamics is missing.

In this work we put forward a perturbative analytical framework, which allows us to account for the momentum transfers between the electron and the atomic core. We restrict the interaction to specific and well defined recollision points on the electron's classical trajectory and obtain an analytical description of the final electron's momentum and hence of Coulomb focusing. Furthermore, we demonstrate the capability of our framework by analyzing the modification of the Coulomb focusing due to non-dipole effects. The latter allows us to explain the mechanism behind the energy-dependent counterintuitive bend of the cusp of the photoelectron momentum distribution in a linearly polarized mid-infrared laser fields.

[1] Y. Huismans et al., Science, **331**, 61 (2011).
[2] A. Ludwig et al., Phys. Rev. Lett. **113**, 243001 (2014).

A 41: Poster Session IIIa

Time: Thursday 16:15–18:15 Location: Orangerie

A 41.1 Thu 16:15 Orangerie

Competing magnetic orders in the fermionic $SU(3)$ Hubbard model with non-Abelian gauge-fields — •Mohsen Hafez-Torbati and Walter Hofstetter — Goethe-Universität, 60438 Frankfurt am Main, Germany

Ultracold fermionic alkaline-earth atoms loaded into optical lattices provide a unique possibility to study not only exotic multi-flavour magnetism, valence-bond-solid states, and quantum spin-liquid phases but also the effect of spin-orbit coupling and the topological properties in multi-component fermionic systems. Here we present results on long-range magnetic order in the large-U limit of the $SU(3)$ fermionic Hubbard model under a uniform non-Abelian gauge field obtained by using the real-space implementation of dynamical mean-field theory. We show the competition between different two-sublattice and three-sublattice magnetic orders in the $SU(3)$ Hubbard model and discuss the effect of uniform non-Abelian gauge-fields on the emergence of exotic magnetism.

A 41.2 Thu 16:15 Orangerie

Studying ion-atom scattering in the ultracold regime with Rydberg molecules — •Nicolas Zuber, Thomas Schmid, Christian Veit, Thomas Dieterle, Christian Tomschitz, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut & Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Germany

Using Rydberg molecules to study the ion-atom scattering extends the methods for observing ion-atom collisions to the ultracold quantum regime [1] so far not reached by the hybrid ion-atom-trap experiments. We present details about our new experimental setup with lithium and rubidium, which will allow us to photoassociate Rydberg molecules and start the ultracold ion-atom scattering event with a very fast two-photon ionization process. We aim to image the scattered wave packet with an ion microscope on our delay line detector to extract a scattering length. The ion microscope is composed of three electrostatic ion lenses providing a tuneable magnification. The field of view is 34 micrometer at the maximum magnification of 1000 with 25 micrometer depth of field and a spatial resolution below one micrometer. The temporal resolution of our detector is 100 ps with a single particle rate up to several MHz.

[1] T. Schmid et al.; *arXiv* 1709.10488 (2017).

A 41.3 Thu 16:15 Orangerie

Towards non-destructive, real-time tranport measurements of interacting fermions — •Hideki Konishi, Kevin E. Roux, Barbara Cilenti, and Jean-Philippe Brantut — Institute of Physics, École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

In recent years, it has become possible to investigate transport phenomena using cold atoms. Previous researches have realized the Landauer setup [1] and a quantum point contact [2] and observed quantized conductance [3] emerging in mesoscopic systems.

Since the detection method implied so far the destructive observation of atom number densities, measurements relied on comparing different samples. This makes the measurements sensitive to even very weak fluctuations in the atomic sample preparation. In order to achieve more precise measurements, we plan to implement quantum non-demolition measurements of the atomic current featuring cavity quantum electrodynamics for fermionic lithium-6 with a high-finesse optical cavity. We will continuously monitor either the change of atom numbers in one of the terminal resorvoirs or motions of atoms within mesoscopic transport channels [4] by phase sensitive detection of the cavity field. In the poster we will detail the non-destructive probing scheme and present the design of the experimental apparatus and the current status of the experiment.

[1] J.-P. Brantut *et al.*, Science **337**, 1069 (2012). [2] D. Husmann *et al.*, Science **350**, 1498 (2015). [3] S. Krinner *et al.*, Nature **517**, 64 (2015). [4] C. Laflamme *et al.*, Phys. Rev. A **95**, 043843 (2017).

A 41.4 Thu 16:15 Orangerie

Towards a shotnoise limited optogalvanic vapor cell — •Markus Fiedler[1,5], Johannes Schmidt[1,5], Ralf Albrecht[1,5], Patrick Schalberger[2,5], Holger Baur[2,5], Robert Löw[1,5], Harald Kübler[1,5], Denis Djekic[3,5], Jens Anders[4,5], Norbert Frühauf[2,5], and Tilman Pfau[1,5] — [1]5th Institute of Physics — [2]Institute for Large Area Microelectronics — [3]Institute for Microelectronics, University of Ulm — [4]Institute for Theory of Electrotechnology — [5]University of Stuttgart, Center for Integrated Quantum Science and Technology (IQST)

We show how we want to integrate a shotnoise limited ion current detection into an optogalvanic vapor cell. Such a device can be used as a sensitive detector for electric and magnetic fields as well as highly excited atoms and molecules. We excite Alkali Rydberg atoms in an electrically contacted vapor cell [1,2]. These atoms are ionized due to collisions with the background gas. A voltage directs these charges towards the electrodes on the inside of the cell, where they are detected with an amplification circuit. Those circuits need to provide stable, low noise amplification under changing environmental conditions. Circuits based on thin film [3] and CMOS [4] technology are proposed. Furthermore, a random sampling Lock-In method aimed at achieving high bandwidth is discussed.

[1] D. Barredo, et al., Phys. Rev. Lett. 110, 123002 (2013)
[2] R. Daschner, et al., Opt. Lett. 37, 2271 (2012)
[3] P. Schalberger, et al., JSID 19, 496-502 (2011)
[4] D. Djekic, et al., ESSCIRC 43, 1386 (2017)

A 41.5 Thu 16:15 Orangerie

Simulations for anisotropic superfluidity in a Dysprosium BEC — •Michael Eisenmann, Matthias Wenzel, Fabian Bötttcher, Jan-Niklas Schmidt, Tim Langen, Igor Ferrier-Barbut, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

One of the most remarkable effects in quantum mechanics, compared to classical systems, is the possibility of superfluid states, for example in ultra cold atom gases, characterized by the existence of frictionless irrotational flow.

This frictionless behaviour only appears below a certain, so called "critical", flow velocity. Another hallmark of superfluidity is the irrotationality of the flow, leading to the creation of vortices in a rotating superfluid.

Already known for decades in liquid helium, superfluid phenomena, like the critical velocity for vortex creation, have been observed in ultra-dilute superfluids of quantum degenerated gases.

In dipolar interacting systems the superfluidity acquires an anisotropic character, resulting in the systems critical velocity depending highly on the flow direction [1].

We are reporting on numerical simulations, allowing us to investigate the effects of anisotropic interactions on the critical flow velocity, as well as the density profile and the lattice structure of vortices in a Dysprosium Bose-Einstein condensate.

[1] Ticknor, et. al., Physical review letters 106, 065301 (2011)

A 41.6 Thu 16:15 Orangerie

Topological properties of interacting fermions in circularly shaken hexagonal optical lattices — •Tao Qin[1], André Eckardt[2], Alexander Schnell[2], Christof Weitenberg[3,4], Klaus Sengstock[3,4,5], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität Frankfurt, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [3]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [4]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany — [5]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany

Circularly shaken hexagonal optical lattices are a versatile platform to realize the Haldane model and study related topological properties. Two groups have realized the Haldane model experimentally with slightly different set-ups [1]. Using real-space Floquet dynamical mean field theory (DMFT) we study edge states and Laughlin charge pumping of fermions with the Falicov-Kimball type interaction in a cylinder structure of the hexagonal optical lattice, and their dependence on dissipation induced by an extra bath. We find that dissipation tends to smear out edge states and induce non-integer charge pumping for a system with high frequency circular shaking. Furthermore, we explore the possibility to restore integer charge pumping at low frequency driving or by introducing disorder.

[1] G. Jotzu *et al.*, Nature **515**, 237(2014); N. Fläschner *et al.*, Science **352**, 1091(2016)

A 41.7 Thu 16:15 Orangerie

Selfbound quantum droplets — •Jan-Niklas Schmidt, Matthias Wenzel, Fabian Böttcher, Michael Eisenmann, Tim Langen, 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 arising from anisotropic, long-range interactions. One example we have observed in our experiment with an ultra-cold quantum gas of Dysprosium is the self-organization similar to the Rosensweig instability in classical ferrofluids. This is observed as modulational instability when tuning the scattering length via narrow Feshbach resonances.

Furthermore we found that the product of the instability is an ensemble of self-bound droplets in a liquid state. This state can only be explained by beyond mean-field corrections arising from quantum fluctuations. In cylindrical harmonic traps, the existance of the modulational instability strongly depends on the trap aspect ratio. We obtain a critical point in the phase diagram representing the lowest trap aspect ratio for which this modulational instability is observed. For lower trap aspect ratios an adiabatic crossover between a BEC and a single droplet state takes place. These results are in good agreement with simulations of the extended Gross-Pitaevskii equation.

A 41.8 Thu 16:15 Orangerie

Towards BEC-borne two-species atom interferometry in space — •Maike D. Lachmann[1], Baptist Piest[1], Dennis Becker[1], Wolfgang Ertmer[1], Ernst M. Rasel[1], and QUANTUS Collaboration[1,2,3,4,5,6,7,8,9] — [1]Leibniz-Universität Hannover — [2]HU Berlin — [3]JGU Mainz — [4]ZARM Bremen — [5]DLR-RY — [6]DLR-SC — [7]FBH Berlin — [8]U Ulm — [9]TU Darmstadt

Tests of the universality of free fall using two-species atom interferometers in space are currently of large interest. By increasing the free evolution time in the interferometer due to the microgravity environment the sensitivity can be enhanced significantly. After the successful launch of the MAIUS-1 mission and the first demonstration of Bose-Einstein condensates in space we aim for two-species atom interferometers on the sounding rocket missions MAIUS-2 and -3. The new system contains, in addition to Rb-87, K-41 as second species and will utilize Raman double-diffraction as beam splitters. The poster will show the mission goals, the setup and the current progress on ground.

QUANTUS & MAIUS are supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR 50WM 1131-1137.

A 41.9 Thu 16:15 Orangerie

Spectroscopy of Rydberg states in ultra cold ytterbium — •Christian Halter, Apoorva Hedge, Mustafa Jumaah, Christian Sillus, Thomas Burg, and Axel Görlitz — Heinrich-Heine-Universität Düsseldorf

Understanding the special features of Rydberg atoms, e.g. dipole-dipole interaction or van-der-Waals blockade, has become of utmost importance in quantum optics. Particularly ultra cold Rydberg atoms are of great interest for the investigation of long range interactions. Hence, in the present study, ultra cold ytterbium is spectroscopically investigated to gain precise knowledge on the Rydberg states. A special feature of ytterbium is that due to its two valance electrons atoms in Rydberg state can be easily manipulated and imaged using optical fields. For the above-mentioned spectroscopy an induced loss of atoms in a magneto-optical trap (MOT), that is caused by the Rydberg excitation, is used to detect the Rydberg states. Applying this method, we could measure several energy levels of Rydberg states in ultra cold ytterbium.

A 41.10 Thu 16:15 Orangerie

Quantum synchronisation in a bistable system — •Matthew Jessop, Andrew Armour, and Weibin Li — School of Physics and Astronomy, and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, University of Nottingham, UK

Classically, two weakly coupled oscillators will lock their relative phase, i.e. the so-called phase synchronisation. In the quantum regime, however, the uncertainty principle requires that a probability distribution description must be instead used. We conduct a theoretical study of quantum synchronisation in a system of two trapped ions in an electric Paul trap. Vibrations (phonons) of each ion are laser cooled to the Lamb-Dicke regime. Using a driving laser, phonons are coupled to electronic states of the ion under a two-phonon resonance condition. When the laser driving strength is weak, phonon excitations are suppressed while a limit cycle is reached at strong driving. We find a bistable regime at the intermediate driving strength where the zero-phonon state and a limit cycle coexist. We explore the emergence of quantum synchronisation when two identical ions are coupled through dipole-dipole interactions. Specifically we focus on the bistable regime where the zero-phonon state and limit cycle synchronise in different ways, leading to distinct phase distributions.

A 41.11 Thu 16:15 Orangerie

Coupled anharmonic oscillators in a two-dimensional ion trap array — •Philip Kiefer, Frederick Hakelberg, Sebastian Schnell, Jan-Philipp Schroeder, Mathias Wittemer, Govinda Clos, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We investigate trapped atomic ions as a platform for quantum simulations [1]. Although one-dimensional systems have delivered groundbreaking results, scaling to larger size and dimension presents a major challenge. We follow a bottom-up approach of single ions in individually controlled trapping sites generated by microfabricated two-dimensional trap arrays. Individually trapped ions represent a system of coupled oscillators, meditated by the Coulomb force, experimentally demonstrated in one-dimensional traps [2].

In our case, we use an equilateral triangular surface trap array, with an ion-ion distance of 40μm, providing individual control of motional mode orientation and frequencies at each site [3]. We show that a large coherent state, generated by a controlled motional excitation, exchanges its population with the other trapping sites. The coupling of the ions can be further controlled by anharmonic contributions of the trapping potential. Moreover we have developed a hybrid magnet setup enabling coherence times of electronic superposition states of greater than six seconds.

[1] New J. Phys. **15**, 085009 (2013)
[2] Nature **471**, 196-203 (2011)
[3] Nat. Com. **7**, 11839 (2016); Phys. Rev. A **94**, 023401 (2016)

A 41.12 Thu 16:15 Orangerie

Measurements of Motional Decoherence in 2D Ion Trap Arrays — •Sebastian Schnell, Frederick Hakelberg, Philip Kiefer, Jan-Philipp Schroeder, Mathias Wittemer, Govinda Clos, Ulrich Warring, and Tobias Schaetz — Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

Trapped ions present a promising system for quantum simulations [1]. In experiments with trapped ions motional coherence needs to be of an equal or larger time scale than typical experimental durations.

We investigate motional coherence times in a conventional Paul trap and a surface-electrode trap using different methods. We present experimental results for variable montional frequencies and excitation amplitudes from single quantum $|\alpha_0|^2 \propto$ 1-10 to $|\alpha_0|^2 \propto 10^3$. We further investigate real time manipulation of control potentials used for tuning of motional mode orientation and frequency [2].

[1] T. Schaetz, New J. Phys. **15**, 085009 (2013)
[2] M. Mielenz *et al.*, Nature Communications **7**, 11839 (2016)

A 41.13 Thu 16:15 Orangerie

Quantum criticality and the Tomonaga-Luttinger liquid in one-dimensional Bose gases — Bing Yang[1,2], Yang-yang Chen[3], Yong-guang Zheng[1,2], •Hui Sun[1,2], Han-ning Dai[1,2], Xi-wen Guan[3], Zhen-sheng Yuan[1,2], and Jian-wei Pan[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, Heidelberg, Germany — [2]University of Science and Technology of China, Hefei, China — [3]Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan, China

We experimentally investigate the quantum criticality and Tomonaga-Luttinger liquid (TLL) behavior within one-dimensional (1D) ultracold atomic gases. Based on the measured density profiles at different temperatures, the universal scaling laws of thermodynamic quantities are observed. The quantum critical regime and the relevant crossover temperatures are determined through the double-peak structure of the specific heat. In the TLL regime, we obtain the Luttinger parameter by probing sound propagation. Furthermore,a characteristic power-law behavior emerges in the measured momentum distributions of the 1D ultracold gas, confirming the existence of the TLL.

A 41.14 Thu 16:15 Orangerie

Two- and four-body spin-exchange interactions in optical lattices — •Bing Yang[1,2], Han-Ning Dai[1,2], Andreas Reingruber[1], Hui Sun[1,2], Yu-Ao Chen[2], Zhen-Sheng Yuan[2,1], and Jian-Wei Pan[2,1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Ultracold atoms in optical lattices represent an ideal platform for modeling elementary spin interactions. Here we report on the observations of two- and four-body spin-exchange interactions in an optical superlattice. Using a spin-dependent superlattice, atomic spins can be coherently addressed and manipulated. Bell states are generated via spin superexchange process and their quantum correlations are detected. A minimum toric code Hamiltonian in which the four-body ring-exchange interaction is the dominant term, is implemented by engineering a Hubbard Hamiltonian in disconnected plaquette arrays. Our work represents an essential step towards studying topological matters with many-body systems and the applications in quantum computation and simulation.

A 41.15 Thu 16:15 Orangerie

Fast and high-fidelity motional control of trapped ions — •Jan-Philipp Schröder, Matthias Wittemer, Frederick Hakelberg, Henning Kalis, Manuel Mielenz, Govinda Clos, Ulrich Warring, and Tobias Schaetz — Albert-Ludwigs-Universität Freiburg, Germany

Laser-cooled ions, trapped in radio-frequency potentials, are promising candidates for experimental quantum simulations. In addition to the manipulation of their electronic states (pseudo spin), precise control of the motional states is crucial.
We report on experiments with Mg^+ ions in a linear rf Paul trap and a triangular surface-electrode trap. An arbitrary waveform generator based on a FPGA enables real-time control of the motional degrees of freedom within microseconds. To apply high-frequency waveforms while suppressing electric-field noise, which would lead to motional heating of the ions, we embed switchable low-pass filters. This allows us to create a short time window with higher cut-off frequencies and thereby faster response. Additionally, we compensate the low-pass properties by utilizing an inverse transfer function of the control circuitry's frequency response. These novel implementations may allow precise studies of phenomena like thermalization [1], quantum memory effects [2] and their time scales in isolated and open quantum systems.

[1] G. Clos et al., Phys. Rev. Lett. **117**, 170401 (2016)
[2] M. Wittemer et al., arXiv:1702.07518 (2017)

A 41.16 Thu 16:15 Orangerie

Rydberg atoms in frustrated optical lattices: numerical study of quantum phases emerging due to the long-range interaction — •Jaromir Panas[1], Andreas Geissler[1], Yongqiang Li[2], Weibin Li[3], and Walter Hofstetter[1] — [1]Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]National University of Defence Technology, 410073 Changsha, P. R. China — [3]University of Nottingham, NG7 2RD Nottingham, United Kingdom

Recent experiments with ultracold Rydberg atoms have shown that the long-range interactions can give rise to spatially ordered structures. It seems that observation of such crystalline phases in a system with Rydberg atoms loaded into optical lattices is also within reach. For such a setup, theoretical studies have predicted a rich phase diagram. In particular, the existence of a series of supersolid and density wave phases with different spatial ordering has been shown for Rydberg atoms in a square lattice. Here we present results of numerical calculations performed for long-range interacting bosons in a triangular lattice. To find the relevant ordering structures, the "frozen"-gas approximation for a deep lattice potential is used. These structures are then investigated using the real-space bosonic dynamical mean-field theory.

A 41.17 Thu 16:15 Orangerie

Dynamical mean-field theory for dissipative ultracold Rydberg gases in optical lattices — •Arya Dhar, Jaormir Panas, Tao Qin, Andreas Geissler, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany

Rydberg-excited ultracold atoms have emerged in recent years as an efficient tool to engineer long-range interactions and simulate a variety of model Hamiltonians [1]. Theoretical studies of Rydberg-excited quantum gases in optical lattices have revealed a number of equilibrium crystalline quantum phases arising due to the competition between the different energy scales [2]. However, observation of these phases in experiments will be affected by dissipative processes such as spontaneous emission and dephasing. Our goal is to develop tools to study steady states and the corresponding non-equilibrium phase diagrams. A promising approach is to combine dynamical mean-field theory (DMFT) with the Lindblad formalism using the auxiliary master equation approach [3]. Here we report on our progress in adapting this method to study dissipative Rydberg-excited quantum gases in optical lattices.

[1] J. Zeiher *et al.*, Nature Physics **12**, 1095 (2016).
[2] A. Geißler *et al.*, PRA **95**, 063608 (2017).
[3] E. Arrigoni *et al.*, PRL **110**, 086403 (2013).

A 41.18 Thu 16:15 Orangerie

Single Rydberg Impurities immersed in a Bose-Einstein condensate — •Thomas Dieterle, Kathrin Kleinbach, Felix Engel, Carolin Dietrich, Robert Löw, Florian Meinert, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

For a single Rydberg atom excited from a Bose-Einstein condensate typically thousands of ground-state atoms reside within the Rydberg electron orbit. The Rydberg electron interacts with these perturbers simultaneously via electron-neutral quantum scattering. This has pronounced effects on the excitation spectrum of the Rydberg atom, leading to line shifts and broadenings, which in turn provide information on the underlying scattering physics. Very recently, the problem has been interpreted as a novel and exotic type of mesoscopic polaron.

As such, it appears very appealing to not only study the excitation spectrum, but also investigate the effect of the impurity on the quantum phase and density distribution of the condensate. In our experiment, we combine high-resolution optical microscopy with control over giant Rydberg impurities with electron orbits reaching the micrometer scale. We will report on the status of our endeavor to exploit the impurity's backaction on the condensate for implementing microscopy of the Rydberg electron orbit.

A 41.19 Thu 16:15 Orangerie

Matter wave abberations in magnetic chip traps — •Srihari Srinivasan and Reinhold Walser — Institut fuer Angewandte Physik, TU Darmstadt

The first Bose-Einstein Condensate (BEC) and atom interferometry in space was reported in early 2017 by the MAIUS sounding rocket experiment [1,2]. The setup uses an atom chip magnetic trap to obtain a BEC. Magnetic chip traps tend to show anharmonicities as atoms are at a close range to conductors on the chip. These anharmonicities present challenges for the experiment sequence in the form of anisotropic expansion of the BEC which are matter wave analogues of optical aberrations, the resulting inhomogeneities in number density and as anomalous collective modes [3] during time dependent processes.
We characterize the anharmonicity of the chip trap using the excited collective modes. We also study the influence of non-adiabatic dynamics during trap manipulation in the experiment sequence in an effort to help suppress anomalous collective modes. This is done as part of a comprehensive simulation suite for an atom interferometer being developed for comparison with experimental data.

[1] MAIUS Mission: http://www.spiegel.de/wissenschaft/technik/bose-einstein-kondensat-erstmals-im-all-erzeugt-a-1131279.html
[2] A. Cho, Science, **357**(6355), 986 (2017).
[3] C. Huepe et al., PRA **68**, 023609 (2003), S. Ronen et al., PRA

74, 013623 (2006).

A 41.20 Thu 16:15 Orangerie

Floquet state engineering in a periodically driven two-body quantum system — •Joaquín Minguzzi, Rémi Desbuquois, Michael Messer, Frederik Görg, Kilian Sandholzer, Gregor Jotzu, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Floquet engineering is a promising approach for the realization of novel phases of matter beyond the reach of static Hamiltonians. The challenge lies in finding out suitable protocols to prepare and characterize a particular Floquet state. Here, we use an ultracold fermionic gas in an optical lattice to experimentally explore different Floquet states in an interacting two-body Hubbard Hamiltonian where the site-to-site potential bias is periodically modulated. Whenever the driving frequency is higher than the energy scales of the underlying static Hamiltonian, we adiabatically connect to a Floquet state by simply ramping up the drive. This protocol is not appropriate in the near-resonant regime, where the driving strongly couples different states. Instead, we use a protocol that not only drives the system, but also changes the static Hubbard parameters. While time-averaged observables over one driving cycle are captured by an effective static Hamiltonian, we also detected the presence of micromotion in the resonantly-driven system. Our findings open up the possibility to explore Floquet engineering in a driven many-body quantum system.

A 41.21 Thu 16:15 Orangerie

Hole dynamics and bound states in a spin chain of Rydberg atoms — •Fabian Letscher[1], David Petrosyan[2], and Michael Fleischhauer[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, D-67663 Kaiserslautern, Germany — [2]Institute of Electronic Structure and Laser, FORTH, GR-71110 Heraklion, Crete, Greece

Spin lattice models play a central role in the studies of quantum magnetism and non-equilibrium dynamics of spin excitations. Here, we investigate the dynamics of 1D spin lattice models realized by coupling atomic ground states to high lying Rydberg states.

First, we discuss a chain of driven dissipative Rydberg superatoms, where each superatom consists of a mesoscopic ensemble of atoms. In the so called facilitation regime (off resonant excitation), a single superatom excitation triggers an excitation cascade of neighboring superatoms. We discuss the relaxation dynamics and show that the steady state resembles a hard rod liquid of holes - a nonexcited superatom surrounded by two excited ones. Second, we discuss the coherent dynamics of two Rydberg excitations immersed in a lattice of ground state atoms dressed to another Rydberg state. We show that the competition between van-der-Waals interaction and resonant dipole exchange interaction leads to the formation of mobile bound states of Rydberg excitations.

A 41.22 Thu 16:15 Orangerie

Self-organization in an opto-magnetically coupled quantum gas — •Nishant Dogra, Manuele Landini, Lorenz Hruby, Katrin Kröger, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

We report on the observation of strong opto-magnetical effects on the self-organization of a degenerate atomic system coupled to a single-mode high-finesse optical cavity and subjected to an off-resonant pump field, propagating transversely to the cavity axis. The opto-magnetical effects are a result of multiple atomic transitions which gives rise to non-zero vectorial polarizability and hence spin dependent atom-cavity (vectorial) coupling. The relative strength of the vectorial coupling with respect to the scalar coupling can be tuned by the polarization of the pump field. We observe spin dependent self-organization threshold and phase of the scattered light in the organized phase as a function of pump field polarization. By starting with a mixture of two spin states, we identify two regimes. In the regime of strong scalar coupling, the self-organization process generates density modulations in the system. By increasing the strength of vectorial coupling beyond a critical point, we observe the appearance of a new self-organization pattern consisting of magnetization modulations, a spin texture. We locate the transition point by analysing the phase of the light scattered by the atoms in the organized phase. Our findings pave the way to the exploitation of opto-magnetic effects for generation of long-range magnetic interactions.

A 41.23 Thu 16:15 Orangerie

Mean-field phase diagram of ultracold bosons inside a cavity — •Lukas Himbert, Rebecca Kraus, Shraddha Sharma, Astrid Elisa Niederle, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

We study a system of ultracold atoms confined by a 2-dimensional optical lattice within a cavity and optomechanically coupled with the cavity mode of the same wavelength as the lattice. The dynamics is described by an extended Bose-Hubbard Hamiltonian with global-range interactions between the atoms. By applying a mean-field approximation, we numerically determine the ground state phase diagram in the grand canonical ensemble. We reproduce the phase diagram presented by Dogra et al. [PRA 94, 023632 (2016)] and identify a Mott insulator, a superfluid, a charge density wave, and a supersolid phase; the latter two exhibit checkerboard order favoured by the global interaction. Moreover, regions separating the superfluid and the supersolid phase exhibit discontinuous jumps of the density as a function of the chemical potential, suggesting a first-order transition. We then consider the inhomogeinity of a harmonic trap and determine its influence on the phase diagram.

A 41.24 Thu 16:15 Orangerie

Upgrade of the Giessen MaMFIT — Marc Keil[1], Stefan Schippers[1], •Alfred Müller[2], and Alexander Borovik Jr[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen — [2]Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen

A Main Magnetic Focus Ion Trap (MaMFIT), a compact tool for spectroscopy of highly-charged ions [1], has been recently installed in Giessen and has already been employed for investigation of dielectronic recombination in highly-charged iridium ions [2]. The original construction, however, permitted experimental access almost exclusively to the ions of the sputtered cathode material, which, presently, is iridium. The main reason for this restriction is the process of evaporative cooling [3]. We report on an upgrade of the MaMFIT in Giessen. A gas inlet system enabling fine-dosed supply of gaseous elements has been designed, built and installed. In addition, a system facilitating periodic dumping of the ion trap has been set up. These measures have greatly enhanced the versatility of the MaMFIT. Now, a much wider spectrum of elements can be accessed. Results of the reference measurements using highly-charged argon ions will be presented. [1] V. P. Ovsyannikov, (2014) arXiv 1403.2168. [2] A. Borovik, Jr et al., to be published. [3] M. B. Schneider, AIP Conf. Proc. 188 (1989) 158

A 41.25 Thu 16:15 Orangerie

Optical dipole trapping in a drop tower experiment — •Marian Woltmann[1], Christian Vogt[1], Sven Herrmann[1], Claus Lämmerzahl[1], and The PRIMUS-Team[1,2] — [1]Center of Applied Space Technology and Microgravity (ZARM), University of Bremen — [2]Institut für Quantenoptik, LU Hannover

The PRIMUS-project develops an optical dipole trap for the use in a dual species (Rb and K) atom interferometer under microgravity conditions. For this purpose a trapping laser with peak power of 10 W at a wavelength of 1960 nm is used in an experimental setup for the Bremen drop tower. Combining an optical dipole trap with a microgravity environment offers significant advantages over current approaches. A dipole trap is capable of trapping all mF-states and features a superior harmonicity of the trapping potential. The latter is especially important for an effective delta-kick collimation, needed for the preparation of BEC-clouds with particularly low effective temperatures. As the trap is solely based on optical interaction, Feshbach resonances will become feasible in microgravity. Within the PRIMUS-project the first ever optical dipole trap in microgravity was realised. In this manner our project also serves as a pathfinder experiment for further dipole trap based cold atom experiments in different microgravity environments. With our poster we will give an overview of the experiment and report on latest experimental results. The PRIMUS-project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 1642.

A 41.26 Thu 16:15 Orangerie

Optical bistability in thermal Rydberg vapor — •Patrick Kaspar, Daniel Weller, Nico Sieber, Robert Löw, and Harald Kübler — 5. Physikalisches Institut, Universität Stuttgart, Deutschland

Vapor cells filled with thermal atomic gas are one promising building block for future applications in quantum communication and sensing [1]. It is therefore crucial to gain a fundamental understanding of all the physical effects happening inside such a cell when addressing the atoms with laser beams. One particularly interesting effect happens when exciting an atomic ensemble to Rydberg states: at large Rabi frequencies compared to the weak probe regime, the system undergoes a hysteresis in the absorption spectrum of an EIT-like excitation scheme [2]. Recently we have shown that dipolar interactions between Rydberg atoms can be ruled out as the origin of this bistability, and have placed Coulomb interactions in the focus of our research: due to the large polarizability of Rydberg states, ionized atoms nearby cause the required energy shift leading to the observed nonlinearity [3]. Here we present our measurement techniques to fully understand the mechanisms involved: a two-species EIT-spectroscopy in rubidium allows us to determine the electric fields present in the vapour cell during Rydberg excitation, and fluorescence detection enables us to study the significantly altered spectrum due to the presence of charged particles.

[1] Nature Physics 8, 819–824 (2012), arXiv:1709.00262(2017)
[2] Phys. Rev. Lett. 111 113901 (2013)
[3] Phys. Rev. A 94, 063820 (2016)

A 41.27 Thu 16:15 Orangerie

Quantum Simulation of Energy Transport with Rydberg Atoms — •Sayali Shevate[1], Tobias Wintermantel[1,2], Yibo Wang[1], and Shannon Whitlock[1,2] — [1]Institut de physique et de chimie des Matériaux de Strasbourg (IPCMS), University of Strasbourg, France 67200 — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

The transport of charge, energy and information is fundamental to the behavior of electronic materials, complex molecules (e.g. light harvesting complexes like Fenna-Matthews-Olson (FMO)) and information networks. Yet, it is still largely unknown which underlying properties of the system lead to the most efficient or robust transport, especially in the presence of quantum effects. Ultracold atoms excited to Rydberg states possessing strong dipolar interactions provide a unique platform for studying fundamental energy transport processes in a fully controllable environment. We propose a novel experimental system for exciting Rydberg atoms in tailored geometries capable of simulating energy transport with almost full control over spatially and temporally correlated disorder. This will provide a route to address how excitations migrate through quantum many-body system possessing non-trivial correlations and how spatially and temporally correlated noise can enhance the robustness and efficiency of energy transport in synthetic quantum systems.

A 41.28 Thu 16:15 Orangerie

Phasetransition of a Bose-Einstein condensate in an optical ring resonator with internal coupling — •Simon C. Schuster, Philip E. Wolf, Sebastian Slama, and Claus Zimmermann — Physikalisches Institut, University Tübingen

We investigate the dynamics of an atomic Bose Einstein condensate interacting with the light modes of a high-finesse ring resonator. Two counterpropagating longitudinal modes of the resonator are coupled by the atoms due to coherent light scattering. Previous work ([1],[2]) explored Collective Atomic Recoil lasing (CARL) and its threshold for various pump-resonator detuning. With our newly developed subrecoil resolving ring resonator we investigate the transition between the CARL-regime and a new steady state regime. This new regime emerges in the presence of additional coupling between the two counterpropagating modes. We present experimental evidence of the steady-state and determine the phase boundary for various internal coupling rates.

[1] D. Schmidt et al., Phys. Rev. Lett. 112, 115302 (2014)
[2] H. Tomczyk et al., Phys. Rev. A 91, 063837 (2015)

A 41.29 Thu 16:15 Orangerie

Autonomous thermal machine for amplification and control of energetic coherence — •Gonzalo Manzano[1,2], Ralph Silva[3], and Juan M. R. Parrondo[1] — [1]Departamento de Física Atómica, Molecular y Nuclear and GISC, Universidad Complutense Madrid, 28040 Madrid, Spain — [2]Instituto de Física Interdisciplinar y Sistemas Complejos IFISC (CSIC-UIB), Campus Universitat Illes Balears, E-07122 Palma de Mallorca, Spain — [3]Group of Applied Physics, University of Geneva, 1211 Geneva 4, Switzerland

We present a model for an autonomous quantum thermal machine comprised by two qubits that is capable of amplifying the coherence in a non-degenerate system by using only thermal resources. This novel method of coherent control allows for the interconversion between energy, both work and heat, and coherence. This model opens up new possibilities in the generation and manipulation of coherence by autonomous thermal machines.

A 41.30 Thu 16:15 Orangerie

Decoherence of Rydberg molecules — •Andrew Hunter, Alex Eisfeld, and Jan-Micheal Rost — Max Planck Institute for the Physics of Complex Systems

A Rydberg atom in the presence of a neutral perturber is investigated using scattering theory. Due to a negative s-wave scattering length at low energies these perturbers can form a bound state with the Rydberg atom, known as a trilobite molecule [1]. These molecules interact strongly with their environment due to their large polarisability or dipole moment [2]. In particular, we study such systems coupled to external environments and the decoherence that results. The prospect of interfacing these molecules with mesoscopic systems such as a moving mirror is then explored.

[1] C. H. Greene, A. S. Dickinson, and H. R. Sadeghpour, Phys. Rev. Lett. 85, 2458 (2000).
[2] P. J. J. Luukko and J. M. Rost, Phys. Rev. Lett. 119, 203001 (2017).

A 41.31 Thu 16:15 Orangerie

Quantum many-body physics under the microscope — •Simon Hollerith[1], Antonio Rubio Abadal[1], Johannes Zeiher[1], Jun Rui[1], Christian Gross[1], and Immanuel Bloch[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, 80539 München, Germany

In our experiment we use a high-resolution objective in order to image and adress ultracold rubidium atoms trapped in a single layer of a three dimensional optical lattice with single-site resolution. Studying the relaxation dynamics of non-equilibrium states under the influence of site-dependent disorder created by our adressing light, we address questions around many-body-localization in two dimensions. Tuning our adressing beam to the magic wavelength where only one of the two spin states interacts with the light field, we study how the localized spins get affected by a thermal bath. In a second project, we use off-resonant coupling to Rydberg states - so called Rydberg dressing - in order to engineer long-range interacting ground state atoms. Using Ramsey sequences, we verify the realization of long-range interacting spin models by measuring spin-spin correlations as well as the total magnetization of our system for variable interaction times.

A 42: Poster Session IIIb

Time: Thursday 16:15–18:15 Location: Zelt Ost

A 42.1 Thu 16:15 Zelt Ost

Probing ferromagnetism in few-fermion correlated spin-flip dynamics — •Georgios Koutentakis, Simeon Mistakidis, and Peter Schmelcher — Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

According to the Stoner instability, the ferromagnetic phase of a spin-1/2 Fermi system occurs for strong interparticle repulsion, resulting in the occupation of states with anti-oriented spins being energetically forbidden. However, the clean realization of a ferromagnetic phase in quantum gases verifying this viewpoint is elusive. We unravel the stability of a fully polarized one-dimensional ultracold few-fermion spin-1/2 gas subjected to inhomogeneous driving of the itinerant spins. The existence of a ferromagnetic-like regime for interaction strengths comparable to the confinement energy is revealed. The two-body spin-spin correlator unveils that the itinerant spins remain close to be maximally aligned throughout the dynamics, despite the magnitude of the average single-spin polarization fluctuating between zero and unity. This implies that the interaction is not able to stabilize the spin-polarization and hence the magnetization of a trapped Fermi gas.

A 42.2 Thu 16:15 Zelt Ost

Preparing and controlling optically trapped Barium Ions for ultracold Atom-Ion Interactions — •Pascal Weckesser, Fabian Thielemann, Yannick Minet, Julian Schmidt, Leon Karpa, Markus Debatin, and Tobias Schaetz — Albert-Ludwigs-Universitaet Freiburg

The interplay of ultracold atoms and ions has recently gained interest in the atomic community [1], due to its wide applications in quantum chemistry [2] and quantum control [3]. In order to control the atom-ion interaction it is necessary to prepare the mixture at ultracold temperatures. Optical trapping of ions [4] provides a new pathway to achieve ultracold atom-ion mixtures, as it overcomes the intrinsic micromotion heating effects of a conventional Paul trap [5], currently limiting experiments to collision energies on the order of a few mK.

Here we present our novel experimental setup combining $^{138}Ba^+$ ions and ^6Li atoms. On this poster we focus on the Barium segment of the experiment. We demonstrate our new ion loading scheme, realised by laser ablation. Furthermore, first optical trapping attempts of the Barium ions in a visible dipole trap (532 nm) will be presented.

[1] A. Haerter et al., Cont. Phys., Vol. 55, issue 1, pages 33-45 (2014).
[2] R.Cote et al. Phys.Rev.Lett. 89.093001 (2002).
[3] Idziaszek et al., Physical Review A 76.3 (2007): 033409.
[4] A. Lambrecht et al., Nature Photonics 11.11 (2017): 704.
[5] M.Cetina et al., Phys.Rev.Lett. 109,253201 (2012)

A 42.3 Thu 16:15 Zelt Ost

Many-Body Quantum Dynamics in the Decay of Bent Dark Solitons of Bose-Einstein Condensates — •Simeon Mistakidis[1], Garyfallia Katsimiga[1], Georgios Koutentakis[1,2], Panagiotis Kevrekidis[3], and Peter Schmelcher[1,2] — [1]Zentrum für optische Quantentechnologien Luruper Chaussee 149 22761 Hamburg — [2]he Hamburg Centre for Ultrafast Imaging, Universit at Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003-4515, USA

We examine the case of a bent dark soliton comparing the mean-field dynamics to a correlated approach. Dynamical snaking of this bent structure is observed, signaling the onset of fragmentation. In contrast to the mean-field approximation "filling" of the vortex core is observed, leading to the formation of filled-core vortices. We show that this filling owes its existence to the dynamical building of an antidark structure developed in the next-to-leading order orbital. We further demonstrate that the aforementioned beyond mean-field dynamics can be experimentally detected using the variance of single shot measurements. Additionally, a variety of excitations including vortices, oblique dark solitons, and open ring dark soliton-like structures building upon higher-lying orbitals is observed. Signatures of the higher-lying orbital excitations emerge in the total density, and can be clearly captured by inspecting the one-body coherence. In the latter context, the localization of one-body correlations exposes the existence of the multi-orbital vortex-antidark structure.

A 42.4 Thu 16:15 Zelt Ost

A Versatile Strontium Quantum Gas Machine with a Microscope — •Oleksiy Onishchenko, Sergey Pyatchenkov, Alexander Urech, Georgios Siviloglou, and Florian Schreck — Institute of Physics, University of Amsterdam, Amsterdam, The Netherlands

Strontium opens new perspectives for Hamiltonian engineering because it is an alkaline-earth element with narrow intercombination lines, metastable excited electronic states, and ten collisionally-stable SU(N)-symmetric nuclear spin states.

We have built a new versatile Sr machine with quantum gas microscope capability. After precooling on a broad blue transition, we collect 10^7 atoms at 2 μK in a narrow-line red MOT, load them into a 1064 nm dipole trap, and evaporatively cool them to obtain either a BEC of 8×10^4 atoms or a degenerate Fermi gas with $T/T_F = 0.3$. We have now also observed for the first time the doubly-forbidden $^1S_0$ - $^3P_2$ transition in ^{87}Sr by direct laser excitation, which opens up possibilities for quantum computation [1] and gauge field engineering.

[1] Daley, A.J., Quant. Inform. Process. 10, 865 (2011).

A 42.5 Thu 16:15 Zelt Ost

Quench-induced phase separation dynamics in a many-body multi-component Bose-Einstein condensate — •Garyfallia Katsimiga[1], Simeon Mistakidis[1], Panagiotis Kevrekidis[2], and Peter Schmelcher[1,3] — [1]Zentrum für optische Quantentechnologien Luruper Chaussee 149 22761 Hamburg — [2]Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003-4515, USA — [3]The Hamburg Centre for Ultrafast Imaging, Universitat Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We examine the quenched dynamics of a binary Bose-Einstein condensate crossing the miscibility-immiscibility threshold and vice versa, both within and beyond the mean-field approximation. Increasing the interspecies repulsion leads to the filamentation of the density of each component, involving shorter wavenumbers (and longer spatial scales) in the many-body approach. These filaments appear to be strongly correlated both at the one- and the two-body level, exhibiting domain-wall structures. Furthermore, following the reverse quench process dark-bright soliton trains are spontaneously generated and subsequently found to decay in the many-body scenario. We utilize single-shot images to provide a clean experimental realization of our current findings via which the filamentation process is clearly captured. To expose further the many-body nature of the observed dynamics direct measurements of the variance of single-shots are performed, verifying the presence of fragmentation but also the entanglement between the species.

A 42.6 Thu 16:15 Zelt Ost

Tailor-made optical potentials with Spatial Light Modulators — •Antonia Klein, Marvin Holten, Luca Bayha, Puneet Murthy, Philipp Preiss, Gerhard Zuern, and Selim Jochim — Physikalisches Institut, University of Heidelberg, Germany

Initializing a system in a desired low entropy state is one of the main challenges of quantum simulation employing ultracold atoms. In most experiments a bulk gas is evaporatively cooled down and loaded into the desired potential.

On this poster we present our new setup following a different bottom-up approach. The idea is to assemble a complicated potential out of many separately prepared building blocks, which can be initialized with very low initial entropy. The required tailor made potentials are created by using a phase modulating Spatial Light Modulator implemented in our group's 2D lithium experiment.

We show first measurements performed with the extended setup. Starting with the simple building block of a double well, we explore the feasibility of several lattice geometries. We also investigate the possibility to study 1D physics with the long term goal of creating topological edge states.

A 42.7 Thu 16:15 Zelt Ost

Single-shot simulations for bosonic and fermionic mixtures — •Georgios Koutentakis[1], Simeon Mistakidis[1], Garyfallia Katsimiga[1], Panagiotis Kevrekidis[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003-4515, USA

ML-MCTDHX offers as a versatile tool for the simulations of bosonic and fermionic atomic mixtures [1]. We extend the recently developed single-shot simulation procedure for single-species bosonic ensembles [2] for the case of atomic mixtures and spinor gases. This extension allows us to track and quantify the correlation dynamics on the level of the full many-body wavefunction relying solely on experimentally tractable quantities.

[1] L. Cao, V. Bolsinger, S. I. Mistakidis, G. M. Koutentakis, S. Krönke, J. M. Schurer, and P. Schmelcher, J. Chem. Phys. **147**, 044106 (2017).
[2] K. Sakmann and M. Kasevich, Nat. Phys. **12**, 451 (2016).

A 42.8 Thu 16:15 Zelt Ost

Many-Body Dark-Bright Soliton Dynamics — •Simeon Mistakidis[1], Garyfallia Katsimiga[1], Georgios Koutentakis[1,2], Panagiotis Kevrekidis[3], and Peter Schmelcher[1,2] — [1]Zentrum für optische Quantentechnologien Luruper Chaussee 149 22761 Hamburg — [2]he Hamburg Centre for Ultrafast Imaging, Universitat Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003-4515, USA

The dynamics of dark-bright solitons beyond the mean-field approximation is investigated. We first examine the case of a single dark-bright soliton and its oscillations within a parabolic trap. Subsequently, we move to the setting of collisions. Fragmentation is present and significantly affects the dynamics, especially in the case of slower solitons and in that of lower atom numbers. It is shown that the presence of fragmentation allows for bipartite entanglement between the distinguishable species. Most importantly the interplay between fragmentation and entanglement leads to the splitting of each of the parent mean-field dark-bright solitons, placed off- center within the parabolic trap, into a fast and a slow daughter solitary wave. The latter process is in direct contrast to the predictions of the mean-field approximation. A variety of excitations including dark-bright solitons in multiple (concurrently populated) orbitals is observed. Dark-antidark states and domain-wall-bright soliton complexes can also be observed to arise spontaneously in the beyond mean-field dynamics.

A 42.9 Thu 16:15 Zelt Ost

Bosonic quantum dynamics following a linear interaction quench in finite optical lattices of unit filling — •Simeon Mistakidis[1], Georgios Koutentakis[1,2], and Peter Schmelcher[1,2] — [1]Zentrum für optische Quantentechnologien Luruper Chaussee 149 22761 Hamburg — [2]he Hamburg Centre for Ultrafast Imaging, Universitat Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The nonequilibrium ultracold bosonic quantum dynamics in finite optical lattices of unit filling following a linear interaction quench from a superfluid to a Mott insulator state and vice versa is investigated. The resulting dynamical response consists of various inter and intraband tunneling modes. We find that the competition between the quench rate and the interparticle repulsion leads to a resonant dynamical response, at moderate ramp times, being related to avoided crossings in the many-body eigenspectrum with varying interaction strength. Crossing the regime of weak to strong interactions several transport pathways are excited. The higher-band excitation dynamics is shown to obey an exponential decay possessing two distinct time scales with varying ramp time. Studying the crossover from shallow to deep lattices we find that for a diabatic quench the excited band fraction decreases, while approaching the adiabatic limit it exhibits a non-linear behavior for increasing height of the potential barrier. The inverse ramping process from strong to weak interactions leads to a melting of the Mott insulator and possesses negligible higher-band excitations which follow an exponential decay for decreasing quench rate.

A 42.10 Thu 16:15 Zelt Ost

Tunable spin-exchange interaction in ytterbium-173 — •Oscar Bettermann[1,2], Nelson Darkwah Oppong[1,2], Luis Riegger[1,2], Moritz Höfer[1,2], Bloch Immanuel[1,2], and Simon Fölling[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Ludwig-Maximilians-Universität, München

Ytterbium as an alkaline-earth-like atom features a metastable excited state, the so-called clock state, that can be directly addressed from the ground state with an ultra-narrow laser. The metastable clock state opens up the possibility of probing interacting two-orbital many-body systems.

Since the ground and clock state have, in general, distinct atomic polarizabilities, the confinement and mobility can be tuned in state-dependent optical lattices. In our implementation, atoms in the clock state are pinned on individual lattice sites whereas ground-state atoms remain mobile. Together with the strong spin-exchanging interaction of ytterbium-173, Kondo-like Hamiltonians can be realized.

We find that the spin-exchange coupling is mediated via super-exchange processes and can be tuned resonantly by varying the confinement. This novel tuning mechanism could potentially be used for studying dynamics of the Kondo and Kondo lattice model with ultracold atoms.

A 42.11 Thu 16:15 Zelt Ost

Expansion dynamics of strongly attractive few-fermion systems — Vincent Klinkhamer, •Ralf Klemt, Jan Hendrik Becher, Andrea Bergschneider, Philipp M. Preiss, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg

In this talk, we present correlation measurements in an expanding and attractively interacting few-body system of fermionic 6Li atoms. We prepare deterministic few-body systems in optical microtraps and then release the atoms into a weaker external confinement. After a time-of-flight expansion, we measure both the position and hyperfine state of each atom with single-atom-resolution. In these measurements, we observe strong correlations between the atoms, depending both on the interaction strength and the confinement potential during the expansion. We explain the expansion dynamics with unitary time evolution and connect it to the fluid-dynamic description of strongly coupled quantum fluids.

A 42.12 Thu 16:15 Zelt Ost

QUANTUS-2 - Ultra Low Expansion Atomic Source for Matter Wave Interferometry in Extended Free Fall — •Peter Stromberger[1], Tammo Sternke[5], Naceur Gaaloul[4], Andre Wenzlawski[1], Patrick Windpassinger[1], and the QUANTUS-Team[1,2,3,4,5,6,7] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz — [2]Institut für Physik, Humboldt-Universität zu Berlin — [3]Ferdinand-Braun-Institut, Leibniz Institut für Höchstfrequenztechnik Berlin — [4]Institut für Quantenoptik, Leibniz-Universität Hannover — [5]ZARM, Universität Bremen — [6]Institut für Quantenphysik, Universität Ulm — [7]Institut für angewandte Physik, TU Darmstadt

QUANTUS-2 is a mobile high-flux rubidium BEC source used for experiments under microgravity in the drop tower in Bremen. To further decrease the expansion rate of the BEC, magnetic lensing - also known as delta-kick collimation - is crucial for observations after long evolution times in the range of seconds. Long evolution times are desirable, because the sensitivity of atom interferometers enhances quadratically with the interrogation time. An observability of the BEC of up to 2.7 s after free expansion was demonstrated. We present new analysis methods and results from simulations to increase our understanding of the used magnetic lens.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economic Affairs and Energy under grant numbers DLR 50 WM 1552-1557.

A 42.13 Thu 16:15 Zelt Ost

Study on transfer induced BEC dynamics in optical waveguides — Sebastian Bode, •Felix Kösel, and Knut Stolzenberg — Institut für Quantenoptik, Hannover, Deutschland

Presentation of the experimental steps towards optically guided atom-interferometry using ^{87}Rb Bose-Einstein condensates. By applying a waveguide the evolution time of the ensemble is increased leading to higher sensitivity of the atom interferometer [1]. Beam-splitters and mirrors will be implemented via Bragg-pulses coupling to the momentum states of the atoms. Furthermore the transfer behaviour of the BEC from a crossed optical dipole trap into the optical waveguide is studied. The aforementioned behaviour results in complex dynamics which become apparent through fragmentations of the BEC due to phase fluctuations.

[1] G. D. McDonald et al., PRA **87**, 013632 (2013)

A 42.14 Thu 16:15 Zelt Ost

Rydberg Dressed Quantum Many-Body Systems — •Nikolaus Lorenz, Lorenzo Festa, Sarah Hirthe, Anne-Sophie Walter, and Christian Gross — Max-Planck-Institut für Quantenoptik, Munich, Germany

We are setting up a novel experiment for the study of quantum many-body systems with engineered long-range interactions. These interactions are induced by off-resonant laser coupling to Rydberg states, so called Rydberg dressing. Our aim is to explore fundamentally new types of quantum matter based on these tailored long-range interactions. A first goal is to study tailored quantum magnets in microtrap arrays, where Potassium provides interesting prospects for deterministic array loading. The microtrap approach has been chosen in order to have a flexible and fast system for experiments that require high statistics. We are developing also the laser system for the ultraviolett light designed to maximize the coupling to Rydberg states. Here we report on the status of the project and the progress done in the last year with the construction of the experimental apparatus.

A 42.15 Thu 16:15 Zelt Ost

A Reaction Microscope for few-body Rydberg Dynamics — •Philipp Geppert, Dominik Arnold, Cihan Sahin, Andreas Müllers, and Herwig Ott — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany

We report on the development of a reaction microscope that is based on our deterministic ion source experiment (C. Sahin et al 2017 *New J. Phys.*) and allows to measure the dynamical evolution of momentum distributions in interacting Rydberg systems. To this purpose, a sample of 10^6 ^{87}Rb atoms will be prepared in a crossed dipole trap. Using a 3-level excitation scheme, some atoms can be excited to atomic or molecular Rydberg states and photoionized by a short laser pulse from a high power CO_2 laser after a variable evolution time. Following small homogeneous electric fields generated by Wiley-McLaren-type ion optics, the produced ions are subsequently detected by a time and position sensitive delay-line detector. By analyzing the trajectories of the recoil ions, we aim to measure momentum distributions of Rydberg molecule wave functions. In this context, special focus lies on butterfly and trilobite molecules, which can be addressed efficiently due to the opportunity of exciting Rydberg p- and f-states. As a next step, stroboscopic monitoring on the internal decay of Rydberg molecules and measurements regarding forces between pairs of Rydberg atoms will be performed.

A 42.16 Thu 16:15 Zelt Ost

Rydberg Optical Feshbach Resonances — •Tanita Eichert[1], Oliver Thomas[1,2], Carsten Lippe[1], and Herwig Ott[1] — [1]Department of physics and research center Optimas, University of Kaiserslautern — [2]Graduate school materials science in Mainz, Staudingerweg 9, 55128 Mainz

In a cloud of ultracold atoms the scattering interaction between a ground state atom and the highly excited Rydberg electron gives rise to an oscillatory potential that supports molecular bound states. We show that by coupling two ground state atoms to a Rydberg molecular state via a laser field, we realize a Rydberg optical Feshbach resonance. By tuning the laser field, the Rydberg optical Feshbach resonance results in a changed interatomic interaction, that we detect as different revival times in collapse and revival experiments in an optical lattice. As off-resonant excitations lead to the formation of Rydberg atoms, we observe an additional interaction shift that is attributed to Rydberg-Rydberg-interactions between the atoms. Long lifetimes of Rydberg molecular states allow us to maintain long sample lifetimes on the order of milliseconds while changing the scattering length by up to 50 Bohr radii. So far optical Feshbach resonances were observed near intercombination transitions in strontium and ytterbium. We believe that Rydberg optical Feshbach resonances open up a whole new field: They are feasible with arbitrary Rydberg molecular states and all atomic species that are able to create Rydberg molecules. Especially this plenitude of molecular states allows to optimize the ratio between the change in scattering length and loss rates in further research.

A 42.17 Thu 16:15 Zelt Ost

Observation of RbSr Feshbach resonances — •Florian Schreck[1], Vincent Barbé[1], Alessio Ciamei[1], Lukas Reichsöllner[1], Benjamin Pasquiou[1], Jacek Szczepkowski[2], Piotr Zuchowski[3], and Jeremy Hutson[4] — [1]University of Amsterdam, The Netherlands — [2]Polish Academy of Sciences, Warsaw, Poland — [3]Nicolaus Copernicus University, Poland — [4]Durham University, United Kingdom

We report the first observation of magnetic Feshbach resonances (FRs) between an alkali and a closed-shell atom, Rb and Sr [1]. In this system none of the strong coupling mechanisms that lead to broad FRs in alkali systems exist. Our work shows that weak coupling mechanisms, as predicted in [2], lead to narrow Rb-Sr Feshbach resonances. We also present spectroscopic studies of the RbSr ground-state potential, performed on several isotopic combinations. These studies enable us to predict the location and width of Feshbach resonances in all stable isotopic mixtures. We identify mixtures for which magnetoassociation of Rb and Sr atoms into molecules should be feasible despite the narrowness of the resonances. This opens a door towards the creation of open-shell, strongly polar molecules.

[1] V. Barbé *et al.*, arXiv:1710.03093 (2017).
[2] P. Żuchowski *et al.*, Phys. Rev. Lett. 105, 153201 (2010).

A 42.18 Thu 16:15 Zelt Ost

Cold Rydberg ions for quantum-technology experiments — •Arezoo Mokhberi[1], Jonas Vögel[1], Justas Andrijauskas[1,2], Patrick Bachor[1,2], Georg Jacob[1], Christian Gumbrich[1,2], Jachen Walz[1,2], and Ferdinand Schmidt-Kaler[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55128, Germany — [2]Helmholtz-Institut Mainz, D-55099, Germany

Cold ions confined in radiofrequency (RF) ion traps are among the most promising candidates for quantum information processing and quantum simulation. In these systems, exciting the ionic electron to high-laying Rydberg states offers a unique opportunity for observing novel effects arising from the interplay between the Coulomb interaction and their giant dipole moments. This offers a new router for investigating strongly correlated many-body quantum systems, for simulating complex systems and for the exploration of non-equilibrium dynamics in structural phase transitions and defect formations [1-3]. We have employed coherent VUV radiation at 122.04 nm for Rydberg excitation of calcium ions in a linear, segmented RF trap. The excitation to 52F, 53F, 66F and 22F states was observed and modelled [4,5]. Using sideband spectroscopy on the quadrupole qubit transition, we have characterized the micromotion effect on the line shape of Rydberg transitions.

References: [1] F. Schmidt-Kaler et al., NJP. 13, 075014 (2011). [2] M. Müller et al., NJP 10, 093009 (2008). [3] S. Ulm et al., Nat. comm. 4, 2290 (2013). [4] T. Feldker et al., PRL 115, 173001 (2015). [5] P. Bachor et al., JPB 49, 154004 (2016).

A 42.19 Thu 16:15 Zelt Ost

Towards a hybrid quantum system of Rydberg atoms and a coplanar waveguide cavity — •Conny Glaser, Helge Hattermann, Li Yuan Ley, Daniel Bothner, Benedikt Ferdinand, Lörinc Sárkány, Reinhold Kleiner, Dieter Kölle und József Fórtagh — CQ Center for Collective Quantum Phenomena and their Applications, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

Coupling Rydberg atoms to coplanar superconducting resonators has been proposed to enable efficient state transfer between solid state systems and ultracold atoms. This coupling could be used for the generation of an atomic quantum memory or the implementation of new quantum gates [1,2].

After the successful demonstration of magnetic coupling between ultracold ground state atoms and a coplanar waveguide resonator, we progress towards coupling Rydberg atoms to the electric field of the cavity. Due to the large dipole moment of Rydberg atoms, the coupling strength to the cavity is expected to be much larger than in the case of ground state atoms. At the same time, Rydberg states are strongly affected by any detrimental fields, such as the electric field of adsorbates on the chipsurface, which lead to spatially inhomogeneous energy shifts. We report on the characterization of these fields, state selective detection of Rydberg atoms and on the progress towards coupling.

[1] L. Sárkány et al., Phys. Rev. A 92, 030303 (2015).
[2] J. D. Pritchard et al., Phys. Rev. A 89, 010301 (2014).

A 42.20 Thu 16:15 Zelt Ost

Is a Steady-State Atom Laser within reach? — •Chun-Chia Chen, Shayne Bennetts, Rodrigo Gonzalez Escudero, Benjamin Pasquiou, and Florian Schreck — Institute of Physics, University of Amsterdam

So far BECs and atom lasers have only been demonstrated as the product of a time sequential, pulsed cooling scheme. Here we will describe a steady-state system demonstrating phase-space densities (PSD) approaching degeneracy and discuss how we might be able to make a steady-state atom laser. By flowing atoms through a series of spatially separated cooling stages and employing a range of novel tricks we recently demonstrated a steady-state strontium MOT with a PSD above 10^{-3} [1], 100 times higher than previous experiments. Now we demonstrate a set of tools, compatible with steady-state operation, to continuously cool and transfer microkelvin-cold atoms from a MOT into a dipole trap reservoir. Furthermore, by combining our novel machine architecture with a lighshift engineering technique we previously demonstrated [2], we protect a BEC from the strong fluorescence of a nearby MOT. Using all these tools on our high PSD MOT, quantum degeneracy in a steady-state system and a steady-state atom laser seem within reach. A steady-state source of degenerate atoms offers great advantages for applications such as next generation degenerate atomic clocks, super-radiant lasers or atom-interferometers for gravitational wave detection.

[1] S. Bennetts *et al.*, Phys. Rev. Lett. 119, 223202 (2017).
[2] S. Stellmer *et al.*, Phys. Rev. Lett. 110, 263003 (2013).

A 42.21 Thu 16:15 Zelt Ost

Towards Ultracold Interactions between Lithium and Barium in an Optical Trap — •Fabian Thielemann, Pascal Weckesser, Yannick Minet, Julian Schmidt, Leon Karpa, Markus Debatin, and Tobias Schaetz — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

The fields of ultracold atoms and trapped ions are important pillars of experimental quantum optics. Recently the expertise of both fields

has been combined in hybrid trapping setups to prepare atom-ion mixtures at low temperatures. For joint systems features like Feshbach resonances at magnetic fields on the order of tens of Gauss or the formation of mesoscopic, weakly bound molecules have been predicted [1,2]. As reaching the ultracold regime in hybrid setups is an experimentally challenging task, this phenomena remain yet to be observed.

In our novel experimental setup we plan to reach the ultracold regime by sympathetically cooling Ba^+ ions in a cloud of ^{6}Li atoms. The atoms and ions will be confined in a combined optical dipole trap to overcome fundamental temperature limits imposed by micromotion of an ion in a radio frequency trap [3,4]. On this poster we will focus on the ^{6}Li branch of the setup. We present characterising measurements of our magneto-optical trap. Further the current state of atom transfer to the dipole trap will be put forward.

[1] M. Tomza et al., Physical Review A 91.4 (2015): 042706.
[2] R.Cote et al. Phys.Rev.Lett. 89.093001 (2002).
[3] M. Cetina et al., Phys.Rev.Lett. 109,253201 (2012).
[4] A. Lambrecht et al., Nat. Phot. 11, 704-707 (2017)

A 42.22 Thu 16:15 Zelt Ost

An Autonomous Clock Based on a Single-Ion Phonon Laser — •Martin Wagener, David von Lindenfels, Thomas Ruster, Ulrich Poschinger, and Ferdinand Schmidt-Kaler — Institut für Physik, Johannes Gutenberg-Universität Mainz

Self-oscillating systems are ubiquitous in nature and technology and can evidently be used for time keeping. Recent theoretical work shows that there exists a connection between time measurement accuracy and thermodynamics [1]. These results suggest, that the minimum dissipated heat is bounded by the clock accuracy and vice versa.

To test this hypothesis in an experiment, we use laser-induced oscillation of a single Ca^+ ion in a Paul trap as a time keeping device. Simultaneous irradiation of cw laser beams red and blue detuned from an optical transition leads to a sustained oscillation at a secular trap frequency - an effect which has been coined 'phonon laser' [2]. We present ongoing measurements investigating the connection between the ion's total photon scattering rate, i.e. the dissipated heat, and the stability of the oscillation in order to test the universality of the connection between time measurements and thermodynamics.

[1] P. Erker et al., Phys. Rev. X 7, 031022 (2017)
[2] K. Vahala et al., Nature Physics 5.9, 682 (2009)

A 42.23 Thu 16:15 Zelt Ost

Optical Trap for an Ultracold 2D Fermi Gas — •Andreas Kell, Martin Link, Kuiyi Gao, and Michael Köhl — Physikalisches Institut, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany

Interacting atomic Fermi gases in two dimensions feature various interesting phenomena and have been the target of many experimental studies in this decade. Our experimental setup produces a large degenerate gas of fermionic lithium in the BEC-BCS crossover. It is upgraded with a new trap geometry, which strongly confines the atoms only along one direction. This leads to a very large aspect ratio required to enter the 2D regime with high atom number. For this purpose a highly elliptical focused blue-detuned beam with a TEM01-like mode profile is employed. The mode profile is generated by phase-shifting one half of the originally Gaussian beam with a phase plate.

A 43: Cold atoms VII - micromachines (joint session A/Q)

Time: Friday 10:30–11:50 Location: K 0.011

Group Report A 43.1 Fri 10:30 K 0.011

Thermodynamics of single-ion machines — •Ulrich Poschinger[1], David von Lindenfels[1], Oliver Gräb[1], Martin Wagener[1], Vidyut Kaushal[1], Jonas Schulz[1], Alexander Friedenberger[2], Eric Lutz[2], and Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Universität Mainz, D-55128 Mainz, Germany — [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

The thermodynamic behaviour of small machines, ultimately far from the thermodynamic limit, is currently attracting much interest. We present the realization of a single-ion 'heat engine' [1]. The working medium is the spin degree of freedom of a single $^{40}Ca^+$ ion, positioned in an optical standing optical wave[2], which couples the spin to the ion motion. The ion is subjected to alternating optical pumping pulses. This gives rise to an effective resonant force mediated by the standing wave, which leads to the onset of oscillations of the ion position, ranging from the motional ground state to some tens of motional quanta. We analyze the work fluctuations occuring while the thermal energy from the laser reservoirs is transferred to the ion motion, and quantify the extractable work.

We also present ongoing work on the experimental study of the performance of an autonomous single-ion 'wall-clock', which is, according to recent theoretical work[3], tied to its waste heat production.

[1] Rossnagel et al., Science **352**, 325 (2016)
[2] Schmiegelow et al., PRL **116**, 033002 (2016)
[3] Erker et al., PRX **7**, 031022 (2017)

A 43.2 Fri 10:50 K 0.011

Unifying paradigms of quantum refrigeration: how resource-control determines fundamental limits — •Fabien Clivaz[1], Ralph Silva[1], Géraldine Haack[1], Jonatan Bohr Brask[1], Nicolas Brunner[1], and Marcus Huber[2] — [1]Department of Applied Physics, University of Geneva, 1211 Geneva 4, Switzerland — [2]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria

In classical thermodynamics the work cost of control can typically be neglected. On the contrary, in quantum thermodynamics the cost of control constitutes a fundamental contribution to the total work cost. Evaluating this contribution is an important but non-trivial problem. Here, focusing on quantum refrigeration, we show how the level of control determines the fundamental limits to cooling. We compare coherent versus incoherent operations, and derive the minimal achievable temperature and associated work cost. We discuss both the single-shot and asymptotic regimes. Our work provides a unified picture of the different approaches to quantum refrigeration developed in the literature, including algorithmic cooling, autonomous quantum refrigerators, and the resource theory of quantum thermodynamics.

A 43.3 Fri 11:05 K 0.011

Is a Stern-Gerlach splitter possible with an ion beam? — •Carsten Henkel[1], Georg Jacob[2], Felix Stopp[2], Ferdinand Schmidt-Kaler[2], Yonathan Japha[3], Mark Keil[3], and Ron Folman[3] — [1]Universität Potsdam — [2]J. Gutenberg-Universität Mainz — [3]B Gurion University of the Negev, Beer Sheva

The Stern-Gerlach effect for free electrons has been discussed since the advent of quantum mechanics and was found to be challenging due to the uncertainty in the Lorentz force [1,2]. We propose realising a spin filter for a pulsed ion beam using the Stern-Gerlach force of a magnetic micro-grating. The field gradient is created by an array of wires integrated into a microchip. In distinction to the standard setup, both the spin and the magnetic field rotate along the beam path [3]. The Ca^+ ions are laser cooled and released from a Paul trap, giving a pulsed beam of approximately 1eV with high brightness and very narrow velocity distribution [4]. Due to the large ion/electron mass ratio, the Lorentz force does not prevent the spin splitting. It can even be put to use, in conjunction with a bias field, in order to balance the image charge interaction and to prevent the ions from crashing onto the chip surface. We discuss semiclassical techniques to simulate the ion trajectories and estimate the spin-dependent splitting of the beam.

[1] B. M. Garraway and S. Stenholm, Contemp. Phys. 43 (2002) 147
[2] H. Batelaan, Am. J. Phys. 70 (2002) 325
[3] E. Enga and M. Bloom, Can. J. Phys. 48 (1970) 2466
[4] G. Jacob & al, Phys. Rev. Lett. 117 (2016) 043001

A 43.4 Fri 11:20 K 0.011

Neural Network States: an alternative description of quantum many body states. — •Jose Nahuel Freitas and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

As is well known, an exponentially large amount of information is needed to describe general quantum states of quantum many body systems. Thus, in order to simulate quantum systems in classical computers, it is important to identify efficient descriptions of physically relevant states. Typical examples of such efficient descriptions are Matrix Product States (MPS), Projected Entangled Pairs States (PEPS) or, in general, Tensor Network States. These parametrizations of quantum states have been employed with high success to study both the ground state and dynamical properties of quantum lattice models in one and two dimensions. However, the amount and range of the quantum correlations (entanglement) that they can capture is severely limited. Recently, it was proposed to leverage the representational power of Neural Networks in order to describe many body quantum states[Science, 355(6325), 602-606]. The family thus obtained, called Neural Network States, seems to be a promising alternative to study systems that are not tractable with usual methods based on TNS. In this talk, we will describe and review the main properties of these states, possible generalizations, and discuss new techniques to manipulate them.

A 43.5 Fri 11:35 K 0.011

Probing quantum dynamical pair correlation functions — •Salvatore Castrignano and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The space-time correlations among particles in e.g. condensed matter systems can be experimentally studied via the so-called Time Domain Interferometry proposed in [1]. In particular the dynamical couple correlation function [2] can be obtained from the recorded interferogram. This scheme has sofar been theoretically studied and successfully tested for target systems whose dynamics can be safely described by classical mechanics.

With the growth of interest toward higly correlated quantum materials, the development of experimental techniques for measuring quantum dynamical correlations is getting more and more interest. In this project we then ask if extensions of the above interferometric setup are capable of accessing the quantum dynamical couple-correlation function of a quantum target. The classical and quantum correlations have different properties and through a theoretical analysis of the setup in a full quantum framework it is shown that these differences are experimentally accessible. Moreover, using elements of measurement theory in classical and quantum frameworks [3], we give a heuristic criterion to understand when to expect quantum or classical behaviour of generic correlation functions.

[1] A. Q. R. Baron et al., Phys. Rev. Lett. 79, 2823 (1997)
[2] L. Van Hove, Phys. Rev. 95, 249 (1954)
[3] P. Uhrich et al., Phys. Rev. A 96, 022127 (2017)

A 44: Precision Spectrosocopy VII (nuclear systems) (joint session A/Q)

Time: Friday 10:30–12:30 Location: K 1.016

A 44.1 Fri 10:30 K 1.016

A direct nuclear laser excitation scheme for ^{229m}Th — •Lars von der Wense[1], Benedict Seiferle[1], Simon Stellmer[2], Johannes Weitenberg[3], Georgy Kazakov[2], Adriana Pálffy[4], and Peter G. Thirolf[1] — [1]Ludwig-Maximilians-Universität München, 85748 Garching, Germany — [2]Technische Universität Wien, 1040 Vienna, Austria — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [4]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

Direct nuclear laser excitation has been a long-standing goal. By today there is only one nuclear excitation known which would allow for direct laser excitation due to its exceptionally low energy of only a few eV above the ground state. This is the metastable first excited state in ^{229}Th. While direct nuclear laser excitation of ^{229}Th ions in a Paul trap is still hindered by insufficient knowledge of the exact isomeric energy value, here a new laser excitation scheme for neutral ^{229}Th atoms on a surface will be presented [1]. This excitation scheme circumvents the requirement of an improved knowlede of the isomeric energy, thereby paving the way for nuclear laser spectroscopy of ^{229m}Th. It is making use of the recently detected internal conversion decay channel of the isomeric state [2] in combination with a short isomeric lifetime [3].

[1] L. v.d.Wense et al., PRL 119, 132503 (2017).
[2] L. v.d.Wense et al., Nature 533, 47-51 (2016).
[3] B. Seiferle et al., PRL 118, 042501 (2017).

Supp. by DFG (TH956/3-2) and Horizon 2020 (664732 "nuClock").

A 44.2 Fri 10:45 K 1.016

Towards a precise energy determination of the ^{229}Th nuclear clock transition — •Benedict Seiferle, Lars v.d. Wense, and Peter G. Thirolf — LMU München, Am Coulombwall 1, 85748 Garching

The first isomeric excited nuclear state of ^{229}Th (denoted with ^{229m}Th) exhibits the lowest transition energy in nuclear physics which has been measured indirectly to be 7.8(5) eV. The uniquely low transition energy which corresponds to a wavelength of approximately 160 nm makes it possible to drive the transition with lasers. This in turn may pave the way for a long list of interesting applications (such as a nuclear optical clock) which has so far been hindered by the rather large uncertainty in the reported energy value. In this talk an experimental scheme is presented that uses internal conversion electrons which are emitted in the ground-state decay of ^{229m}Th [1,2] and first results are shown. With these measurements a precise and direct determination of the excitation energy is in reach.

[1] L. v.d. Wense et al., Nature 533, 47-51 (2016).
[2] B. Seiferle et al., PRL 118, 042501 (2017).

This work was supported by the European Union's Horizon 2020 research and innovation programme under grant agreement 664732 "nuClock" & by DFG Grant No. Th956/3-2.

A 44.3 Fri 11:00 K 1.016

Laser spectroscopic characterization of the nuclear clock isomer ^{229m}Th — •Johannes Thielking[1], Maksim V. Okhapkin[1], Przemysław Głowacki[1], David-Marcel Meier[1], Lars von der Wense[2], Benedict Seiferle[2], Christoph E. Düllmann[3,4,5], Peter G. Thirolf[2], and Ekkehard Peik[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Ludwig-Maximilians-Universität München, 85748 Garching, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [4]Helmholtz-Institut Mainz, 55099 Mainz, Germany — [5]Johannes Gutenberg-Universität, 55099 Mainz, Germany

The thorium-229 nucleus possesses a unique first excited state at an energy of only about 7.8 eV, coupled to the ground state by a transition with a natural linewidth in the mHz range. This transition can be used as a reference for an optical clock that is highly immune to field-induced frequency shifts and as a sensitive probe of temporal variations of fundamental constants. Despite many experimental efforts, fundamental properties of the isomer were still unknown. In this presentation we report on the first measurement of the nuclear moments and the mean square charge radius of the isomer [1]. This was achieved via high-resolution spectroscopy of the hyperfine structure of trapped $^{229}Th^{2+}$ ions using two-step laser excitation. Our results yield a key feature in the ongoing experimental search for the direct optical excitation of the nuclear transition, as well as the future nuclear clock operation.

[1] J. Thielking et al., arXiv preprint arXiv:1709.05325 (2017).

A 44.4 Fri 11:15 K 1.016

Hyperfine structure and isomeric shifts in $^{229}Th^{2+}$ — •Robert A. Müller[1,2], Andrey V. Volotka[3], Stephan Fritzsche[2,4], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Technische Universität Braunschweig, Germany — [3]Helmholtz-Institute Jena, Germany — [4]Friedrich-Schiller-Universität Jena, Germany

In the past decade systems that are sensitive to possible time variations of α attracted much interest [1]. Besides the comparison of two atomic clocks, nuclear transitions could be used for the search of such variations. The isotope ^{229}Th is a particularly suitable candidate, because of its low lying isomeric state ^{229m}Th which is accessible to optical lasers. The sensitivity of the ^{229}Th→^{229m}Th transition to variations of α has been only estimated so far [2]. For a more accurate determination of this sensitivity and for the analysis of related experiments precise knowledge about the nuclear moments, as well as the isomeric shift of electronic levels is needed. In this contribution we will, therefore, discuss highly accurate calculations for the hyperfine structure of the $^{229}Th^{2+}$ ion. We used these results to precisely determine the nuclear moments of the nuclear isomer ^{229m}Th. Moreover we calculated the isomeric shift of electronic levels in Th^{2+}. All calculations have been performed using the multi-configurational Dirac-Fock method as well as a combination of configuration interaction and many-body perturbation theory.

[1] J. K. Webb *et al.*, Phys. Rev. Lett. **87**, 091301 (2001)
[2] V. V. Flambaum, Phys. Rev. Lett. **97**, 092502 (2006)

A 44.5 Fri 11:30 K 1.016

Towards coherent control of the ^{229}Th isomeric transition in VUV-transparent crystals — •Brenden Nickerson and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Current efforts in the development of a nuclear frequency standard based on the isomeric state of ^{229m}Th at approx. 7.8 eV have been centered around precisely determining its energy. The unique lowest transition in the ^{229}Th nucleus with frequency in the vacuum ultraviolet (VUV) range and very narrow linewidth promises enhanced precision and amazing stability [1]. A very exact measurement of the isomeric transition energy has been elusive, with the first confirmation of the level decay coming only recently [2].

Here, we investigate collective effects that may allow for coherent control of the isomeric transition in $^{229}Th:CaF_2$ VUV-transparent crystals. The collectively enhancement scattering in forward direction is considered [3]. Starting from this setup, we investigate the effect of pulsed lasers, coincident pulses, different pulse phases and of magnetic fields for the intensity spectrum. By taking advantage of such effects we aim to design a more sensitive nuclear excitation scheme to resolve not only the transition energy but provide a clear signature of the excitation.

[1] W. G. Rellergert *et al.*, Phys. Rev. Lett. 104, 200802 (2010).
[2] L. von der Wense *et al.*, Nature 533, 47-51 (2016).
[3] W.-T. Liao *et al.*, Phys. Rev. Lett. 109, 262502 (2012).

A 44.6 Fri 11:45 K 1.016

Laser spectroscopy of the heaviest actinides — •S. Raeder[1,2], D. Ackermann[2,3], H. Backe[4], M. Block[1,2,4], B. Cheal[6], P. Chhetri[2,5], C. E. Düllmann[1,2,4], M. Eibach[2,7], J. Even[8], R. Ferrer[9], F. Giacoppo[1,2], S. Götz[1,2,4], F.P. Hessberger[2,5], O. Kaleja[2,4,10], J. Khuyagbaatar[1,2], P. Kunz[11], M. Laatiaoui[9], F. Lautenschläger[2,5], W. Lauth[4], L. Lens[2,4], N. Lecesne[3], A. K. Mistry[1,2], E. Minaya Ramirez[12], Th. Walther[5], A. Yakushev[1,2], and Z. Zhang[13] — [1]Helmholtz-Institut Mainz — [2]GSI — [3]GANIL — [4]JGU Mainz — [5]TU Darmstadt — [6]Uni of Liverpool — [7]Universität Greifswald — [8]KVI-CART, Uni of Groningen — [9]KU-Leuven — [10]MPIK — [11]TRIUMF — [12]IPNO — [13]IMP Lanzhou

Laser spectroscopy of transfermium elements with $Z>100$ probes the influence of electron correlation, relativistic and QED effects on the atomic shell structure. These studies are hampered by low production rates and the fact that atomic information is initially available only from theoretical predictions. Applying the sensitive Radiation Detected Resonance Ionization Spectroscopy technique at the SHIP velocity filter in GSI, optical transitions in the element nobelium (Z=102) were detected for the first time. Besides the characterization of a strong optical ground-state transition in the isotopes ^{252,253,254}No, Rydberg states were measured enabling the extraction of the first ionization potential of nobelium with a high precision. These results will be discussed as well as the prospects for future investigations involving the study of additional nobelium isotopes and the exploration of the atomic structure of the next heavier element, lawrencium (Z=103).

A 44.7 Fri 12:00 K 1.016

Development of an Ion Mobility Spectrometer for Mobility Measurement of Actinides — •E. Rickert[1,3], H. Backe[3], M. Block[1,2,3], Ch. E. Düllmann[1,2,3], T. Kron[1,2], M. Laatiaoui[1,2,4], W. Lauth[3], S. Lohse[1], F. Schneider[1,3], and S. Raeder[1,2] — [1]Helmholtz-Institut Mainz — [2]GSI — [3]JGU Mainz — [4]KU Leuven

Ion mobility measurements are a powerful tool to investigate ion-atom interaction potentials. Their sensitivity to the electronic configuration has been demonstrated for many elements across the periodic table. Especially for heavy elements, the impact of relativistic effects on the electron configuration may lead to deviations in the periodicity, hence to distinct ion mobilities [Laatiaoui2012] as recently proven in the lanthanide region. A conceptual design for an ion mobility spectrometer is being developed to enable systematic ion mobility spectrometry also across the actinide series. Actinide ions will be created via a two-step photoionization in argon gas. This will allow an element-selective detection. In the talk, the current status and future plans are presented.

[Laatiaoui2012]:Laatiaoui, M. et al., EPJD (2012) 66:232

A 44.8 Fri 12:15 K 1.016

Desorption enthalpy studies of the heaviest actinides for laser spectroscopic investigations — •T. Murböck[1], D. Ackermann[1,2], H. Backe[3], M. Block[1,3,4], B. Cheal[5], P. Chhetri[1,6], Ch. E. Düllmann[1,3,4], M. Eibach[1,7], J. Even[8], R. Ferrer[9], F. Giacoppo[1,4], S. Götz[1,3,4], F.P. Hessberger[1,4], O. Kaleja[1,3,10], J. Khuyagbaatar[1,4], P. Kunz[11], M. Laatiaoui[1,4], F. Lautenschläger[1,6], W. Lauth[3], L. Lens[1,3], N. Lecesne[2], A. K. Mistry[1,4], E. Minaya Ramirez[12], S. Raeder[4], P. Van Duppen[9], Th. Walther[6], A. Yakushev[1,4], and Z. Zhang[13] — [1]GSI — [2]GANIL — [3]Universität Mainz — [4]HI Mainz — [5]University of Liverpool — [6]TU Darmstadt — [7]Universität Greifswald — [8]KVI-CART, University of Groningen — [9]KU-Leuven — [10]MPIK — [11]TRIUMF — [12]IPN Orsay — [13]IMP Lanzhou

To probe the atomic shell structure of the heaviest actinides with Z>100, the Radiation Detected Resonance Ionization Spectroscopy (RADRIS) technique is applied at SHIP at GSI. After production in high-energy fusion-evaporation reactions the recoil ions are stopped in a buffer-gas cell and collected onto a filament. Subsequent thermal evaporation as neutral atoms allows to probe the atomic structure using laser spectroscopy. The desorption enthalphy of these elements crucially determines the efficiency of the evaporation and the RADRIS method. In this talk, evaporation of nobelium (Z=102) and lawrencium (Z=103) from tantalum is revisited. Prospects for desorption studies from a larger variety of surfaces to extend laser-spectroscopic investigations to heavier elements will be discussed.

A 45: Ultracold Atoms II (joint session Q/A)

Time: Friday 10:30–12:30 Location: K 1.022

A 45.1 Fri 10:30 K 1.022

Quantum optimal control for fast atom transport in an optical lattice — •Manolo Rivera[1], Thorsten Groh[1], Natalie Thau[1], Carsten Robens[1], Wolfgang Alt[1], Dieter Meschede[1], Antonio Negretti[2], Tommaso Calarco[3], Simone Montagero[3], and Andrea Alberti[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany — [3]Institut für komplexe Quantensysteme, Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany

We realize fast atom transport in a polarization-synthesized state-dependent optical lattice reaching transport times down to the harmonic oscillator period of around $20\mu s$ over one lattice site ($\approx 0.5\mu m$). Atom transport at such durations reaches the quantum speed limit that we have obtained from numerical simulations of the Schrödinger equation. The transport operations are computed using optimal control theory and reach high fidelities, meaning that the atoms prepared in the ground state remain there after the transport. This is experimentally confirmed by measuring the excitation spectrum of the transported atoms by means of microwave sideband spectroscopy. The current experiment is based on an open-loop approach where the transport operations are theoretically computed. A closed-loop approach using the optimization algorithm directly in the experimental sequence allows us to further improve the fidelity of the optimal control transport operations.

A 45.2 Fri 10:45 K 1.022

Tuning the Scattering Length by Periodic Modulation —

•Christoph Dauer, Axel Pelster, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, Technical University of Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

We consider the scattering problem of two ultracold particles with a small time-periodic modulation of the attractive potential, which can be achieved by using a Feshbach resonance. The steady state is described by the Floquet formalism, which leads to a recurrence formula for an effective scattering length a_{eff}. For frequencies corresponding to the bound-state of the potential without driving, we observe strong resonances, which allow the tuning to very large positive and negative values of a_{eff} with relatively small imaginary parts.

A 45.3 Fri 11:00 K 1.022

A two-species five-beam magneto-optical trap for highly magnetic Er and Dy atoms — •Arno Trautmann[1], Philipp Ilzhöfer[1,2], Gianmaria Durastante[1,2], Alexander Patscheider[1,2], Manfred Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Austria — [2]Institut für Experimentalphysik und Zentrum für Quantenoptik, Universität Innsbruck, Austria

We report on the first realization of a two-species magneto-optical trap (MOT) for erbium and dysprosium. The MOT operates on an intercombination line for the respective species. Owing to the narrow-line character of such a cooling transition and the action of gravity, we demonstrate a novel trap geometry employing only five beams in orthogonal configuration. We observe that the mixture is cooled and trapped very efficiently, with up to 5×10^8 Er atoms and 10^9 Dy atoms at temperatures of about $10\,\mu$K. Our results offer an ideal starting condition for the creation of a dipolar quantum mixture of highly magnetic atoms.

A 45.4 Fri 11:15 K 1.022

Few bosons in a double well — •Frank Schäfer[1], Miguel Bastarrachea[1], Axel U. J. Lode[2,3], Laurent de Forges de Parny[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [2]Wolfgang Pauli Institute c/o Faculty of Mathematics, University of Vienna, Oskar-Morgenstern Platz 1, 1090 Vienna, Austria — [3]Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

We investigate the spectral and dynamical properties of interacting bosons in a double well. A combination of exact diagonalization with a multi-configurational time-dependent Hartree approach allows us to analyse the time evolution of two- and three- particle states for variable initial conditions, and furthermore subject to (a-)diabatic switching of the tunnelling barrier. We discuss first results for the particles initially prepared at the ground state or at the saddle-point energy, and contrast single- vs. many-particle aspects of the dynamics.

A 45.5 Fri 11:30 K 1.022

Diffusion of Ultracold Atoms Coupled to tailored Bath — •Daniel Adam, Tobias Lausch, Daniel Mayer, Felix Schmidt, Quentin Bouton, and Artur Widera — TU Kaiserslautern, Department of Physics, Kaiserslautern, Germany

Diffusion is an essential phenomenon in nature, occurring in various systems from biological cells to traffic models. Ultracold atoms are ideal model systems to go beyond the mere observation of single particle diffusion, and to engineer the surrounding baths by external fields.

Here, we consider the diffusion of single neutral atoms trapped in a periodic potential and coupled to a near-resonant light field forming the bath. This bath defines both fluctuations as well as the diffusion coefficient via the laser cooling properties of the optical molasses. The diffusion coefficient significantly determines the dynamics of a diffusing tracer, thus its knowledge is of central importance to understand the fundamental diffusion. I will present a method to measure the diffusion coefficient directly with single Cs-atoms confined in a harmonic potential. This method is similar to the method of tethered particle motion known for the observation of DNA dynamics.

Precise knowledge of the diffusion coefficient as a function of external experimental parameters opens the route for quantitative measurements of diffusion in complex potential landscapes or non-equilibrium situations.

A 45.6 Fri 11:45 K 1.022

Revealing Quantum Statistics with a Pair of Distant Atoms — Christian Roos[1], •Andrea Alberti[2], Dieter Meschede[2], Philipp Hauke[3], and Hartmut Häffner[4] — [1]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Austria — [2]Institut für Angewandte Physik der Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany — [3]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 21a, 6020 Innsbruck, Austria — [4]Department of Physics, University of California, Berkeley, California 94720, USA

Quantum statistics have a profound impact on the properties of systems composed of identical particles. At the most elementary level, Bose and Fermi quantum statistics differ in the exchange phase, either 0 or π, which the wave function acquires when two identical particles are exchanged. I will report on a scheme to directly probe the exchange phase with a pair of massive particles by physically exchanging their positions [1]. I present two protocols realizing this scheme where the particles always remain spatially well separated, thus ensuring that the exchange contribution to their interaction energy is negligible and that the detected signal can only be attributed to the exchange symmetry of the wave function. Finally, I discuss possible implementations using a pair of atoms confined in polarization-synthesized optical lattices or trapped ions forming a one-dimensional quantum rotor.

[1] C. F. Roos, A. Alberti, D. Meschede, P. Hauke, and H. Häffner, Phys. Rev. Lett. **119**, 160401 (2017).

A 45.7 Fri 12:00 K 1.022

Signatures of indistinguishability in bosonic many-body dynamics — •Tobias Brünner[1], Gabriel Dufour[1,2], Alberto Rodriguez[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität-Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [2]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität-Freiburg, Albertstraße 19, D-79104 Freiburg, Germany

Many-body interference occurs as a fundamental process during the evolution of a quantum system consisting of two or more indistinguishable particles. The (measurable) consequences of this interference, as a function of the particles' mutual indistinguishability, was studied for non-interacting photons transmitted through beam-splitter arrays. However, the role of many-body interference in the dynamics of interacting particles, e.g. cold atoms in optical lattices, had so far remained unclear. We identify a quantifier of the particles' mutual indistinguishability attuned to time-continuously evolving systems of (interacting) particles, which predicts the dynamical behaviour of observables influenced by genuine few-body interference. Our measure allows a systematic exploration of the role of many-body interference in the non-, weakly, and strongly interacting regimes.

A 45.8 Fri 12:15 K 1.022

Survival probability of coherent states in regular regimes — •Miguel A. Bastarrachea-Magnani[1], Sergio A. Lerma-Hernández[2], Jorge Chávez-Carlos[3], Lea F. Santos[4], and Jorge G. Hirsch[3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany — [2]Facultad de Física, Universidad Veracruzana, Xalapa, México — [3]Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, México — [4]Department of Physics, Yeshiva University, New York, USA

We study the behavior of coherent states under unitary quantum dynamics in systems with one and two degrees of freedom. To this end, we employ the Dicke Hamiltonian, a paradigmatic model of quantum optics. Within the regular regime of the spectrum, the distribution of the coherent states in the eigenstate basis consists of quasi-harmonic sub-sequences of energies with gaussian weights. This allows to derive analytical expressions for the survival probability of the coherent states. The analytical expressions describe the time evolution in agreement with numerical results up to the decay of the survival probability oscillations. We explore how this decay rate is related to the anharmonicity of the spectrum, and, for the chaotic regime of the Dicke model, to interference terms due to the contributions of different subsequences of eigenstates to the coherent states. Moreover, we correlate the dynamics of the coherent states with the classical limit of the model, to elucidate how these interference terms are related to the onset of chaos in the spectrum. Since most bounded Hamiltonians have a regular regime at low energies, the approach has broad applicability.

A 46: Precision Measurements and Metrology (Optical Clocks) (joint session Q/A)

Time: Friday 10:30–12:15 Location: K 2.013

A 46.1 Fri 10:30 K 2.013

Precision Paul trap for frequency metrology with Coulomb crystals — •André P. Kulosa, Dimitri Kalincev, Jan Kiethe, Tabea Nordmann, Nimrod Hausser, Chih-Han Yeh, Alexandre Didier, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Deutschland

We report on our new scalable precision ion trap capable of trapping Coulomb crystals with 100 ions and more in each of the trap segments. We demonstrate that the excellent control of 3D excess micromotion over a single ion [1] also holds for a linear chain of 14 ions via spatial imaging with atomic resolution. We find that in a trap segment of our ion trap the time dilation shift due to axial micromotion is as low as 10^{-19} over a range of 400μm and below 10^{-18} within 2mm. After quench-assisted cooling of a single $^{172}Yb^+$ ion to its motional ground state, we observe a heating rate of less than 1 phonon/s and in total a $1/f$ dependence on electric field noise induced by fluctuating charges on the trap electrodes. Based on further experimental investigations of the trap environment, we derive an uncertainty budget close to 1×10^{-19} for a multi-ion clock operated with mixed In^+/Yb^+ crystals.

[1] J. Keller et al., *J. Appl. Phys.* **118**, 104501 (2015)

A 46.2 Fri 10:45 K 2.013

^{24}Mg optical lattice clock — •Nandan Jha, Dominika Fim, Klaus Zipfel, Steffen Rühmann, Steffen Sauer, Waldemar Friesen-Piepenbrink, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Magnesium is a promising candidate for an optical lattice clock due to its low black body radiation sensitivity. In our previous measurements, the tunneling induced broadening for the bosonic ^{24}Mg in shallow lattices had limited the linewidth of the clock transition to kHz scale [1]. We have improved upon these measurements by increasing the intra-cavity optical lattice power to perform spectroscopy in a $50\,E_r$ deep lattice. Reduced tunneling along with improved detection efficiency further allowed us to operate at lower excitation fields to achieve a linewidth below 50 Hz. With the reduced linewidth, we have performed our first systematic shift measurements with an overall error budget in the 10^{-15} regime. The fiber link setup by the group of G. Grosche between IQ, Hannover and PTB, Braunschweig [2] allowed us to compare the Mg lattice clock against the frequency references at PTB. In this contribution, we discuss our systematic shift measurements, as well as our efforts towards further improving the line-Q factor of the clock transition.

[1] A. Kulosa et al., Phys. Rev. Lett. **115**, 240801 (2015).
[2] G. Grosche, Opt. Lett. **39**, 2545 (2014).

A 46.3 Fri 11:00 K 2.013

An iodine frequency reference based on an ECDL at 1064 nm for a sounding rocket mission. — •Franz Balthasar Gutsch[1], Klaus Döringshoff[1], Vladimir Schkolnik[1,2], Markus Krutzik[1,2], Achim Peters[1,2], and Team JOKARUS[1,2,3,4,5] — [1]Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut, Berlin — [3]ZARM, Uni Bremen — [4]Johannes Gutenberg-Universität Mainz — [5]Menlo Systems GmbH, Martinsried

Within the JOKARUS collaboration, we built a autonomously operating, active optical absolute frequency reference at 1064 nm based on molecular iodine that is scheduled for launch on a sounding rocket (TEXUS 54) in April 2018. Laser-based frequency references with high accuracy and stability are needed for space missions dedicated to precision tests of fundamental physics, Earth observation, navigation or gravitational wave astronomy. Frequency stabilization to the narrow, sub-MHz hyperfine transitions of the iodine R(56)32-0 line provides the means to fulfill the requirements of planned missions like LISA or NGGM. Our system relies on modulation transfer spectroscopy of iodine gas at 532 nm, using a frequency-doubled, micro-integrated, narrow-linewidth ECDL MOPA. In order to verify the lock stability, there will be an in-flight comparison to an RF-clock-referenced frequency comb. In this talk, we report on the system design, performance and results of environmental testing. Further, we present the auto-lock as well as our approach to experiment control. This work is supported by the DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant number DLR 50WM 1646.

A 46.4 Fri 11:15 K 2.013

Characterisation of a Reference Cavity for a Transportable Sr Optical Clock. — •Sofia Herbers, Sebastian Häfner, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Ultra-stable high-finesse cavities are used, inter alia, in interrogation lasers of optical clocks, that are employed for relativistic geodesy or test of fundamental physics.

One limiting factor of ultra-stable high-finesse cavities is the Brownian noise of the mirror coatings. This noise is reduced for state-of-the-art cavities by using single-crystalline mirror coatings. Furthermore, the cavity needs to be isolated from environmental conditions like seismic noise or temperature fluctuations that result in a length change of the cavity. Therefore, special mounts have to be employed to decouple the cavity from seismic noise. However, for a transportable cavity, most of these approaches like a soft and loose mounting are not suitable. Thus, other solutions must be found that do not degrade the cavity performance.

Here, we present the characteristics of a transportable 20 cm long reference resonator for a transportable Sr lattice clock heading for a fractional frequency instability of $1 \cdot 10^{-16}$ using single-crystalline mirrors with a finesse up to 300 000 as well as a rigid cavity mounting.

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A 46.5 Fri 11:30 K 2.013

Possibility of laser stabilization with trapped cavity-coupled ions — •Georgy Kazakov[1,2] and Thorsten Schumm[1] — [1]Technische Universität Wien — [2]Wolfgang Pauli Institut

The concept of an active optical frequency standards was proposed about 10 years ago [1,2]. The idea is to use optically trapped alkaline-earth atoms as a gain medium to built an extremely narrow-line laser, whose frequency will be robust to fluctuations of the cavity length. The main challenge towards the realization of this concept is the short trap lifetime of the atoms. Recently we showed [3], that in such a laser, neutral atoms may be replaced by charged ions in a radio-frequency Paul trap with much longer lifetime. Our idea is based on the effect of syncronization of radiating dipoles and on the possibility to compensate (in leading orders) micromotion-induced shifts for some ion species in specially designed traps. We discuss in detail the perspectives of creating of the bad cavity laser based on a Coulomb crystal in the linear Paul trap. We consider compensation of the micromotion-induced shifts, coupling of the quadrupole transition with the cavity mode in different geometries, various ion species and clock transitions as well as pumping schemes, and estimate attainable characteristics of different trapped-ion bad-cavity lasers.

[1] J. Chen, X. Chen, Proceedings of the 2005 IEEE Int. Freq. Cont. Symp. Exp. 608 (2005) [2] D. Meiser et al, Phys. Rev. Lett. 102, 163601 (2009) [3] G. Kazakov et al, Phys. Rev. A 96, 023412 (2017)

A 46.6 Fri 11:45 K 2.013

QUEEN: Design Study for Optical Frequency References on Small Satellites — •Aline N. Dinkelaker[1], Heike Christopher[2], Doreen Brandt[2], Philipp Werner[3], Julian Bartholomäus[3], Merlin F. Barschke[3], and Markus Krutzik[1] — [1]Humboldt-Universität zu Berlin — [2]FBH Berlin — [3]TU Berlin

Optical frequency references are key to fundamental physics experiments involving cold atoms or optical atomic clocks. For future experiments in space, the frequency references have to be compact and robust in order to meet the size, weight and power (SWaP) requirements while providing the experiments with frequency stabilized light of sufficient optical output power. In the Phase 0/A study QUEEN, a mission for the demonstration of optical frequency references is investigated. Small satellites are ideally suited for in-orbit demonstration as they allow rapid, iterative mission development. For QUEEN, the modular, flight-proven TUBiX20 platform by TU Berlin will be adjusted to match the payload's requirements. We examine the use of a micro-integrated, frequency-stabilized semiconductor diode laser system by HU Berlin and FBH for in-orbit demonstration of an optical frequency

reference and present possible mission scenarios. Long-term tests in orbit –specifically with respect to thermal variation and exposure to radiation– thus complement existing experiments in drop towers and on sounding rockets.

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A 46.7 Fri 12:00 K 2.013

Laser-induced electronic bridge for characterization of the ^{229m}Th isomer transition with a tunable optical laser — •Pavlo Bilous[1], Ekkehard Peik[2], and Adriana Pálffy[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

The isotope ^{229}Th is unique among the other nuclei due to its long-lived first excited state ^{229m}Th at the energy of 7.8 eV lying in the optical range. Its decay to the ground state has very narrow width and high stability to external fields, rendering ^{229}Th a candidate for a first nuclear clock at unprecedentedly high relative accuracy of 10^{-19}. Precise knowledge of the transition parameters such as energy and γ-decay rate is however needed for its implementation.

Due to the low energy of the state ^{229m}Th the nuclear transition can be strongly coupled to the atomic shell processes with considerable enhancement of the nuclear decay rate. An example of such processes is laser-induced electronic bridge (LIEB) [1]. The excited nuclear state decays by transfering its energy to the outer electrons. The electronic shell is then promoted to a high-lying bound state by absorption of a laser photon and a virtual photon coming from the nucleus. Here we investigate theoretically LIEB as a means for precise determination of the ^{229m}Th energy and γ-decay rate. Depending on the actual value of the nuclear transition energy, the enhancement factor compared to the radiative nuclear decay can achieve up to 10^8 [1].

[1] P. V, Bilous, E. Peik and A. Pálffy, New J. Phys. in press (2017)