Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture halls H1; Poster P)

Invited Talks

A 1.1	Mon	10:45–11:15	H1	**Time-resolved X-ray Imaging of Anisotropic Nanoplasma Expansion** — •Christian Peltz, Christoph Bostedt, Mathias Kling, Thomas Brabec, Eckart Ruehl, Artem Rudenko, Tais Gorkhover, Thomas Fennel
A 1.2	Mon	11:15–11:45	H1	**Scattering of twisted x-rays from a crystal** — •Anton Peshkov, Stephan Fritzsche, Andrey Surzhykov
A 3.1	Tue	10:45–11:15	H1	**Probing electronic wavefunctions and chiral structure using all-optical attosecond interferometry** — •Michael Krüger, Doron Azoury, Omer Kneller, Shaked Rozen, Barry D. Bruner, Alex Clergerie, Bernard Pons, Baptiste Fabre, Yann Mairesse, Oren Cohen, Olga Smirnova, Nirit Dudovich
A 3.2	Tue	11:15–11:45	H1	**Highly nonlinear ionization of atoms induced by intense HHG pulses** — Björn Senfftleben, Martin Kretschmar, Andreas Hoffmann, Mario Sauppe, Johannes Tümmler, Ingo Will, Tamás Nagy, Marc J. J. Vrakking, Daniela Rupp, •Bernd Schütte
A 3.3	Tue	11:45–12:15	H1	**Towards fast adaptive resonant x-ray optics** — Miriam Gerharz, •Jörg Evers
A 3.4	Tue	12:15–12:45	H1	**Control of complex Fano resonances by shaped laser pulses** — Camilo Granados, Nicola Mayer, Evgenii Ikonnikov, Misha Ivanov, •Oleg Kornilov
A 4.1	Tue	14:00–14:30	H1	**Reducing their complexity and miniaturise BEC interferometers** — •Waldemar Herr, Hendrik Heine, Alexander Kassner, Christoph Künzler, Marc C. Wurz, Ernst M. Rasel
A 4.2	Tue	14:30–15:00	H1	**Dynamics of a mobile hole in a Hubbard antiferromagnet** — •Martin Lebrat, Geoffrey Ji, Muqing Xu, Lev Haldar Kendrick, Christie S. Chiu, Justus C. Brüggenjürgen, Daniel Greif, Annabelle Bohrdt, Fabian Grusdt, Eugene Demler, Markus Greiner
A 4.3	Tue	15:00–15:30	H1	**Interaction-induced lattices for bound states: Designing flat bands, quantized pumps and higher-order topological insulators for doublons** — •Grazia Salerno, Giandomenico Palumbo, Nathan Goldman, Marco Di Liberto
A 14.1	Wed	10:45–11:15	H1	**Improving the scaling in many-electron quantum dynamics simulations** — •Michael Bonitz, Niclas Schlünzen, Jan-Philip Joost, Iva Brezinova
A 14.2	Wed	11:15–11:45	H1	**Imaging anisotropic dynamics in superfluid helium nanodroplets** — •B. Langbehn, K. Sander, Y. Ovcharenko, C. Peltz, A. Clark, M. Coreno, R. Cucini, A. Demidovich, M. Drabbels, P. Finetti, M. Di Fraia, L. Giannessi, C. Grazioli, D. Iablonskyi, A. C. LaForge, T. Nishiyama, V. Oliver Álvarez de Lara, P. Piseri, O. Plekan, K. Ueda, J. Zimmermann, K. C. Prince, F. Stienkemeier, C. Callegari, T. Fennel, D. Rupp, T. Möller
A 14.3	Wed	11:45–12:15	H1	**Fragmentation of HeH^+ in strong laser fields** — •Florian Oppermann, Philipp Wustelt, Saurabh Mhatre, Stefanie Gräfe, Gerhard G. Paulus, Manfred Lein

A 15.1	Wed	14:00–14:30	H1	**Laser spectroscopy of the heaviest actinides** — •Premaditya Chhetri, Dieter Ackermann, Hartmut Backe, Michael Block, Bradley Cheal, Christoph Emanuel Düllmann, Julia Even, Rafael Ferrer, Francesca Giacoppo, Stefan Götz, Fritz Peter Hessberger, Mark Huyse, Oliver Kaleja, Jadambaa Khuyagbaatar, Peter Kunz, Mustapha Laatiaoui, Werner Lauth, Lotte Lens, Enrique Minaya Ramirez, Andrew Mistry, Tobias Murböck, Sebastian Raeder, Fabian Schnieder, Piet Van Duppen, Thomas Walther, Alexander Yakushev
A 15.2	Wed	14:30–15:00	H1	**Status update of the muonic hydrogen ground-state hyperfine splitting experiment** — •A. Ouf, R. Pohl on behalf of the CREMA collaboration
A 15.3	Wed	15:00–15:30	H1	**Coupled ions in a Penning trap for ultra-precise *g*-factor differences** — •Tim Sailer, Vincent Debierre, Zoltán Harman, Fabian Heisse, Charlotte König, Jonathan Morgner, Bingsheng Tu, Andrey Volotka, Christoph H. Keitel, Klaus Blaum, Sven Sturm
A 15.4	Wed	15:30–16:00	H1	**Unraveling the mechanisms of single- and multiple-electron removal in energetic electron-ion collisions: from few-electron ions to extreme atomic systems.** — •Alexander Borovik Jr
A 17.1	Thu	10:45–11:15	H1	**BECCAL - Quantum Gases on the ISS** — •Lisa Wörner, Christian Schubert, Jens Grosse, Claus Braxmaier, Ernst Rasel, Wolfgang Schleich, the BECCAL collaboration
A 17.2	Thu	11:15–11:45	H1	**Ultracold polar ^{23}Na^{39}K ground-state molecules** — •Kai Konrad Voges, Philipp Gersema, Mara Meyer zum Alten Borgloh, Torsten Hartmann, Torben Alexander Schulze, Leon Karpa, Alessandro Zenesini, Silke Ospelkaus
A 17.3	Thu	11:45–12:15	H1	**Anderson localization in a Rydberg composite** — •Matthew Eiles, Alexander Eisfeld, Jan-Michael Rost

Invited talks of the joint symposium Trends in atom interferometry (SYAI)

See SYAI for the full program of the symposium.

SYAI 1.1	Mon	14:00–14:30	Audimax	**Atom interferometry and its applications for gravity sensing** — •Franck Pereira dos Santos, Luc Absil, Yann Balland, Sébastien Merlet, Maxime Pesche, Raphaël Piccon, Sumit Sarkar
SYAI 1.2	Mon	14:30–15:00	Audimax	**Atom interferometry for advanced geodesy and gravitational wave observation** — •Philippe Bouyer
SYAI 1.3	Mon	15:00–15:30	Audimax	**3D printing methods for portable quantum technologies** — •Lucia Hackermüller
SYAI 1.4	Mon	15:30–16:00	Audimax	**Fundamental physics with atom interferometry** — •PAUL HAMILTON

Invited talks of the joint symposium SAMOP Dissertation Prize 2021 (SYAD)

See SYAD for the full program of the symposium.

SYAD 1.1	Tue	10:45–11:15	Audimax	**Attosecond-fast electron dynamics in graphene and graphene-based interfaces** — •Christian Heide
SYAD 1.2	Tue	11:15–11:45	Audimax	**About the interference of many particles** — •Christoph Dittel
SYAD 1.3	Tue	11:45–12:15	Audimax	**Supersolid Arrays of Dipolar Quantum Droplets** — •Fabian Böttcher
SYAD 1.4	Tue	12:15–12:45	Audimax	**Quantum Logic Spectroscopy of Highly Charged Ions** — •Peter Micke

Invited talks of the joint symposium The state of the art in actinide research (SYAR)

See SYAR for the full program of the symposium.

SYAR 1.1	Wed	10:45–11:15	Audimax	**Application of Inorganic Mass Spectrometry in Nuclear Forensics** — •Klaus Mayer, Maria Wallenius, Zsolt Varga, Magnus Hedberg, Michael Krachler
SYAR 1.2	Wed	11:15–11:45	Audimax	**Actinide elements and fundamental nuclear structure studies** — •Iain Moore

SYAR 1.3	Wed	11:45–12:15	Audimax	**Pushing the Limits: Detection of Long-Lived Actinides at VERA** — •Karin Hain, Michael Kern, Jixin Qiao, Francesca Quinto, Aya Sakaguchi, Peter Steier, Gabriele Wallner, Andreas Wiederin, Akihiko Yokoyama, Robin Golser
SYAR 1.4	Wed	12:15–12:45	Audimax	**Use of the actinides in medical research** — •Thomas Elias Cocolios

Invited talks of the joint symposium Awards Symposium (SYAW)

See SYAW for the full program of the symposium.

SYAW 1.1	Wed	13:30–14:15	Audimax	**Frequency comb spectroscopy and interferometry** — •Nathalie Picqué
SYAW 1.2	Wed	14:15–15:00	Audimax	**Capitalizing on Schrödinger** — •Wolfgang P. Schleich
SYAW 1.3	Wed	15:00–15:45	Audimax	**Quantum information processing with macroscopic objects** — •Eugene Polzik

Invited talks of the joint symposium Hot topics in cold molecules: From laser cooling to quantum resonances (SYCM)

See SYCM for the full program of the symposium.

SYCM 1.1	Fri	14:00–14:30	Audimax	**Collisions between laser-cooled molecules and atoms** — •Michael Tarbutt
SYCM 1.2	Fri	14:30–15:00	Audimax	**Trapped Laser-cooled Molecules for Quantum Simulation, Particle Physics, and Collisions** — •John Doyle
SYCM 1.3	Fri	15:00–15:30	Audimax	**Quantum-non-demolition state detection and spectroscopy of single cold molecular ions in traps** — •Stefan Willitsch
SYCM 1.4	Fri	15:30–16:00	Audimax	**Quantum state tomography of Feshbach resonances in molecular ion collisions via electron-ion coincidence spectroscopy** — •Edvardas Narevicius

Sessions

A 1.1–1.2	Mon	10:45–11:45	H1	**Atomic clusters / Collisions, scattering, correlation**
A 2.1–2.21	Mon	16:30–18:30	P	**Precision spectroscopy of atoms and ions (joint session A/Q)**
A 3.1–3.4	Tue	10:45–12:45	H1	**Attosecond physics / Interaction with VUV and X-ray light**
A 4.1–4.3	Tue	14:00–15:30	H1	**Ultracold atoms, ions, and BEC I (joint session A/Q)**
A 5.1–5.10	Tue	16:30–18:30	P	**Atomic clusters (together with MO)**
A 6.1–6.4	Tue	16:30–18:30	P	**Atomic systems in external fields**
A 7.1–7.4	Tue	16:30–18:30	P	**Attosecond physics**
A 8.1–8.2	Tue	16:30–18:30	P	**Collisions, scattering, and correlation phenomena**
A 9.1–9.6	Tue	16:30–18:30	P	**Interaction with strong or short laser pulses**
A 10.1–10.4	Tue	16:30–18:30	P	**Interaction with VUV and X-ray light**
A 11.1–11.5	Tue	16:30–18:30	P	**Ultra-cold plasmas and Rydberg systems (joint session A/Q)**
A 12.1–12.5	Tue	16:30–18:30	P	**Highly charged ions and their applications**
A 13.1–13.17	Tue	16:30–18:30	P	**Quantum Gases and Matter Waves (joint session Q/A)**
A 14.1–14.3	Wed	10:45–12:15	H1	**Interaction with strong or short laser pulses**
A 15.1–15.4	Wed	14:00–16:00	H1	**Precision spectroscopy of atoms and ions / Highly charge ions (joint session A/Q)**
A 16.1–16.27	Wed	16:30–18:30	P	**Ultra-cold atoms, ions, and BEC (joint session A/Q)**
A 17.1–17.3	Thu	10:45–12:15	H1	**Ultracold atoms, ions, and BEC II / Ultracold plasmas and Rydberg systems (joint session A/Q)**
A 18	Thu	12:30–13:30	MVA	**Annual General Meeting**

Annual General Meeting of the Atomic Physics Division

Thursday 12:30–13:30 MVA

- Bericht

- Wahl
- Verschiedenes

A 1: Atomic clusters / Collisions, scattering, correlation

Time: Monday 10:45–11:45 Location: H1

Invited Talk A 1.1 Mon 10:45 H1

Time-resolved X-ray Imaging of Anisotropic Nanoplasma Expansion — •Christian Peltz[1], Christoph Bostedt[2], Mathias Kling[3], Thomas Brabec[4], Eckart Ruehl[5], Artem Rudenko[6], Tais Gorkhover[7], and Thomas Fennel[1] — [1]Institute of Physics, University of Rostock, Germany — [2]Paul Scherrer Institute, Villigen, Switzerland — [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), giving unprecedented insight into the spatio-temporal evolution of the nanoplasma expansion.

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

Invited Talk A 1.2 Mon 11:15 H1

Scattering of twisted x-rays from a crystal — •Anton Peshkov[1,2], Stephan Fritzsche[3,4], and Andrey Surzhykov[1,2] — [1]Technische Universität Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Helmholtz-Institut Jena, Germany — [4]Friedrich-Schiller-Universität Jena, Germany

The elastic scattering of x-rays by bound atomic electrons is known to be an excellent probe of the structure of matter. One of the most intriguing example here is x-ray crystallography used to determine the arrangement of atoms in a crystal. The essential physics of this process has been known and understood for many years for the incident plane-wave radiation. However, this is not the case for twisted light beams that carry a nonzero projection of the orbital angular momentum (OAM) onto their propagation direction and whose intensity pattern has an annular character. In order to understand how the scattering from crystals depends on the "twistedness" of incident x-rays, we present here a theoretical analysis of the elastic scattering of Bessel beams from a single crystal of lithium. Our numerical calculations show that the scattering cross section is sensitive to the OAM projection of twisted beams and differs from the standard plane-wave case when the size of the crystal is reduced to the nanometer scale.

[1] A. A. Peshkov *et al.*, Phys. Scr. 94, 105402 (2019).

A 2: Precision spectroscopy of atoms and ions (joint session A/Q)

Time: Monday 16:30–18:30 Location: P

A 2.1 Mon 16:30 P

Interorbital interactions in an SU(2)⊗SU(6)-symmetric Fermi-Fermi mixture — •Koen Sponselee[1], Benjamin Abeln[1], Marcel Diem[1], Nejira Pintul[1], Klaus Sengstock[1,2], and Christoph Becker[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institute for Laser Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We characterise the *s*-wave interactions in interorbital ^{171}Yb-^{173}Yb Fermi-Fermi mixtures [1], where either ^{171}Yb is excited to the $^3P_0$ state while leaving ^{173}Yb in the ground state, or vice versa.

Using high-resolution clock spectroscopy, we measure the elastic scattering lengths and directly show the SU(2)⊗SU(6) symmetry of both interisotope interactions, which turn out to be attractive and similar. We further measure losses in these interorbital Fermi-Fermi mixtures and observe a difference of about two orders of magnitude between both interisotope interactions.

Along with other known $^1S_0$-$^3P_0$ state interactions of ytterbium, these measurements can be used as a benchmark for future ground-excited state Yb_2 molecular potential models.

This work is supported by the DFG within the SFB 925.

[1] B. Abeln, K. Sponselee, M. Diem, N. Pintul, K. Sengstock, and C. Becker, Phys. Rev. A **103**, 033315 (2021)

A 2.2 Mon 16:30 P

Electronic structure of superheavy element ions from ab initio calculations — •Harry Ramanantoanina[1], Anastasia Borschevsky[2], Michael Block[3], and Mustapha Laatiaoui[1] — [1]Johannes Gutenberg-Universität Mainz, Deutschland — [2]University of Groningen, The Netherlands — [3]GSI Helmholtzzentrum für Schwerionenforschung Darmstadt, Deutschland

Within the framework of the recent Laser Resonance Chromatography (LRC) project, we are developing a theoretical approach to study the properties of superheavy elements ions. In this context, we use a fully relativistic model based on the 4-component Dirac Hamiltonian and multireference configuration interaction method to deal with the electronic structure and spectroscopic properties. In this presentation, we are reporting our first results of Lr+ (Z = 103), Rf+ (Z = 104) and Db+ (Z = 105). To validate the theoretical method, we have also calculated the energy spectrum of Lu+, Hf+ and Ta+, which are the lighter element homologue of the investigated superheavy ions, and we have compared the theoretical results with experimental data. Overall, the calculated energy levels and spectroscopic properties were in good agreement with the experimental data, confirming the suitability of the theoretical approach for this study and allowing us to expect good quality of the prediction for superheavy ions. The theoretical results are further discussed in terms of optical pumping schemes of metastable electronic states of the superheavy ions, very relevant for setting up future LRC experiments. This study is supported by the European Research Council (ERC) (Grant Agreement No. 819957).

A 2.3 Mon 16:30 P

Current status of the Al^+ ion clock at PTB — •Fabian Dawel[1,2], Johannes Kramer[1,2], Steven A. King[1,2], Ludwig Krinner[1,2], Lennart Pelzer[1,2], Stephan Hannig[1,2,3], Kai Dietze[1,2], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch Technische Bundesanstalt, 38116 Braunschweig — [2]Leibniz Universität Hannover, 30167 Hannover — [3]DLR, Institut für Satellengeodäsie und Inertialsensorik (DLR-SI)

Since 1967 time is defined via a hyperfine transition in caesium-133. Optical clocks offer advantages in terms of statistical and systematic uncertainties over microwave clocks. A particularly promising candidate is the transition $^1S_0 \rightarrow ^3P_0$ of $^{27}Al^+$, with advantageous atomic properties resulting in small uncertainties in magnetic, electric and black-body shifts. Here we review the design and operation of the $^{27}Al^+$ clock at PTB. In our clock implementation, Al^+ is co trapped with $^{40}Ca^+$ in a linear Paul trap. The working principle of quantum logic spectroscopy and a lifetime-limited excitation rabi cycle on the Al^+ logic transition is demonstrated. We will present an evaluation of systematic frequency shifts using the more sensitive Ca^+ as a proxy. All investigated shifts have an uncertainty below 10^{-18}. First measurements on the Al^+ clock transition will be presented with a power-broadened linewidth of 48 Hz.

A 2.4 Mon 16:30 P

Measurement of Magnetic Moments in Heavy, Highly Charged Ions With Laser-Microwave Double-Resonance Spectroscoypy — •Khwaish Anjum[1,2], Patrick Baus[3], Gerhard Birkl[3], Manasa Chambath[1,4], Kanika[1,5], Jeffrey Klimes[1,5,6], Wolfgang Quint[1,5], and Manuel Vogel[1] — [1]GSI Helmholtzzentrum für Schwerionenforschung — [2]Delhi Technology University — [3]Institute for Applied Physics, TU Darmstadt — [4]Amrita Vishwa Vidyapeetham — [5]Heidelberg Graduate School for Fundamental Physics — [6]Max Planck Institute for Nuclear Physics

The ARTEMIS Penning trap will use laser-microwave double-resonance spectroscopy to measure the intrinsic magnetic moments of both electrons and nuclei in heavy, highly charged ions (HCIs). The (hyper)fine and Zeeman transitions of such HCIs in ARTEMIS are in the optical or microwave regimes respectively. A closed optical cycle probes successful induction of spin flips by microwave stimulus.

The spectroscopy trap of ARTEMIS uses a half-open design with a transparent, conductive endcap. This enables ≈ 2 sr conical access to the trap center for irradiation and detection of fluorescent light. This is more than an order of magnitude greater than conventional cylindrical designs with similar harmonicity and tunability. On the opposite side, cooled ion bunches are injected from an adjacent trap, where they are created by electron impact ionization.

Currently, ARTEMIS is working on systematics measurements with boron-like Ar^{13+} and preparing for capture of heavy HCIs such as hydrogen-like Bi^{82+} from the HITRAP facility at GSI.

A 2.5 Mon 16:30 P

A New Experiment for the Measurements of the Nuclear Magnetic Moment of $^3He^{2+}$ and the Ground-State Hyperfine Splitting of $^3He^+$ — •Annabelle Kaiser[1,2], Antonia Schneider[1], Bastian Sikora[1], Andreas Mooser[1], Stefan Dickopf[1,2], Marius Müller[1], Alexander Rischka[1], Stefan Ulmer[3], Jochen Walz[4,5], Zoltan Harman[1], Christoph H. Keitel[1], and Klaus Blaum[1] — [1]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [2]Heidelberg University, Heidelberg, Germany — [3]RIKEN, Wako, Japan — [4]Johannes Gutenberg-University, Mainz, Germany — [5]Helmholtz-Institute Mainz, Germany

The Heidelberg ^{3}He-experiment is aiming at the first direct high-precision measurement of the nuclear magnetic moment of $^3He^{2+}$ with a relative uncertainty on the 10^{-9} level and an improved measurement of the ground-state hyperfine splitting of $^3He^+$ by at least one order of magnitude. The helion nuclear magnetic moment is an important parameter for the development of hyperpolarized ^{3}He-NMR-probes for absolute magnetometry. The HFS measurement of $^3He^+$ is sensitive to nuclear structure effects and would give information about such effects in a three-nucleon system. For the $^3He^+$ and $^3He^{2+}$ measurements, two and four Penning trap setups were designed respectively, and similar techniques as already demonstrated in proton and antiproton magnetic moment measurements [1,2] are going to be applied. The current status of the experiment is presented.

[1] Schneider et al., Science Vol 358, 1081 (2017)
[2] Smorra et al., Nature, Vol 550, 371 (2017)

A 2.6 Mon 16:30 P

Self-injection locked laser system for quantum logic and entanglement operations — •Ludwig Krinner[1,2], Lennart Pelzer[1], Kai Dietze[1], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116, Braunschweig — [2]Leibniz Universität Hannover, Welfengarten 1, 30167, Hannover

While diode lasers have become a prevalent tool for the cooling and coherent manipulation of atoms and ions, they typically show an inconvenient and sometimes even problematic amount of noise at Fourier frequencies of a few hundred kilohertz to a few megahertz. Especially in the case of trapped ions, this coincides with the motional frequencies of the secular motion. Excess noise can compromise coherent manipulation of sideband transitions, such as sideband cooling or entanglement operations by incoherently driving the much stronger carrier transitions. We demonstrate a self-injection locked laser system using the transmitted light of a medium-finesse linear cavity. The system can easily be adapted from an existing standard Pound-Drever-Hall laser locking scheme using a linear cavity, as opposed to Y-shaped or bow-tie cavities, which are usually employed for self-injection locking. We demonstrate the excellent suppression of high frequency noise by measuring incoherent excitation 0.3 . . . 4 MHz away from the carrier transition using a single trapped $^{40}Ca^+$ ion as a probe, finding an inferred reduction of over 30 dB in noise spectral density compared to a state-of-the art external-cavity diode laser.

A 2.7 Mon 16:30 P

Laser photodetachment spectroscopy in an MR-ToF device — •David Leimbach for the GANDALPH and MIRACLS collaborations — Department of Physics, University of Gothenburg, Gothenburg, Sweden — CERN, Geneva, Switzerland — Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany

The electron affinity (EA) is the energy released when an additional electron is bound to a neutral atom, creating a negative ion. Due to the lack of a long-range Coulomb attraction, the EA is dominated by electron-correlation effects. A prime example for the importance of the accurate description of the electron correlation is the theoretical calculation of the specific mass shift, which is an indispensable ingredient when extracting nuclear charge radii from laser-spectroscopy work. Although the isotope shift (IS) in the EA of the stable chlorine isotopes has been determined experimentally, recent calculations improved the theoretical precision beyond the measurement precision. By using a MR-ToF device we are able to perform laser photodetachment spectroscopy while reusing the ion beam, thereby increasing the efficiency in the detection method. Additionally, we will extend this type of studies to long-lived radionuclides for the first time by determining the IS of 36Cl. This novel approach could be applied to IS measurements of short-lived isotopes as well as EA determination of sparsely produced and eventually superheavy radioelements. We will present the technique, developments and status of the experimental campaign.

A 2.8 Mon 16:30 P

Current status of the transportable ^{87}Sr lattice clock at PTB — •Tim Lücke, Ingo Nosske, Chetan Vishwakarma, Sofia Herbers, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

The prospect of direct observation and accurate determination of gravitational potential differences led to great efforts to develop transportable optical clocks within the last decade. At PTB, we are operating a ^{87}Sr lattice clock in an air-conditioned car trailer for chronometric leveling. Here we present a recent uncertainty evaluation of our clock reaching the very low 10^{-17} regime. Furthermore, we explore future measures to reduce its uncertainty into the 10^{-18} regime including a new physics package allowing the transport of the atoms into a cryogenic interrogation chamber by a moving lattice.

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 434617780 - SFB 1464 Terra Q and Project-ID 390837967 - EXC-2123 QuantumFrontiers.

A 2.9 Mon 16:30 P

Interrogating the temporal coherence of EUV frequency combs with highly charged ions — •Chunhai Lyu, Stefano M. Cavaletto, Christoph H. Keitel, and Zoltán Harman — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

An extreme-ultraviolet (EUV) frequency comb is usually generated via intra-cavity high-order harmonic generation of an infrared (IR) frequency comb. However, whether the temporal coherence of the IR frequency comb is preserved in the corresponding EUV frequency comb is still under debate. Here, we put forward a scheme to directly infer the temporal coherence of EUV frequency combs via spectroscopy of highly charged Mg-like ions. The fluctuations of the carrier-envelope phase between EUV pulses is modelled as a random walk process. Based on numerical simulations, we show that the coherence time of the EUV frequency comb can be determined from the excitation spectrum of given ionic transitions. This scheme will provide a verification of the temporal coherence of an EUV frequency comb at timescales several orders of magnitude longer than current state of the art, and at the same time will enable high-precision spectroscopy of EUV transitions down to the 15th digit.

[1]. Phys. Rev. Lett. 98, 070801 (2020).

A 2.10 Mon 16:30 P

Construction and tests of image-current detection systems for the transportable antiproton trap STEP. — •Fatma Abbass[1], Christian Will[1], Daniel Popper[1], Matthew Bohman[1,7], Markus Wiesinger[1], Markus Fleck[7], Jack Devlin[2,7], Stefan Erlewein[2,7], Julia Jaeger[2,7], Barbara Latacz[7], Peter Micke[7], Klaus Blaum[3], Christian Ospelkaus[4], Wolfgang Quint[6], Yasuyuki Matsuda[5], Yasunori Yamazaki[7], Jochen Walz[1,8], Stefan Ulmer[7], and Christian Smorra[1] — [1]nstitut für Physik, Johannes Gutenberg-Universität, Staudingerweg 7, D-55128 Mainz, Germany — [2]CERN, 1211 Geneva, Switzerland — [3]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany — [4]Physikalisch-Technische Bundesanstalt, D-38116 Braunschweig, Ger-

many — [5])Graduate School of Arts and Sciences, University of Tokyo, Tokyo 153-8902, Japan — [6]GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt, Germany — [7]RIKEN, Fundamental Symmetries Laboratory, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan — [8])Helmholtz-Institut Mainz, D-55099 Mainz, Germany

We develop a Penning trap image current detection systems including a cyclotron detection system. The image current detection systems which I developed and tested are made up of superconducting toroidal coils and cryogenic amplifiers. As a result, I was able to achieve a higher Q-value with toroidal coils than we had previously achieved using solenoids.

A 2.11 Mon 16:30 P

High-Resolution Electron-Ion Collision Spectroscopy with Slow Cooled Pb^{78+} Ions in the CRYRING@ESR Storage Ring — •Sebastian Fuchs[1,2], Carsten Brandau[1,3], Esther Menz[3,4,5], Michael Lestinsky[3], Alexander Borovik Jr[1], Yanning Zhang[6], Zoran Andelkovic[3], Frank Herfurth[2], Christophor Kozhuharov[3], Claude Krantz[3], Uwe Spillmann[3], Markus Steck[3], Gleb Vorobyev[3], Dariusz Banaś[7], Michael Fogle[8], Stephan Fritzsche[4,5], Eva Lindroth[9], Xinwen Ma[10], Alfred Müller[1], Reinhold Schuch[9], Andrey Surzhykov[11,12], Martino Trassinelli[13], Thomas Stöhlker[3,4,5], Zoltan Harman[14], and Stefan Schippers[1,2] — [1]JLU Gießen — [2]HFHF Campus Gießen — [3]GSI — [4]HI Jena — [5]FSU Jena — [6]Xi'an Jiaotong University — [7]JKU Kielce — [8]Auburn University — [9]Stockholm University — [10]IMPCAS Lanzhou — [11]TU Braunschweig — [12]PTB — [13]UPMC Paris — [14]MPIK

The experimental technique of dielectronic recombination (DR) collision spectroscopy is a very successful approach for studying the properties of ions. Due to its versatility and the high experimental precision DR spectroscopy plays an important role in the physics program of the SPARC collaboration. CRYRING@ESR is particularly attractive for DR studies, since it is equipped with an electron cooler that provides an ultra-cold electron beam promising highest experimental resolving power. Here, we report on recent results from the first DR experiment with highly charged ions in the heavy-ion storage ring CRYRING@ESR of the international FAIR facility in Darmstadt.

A 2.12 Mon 16:30 P

Towards direct optical excitation of the nuclear clock isomer ^{229m}Th — •Johannes Thielking, Maksim V. Okhapkin, Jascha Zander, Johannes Tiedau, Gregor Zitzer, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

The transition of the ^{229}Th nucleus between its ground state and its uniquely low-lying isomer at about 8 eV has been proposed as a frequency reference for a highly precise type of optical clock [1]. Although several advances have been made in determining the transition energy and nuclear properties [2], its optical excitation is still pending. To this end, we are currently developing a vacuum ultraviolet (VUV) laser system based on resonance enhanced four-wave difference mixing in xenon. The mixing process is driven by two pulsed dye laser amplifiers with a pulse duration of 10 ns. The amplifiers are seeded with cw ring lasers to achieve a Fourier transform limited bandwidth. The laser system provides VUV pulses with photon numbers of about 10^{13} per pulse and a broad tunability that covers the current uncertainty range of the nuclear excitation energy. Here we will report on the current status of the laser development, as well as future experiments to excite the isomeric state in trapped ions and a Th-doped crystal.

[1] E. Peik, Chr. Tamm, Europhys. Lett. 61, 181 (2003).
[2] K. Beeks et al., Nature Reviews Physics 3(4), 238-248 (2021).

A 2.13 Mon 16:30 P

High-Precision Spectroscopy of Single Molecular Hydrogen Ions in a Penning Trap at Alphatrap — •Charlotte M. König, Fabian Heisse, Jonathan Morgner, Tim Sailer, Bingsheng Tu, Klaus Blaum, and Sven Sturm — Max-Planck-Institut für Kernphysik, 69117 Heidelberg

As the simplest molecules, molecular hydrogen ions (MHI) are an excellent system for testing QED. In collaboration with the group of Stephan Schiller (Heinrich-Heine-University Düsseldorf), we plan to perform high-precision spectroscopy on single MHI in the Penning-trap setup of Alphatrap [1]. The first measurements, in the microwave and MHz regime, will investigate the hyperfine structure of HD^+. This will allow extracting the bound g-factors of the constituent particles and coefficients of the hyperfine hamiltonian, from which rovibrational laser spectroscopy performed on this ion species can benefit [2].
In the future, we aim to extend our methods to single ion rovibrational laser spectroscopy of H_2^+ at IR wavelengths enabling the ultra precise determination of fundamental constants, such as $m_\mathrm{p}/m_\mathrm{e}$ [3]. The development of the required techniques for this measurement will be an important step towards spectroscopy of an antimatter $\overline{H_2^-}$ ion for tests of matter-antimatter symmetry [4]. In this contribution, I will present an overview of the experimental setup and the measurement schemes.

[1] S. Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 1425-1491 (2019)
[2] I. V. Kortunov, *et al.*, Nature Physics **17**, 569 573 (2021)
[3] J.-Ph. Karr, *et al.*, Phys. Rev. **A94**, 050501(R) (2016)
[4] E. Myers, Phys. Rev. **A98**, 010101(R) (2018)

A 2.14 Mon 16:30 P

A cryogenic Penning trap system for sympathetic laser cooling of atomic ions and protons — •Julia-Aileen Coenders[1], Johannes Mielke[1], Teresa Meiners[1], Malte Niemann[1], Amado Bautista-Salvador[2], Ralf Lehnert[3], Juan Manuel Cornejo[1], Stefan Ulmer[4], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [3]Indiana University Center for Spacetime Symmetries, Bloomington, IN 47405, USA — [4]Ulmer Fundamental Symmetries Laboratiory, RIKEN, Wako, Saitama 351-0198, Japan

High precision measurements of the fundamental properties of protons and antiprotons carried out within the BASE collaboration serve as tests of CPT invariance in the baryon sector. However, present experiments fight against systematic uncertainties depending on the motional amplitude of the particle. To this end, experimental schemes based on sympathetic cooling of single (anti-)protons through co-trapped laser cooled atomic ions can contribute to the ongoing strive for improved precision through fast preparation times and low particle temperatures.

Here we present a cryogenic Penning trap system for free space coupling of two particles via Coulomb interaction in an engineered double-well potential. We report on recent results of thermometry measurements with $^9Be^+$ ions and sideband cooling of the same. Prospects for sympathetic cooling of protons in a micro-coupling trap will be discussed.

A 2.15 Mon 16:30 P

Towards high precision quantum logic spectroscopy of single molecular ions — •Maximilian J. Zawierucha[1], Till Rehmert[1], Fabian Wolf[1], and Piet O. Schmidt[1,2] — [1]Physikalisch- Technische Bundesanstalt, Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

High precision spectroscopy of trapped molecular ions constitutes a promising tool for the study of fundamental physics. Possible applications include the search for a variation of fundamental constants and measurement of the electric dipole moment of the electron.

Compared to atoms, molecules offer a rich level structure, permanent dipole moment and large internal electric fields which make them exceptionally well suited for those applications.

However, the additional rotational and vibrational degrees of freedom result in a dense level structure and absence of closed cycling transitions. Therefore, standard techniques for cooling, optical pumping and state detection cannot be applied. This challenge can be overcome by quantum logic spectroscopy.

In addition to the molecular ion, a well-controllable atomic ion is co-trapped, coupling strongly to the molecule via the Coulomb interaction. The shared motional state can be used as a bus to transfer information about the internal state of the molecular ion to the atomic ion, where it can be read out using fluorescence detection.

Here, we present the status of our experiment, aiming at high precision quantum logic spectroscopy of molecular oxygen ions.

A 2.16 Mon 16:30 P

Experimental and simulation progress of the Laser Resonance Chromatography technique — •EunKang Kim[1,2], Michael Block[1,2,3], Mustapha Laatiaoui[1,2], Harry Ramanantoanina[1,2], Elisabeth Rickert[1,2,3], Elisa Romero Romero[1,2,3], Philipp Sikora[1], and Jonas Schneider[1] — [1]Department Chemie, Johannes Gutenberg-Universität, Fritz-Strassmann Weg 2, 55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, Staudingerweg 18, 55128 Mainz, Germany — [3]GSI, Planckstraße 1, 64291 Darmstadt, Germany

The superheavy elements present an experimental challenge as they exhibit low production yields and very short half-lives, and their atomic structure is barely known. Traditional techniques like monitoring fluorescence are no longer suitable as they lack the sensitivity required for superheavy element research. To overcome this challenge, a new technique called *Laser Resonance Chromatography* (LRC) is proposed for probing the heaviest product ions in situ. In this contribution, I will explain the principle, configuration, simulation and progress of the LRC experiment. This work is supported by the European Research Council (ERC) (Grant Agreement No. 819957).

A 2.17 Mon 16:30 P

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

The theoretical uncertainty of the bound-electron g-factor in high-Z hydrogenlike ions is dominated by uncalculated Feynman diagrams with two self-energy loops. In our previous study, we have obtained full results for the loop-after-loop diagrams, and partial results for the nested and overlapping loop diagrams by taking into acount the Coulomb interaction in intermediate states to zero and first order [1].

In this work, we present our results for the so-called M-term contribution. This corresponds to the ultraviolet finite part of nested and overlapping loop diagrams in which the Coulomb interaction in intermediate states is taken into account to all orders.

Our results will be highly relevant for planned near future tests of QED in high-Z ions as well as for an independent determination of the fine-structure constant α from the bound-electron g-factor.

[1] B. Sikora, V. A. Yerokhin, N. S. Oreshkina et al., Phys. Rev. Research 2, 012002(R) (2020).

A 2.18 Mon 16:30 P

Theory of the Zeeman and hyperfine splitting of the ^{3}He$^+$ ion — •Bastian Sikora, Zoltán Harman, Natalia S. Oreshkina, Igor Valuev, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

When exposed to an external magnetic field, the combined hyperfine and Zeeman effect leads to a splitting of the ground state of the ^{3}He$^+$ ion into four sublevels. Measurements of transition frequencies [1] between these sublevels allow the determination of the bound electron's g-factor, the ground-state hyperfine splitting in the absence of an external magnetic field as well as the magnetic moment of the nucleus, shielded by the presence of the bound electron.

We present the theoretical calculation of the shielding constant which is required to extract the magnetic moment of the bare nucleus. Furthermore, we present the theory of the ground-state hyperfine splitting and the bound-electron g-factor. The theoretical accuracy of the bound-electron g-factor is limited by the accuracy of the fine-structure constant α. Furthermore, assuming the correctness of theory of hyperfine splitting, one can extract the nuclear Zemach radius from the experimental hyperfine splitting value.

[1] A. Mooser, A. Rischka, A. Schneider, et al., J. Phys.: Conf. Ser. 1138, 012004 (2018)

A 2.19 Mon 16:30 P

Engineering Atom-Photon and Atom-Atom Interactions with Nano-photonics — •Artur Skljarow[1], Benyamin Shnirman[1], Harald Kübler[1], Hadiseh Alaeian[2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Germany — [2]Departments of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana, USA

We study an integrated silicon photonic chip, composed of several subwavelength ridge and slot waveguides, immersed in a micro-cell with rubidium vapor. With the help of a two-photon excitation, we observe that the guided mode transmission spectrum gets modified when the photonic mode is coupled to rubidium atoms through its evanescent tail. We also investigate the coupling of atomic vapor to slot waveguides. The slot mode constrains the probed atomic density to an effective one-dimensional system. This is interesting to study the collective atom-atom interactions in 1D. We developed a Monte-Carlo simulation method to predict and interpret the measured data. In addition to the silicon plattform we are also fabricating and investigating Nano-devices made of silicon nitride. In order to reach the interesting quantum regime with thermal vapors we plan to create a non-linearity by enhancing the light field with a photonic crystal cavity. We have fabricated these devices with a novel underetching technique where specified regions with the Si3N4 PhCs are suspended in air. This technique allows direct coupling into the cavity via the waveguide and enables a more versatile design of the chip.

A 2.20 Mon 16:30 P

High-Resolution Microcalorimeter Measurement of X-Ray Transitions in He-like Uranium at CRYRING@ESR — •Felix Martin Kröger[1,2,3], Steffen Allgeier[4], Andreas Fleischmann[4], Marvin Friedrich[4], Alexandre Gumberidze[3], Marc Oliver Herdrich[1,2,3], Daniel Hengstler[4], Patricia Kuntz[4], Michael Lestinsky[3], Bastian Löher[3], Esther Babette Menz[1,2,3], Philip Pfäfflein[1,2,3], Uwe Spillmann[3], Günter Weber[1,2,3], Christian Enss[4], and Thomas Stöhlker[1,2,3] — [1]HI Jena, Fröbelstieg 3, Jena, Germany — [2]IOQ Jena, FSU Jena, Max-Wien-Platz 1, Jena, Germany — [3]GSI, Planckstraße 1, Darmstadt, Germany — [4]KIP, RKU Heidelberg, Im Neuenheimer Feld 227, Heidelberg, Germany

We present the first application of metallic magnetic calorimeter detectors for high resolution X-ray spectroscopy at the electron cooler of CRYRING@ESR, the low energy storage ring of GSI, Darmstadt. Within the experiment, X-ray radiation emitted as a result of recombination events between the cooler electrons and a stored beam of U^{91+} ions was studied. For this purpose, two maXs detectors were positioned under observation angles of 0° and 180° with respect to the ion beam axis. This report will focus on details of the experimental setup, its performance and its integration into the storage ring environment.

This research has been conducted in the framework of the SPARC collaboration, experiment E138 of FAIR Phase-0 supported by GSI. We acknowledge substantial support by ErUM-FSP APPA (BMBF n° 05P19SJFAA).

A 2.21 Mon 16:30 P

maXs100: A 64-pixel Metallic Magnetic Calorimeter Array for the Spectroscopy of Highly-Charged Heavy Ions — •S. Allgeier[1], M. Friedrich[1], A. Gumberidze[2], M.-O. Herdrich[2,3,4], D. Hengstler[1], F. M. Kröger[2,3,4], P. Kuntz[1], A. Fleischmann[1], M. Lestinsky[2], E. B. Menz[2,3,4], Ph. Pfäfflein[2,3,4], U. Spillmann[2], B. Zhu[4], G. Weber[2,3,4], Th. Stöhlker[2,3,4], and Ch. Enss[1] — [1]KIP, Heidelberg University — [2]GSI, Darmstadt — [3]IOQ, Jena University — [4]HI Jena

Metallic magnetic calorimeters (MMCs) are energy-dispersive X-ray detectors which provide an excellent energy resolution over a large dynamic range combined with a very good linearity. MMCs are operated at millikelvin temperatures and convert the energy of each incident photon into a temperature pulse which is measured by a paramagnetic temperature sensor. The resulting change of magnetisation is read out by a SQUID magnetometer. For the investigation of electron transitions in U^{90+} at CRYRING@FAIR we developed the 2-dimensional maXs-100 detector array within the framework of the SPARC collaboration. It features 8x8 pixels with a detection area of 1 cm^2 and 50 μm thick absorbers made of gold, resulting in a stopping power of 40 % at 100 keV. An energy resolution of 40 eV at 60 keV was demonstrated in co-added spectra. The non-linearity of the detector system including the read-out chain was shown to be in the range of 0.2 % @ 136 keV. We will discuss the cryogenic setup of the two detector systems used during the beam time in April 2021, as well as the properties of the maXs-100 detector array including a sub-eV absolute energy calibration.

A 3: Attosecond physics / Interaction with VUV and X-ray light

Time: Tuesday 10:45–12:45 Location: H1

Invited Talk A 3.1 Tue 10:45 H1

Probing electronic wavefunctions and chiral structure using all-optical attosecond interferometry — •Michael Krüger[1,2], Doron Azoury[1], Omer Kneller[1], Shaked Rozen[1], Barry D. Bruner[1], Alex Clergerie[3], Bernard Pons[3], Baptiste Fabre[3], Yann Mairesse[3], Oren Cohen[2], Olga Smirnova[4], and Nirit Dudovich[1] — [1]Department of Physics of Complex Systems, Weizmann Institute of Science, 76100 Rehovot, Israel — [2]Department of Physics and Solid State Institute, Technion, 32000 Haifa, Israel — [3]Université de Bordeaux, CNRS - CEA, CELIA, Talence, France — [4]Max-Born-Institut, 12489 Berlin, Germany

Phase retrieval of electronic wavefunctions generated by photoionization has been a longstanding challenge. Here we measure the time-reversed process of photoionization – photorecombination – in attosecond pulse generation. We demonstrate all-optical interferometry of two independent phase-locked attosecond light sources [1]. Our measurement enables us to directly determine the phase shift associated with electron scattering and with structural minima in atomic systems.

In a second study, we superimpose two attosecond light sources with perpendicular polarization, achieving direct time-domain polarization control [2]. We establish an extreme-ultraviolet lock-in detection scheme, allowing the isolation and amplification of weak chiral signals. We demonstrate our scheme by a phase-resolved measurement of magnetic circular dichroism.

[1] D. Azoury et al., Nature Photonics 13, 54 (2019).
[2] D. Azoury et al., Nature Photonics 13, 198 (2019).

Invited Talk A 3.2 Tue 11:15 H1

Highly nonlinear ionization of atoms induced by intense HHG pulses — Björn Senfftleben[1], Martin Kretschmar[1], Andreas Hoffmann[1], Mario Sauppe[1,2], Johannes Tümmler[1], Ingo Will[1], Tamás Nagy[1], Marc J. J. Vrakking[1], Daniela Rupp[1,2], and •Bernd Schütte[1] — [1]Max-Born-Institut Berlin — [2]ETH Zürich

High-harmonic generation (HHG) is typically considered to be a weak source of extreme-ultraviolet (XUV) photons. Here we demonstrate a very intense source of few-femtosecond XUV pulses based on HHG, reaching intensities up to 7×10^{14} W/cm^2 [1]. These pulses enable us to ionize Ar atoms up to Ar^{5+}, requiring the absorption of at least 10 XUV photons. This number can be appreciated by considering that it is similar to the number of near-infrared (NIR) photons absorbed in a typical strong-field ionization experiment.

Our results are the consequence of a novel scaling scheme, showing that the optimization of the XUV intensity requires conditions that are distinctly different from the conditions that are required to optimize the HHG pulse energy. An important advantage of our approach is that we use a moderate NIR pulse driving energy ($\approx$ 10 mJ). Therefore, our results make it possible to perform experiments requiring intense XUV pulses in a much larger number of laboratories than is currently the case. This substantially improves the prospects for nonlinear XUV optics experiments, single-shot coherent diffractive imaging of isolated nanotargets as well as attosecond-pump attosecond-probe experiments.

[1] B. Senfftleben *et al.*, arXiv:1911.01375

Invited Talk A 3.3 Tue 11:45 H1

Towards fast adaptive resonant x-ray optics — Miriam Gerharz and •Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Visible light can easily be manipulated using reflective or refractive elements, such as lenses, phase plates, or mirrors. At x-ray energies, the real part of the complex refractive index approaches 1, such that these concepts require revision. As a result, an impressive toolbox of alternative methods has been developed, e.g., based on crystal optics.

In this talk, I will introduce a new concept for fast adaptive x-ray optics, which in particular aims at dynamical control during single experimental cycles. Our approach uses piezo-control methods, which allow one to mechanically displace a solid-state target containing resonances much faster than the lifetime of the resonances. Such displacements create relative phase shifts, which already have been employed successfully to manipulate the time- or energy spectra of x-ray pulses.

For applications in x-ray optics, we associate the phase shifts to an effective real part of the refractive index. The key idea then is that such mechanically-induced phase shifts are independent of the thickness of the target. As a result, the real part of the x-ray refractive index can effectively be increased substantially, without increasing its imaginary part. This approach provides access to high refractive index contrasts at x-ray energies together with low absorption, and thereby opens an avenue to entirely new concepts in x-ray optics.

Invited Talk A 3.4 Tue 12:15 H1

Control of complex Fano resonances by shaped laser pulses — Camilo Granados, Nicola Mayer, Evgenii Ikonnikov, Misha Ivanov, and •Oleg Kornilov — Max-Born-Institute, Berlin

Ultrafast pulsed lasers and high-order harmonic generation have opened access to time-dependent studies in the extreme ultriviolet (XUV) photon energy range. Excited states accessible in the XUV region often have a complex character combining several coupled electronic states, such as multi-state Fano resonances, and undergo ultrafast relaxation dynamics via autoionization, dissociation or relaxation at conical intersections. Recently we investigated dynamics of the complex excited molecular states using time-resolved photoelectron [1,2] and photoion [3] spectroscopy with wavelength-selected XUV pulses. In this contribution we explore how these dynamics can be controlled by temporal and frequency shaping of the near-infrared pulses used to probe the relaxation dynamics induce by XUV.

[1] M. Eckstein et al., Phys. Rev. Lett. 116, 163003 (2016). [2] M. Eckstein et al., Faraday Discuss. 194, 509 (2016). [3] G. Reitsma et al., J. Phys. Chem. A 123, 3068 (2019).

A 4: Ultracold atoms, ions, and BEC I (joint session A/Q)

Time: Tuesday 14:00–15:30 Location: H1

Invited Talk A 4.1 Tue 14:00 H1

Reducing their complexity and miniaturise BEC interferometers — •Waldemar Herr[1], Hendrik Heine[1], Alexander Kassner[2], Christoph Künzler[2], Marc C. Wurz[2], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität, Hannover, Germany — [2]Institut für Mikroproduktionstechnik, Leibniz Universität, Hannover

Matterwave interferometry with Bose Einstein Condensates (BEC) promises exciting prospects in inertial sensing and research on fundamental physics both on ground and in space. By now, we can create BECs very efficiently by using atom chips and compact realisations have already been shown, e.g. by creating the first BEC in space on a sounding rocket mission. However, for in-field or satellite-borne applications, it is vital to further reduce the complexity in order to lower size, weight and power demands and to transform BEC interferometers to easy-to-use devices.

In this talk, different aspects ranging from interferometry schemes, sensor fusion concepts and results on a magneto optical trap and sub-Doppler cooling using only a single beam of light in combination with an optical grating on an atom chip will be discussed.

Invited Talk A 4.2 Tue 14:30 H1

Dynamics of a mobile hole in a Hubbard antiferromagnet — •Martin Lebrat, Geoffrey Ji, Muqing Xu, Lev Haldar Kendrick, Christie S. Chiu, Justus C. Brüggenjürgen, Daniel Greif, Annabelle Bohrdt, Fabian Grusdt, Eugene Demler, and Markus Greiner — Harvard University, Cambridge, MA, USA

The interplay between spin and charge underlies much of the phenomena of the doped Hubbard model. Quantum simulation of the Hubbard model using quantum gas microscopy offers site-resolved readout and manipulation, enabling detailed exploration of the relationship between the two. We use this platform to explore spin and charge dynamics upon the delocalization of an initially-pinned hole dopant. We first prepare a two-component quantum gas of Lithium-6 loaded into a square optical lattice at half-filling and strong interactions, where the atoms exhibit antiferromagnetic spin ordering. During the loading process, we use a digital micromirror device to pin a localized hole dopant into the antiferromagnet. We then release the dopant and examine how it interacts with and scrambles the surrounding spin environment. The microscopic dynamics of dopants may provide further insight into the phases that appear in the doped Hubbard model.

Invited Talk A 4.3 Tue 15:00 H1

Interaction-induced lattices for bound states: Designing flat bands, quantized pumps and higher-order topological insulators for doublons — •Grazia Salerno, Giandomenico Palumbo, Nathan Goldman, and Marco Di Liberto — Center for Nonlinear Phenomena and Complex Systems,Universit *e Libre de Bruxelles, CP 231, Campus Plaine, B-1050 Brussels, Belgium

Bound states of two interacting particles moving on a lattice can exhibit remarkable featuresthat are not captured by the underlying single-particle picture. Inspired by this phenomenon, weintroduce a novel framework by which genuine interaction-induced geometric and topological effectscan be realized in quantum-engineered systems. Our approach builds on the design of effectivelattices for the center-of-mass motion of two-body bound states, which can be created throughlong-range interactions. This general scenario is illustrated on several examples, where flat-bandlocalization, topological pumps and higher-order topological corner modes emerge from genuineinteraction effects. Our results pave the way for the exploration of interaction-induced topologicaleffects in a variety of platforms, ranging from ultracold gases to interacting photonic devices.

A 5: Atomic clusters (together with MO)

Time: Tuesday 16:30–18:30 Location: P

A 5.1 Tue 16:30 P

Competition of photon and electron emission in interatomic decay of heterogeneous noble gas clusters — •Lutz Marder[1], André Knie[1], Christian Ozga[1], Christina Zindel[1], Clemens Richter[2], Uwe Hergenhahn[2,3], Arno Ehresmann[1], and Andreas Hans[1] — [1]Institute of Physics, University of Kassel, Kassel, Germany — [2]Leibniz Institute of Surface Modification, Leipzig, Germany — [3]Max Planck Institute for Plasma Physics, Greifswald, Germany

Noble gas clusters represent prototype systems for the investigation of fundamental atomic and molecular processes. Van-der-Waals bonds enable new relaxation pathways not available in isolated systems. In recent years many of these have been studied, often using coincidence measurement techniques.

Here, we present our state-of-the-art experiment where both electrons and photons were detected in coincidence, which allows for investigation of multi-particle decay pathways after excitation with synchrotron radiation. The results show that the addition of krypton to pure neon clusters strongly alters the emission by the opening of a faster ionizing decay channel compared to the radiative decay.

A 5.2 Tue 16:30 P

Atomic Physics in geographical systems — •Raquel Bustamante — Universidad Nacional de Lujan, Buenos Aires, Argentina

Silica microcombs have a high potential for generating tens ofgigahertz ofoptical pulse trains with ultralow timing jitter, which is highlysuitable for higher speed and higher bandwidth information systems. So far, the accurate characterization of timing jitter in microcombs has been limited by the mea- surement methods although theoretically predicted to be >20dB better performance, the true erformance has not been accurately measured until now. Here, using a self-heterodyne-based measurement method with 20 resolution, wehow that 2.6-fs rms timing jitter is possible for 22-GHz silica microcombs. We identified their origins, which suggests that silica microcombs may achieve 200-as-level jitter by better intensity noise control. This jitter performance can greatly benefit many high-speed and high-bandwidth applications including analog-to-digitalconversion, microwave generation, and optical ommunications.

A 5.3 Tue 16:30 P

Time-resolved dynamics in xenon clusters induced by intense XUV pulses — •M Sauppe[1], T Bischoff[2], C Bomme[3], C Bostedt[4], B Erk[5], T Feigl[6], L Flueckiger[7], T Gorkhover[8], K Kolatzki[1], B Langbehn[2], D Rompotis[9], B Senfftleben[10], R Treusch[5], A Ulmer[2], J Zimbalski[2], J Zimmermann[1], T Moeller[2], and D Rupp[1] — [1]ETH Zurich — [2]TU Berlin — [3]IRAMIS — [4]PSI, EPFL — [5]DESY — [6]optiXfab — [7]La Trobe University — [8]Uni Hamburg — [9]XFEL — [10]MBI

Short-wavelength free-electron laser (FEL) enable the investigation of laser-matter-interaction at high photon energies with an unprecedented high spatial and temporal resolution. Rare gas clusters are an ideal testbed for such studies, e.g. due to their tunability in size and lag of paths for energy dissipation. Clusters exposed to tightly focused FEL pulses are quickly transformed into a non-equilibrium state. Photoionization and emission of kinetic electrons occurs within (sub-)femtoseconds, followed by the formation of a nanoplasma of ions and Coulomb-trapped electrons. Energy redistribution and expansion processes may last up to nanoseconds. Using two XUV pulses in a pump-probe scheme with a maximum time-delay of 650 ps, we were able to trace electron-ion recombination and the cluster expansion in a so far unexplored time-regime. As a result of the preceding expansion we found a reduced electron-ion-recombination for increasing time-delays. Further, the analysis of ion kinetic energies showed a plasma driven expansion for smaller clusters. For larger clusters, we found a growing importance of a coulomb explosion of the outer cluster shells.

A 5.4 Tue 16:30 P

A compact UV/VUV spectrometer with fixed VLS gratings for overview luminescence measurements — •Nils Kiefer, Andreas Hans, André Knie, and Arno Ehresmann — Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Universität Kassel,Heinrich-Plett-Straße 40, 34132 Kassel, Germany

We present a design study for the energy resolved photon detection in the UV and XUV energy regime. A grating with Variable Line Spacing (VLS) allows for dispersion of a wide spectral range onto flat detector surfaces. With two VLS gratings in parallel, spectra from 30nm to 120nm and 120nm to 300nm can be imaged simultaneously, but spatially separated. Managing coincidence capabilities and single photon detection, two position and time resolving MCP-based detectors will be used. Exemplary showcase-applications at FAIR (Facility of Antiproton and Ion Research) and synchrotron radiation facilities will be outlined. With this compact spectrometer with high efficiency and high resolution from 30nm to 300nm, it will be possible to collect time efficiently wide range luminescence spectra in experiments for the characterization of the highly charged ion beams and synchrotron radiation served AMO experiments.

A 5.5 Tue 16:30 P

Quantum Coherent Diffractive Imaging — •Björn Kruse[1], Benjamin Liewehr[1], Christian Peltz[1], and Thomas Fennel[1,2] — [1]Institute for Physics, University of Rostock, Albert-Einstein-Str. 23, D-18059 Rostock, Germany — [2]Max-Born-Institut, Max-Born-Str. 2A, D-12489 Berlin, Germany

Coherent diffractive imaging (CDI) of isolated helium nanodroplets has been successfully demonstrated with a lab-based HHG source [1] operating in the vicinity of the 1s - 2p transition of helium. To reconstruct the shape and orientation of nanoparticles, CDI experiments have so far been analyzed in terms of a classical linear response description [2]. However, for strong laser fields and especially for resonant excitation, population dynamics of bound electrons and stimulated emissions may become important, violating the assumptions underlying a linear and classical description.

We developed a density matrix-based scattering model in order to include such quantum effects in the local medium response and explore the transition from linear to non-linear CDI for the resonant scattering from Helium nanodroplets [3]. The resulting substantial departures from the linear response case for already experimentally reachable pulse parameters leads to the proposal of quantum coherent diffractive imaging (QCDI) as a promising novel branch in strong-field XUV and x-ray physics.

[1] D. Rupp et al., Nat. Commun. 8, 493 (2017)
[2] I. Barke et al., Nat. Commun. 6, 6187 (2015)
[3] B. Kruse et al., J. Phys. Photonics 2, 024007 (2020)

A 5.6 Tue 16:30 P

Investigation of virtual photon dissociation in van der Waals clusters by electron photon spectroscopy — •Carolin Honisch, Nils Kiefer, Dana Bloss, Catmarna Küstner-Wetekam, Lutz Marder, Arno Ehresmann, and Andreas Hans — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

Within the natural environment, atoms or molecules do not occur in isolation and the influence of the presence of neighboring atoms or molecules is of high interest. A good prototypical system for this situation is represented by van der Waals clusters. In recent years, several novel processes have been discovered to occur in these weakly bound systems that are discussed to play an important role in the study of radiation damage due to charge or energy transfer to distant neighbors and subsequent slow electron emission. Within this context, the process of virtual photon dissociation was also predicted, in which ionization or excitation of an atom or molecule followed by energy transfer can dissociate a neighboring molecule. Here we present a scheme to experimentally detect this process using the coincident detection of electrons and photons. For this purpose, we use a setup developed for electron-photon coincidence experiments, which has been successfully used for experiments of this kind recently.

A 5.7 Tue 16:30 P

Analysis of x-ray single-shot diffractive imaging using the propagation multislice method — •Paul Tuemmler, Björn Kruse, Christian Peltz, and Thomas Fennel — Institut für Physik, Universität Rostock

Single-shot wide-angle x-ray scattering has enabled the three-dimensional characterization of free nanoparticles from a single scattering image [1,2,3]. Key to this method is the fact, that the scattering patterns contain information of density projections on differently oriented projection planes. Wide-angle scattering typically requires XUV photon energies where absorption and attenuation cannot be neglected in the description of the scattering process [4,5].

The multislice Fourier transform (MSFT) method, which provides a fast scattering simulation within the Born approximation, can be extended to also include these propagation effects. In this presentation the performance of conventional MSFT and propagation MSFT will be discussed and compared to exact results obtained from Mie theory. As a first application, selective resonant scattering from core shell systems is explored.

[1] I. Barke , Nat. Commun. **6**, 6187 (2015).
[2] K. Sander , J. Phys. B **48**, 204004 (2015).
[3] C. Peltz , Phys. Rev. Lett. **113**, 133401 (2014).
[4] D. Rupp , Nat. Commun. **8**, 493 (2017).
[5] B. Langbehn , Phys. Rev. Lett. **121**, 255301 (2018).

A 5.8 Tue 16:30 P

X-ray induced dissociation dynamics of isoelectronic homo- and heteronuclear clusters — •Frederic Ussling[1] and Coauthors of Community Beamtime Proposal No. 2176[2] — [1]ETH Zurich, Switzerland — [2]European XFEL, Germany

With the development of X-ray free-electron lasers (FELs) high-resolution coherent diffractive imaging (CDI) of individual nanometer-sized specimen like viruses or large biomolecules within a single exposure has become possible [1]. However, the intense X-ray pulse quickly alters the target's structure and subsequent dissociation dynamics may blur the diffraction pattern thus limiting the resolution [2]. Hence, a profound understanding of the interaction between matter and intense X-rays is indispensable for an unambiguous interpretation of the data. In order to investigate the interaction of light with matter, atomic and molecular clusters can serve as an ideal testbed. In particular, neon and methane are interesting systems for a comparative study of homonuclear and heteronuclear specimen [3], since they have comparable masses and number of electrons. We studied neon and methane clusters irradiated with intense FEL pulses at 1 keV photon energy by recording the resulting ionic fragments. We find that in a certain intensity regime, the fast ejection of protons from the methane cluster strongly influences the dynamics, in line with theoretical work [3].

[1] H.N. Chapman et al., Nature 470, 73-77 (2011)
[2] R. Neutze et al., Nature 406, 752-757 (2000)
[3] P. Di Cintio et al., PRL 111, 123401 (2013)

A 5.9 Tue 16:30 P

Diffractive imaging of large neon clusters with a high harmonic generation source — •Leonie Werner[1], Bruno Langbehn[1], Alessandro Colombo[2], Ehsan Hassanpour Yesaghi[2], Andreas Hoffmann[3], Katharina Kolatzki[2], Martin Kretschmar[3], Tamás Nagy[3], Mario Sauppe[2], Bernd Schütte[3], Björn Senfftleben[3], Rudi Tschammer[4], Johannes Tuemmler[3], Marc Vrakking[3], Ingo Will[3], Thomas Möller[1], and Daniela Rupp[2,3] — [1]TU Berlin — [2]ETH Zürich — [3]MBI Berlin — [4]BTU Cottbus-Senftenberg

Coherent diffractive imaging of individual nanoparticles, such as viruses, nanocrystals or clusters, has become feasible with the intense X-ray or extreme ultraviolet (XUV) light pulses free-electron lasers provide. Only recently, the development of powerful high harmonic generation sources delivering intense harmonics up to the XUV regime enabled laboratory-based imaging experiments. The scattering of multiple harmonics leads to multicolor diffraction patterns containing information on the nanoparticle shape. In an experiment at the Max-Born-Institute, Berlin, we studied the structure of large neon clusters. By comparing simulated scattering patterns with the experimental data we identified structures typical for rare gas cluster growth by coagulation. In addition when the neon clusters are produced from the liquid phase, scattering patterns indicating facet-like structures are observed.

A 5.10 Tue 16:30 P

Angular resolved photoemission of metal atoms embedded in helium nanodroplets in the MPI regime — •Bennet Krebs, Michael Zabel, Lev Kazak, and Josef Tiggesbäumker — Institut für Physik, Universität Rostock, Germany

Angular resolved photoelectron emission spectra of single metal atoms embedded in helium nanodroplets are measured, analyzed and compared to free atoms. A femtosecond laser system provides 110 fs, linear polarised laser pulses, which are used to ionize the atomic targets in the multiphoton regime (I$\approx 10^{13\cdots14}$W/cm^2) without ionizing the helium nanodroplet itself. Furthermore a time delay controlled two color setup with overlapping $2\omega/\omega$ (400 nm/800 nm) fields is used to probe the attosecond dynamics. For this we apply the highly sensitive Phase-of-the-Phase (PoP) method, which has been previously used to extract information about photoelectron trajectories. Compared to the anisotropic above-threshold-ionization (ATI) signals from free atoms a near isotropic emission is obtained for the embedded species. Furthermore, an enhancement of ATI signals and additional ATI orders can be observed. In the same vein we see a reduction of relative phase contrast. The impact of elastic scattering of the electrons with the surrounding helium environment will be discussed.

A 6: Atomic systems in external fields

Time: Tuesday 16:30–18:30 Location: P

A 6.1 Tue 16:30 P

Trichromatic shaper-based quantum state holography — •Kevin Eickhoff, Lea-Christin Feld, Darius Köhnke, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität, Oldenburg, Deutschland

We present a shaper-based quantum state holography (SQuaSH) scheme based on the holographic generation of photoelectron superposition wave packets by multiphoton ionization (MPI) using pulse-shaper-generated trichromatic pump-probe-reference femtosecond pulse sequences. Differential detection of the created photoelectron wave packets enables the measurement of quantum phases imprinted in the hologram by the ionization dynamics. We implement the scheme experimentally by combining trichromatic white light shaping with velocity map imaging (VMI) of photoelectron wave packets, and investigate the MPI of potassium atoms. By interference of a probe wave packet, created by (2+1) resonance-enhanced MPI (REMPI) via the $3d$-state being two-photon resonant with the pump-pulse, and a reference wave packet from non-resonant three-photon ionization of the $4s$ ground state, we create f-type photoelectron holograms. Coherent control of the holograms by the relative optical phases of the pulse sequence is demonstrated and utilized to separate the phase-sensitive part of the hologram from the phase-insensitive background. Then we apply the scheme to determine time- and energy-dependent atomic ionization phases arising due to the time-evolution of the excited system and the detuning of the pump-pulse from the $3d$-state.

A 6.2 Tue 16:30 P

Coherent control mechanisms in bichromatic multiphoton ionization — •Lea-Christin Feld, Kevin Eickhoff, Darius Köhnke, Lars Englert, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität, Oldenburg, Deutschland

We study two basic physical mechanisms underlying the coherent control of atomic multiphoton ionization (MPI) with bichromatic polarization-shaped femtosecond laser pulses, termed interband and intraband interference. The simultaneous measurement of energetically separated photoelectrons from both mechanisms in a single photoelectron momentum distribution (PMD) allows to compare the corresponding phase and polarization control of the angular distributions. Experimentally, we combine bichromatic polarization pulse shaping of a carrier-envelope phase-stable supercontinua with photoelectron tomography. The controllability of the PMD is investigated in three scenarios. First, counterrotating circularly polarized pulses are employed to contrast phase-insensitive angular momentum eigenstates created by intraband interference with a phase-sensitive c_7 rotationally symmetric free electron vortex (FEV) from pure interband interference. Second, orthogonal linearly polarized pulses are used to compare the phase-independence of a six-lobed angular momentum wave packet from intraband interference to the sensitivity of a complex shaped interband PMD in the presence of phase fluctuations. Finally, we demonstrate phase control of a photoelectron hologram from mixed interband interference. The azimuthal rotation of the hologram maps the time evolution of the bound state wave packet, allowing for FEV spectroscopy.

A 6.3 Tue 16:30 P

Free electron vortices meet optical vortex beams: Analogies and Differences — •Darius Köhnke[1], Kevin Eickhoff[1], Lea-Christin Feld[1], Stefanie Kerbstadt[1,2], Lars Englert[1], Tim Bayer[1], and Matthias Wollenhaupt[1] — [1]Carl von Ossietzky Universität Oldenburg, Carl-von-Ossietzky-Straße 9-11, D-26129 Oldenburg, Germany — [2]Center for Free-Electron Laser Science (CFEL), Deutsches Elektronen Synchrotron DESY, Notkestraße 85, D-22607 Hamburg, Germany

In recent years, vortex states have attracted significant interest in various fields of physics ranging from fundamental studies of light-matter interaction to advanced optical applications. Here, we present a comparative study of free electron vortices created by atomic multiphoton ionization and optical vortex beams generated with a holographic technique. On the one hand we use spectral pulse shaping to generate polarization-tailored carrier-envelope phase stable bichromatic laser pulses creating photoelectron vortices. On the other hand we employ computer generated holograms for spatial tailoring of a laser beam forming optical vortex beams. While both methods can be interpreted as an advanced double slit experiment in either the spectral or spatial domain, the resulting topological properties of the vortex states are quite different. We discuss the different topological properties as well as their manipulation. Further we demonstrate control of the symmetry and orientation of the vortex states in both scenarios.

A 6.4 Tue 16:30 P

Mass defect, time dilation and second order Doppler effect in trapped-ion optical clocks — •Victor Jose Martinez Lahuerta[1], Simon Eilers[1], Marius Schulte[1], Tanja Mehlstäubler[2], Piet Schmidt[2,3], and Klemens Hammerer[1] — [1]Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute), Leibniz University Hannover — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [3]Institute for Quantum optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover

We derive an approximate relativistic Hamiltonian for the center of mass and internal dynamics of an electromagnetically bound, charged two-particle system in external electromagnetic and gravitational fields. This extends earlier work by Sonnleitner and Barnett and Schwartz and Giulini to hydrogen-like ions. We apply this Hamiltonian to describe the relativistic coupling of the center of mass and internal dynamics of cold ions in Paul traps, including the effects of micromotion. In this way, we are able to provide a systematic fully quantum mechanical treatment of relativistic frequency shifts and their standard deviation in atomic clocks based on trapped ions. Our approach reproduces known formulas for the second order Doppler shift, which were previously derived on the basis of semi-classical arguments. We also complement and clarify recent discussions on the role of time dilation and mass defect in ion clocks.

A 7: Attosecond physics

Time: Tuesday 16:30–18:30 Location: P

A 7.1 Tue 16:30 P

Time Delay and Nonadiabatic Calibration of the Attoclock — •Ossama Kullie — University of Kassel

The measurement of the tunneling time in attosecond experiments, termed attoclock, triggered a hot debate about the tunneling time, the role of time in quantum mechanics and the separation of the interaction with the laser pulse into two regimes of a different character, the multiphoton and the tunneling (field-) ionization. In the adiabatic field calibration, we showed in earlier works [1] that our real tunneling time approach fits well to the experimental data of the attoclock. In the present work [2], we show that our model can explain the experimental results in the nonadiabatic field calibration, where we reach a good agreement with the experimental data of Hofmann et al. (J. of Mod. Opt. **66**, 1052, 2019). Moreover, our result is confirmed by the numerical integration of the time-dependent Schrödinger equation of Ivanov et al. (Phys. Rev. A **89**, 021402, 2014). Our model is appealing because it offers a clear picture of the multiphoton and tunneling parts. In the nonadiabatic case, the barrier region itself is mainly driven by multiphoton absorption, where the number of the absorbed photons to be characterized by the barrier height. Surprisingly, at a field strength $F < F_a$ (the atomic field strength) the model always indicates a time delay with respect to the lower quantum limit at $F = F_a$. [1] O. Kullie, PRA **92**, 052118 (2015), J. Phys. B 49 , 095601 (2016). [2] O. Kullie, submitted .... (2021), arXiv:2005.09938.

A 7.2 Tue 16:30 P

Signatures and Scaling of the Strong-Field Ionization Response in Low-Order Harmonic Generation — •Benjamin Liewehr[1], Björn Kruse[1], Christian Peltz[1] und Thomas Fennel[1,2] — [1]Institute for Physics, University of Rostock, Albert-Einstein-Str. 23, D-18059, Rostock, Germany — [2]Max-Born-Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Strasse 2A, D-12489 Berlin, Germany

The notion of nonlinear response in dielectric solids has been successfully extended to the strong field ionization regime by linking high-order harmonic generation (HHG) to Bloch oscillations and interband recombination [1,2]. Recently, however, it was shown that these mechanisms cannot explain the emission of low harmonic orders which, instead, are generated by the strong field tunneling excitation that drives Brunel [3] and injection currents. While the tunneling injection current has been identified as the dominant mechanism close to the damage threshold [4], it is so far not known to which extent information about the transient excitation is imprinted on emitted low-order harmonics. Employing an ionization-radiation model, we examine the scaling behavior of ionization induced low-order harmonics and discuss mechanisim specific signatures for different polarization configurations.

[1] T. T. Luu, et al. Nature **521**, 498 (2015)
[2] G. Vampa, et al. Nature **522**, 462 (2015)
[3] F. Brunel, J. Opt. Soc. Am. B **4**, 521 (1990)
[4] P. Jürgens, B. Liewehr, B. Kruse, et al. Nat. Phys. **16**, 1035 (2020)

A 7.3 Tue 16:30 P

Classical model for collisional delays in attosecond streaking at solids — •Elisabeth A. Herzig[1], Lennart Seiffert[1], and Thomas Fennel[1,2] — [1]Universität Rostock — [2]MBI Berlin

Scattering of electrons in solids is at the heart of laser nanomachining, light-driven electronics, and radiation damage. Accurate theoretical predictions of the underlying dynamics require precise knowledge of low-energy electron transport involving elastic and inelastic collisions. Recently, real-time access to electron scattering in dielectric nanoparticles via attosecond streaking has been reported [1,2]. Semiclassical transport simulations [3] enabled to identify that the presence of the field inside of a dielectric nanosphere cancels the influence of elastic scattering, enabling selective characterization of the inelastic scattering time [1]. However, so far a clear picture of the underlying physics was lacking. Here, we present an intuitive classical model for the prediction of collision-induced contributions to the delays in attosecond streaking at solids.

[1] L. Seiffert et al., Nat. Phys. **13**, 766-770 (2017)
[2] Q. Liu et al., J. Opt. **20**, 024002 (2018)
[3] F. Süßmann et al., Nat. Commun. **6**, 7944 (2015)

A 7.4 Tue 16:30 P

Chiral imaging with twisted photoelectrons — Xavier Barcons[1], Andrés Ordonez[1], Maciej Lewenstein[1], and •Andrew Maxwell[1,2] — [1]ICFO - Institut de Ciencies Fotoniques, Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona), Spain — [2]Department of Physics and Astronomy, Aarhus University, DK-8000 Aarhus C, Denmark

The orbital angular momentum (OAM) of a free particle is a quantized observable leading to a rotating vortex wave. *Twisted* light and electrons have huge potential in imaging of matter in attosecond physics. Much attention has been devoted to the OAM of light fields, but in this work we will focus on the less-studied photoelectron OAM (PEOAM), exploring the great potential to image chiral matter.

In previous work, we developed an adapted version of the well-known strong-field approximation (SFA), to derive strong-field conservation laws for the OAM twisted electrons. This was exploited, in other work, to provide an alternative interpretation on existing experimental work of vortex interferences caused by strong field ionization.

Now we investigate the ability to probe chiral states with PEOAM. Exploiting a construction of chiral states from hydrogenic orbitals, allows an analytical and numerical demonstration of how chirality is encoded in the PEOAM. We will show, that asymmetries maybe observed in the OAM resolved photoelectron momentum distributions for strong-field ionization via a *linearly* polarized field. Thus, paving the way for a new kind of chiral specific imaging technique that, unlike photoelectron circular dichroism, may use linear fields.

A 8: Collisions, scattering, and correlation phenomena

Time: Tuesday 16:30–18:30 Location: P

A 8.1 Tue 16:30 P

Near-adiabatic collisions of Xe54+ +Xe at the ESR Storage ring — •Siegbert Hagmann[1], Pierre-Michel Hillenbrand[1,2], Jan Glorius[1], Uwe Spillmann[1], Yuri Litvinov[1], Yuri Kozhedub[6], Ilya Tupitsyn[6], Michael Lestinsky[1], Alexander Gumberidze[1,3], Sergij Trotsenko[1,4], Markus Steck[1], Robert Grisenti[1,2], Niikos Petridis[1,2], Shahab Sanjari[1], Carsten Brandau[1], Ester Menz[1], Timo Morgenroth[1], and Thomas Stoehlker[1,4,5] — [1]Helmholtzzentrum GSI, Darmstadt — [2]Inst. f. Kernphysik, Univ. Frankfurt — [3]EMMI GSI-Darmstadt — [4]Helmholtz Inst Jena — [5]Inst.f.Quantenelektronik Univ Jena — [6]Dep Phys. St Petersburg State Univ

We study multi-electron transfer processes in near adiabatic collisions of bare, H-like and He-like Xe54+*52+ ions with Xe atoms and measure emitted target- and projectile K- and L- x rays in coincidence with projectiles which have captured 3 to 6 electrons, and with time of flight of recoiling Xe target ions. Shells beyond the projectile P shell are significantly populated; K x rays from high n shells indicate that outer shell transfer dominantly ends in low l states, decaying directly to the K shell. Single capture favors capture into the 2p3/2 over the 2p1/2 state and multiple capture n*3 the 2p1/2 populates than the 2p3/2 state. For the target K x ray spectra, we observe that the ratio K- satellite/K-hypersatellite yields is enhanced over the predictions by a relativistic theory.

A 8.2 Tue 16:30 P

Atom-molecule and molecule-molecule collisions in NaK quantum gases — •Philipp Gersema[1], Mara Meyer zum Alten Borgloh[1], Kai Konrad Voges[1], Torsten Hartmann[1], Leon Karpa[1], Alessandro Zenesini[2], and Silke Ospelkaus[1] — [1]Leibniz Universität Hannover — [2]Universita di Trento

Ultracold polar ground-state molecules provide an excellent platform for the study of atom-molecule and molecule-molecule collisions in the quantum regime. For endoergic collision channels, it has been suggested that long-lived collisional complexes form which can then be removed from the trap by additional mechanisms such as light-excitation.

Here, we investigate atom-molecule and molecule-molecule collisions in quantum gases of $^{23}Na^{39}K$. We probe photo-induced loss of four-body complexes forming in molecule-molecule collisions in chopped optical dipole traps and find the lower limit of the complex lifetime to be much larger than the lifetime derived from RRKM theory.

We also present studies of atom-molecule collisions including loss between molecules and ^{39}K atoms in several spin states.

A 9: Interaction with strong or short laser pulses

Time: Tuesday 16:30–18:30 Location: P

A 9.1 Tue 16:30 P

Modeling ultrashort laser pulses in nonlinear media using FDTD — •Jonas Apportin, Christian Peltz, Björn Kruse, Benjamin Liewehr, and Thomas Fennel — Institute for Physics, Rostock, Germany

The Finite-Differences-Time-Domain (FDTD) method provides a real-time solution to Maxwell's equations on a spatial grid that can be easily extended by rate equations for e.g. ionization and is therefore optimally suited for the modeling of nonlinear laser-material interaction close to the damage threshold. However, the tight focusing conditions associated with high laser intensities result in non-Gaussian beam profiles that no longer obey the typically applied paraxial approximation, thereby considerably complicating their description within the FDTD framework. We apply an efficient description of such tightly focused beams, based on the decomposition of the laser profile into plane waves and their separate propagation including the compensation of numerical dispersion. The nonlinear material response is modeled using nonlinear Lorentz oscillators for Kerr-type nonlinearities [1] and Brunel as well as injection currents associated with the excitation of electrons into the conduction band for higher order nonlinearities [2]. First simulation results for strong and ultrashort laser pulses tightly focused into thin fused silica films ($d \approx 10\mu m$) show the formation of a pronounced ionization grating due to standing waves at the rear material surfaces.

[1] C. Varin et al., Comput. Phys. Commun. **222** 70-83 (2018)
[2] P. Jürgens et al., Nature Physics **160**, 1035-1039 (2020)

A 9.2 Tue 16:30 P

Ignition of a helium nanoplasma by pump-probe multiple ionization of a dopant core — •Cristian Medina[1], Dominik Schomas[1], Markus Debatin[1], Ltaif Ltaif[2], Robert Moshammer[3], Thomas Pfeifer[3], Hoque Ziaul[4], Andreas Hult[4], Maria Krikunova[4], Frank Stienkemeier[1], and Marcel

Mudrich[2] — [1]University of Freiburg , Freiburg , Germany — [2]Aarhus University, Aarhus , Denmark — [3]Max-Planck-Institut für Kernphysik, Heidelberg. Germany — [4]- Extreme Light Institute, Prague, Czech Rep.

Helium nanoplasmas are usually created by intense near-infrared laser pulses. After tunnel ionization of the cluster or some dopant atoms, the cluster fully avalanche-ionizes as the electrons are driven back and forth through the cluster by the laser field. We demonstrate a different scheme for igniting the nanoplasma on doped helium nanodroplets. An ultrashort X-ray pulse (FLASH-1 at DESY, Hamburg) or the 19th higher harmonics from an 800 nm pulse (ELI, Prague) first inner-shell ionizes the dopant cluster, followed by Auger decay and charge-transfer ionization of the helium shell. A second near-infrared pulse drives the nanoplasma at variable delay with respect to the pump pulse. At certain delay times, a resonance appears, indicated by an increase of the ignition probability, evidenced by the rise of He+ and He2+ ion yields, the hit rate as well as the electron kinetic energy.

A 9.3 Tue 16:30 P

HILITE - stored ions for non-linear laser-ion experiments — •Markus Kiffer[1], Stefan Ringleb[1], Nils Stallkamp[1,2], Belá Arndt[3], Sugam Kumar[4], Gerhard Paulus[1,5], Wolfgang Quint[2,6], Thomas Stöhlker[1,2,5], and Manuel Vogel[2] — [1]Friedrich-Schiller-Universität, Jena — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [3]Goethe Universität Frankfurt, Frankfurt — [4]Inter-University Accelerator Centre, New Delhii — [5]Helmholtz-Institut Jena, Jena — [6]Ruprecht Karls-Universität Heidelberg, Heidelberg

The development of free-electron lasers with photon energies in the XUV to X-ray regime opens up new possibilities to investigate nonlinear laser-matter interaction. Ionic systems with only one active electron are of particular interest - especially hydrogen-like systems.

To investigate such systems we have built and commissioned the HILITE (**H**igh-**I**ntensity **L**aser **I**on-**T**rap **E**xperiment) Penning trap. The ions are produced by an Electron-Beam Ion Trap (EBIT), selected by a Wien filter, and captured dynamically in the trap centre.

Last year we conducted our first Beam time at the FLASH2 FEL laser facility at DESY in Hamburg, where we wanted to investigate two photon ionisation of O^{5+}. We have had to deal with unexpectedly bad vacuum conditions which limited the storage time and significantly increased the background signal.

We will present the setup, the commissioning results and results from our first beamtime. We will also present envisaged upgrades of the setup.

A 9.4 Tue 16:30 P

Strong-field ionization mechanisms of selectively prepared doubly excited states in helium — •Gergana D. Borisova[1], Hannes Lindenblatt[1], Severin Meister[1], Florian Trost[1], Patrizia Schoch[1], Veit Stooss[1], Markus Braune[2], Rolf Treusch[2], Harald Redlin[2], Nora Schirmel[2], Paul Birk[1], Maximilian Hartmann[1], Christian Ott[1], Robert Moshammer[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Deutschland — [2]Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Deutschland

Atomic and molecular systems have one, or a few, energetically lowest ground states but a multitude of excited states, all exhibiting different electron correlation. To gain new insights into the role of the initial state, with its specific electron correlation, for the ionization process, we conducted a two-color extreme ultraviolet (XUV)-infrared (IR) experiment using a reaction microscope (ReMi) to study IR strong-field ionization out of selectively prepared doubly excited states in helium in the XUV energy region between 59 eV and 80 eV, with XUV light provided by the free-electron laser in Hamburg FLASH. Both single- and double-ionization have been observed and the impact of different strong-field ionization mechanisms will be discussed, also in comparison with model calculations.

A 9.5 Tue 16:30 P

Contributions of edge-currents on the high-order harmonic generation in topological insulators — •Christoph Jürss and Dieter Bauer — University of Rostock, Institute of Physics, Rostock, Germany

Edge-states in topological insulators are localized on the edge of the solid system. They are robust against various perturbations. Edge currents allow a scatter-free electronic transport along the edge of the solid. In our work, the influence of edge-currents in the topological Haldanite material is simulated. The harmonic spectra for finite and the bulk system are compared and the contributions from the edge are identified. The frequency of the emitted light from the edge-current strongly depends on the size of the material, which opens new possibilities for multiple applications.

A 9.6 Tue 16:30 P

Imaging ultrafast laser-driven dynamics in thin foils via inline holography — •Richard Altenkirch, Christian Peltz, Franziska Fennel, Stefan Lochbrunner, and Thomas Fennel — Institute for Physics, Rostock, Germany

Well controlled laser material processing with a spatial resolution on the scale of the laser wavelength is key to the realization of a large variety of applications. Respective developments will strongly benefit from a full spatial and temporal characterization of the laser-induced plasma evolution. To this end, we implemented an experiment based on coherent diffractive imaging (CDI), a technique well known from free particle characterization using XUVs and Xrays [1]. The probe pulse images the spatial plasma profile evolution induced by the pump pulse in a thin gold foil. The resulting scattering images are used for a reconstruction via phase retrieval [2]. In contrast to typical Xray CDI experiments, we record a superposition of scattered radiation and the radiation transmitted through the intact foil, leading to holographic signatures. Here, we present a systematic numerical analysis of the role of these holographic features for the object reconstruction as well as the optimal experimental conditions. We further present a first successful application of the reconstruction method to experimental data, i.e. laser-drilled holes.

[1] H. Chapman et al., Nature Physics **2** 839-843 (2006)
[2] J. Fienup, Appl. Opt. **21**, 2758-2769 (1982)

A 10: Interaction with VUV and X-ray light

Time: Tuesday 16:30–18:30 Location: P

A 10.1 Tue 16:30 P

Towards X-Ray Ramsey Interferometry using Nuclear Resonant Scattering — •Lukas Wolff and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Nonlinear spectroscopic techniques such as multidimensional spectroscopy or pump-probe spectroscopy have become indispensable tools for probing ultrafast dynamics of quantum systems in the optical and infrared regime. In contrast, precise control of timing and phase properties of light pulses in the X-ray and XUV-regime still remains challenging due to the properties of available coherent X-ray sources and optics. In the hard X-ray regime, Mößbauer nuclei featuring exceptionally narrow resonances can be employed to split light from modern high-brilliance coherent x-ray sources into double-pulses with characteristic spectral features. High-precision control of the relative phase between these double-pulses was demonstrated recently using fast mechanical motion of nuclear targets.

Here, we explore the possibility of using X-ray double-pulses created with Mößbauer nuclei to implement Ramsey interferometry in the low-excitation regime of nuclear resonant scattering. Our findings may help to pave the way towards multi-pulse control and probe schemes in the hard X-ray regime.

A 10.2 Tue 16:30 P

Fast resonant adaptive x-ray optics via mechanically-induced refractive-index enhancements — •Miriam Gerharz and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg

In this project we introduce a concept for fast resonant adaptive x-ray optics. Using piezo-control methods, we can displace a solid-state target much faster than the lifetime of its resonances. Because in nuclear forward scattering the interference of the sample response with the prompt pulse (fs-ps long) is crucial, the displacement induces a phase shift. This mechanically induced phase shift can be associated with an additional contribution on resonance to the real part of the refractive index while the imaginary part remains unchanged. Hence, we can achieve polarization control by mechanically-induced birefringence without changes in absorption. We demonstrate the approach with two examples: the conversion from linear polarization as often provided by synchrotrons to circular polarization and the rotation of linear polarization, which together with a polarimeter can be used for switching within a single experimental cycle.

A 10.3 Tue 16:30 P

Comprehensive investigation of nondipole effects in photoionization of the He 1*s* and Ne 2*s* shells — •Ticia Buhr[1], Levente Ábrók[2], Alfred Müller[1], Stefan Schippers[1], Ákos Kövér[2], and Sándor Ricz[2] — [1]Justus-Liebig-Universität Gießen, Giessen, Germany — [2]Institute for Nuclear Research, Debrecen, Hungary

Nondipole effects strongly modify the polar- and azimuthal-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 azimuthal angles covering a solid angle of about 2π at 100 eV and 200 eV photon energies using linearly polarized synchrotron radiation. The photoelectrons were detected with an ESA-22-type electrostatic electron spectrometer [2] in in-plane and in out-of-plane geometry as determined by the photon momentum and polarization vectors. The observed difference between the experimental and theoretical angular distributions might be explained by the neglected terms in the calculation [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 10.4 Tue 16:30 P

Inner-shell-ionization-induced femtosecond structural dynamics of water molecules imaged at an x-ray free-electron laser — •Ludger Inhester[1], Till Jahnke[2], Renaud Guillemin[3], and Maria Novella Piancastelli[3,4] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]European XFEL GmbH, Schenefeld, Germany — [3]Sorbonne Université, CNRS, LCPMR, Paris, France — [4]Uppsala University, Uppsala, Sweden

Further co-authors are given on the poster
We have exposed isolated water molecules to short x-ray pulses from a free-electron laser and detected momenta of all produced ions in coincidence. By combining experimental results and theoretical modeling, we can image the dissociation dynamics of water after core-shell ionization and subsequent Auger decay in unprecedented detail and uncover fundamental dynamical patterns relevant for the radiation damage in aqueous environments.

A 11: Ultra-cold plasmas and Rydberg systems (joint session A/Q)

Time: Tuesday 16:30–18:30 Location: P

A 11.1 Tue 16:30 P

Ultrafast Electron Cooling in an Ultracold Microplasma — •Mario Grossmann, Tobias Kroker, Julian Fiedler, Jette Heyer, Markus Drescher, Klaus Sengstock, Philipp Wessels-Staarmann, and Juliette Simonet — The Hamburg Centre for Ultrafast Imaging (CUI), Luruper Chaussee 149, 22761 Hamburg

We utilize the strong light-field of a focused femtosecond laser pulse to instantaneously and locally ionize a controlled number of atoms within a ^{87}Rb Bose-Einstein condensate.
The large atomic densities above 10^{20} m^{-3} combined with low ion temperatures below 40 mK give rise to an initially strongly coupled plasma with up to a few thousand electrons and ions.
Our experimental setup allows us to tune the density, volume and number of ionized atoms as well as the excess energy after ionization which sets the neutrality of the ultracold plasma.
By directly measuring the kinetic energy of the emerging electrons from a highly charged plasma we observe a cooling of the electronic component from 5250 K to 10 K in less then 500 ns.
The finite particle number permits us to perform exact numerical calculations of the plasma dynamics with long-range Coulomb interactions in excellent agreement with our experimental data. These simulations reveal the picosecond dynamics of each particle as well as the ultrafast energy transfer between the electronic and ionic components of the plasma, bridging the natural time-scales of ultracold neutral plasma and ionized nanoclusters.

A 11.2 Tue 16:30 P

Quantum sensing protocol for motionally chiral Rydberg atoms — Stefan Yoshi Buhmann[1], Steffen Giesen[2], Mira Diekmann[2], Robert Berger[2], •Stefan Aull[3], Markus Debatin[3], Peter Zahariev[3,4], and Kilian Singer[3] — [1]Theoretische Physik III, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Fachbereich Chemie, Philipps-Universität Marburg, Hans-Meerwein-Str 4, Marburg 35032, Germany — [3]Experimentalphysik I, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [4]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72, Tzarigradsko Chaussee, 1784 Sofia, Bulgaria

A quantum sensing protocol is proposed for demonstrating the motion-induced chirality of circularly polarised Rydberg atoms. To this end, a cloud of Rydberg atoms is dressed by a bichromatic light field. This allows to exploit the long-lived ground states for implementing a Ramsey interferometer in conjunction with a spin echo pulse sequence for refocussing achiral interactions. Optimal parameters for the dressing lasers are identified. Combining a circularly polarised dipole transition in the Rydberg atom with atomic centre-of-mass motion, the system becomes chiral. The resulting discriminatory chiral energy shifts induced by a chiral mirror are estimated using a macroscopic quantum electrodynamics approach.

A 11.3 Tue 16:30 P

Reconstructing three-dimensional density distributions from absorption images — Henrik Zahn[1], •Maximilian Klaus Müllenbach[2], Titus Franz[2], Clément Hainaut[2], Gerhard Zürn[2], and Matthias Weidemüller[2] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

We present a novel method to reconstruct a three-dimensional density distribution from its two-dimensional projection in a suitably chosen direction as long as the distribution has an a-priori known continuous symmetry. Our method extends the well-known Abel transform for distributions with axial or spherical symmetry to distributions with more general continuous symmetries. A-priori knowledge of the present symmetries allows us to solve the inversion problem by finding the density distribution's values along its isolines. We apply our method to two distinct settings, the first one being such that Abel inversion can be applied, i.e. rotational symmetry about an axis perpendicular to the integration direction. In the second setting we apply our method to study excitation dynamics of Rydberg atoms, featuring a complex symmetry determined by the cigar-like shape of the ground state density distribution and the axially symmetric excitation laser, angled at 45° with respect to the ground state symmetry axis.

A 11.4 Tue 16:30 P

Towards an optogalvanic flux sensor for nitric oxide based on Rydberg excitations — Patrick Kaspar[1,5], Fabian Munkes[1,5], •Yannick Schellander[3], Lars Baumgärtner[2], Lea Ebel[1], Denis Djekic[2], Patrick Schalberger[3], Holger Baur[3], Jens Anders[2,5], Edward Grant[4], Norbert Frühauf[3], Robert Löw[1,5], Tilman Pfau[1,5], and Harald Kübler[1,5] — [1]5 Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [2]Institut für Intelligente Sensorik und Theoretische Elektrotechnik, Universität Stuttgart, Pfaffenwaldring 47, 70569 Stuttgart — [3]Institut für Großflächige Mikroelektronik, Universität Stuttgart, Allmandring 3b, 70569 Stuttgart — [4]Department of Chemistry & Department of Astronomy, The University of British Columbia, 2036 Main Mall, Vancouver, BC Canada V6T 1Z1 Vancouver, Canada — [5]Center for Integrated Quantum Science and Technology, Universität Stuttgart

We demonstrate the applicability of a new kind of gas sensor based on Rydberg excitations. From a gas mixture the molecule in question is excited to a Rydberg state. By succeeding collisions with all other gas components this molecule becomes ionized and the emerging electrons can be measured as a current. In a proof of concept experiment a detection limit of 10 ppm in a background of He was demonstrated [1,2]. We show first results of the continous wave sensor prototype and first signals of Doppler-free laser spectroscopy on nitric oxide.

[1] J. Schmidt, et. al., *Appl. Phys. Lett.* **113**, 011113 (2018)
[2] J. Schmidt, et. al., SPIE **10674** (2018)

A 11.5 Tue 16:30 P

Two-dimensional spectroscopy of Rydberg gases — •Kaustav Mukherjee[1], Himangshu Prabal Goswami[2,4], Shannon Whitlock[3], Sebastian Wüster[1], and Alexander Eisfeld[4] — [1]Indian Institute of Science Education and Research, Bhopal, India — [2]Gauhati University, Guwahati, India — [3]University of Strasbourg and CNRS, Strasbourg, France — [4]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Two-dimensional (2D) spectroscopy uses multiple electromagnetic pulses to infer the properties of a complex system. A paradigmatic class of target systems is molecular aggregates, for which one can obtain information on the eigenstates, various types of static and dynamic disorder, and relaxation processes. However, two-dimensional spectra can be difficult to interpret without precise knowledge of how the signal components relate to microscopic Hamiltonian parameters and system-bath interactions. Here we show that two-dimensional spectroscopy can be mapped in the microwave domain to highly controllable Rydberg quantum simulators. By porting 2D spectroscopy to Rydberg atoms, we firstly open the possibility of its experimental quantum simulation, in a case where parameters and interactions are very well known. Secondly, the technique may provide additional handles for experimental access to coherences between system states and the ability to discriminate different types of decoherence mechanisms in Rydberg gases. We investigate the requirements for a specific implementation utilizing multiple phase-coherent microwave pulses and a phase cycling technique to isolate signal components.

A 12: Highly charged ions and their applications

Time: Tuesday 16:30–18:30 Location: P

A 12.1 Tue 16:30 P

Fundamental physics with highly charged ions — •Alexander Wilzewski[1], Lukas J. Spiess[1], Steven A. King[1], Peter Micke[1,2], Erik Benkler[1], Tobias Leopold[1], Michael K. Rosner[2], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Max-Planck-Instituts für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Highly charged ions (HCIs) increase the number of optical transitions that can be probed with optical-clock-like accuracy, they are particularly interesting for isotope shift measurements and King plot analyses [1]. In our experiment, we extract HCIs from an electron-beam ion trap (EBIT) and transfer them through a beamline to a linear Paul trap where they are recaptured and sympathetically cooled by laser-cooled Be^+ ions. and We have subsequently performed quantum logic spectroscopy on a HCI-Be^+ two-ion crystal [2]. We are currently evaluating the systematic uncertainties of our $^{40}Ar^{13+}$ clock in order to determine the isotope shift between $^{40}Ar^{13+}$ and $^{36}Ar^{13+}$ with sub-Hz accuracy. Since Ca^{14+} offers many stable isotopes for a King plot analysis, we will extend the isotope shift measurements afterwards to this species, for which loading into an EBIT from a solid target was recently demonstrated, and a clock laser system is under construction.

[1] J. C. Berengut *et al.*, Phys. Rev. Research **2** (2020), [2] P. Micke *et al.*, Nature **578** (2020)

A 12.2 Tue 16:30 P

Laser cooling of stored relativistic bunched ion beams at the ESR — •Sebastian Klammes[1,2], Lars Bozyk[1], Michael Bussmann[3], Noah Eizenhöfer[2], Volker Hannen[4], Max Horst[2], Daniel Kiefer[2], Nils Kiefer[5], Thomas Kühl[1,6], Benedikt Langfeld[2], Xinwen Ma[7], Wilfried Nörtershäuser[2], Rodolfo Sánchez[1], Ulrich Schramm[3,8], Mathias Siebold[3], Peter Spiller[1], Markus Steck[1], Thomas Stöhlker[1,6,9], Ken Ueberholz[4], Thomas Walther[2], Hanbing Wang[7], Weiqiang Wen[7], Daniel Winzen[4], and Danyal Winters[1] — [1]GSI Darmstadt — [2]TU Darmstadt — [3]HZDR Dresden — [4]Uni Münster — [5]Uni Kassel — [6]HI Jena — [7]IMP Lanzhou — [8]TU Dresden — [9]Uni-Jena

At heavy-ion storage rings, almost all experiments strongly benefit from cooled ion beams, i.e. beams which have a small longitudinal momentum spread and a small emittance. During the last two decades, laser cooling has proven to be a powerful tool for relativistic bunched ion beams, and its "effectiveness" is expected to increase further with the Lorentz factor (γ). The technique is based on resonant absorption (of photon momentum & energy) in the longitudinal direction and subsequent spontaneous random emission (fluorescence & ion recoil) by the ions, combined with moderate bunching of the ion beam. Laser cooling can also achieve a stronger and faster cooling than electron and stochastic cooling. We will report on recent (May 2021) preliminary results from a laser cooling test beamtime at the ESR at GSI in Darmstadt, Germany. We will also present our plans and progress for laser cooling experiments at FAIR (SIS100).

A 12.3 Tue 16:30 P

An Optical Clock based on a Highly Charged Ion — •Lukas J. Spiess[1], Steven A. King[1], Peter Micke[1,2], Alexander Wilzewski[1], Erik Benkler[1], Tobias Leopold[1], José R. Crespo López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

Highly charged ion (HCI) offer narrow transitions suitable for high-accuracy optical clocks with predicted uncertainties below 10^{-18}, since they are intrinsically less sensitive to external perturbations [1]. At the same time, the strongly relativistic character of the remaining electrons renders HCI particularly sensitive to physics beyond the Standard Model. Previously, we have demonstrated that a single HCI can be extracted from a hot plasma and injected into laser-cooled Be^+ ions. This allowed for the first demonstration of quantum logic spectroscopy using HCI and enabled high-precision spectroscopy [2].

Here, we will present optical-clock like interrogation of the 441 nm transition in Ar^{13+} and the evaluation of systematic shifts with an expected uncertainty of below 10^{-16} [3]. This is leading up to our absolute frequency measurement of Ar^{13+}, which will be the first time a transition in any HCI is measured with sub-Hz accuracy.

[1] M. G. Kozlov *et al.*, Rev. Mod. Phys. **90**, 045005 (2018)
[2] P. Micke *et al.*, Nature **578**, p. 60-65 (2020)
[3] S. A. King *et al.*, arXiv:2102.12427 (2021)

A 12.4 Tue 16:30 P

***g*-Factor Measurements of Heavy Highly Charged Ions in a Penning Trap** — •J. Morgner, C. M. König, T. Sailer, F. Heisse, B. Tu, V. A. Yerokhin, B. Sikora, Z. Harman, J. R. Crespo López-Urrutia, C. H. Keitel, S. Sturm, and K. Blaum — Max-Planck-Institute für Kernphysik, Saupfercheckweg 1, DE-69117 Heidelberg

Quantum electrodynamics (QED) has shown great success in describing microscopic systems, e.g. single ions. In low electromagnetic fields, QED has been tested with unprecedented high precision [1]. Therefore, it is especially interesting to test QED in extremely high fields by comparing theoretical and experimentally measured bound-electron g-factors of single ions. In extreme cases, e.g. $^{208}Pb^{81+}$, only a single electron is bound to the nucleus, which therefore experiences strong electric fields up to 10^{18} V/m. The Penning trap setup of ALPHATRAP is dedicated to measure these bound-electron g-factors in even the heaviest highly charged ion systems with a relative precision better than $1 \cdot 10^{-10}$ [2].

In this contribution, the status of a recent g-factor measurement of hydrogen-like and lithium-like ^{118}Sn is presented. This probes the bound-electron g-factor of heavy highly charged ions with a precision previously inaccessible. Further, progress on an electron beam ion trap is presented. In the future, this could provide ALPHATRAP with even heavier highly charged ion systems up to hydrogen-like lead.

[1] D. Hanneke *et al*, PRL **100**, 120801 (2008)
[2] S. Sturm *et al*, EPJ **227**, 1425*1491 (2019)

A 12.5 Tue 16:30 P

First DR experiments at CRYRING@ESR — •Esther Babette Menz[1,2,3], Michael Lestinsky[1], Sebastian Fuchs[4,5], Weronika Biela-Nowaczyk[6], Alexander Borovik Jr.[4], Carsten Brandau[1,4], Claude Krantz[1], Gleb Vorobyev[1], Bela Arndt[1], Alexandre Gumberidze[1], Pierre-Michel Hillenbrand[1], Tino Morgenroth[1,2,3], Ragandeep Singh Sidhu[1], Stefan Schippers[4,5], and Thomas Stöhlker[1,2,3] — [1]GSI, 64291 Darmstadt — [2]Helmholtz-Institut Jena, 07743 Jena — [3]IOQ, Friedrich-Schiller-Universität, 07743 Jena — [4]I. Phys. Institut, Justus-Liebig-Universität, 35390 Giessen — [5]Helmholtz Forschungsakademie Hessen für FAIR, Campus Giessen, 35392 Giessen — [6]Institute of Physics, Jagiellonian University, 31-007 Kraków, Poland

After its move from Stockholm to GSI, CRYRING@ESR is now back in operation with previously inaccessible ion species available from the accelerator complex as well as a smaller selection from a local injector. The first merged-beam DR measurements were performed at the CRYRING@ESR electron cooler and we will present the newly established particle detection and data acquisition setup and the results of DR measurements of astrophysically relevant neon ions in low charge states. A test run in May 2020 with Ne^{7+} from an ECR source was used to commission the setup and study electron beam temperatures. It demonstrated an undegraded resolution compared to previous measurements. It was followed up in May 2021 by a scheduled experiment on astrophysically relevant low-energy DR of Ne^{2+}.

A 13: Quantum Gases and Matter Waves (joint session Q/A)

Time: Tuesday 16:30–18:30 Location: P

A 13.1 Tue 16:30 P

Coherent and dephasing spectroscopy for single-impurity probing of an ultracold bath — •Daniel Adam, Quentin Bouton, Jens Nettersheim, Sabrina Burgardt, and Artur Widera — Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

Individual impurities immersed in a gas form a paradigm of open quantum systems. Especially, nondestructive quantum probing has gained significant interest in recent years. Here, we report on probing the coherent and dephasing dynamics of single impurities in a bath to extract information about the impurity's environment. Experimentally, we immerse single Cs atoms into a Rb bath and perform a Ramsey spectroscopy on the Cs clock transition. The Ramsey fringe is modified by a differential shift of the collisional (kinetic) energy when the two Cs states superposed interact with the Rb bath. The shift is affected by the bath density and the details of the Rb-Cs interspecies scattering length. By preparing the system close to a low-magnetic field Feshbach resonance, we enhance the dependence on the temperature due to the strong dependence of the s-wave scattering length on the collisional energy. By analyzing the coherent phase evolution and decay of the Ramsey fringe contrast, we probe the Rb cloud's density and temperature with minimal perturbation of the cloud.

A 13.2 Tue 16:30 P

Compressibility of a two-dimensional homogeneous Bose gas in a box — •Leon Espert Miranda, Erik Busley, Kirankumar Umesh, Frank Vewinger, Martin Weitz, and Julian Schmitt — Institut für Angewandte Physik, Universität Bonn, Bonn, Germany

Homogeneous quantum gases enable studies of the collective behavior in quantum materials ranging from superfluids to neutron stars. A particular example for quantum matter are Bose-Einstein condensates (BEC). Here we realize an optical quantum gas in a box potential inside a nanostructured microcavity and observe BEC in the finite-size homogeneous 2D system. By exerting a force on the photon gas, we probe its compressibility and equation of state, demonstrating the physical significance of the infinitely compressible BEC in an ideal gas.

A 13.3 Tue 16:30 P

Optical Potentials based on Conical Refraction for Bose-Einstein Condensates — •Dominik Pfeiffer, Ludwig Lind, and Gerhard Birkl — Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Optical trapping and guiding potentials based on conical refraction (CR) in a biaxial crystal present a versatile tool for the manipulation of atomic matter waves in atomtronics circuits. Based on the specific properties of CR, we generate a three-dimensional dark focus optical trapping potential for ultra-cold atoms and Bose-Einstein condensates. This 'optical bottle' is created by a single blue-detuned laser beam and gives full 3D confinement of cold atoms. We present the experimental implementation and give a detailed analysis of the trapping properties.

A 13.4 Tue 16:30 P

Exploring the nature of the steady state of non-interacting fermionic atoms coupled to a dissipative cavity — •Jeannette De Marco, Catalin Halati, Ameneh Sheikhan, and Corinna Kollath — Physikalisches Institut, University of Bonn, Nussallee 12, 53115 Bonn, Germany

We investigate the influence of a strong symmetry of the Liouvillian on the nature of the steady state for a non-interacting fermionic chain globally coupled to a lossy optical cavity. Using a newly developed many-body adiabatic elimination technique, we capture the dissipative nature of the quantum light field as well as the global coupling to the cavity mode beyond the mean-field ansatz. For finite systems, we show that the existence of a strong symmetry leads to multiple steady state solutions and we investigate how the dissipative phase transition to self-organized states occurs for the different symmetry sectors.

A 13.5 Tue 16:30 P

Transport through a lattice with a local particle loss — •Anne-Maria Visuri[1], Corinna Kollath[1], and Thierry Giamarchi[2] — [1]Physikalisches Institut, University of Bonn, Nussallee 12, 53115 Bonn, Germany — [2]Department of Quantum Matter Physics, University of Geneva, 24 quai Ernest-Ansermet, 1211 Geneva, Switzerland

The effect of dissipation on transport is relevant for the fundamental understanding of quantum mechanics as well as the development of quantum technologies. Dissipative transport has recently been probed in experiments with ultracold atoms, where one can engineer controlled dissipation mechanisms in the form of a particle losses. We study transport through a chain of coupled sites, which is connected to reservoirs at both ends, and analyze the effect of a local particle loss on transport. The reservoirs are described as free spinless fermions. We characterize the particle transport by calculating the conductance, loss current, and particle density in the steady state using the Keldysh formalism for open quantum systems. We find that for specific values of the chemical potential in the lattice, transport is unaffected by the local particle loss. This is understood by considering the single-particle eigenstates in a lattice with open boundary conditions.

A 13.6 Tue 16:30 P

Developing MPS-methods for a Fermi-Hubbard model coupled to a dissipative photonic mode — •Luisa Tolle — Physikalisches Institut, University of Bonn, Germany

We present the current status of the development of a numerical exact method describing the time evolution of an interacting Fermi-Hubbard chain coupled globally to a dissipative photonic mode.

A physical realization of the considered model is e.g. an ultracold atomic gas in an optical lattice coupled to a photonic mode of an optical cavity. In order to capture the open nature of the photons in the time evolution we perform the purification on the density matrix. In this context we extend time-dependent matrix product techniques to include the global coupling of the photonic mode to the interacting atoms and deal with the very large Hilbert space of the photonic mode. This allows to study the long-time dynamics of the system towards the self-organization transition.

A 13.7 Tue 16:30 P

Multi-axis and high precision rotation sensing with Bose-Einstein condensates — •Sven Abend[1], Christian Schubert[1,2], Matthias Gersemann[1], Martina Gebbe[3], Dennis Schlippert[1], and Ernst M. Rasel[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V., Institut für Satellitengeodäsie und Inertialsensorik — [3]ZARM, Universität Bremen

Atom interferometers are versatile tools to measure inertial forces and were utilised as accurate gravimeters. Exploiting the Sagnac effect by enclosing an area with matterwaves enables rotation measurements. We present a concept for a multi-loop atom interferometer with a scalable area formed by light pulses, making use of twin-lattice atom interferometry.

Addionally, we create two simultaneous atom interferometers out of a single Bose-Einstein condensate (BEC), to differntiate between rotations and accelerations. Our method exploits the precise motion control of BECs combined with the precise momentum transfer by double Bragg diffraction for interferometry. Consequently, the scheme avoids the complexity of two BEC sources. We show our experimental results and discuss the extension to a six-axis quantum inertial measurement unit.

This work is supported by the Ministry for Economic Affairs and Energy (BMWi) due to the enactment of the German Bundestag under Grand No. DLR 50RK1957 (QGyro).

A 13.8 Tue 16:30 P

Bound Pairs Scattering off a Floquet Driven Impurity — •Friedrich Hübner, Ameneh Sheikhan, and Corinna Kollath — HISKP, University of Bonn, Nussallee 14-16, 53115 Bonn, Germany

We study how bound pairs of Fermions in a Fermi-Hubbard chain scatter off a driven impurity which is a single site with a shaken chemical potential. We thereby extend the work of Thuberg et al. [1] who considered non-interacting single particles.

In the limit where the hopping parameter J is much smaller than the Hubbard interaction U – as long as U is not an integer multiple of the driving frequency ω – we can derive an effective Hamiltonian governing the motions of pairs by means of a Floquet-Schrieffer-Wolff transformation. From it we calculate the pair transmission through the impurity and compare it to the single particle transmission. We validate the result by exact diagonalization and find that it is still a good approximation for finite $J/|U|$ throughout the non-resonant case.

We also analytically study the resonant case where U is an integer multiple of ω which leads to pair breaking by absorbing energy from the drive. Contrary to our expectation we find that pair breaking is suppressed for $J \ll |U|$.

[1] D. Thuberg, S. Reyes, S. Eggert, PhysRevB.93.180301 (2016)

A 13.9 Tue 16:30 P

Unsupervised machine learning of topological phase transitions from experimental data — •Niklas Käming[1], Anna Dawid[2,3], Korbinian Kottmann[3], Maciej Lewenstein[3,4], Klaus Sengstock[1,5,6], Alexandre Dauphin[3], and Christof Weitenberg[1,5] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland — [3]Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona), Spain — [4]ICREA, Pg. Lluís Campanys 23, 08010 Barcelona, Spain — [5]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [6]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Identifying phase transitions is one of the key challenges in quantum many-body physics. Recently, machine learning methods have been shown to be an alternative way of localising phase boundaries from noisy and imperfect data without the knowledge of the order parameter. Here, we apply different unsupervised machine learning techniques to experimental data from ultracold atoms. In this way, we obtain the topological phase diagram of the Haldane model in a completely unbiased fashion. We show that these methods can successfully be applied to experimental data at finite temperatures and to the data of Floquet systems when post-processing the data to a single micromotion phase.

A 13.10 Tue 16:30 P

Mixing fermionic ^{6}Li impurities with a Bose-Einstein condensate of ^{133}Cs — •Binh Tran, Eleonora Lippi, Manuel Gerken, Michael Rautenberg, Marcia Kroker, Lauriane Chomaz, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Fermionic ^{6}Li impurities in a ^{133}Cs Bose-Einstein condensate (BEC) realize a very well controllable version of the Bose polaron, a quasiparticle emulating the Fröhlich polaron problem as known from solid-state physics. I will describe our upgraded scheme for trapping and combining degenerate gases of Li and Cs. We create a BEC of Cs atoms at high magnetic fields (>880 G), where a broad Feshbach resonance between Li and Cs allows to control the sign and the strength of interactions. By means of two crossed optical dipole traps of vastly different volumes, we make use of an efficient "dimple-trick" to increase the phase-space density, which we describe both theoretically and experimentally, before performing forced evaporative cooling. A tightly confining movable optical dipole trap of 880.25 nm wavelength, which realizes a tune-out wavelength for Cs, allows to store, move, and confine a Li cloud within a small volume of the Cs BEC without imposing any additional confinement to Cs.

A 13.11 Tue 16:30 P

Time-domain optics for atomic quantum matter — •Simon Kanthak[1,2], Martina Gebbe[3], Matthias Gersemann[4], Sven Abend[4], Ernst M. Rasel[4], Markus Krutzik[1,2], and the QUANTUS team[1,2,3,4] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut, Berlin — [3]ZARM, Universität Bremen — [4]Institut für Quantenoptik, LU Hannover

We investigate time-domain optics for atomic quantum matter. Within a matter-wave analog of the thin-lens formalism, we study optical lenses of different shapes and refractive powers to precisely control the dispersion of Bose-Einstein condensates. Anharmonicities of the lensing potential are incorporated in the formalism with a decomposition of the center-of-mass motion and expansion of the atoms, allowing to probe the lensing potential with micrometer resolution. By arranging two lenses in time formed by the potentials of an optical dipole trap and an atom-chip trap, we realize a magneto-optical matter-wave telescope. We employ this hybrid telescope to manipulate the expansion and aspect ratio of the ensembles. The experimental results are compared to numerical simulations that involve Gaussian shaped potentials to accommodate lens shapes beyond the harmonic approximation.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under Grant No. 50WM1952 (QUANTUS-V-Fallturm).

A 13.12 Tue 16:30 P

A new experiment for programmable quantum simulation using ultracold 6Li atoms — •Armin Schwierk, Tobias Hammel, Micha Bunjes, Maximilian Kaiser, Leo Walz, Philipp Preiss, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Efficient quantum simulation using ultracold atoms is typically limited by a variety of experimental factors like available laser power or the numerical aperture of the objective. These factors strongly limit achievable cycle times to around a few seconds, posing a problem when high statistics and good control of the atoms are needed. We are building a new Lithium-6 experiment, with which we aim to reduce the cycle time to below one second. All parts of the apparatus will be build up from modular blocks to increase adaptability, stability and control over the system.

In this poster, we will present the current state of the development of the experiment. The design evolves around a small octagonal glass cell with a diameter of only 5cm and large optical access of up to 0.85NA vertically and 0.3NA horizontally. The small size of the glass cell enables the use of small and fast tuneable magnetic field coils close to the atoms, allowing versatile control of the magnetic fields. A high flux 2D-MOT as precooling stage will help in reducing the cycle times and in making the whole experiment a lot more compact with a distance of 30cm from 2D-MOT centre to the centre of the glass cell. With this new apparatus, we take a first step towards easily and versatile programmable quantum simulation.

A 13.13 Tue 16:30 P

Few Fermions in optically rotating traps — •Philipp Lunt, Paul Hill, Diana Körner, Jonas Drotleff, Daniel Dux, Ralf Klemt, Selim Jochim, and Philipp Preiss — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

The formal equivalence of electrons in an external magnetic field and neutral atoms in rapidly rotating traps opens up new avenues to study fractional quantum hall physics with ultracold atomic gases.

In order to access the microscopic level of strongly correlated quantum hall states we build on our previously established experimental methods - the deterministic preparation of ultracold ^{6}Li few Fermion systems in low dimensions [1,2], as well as local observation of their correlation and entanglement properties on the single atom level [3].

Here, we present current experimental progress towards adiabatic preparation of deterministic few Fermion states in rapidly rotating optical potentials. We achieve rotation in an all-optically manner by interference of a Gaussian and Laguerre-Gaussian (LG) mode generated by a spatial light modulator [4]. In particular, we showcase the optical setup, which includes elaborate methods to cancel phase aberrations in order to meet the challenging requirement regarding the isotropy of the potential geometry.

[1] Serwane et al. Science 332 (6027), 336-338 [2] Bayha et al. Nature 587, 583-587 (2020) [3] Bergschneider et al. Nat. Phys. 15, 640-644 (2019) [4] Palm et al 2020 New J. Phys. 22 083037

A 13.14 Tue 16:30 P

Numerical simulation of out of equilibrium dynamics of Dicke model — •Marcel Nitsch — Physikalisches Institut, University of Bonn, Nussallee 12, 53115 Bonn, Germany

The time dependent matrix product state algorithms are strong tools to simulate the out of equilibrium dynamics of many body quantum systems. A new method was introduced to calculate the time evolution of a system represented by a matrix product state which is based on the Dirac-Frenkel time-dependent variational principle. Compared to the conventional time evolution using a Trotter-Suzuki splitting of the Hamiltonian, the new method promises more stable and more efficient calculations for systems with longer ranged interactions. In this poster I briefly explain the time-dependent variational principle method and present a comparison between both methods for the Dicke model. This model describes the behaviour of two-level atoms coupled to a cavity field. In the matrix product state formalism, this corresponds to a global one-to-all coupling.

A 13.15 Tue 16:30 P

Observation of Cooper pairs in a few-body system — Marvin Holten, Luca Bayha, •Keerthan Subramanian, Sandra Brandstetter, Carl Heintze, Philipp Preiss, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Heidelberg, Germany

Recent advances in deterministic preparation of few-body systems have led to the observation of an emergence of a quantum phase transition [1] and single particle detection methods have resulted in the first observation of Pauli crystals [2] demonstrating correlations in a non-interacting system due to quantum statistics.

In this poster we present the first direct observation of Cooper pairs in a few-body system of ^{6}Li atoms. We deterministically prepare low entropy samples of a two-component Fermi gas in a 2D harmonic oscillator potential and directly observe the full spin and single particle resolved momentum distribution enabling us to extract correlation functions of any order. We demonstrate the crossover from no pairing to Cooper-pairing at the Fermi surface to softening of the Fermi surface and pairing at all momenta as the interaction is increased.

In the future we plan to extend our imaging scheme to obtain single atom resolved images of the in-situ cloud [3]. This would allow us to tackle questions related to 2D Fermi superfluids concerning the nature of the normal phase and pairing in spin-imbalanced systems.

[1] L. Bayha, et al. Nature 587.7835 (2020): 583-587.
[2] M. Holten, et al. Physical Review Letters 126.2 (2021): 020401
[3] L. Asteria, et al. arXiv:2104.10089 (2021).

A 13.16 Tue 16:30 P

Realization of an anomalous Floquet topological system with ultracold atoms — •Christoph Braun[1,2,3], Raphaël Saint-Jalm[1,2], Alexander Hesse[1,2], Monika Aidelsburger[1,2], and Immanuel Bloch[1,2,3] — [1]Ludwig-Maximilians-Universität München, München, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), München, Germany — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany

Floquet engineering has proven as a powerful experimental tool for the realization of quantum systems with exotic properties. We study anomalous Floquet systems that exhibit robust chiral edge modes, despite all Chern numbers being equal to zero. The system consists of bosonic atoms in a periodically driven honeycomb lattice and we infer the topological invariants from measurements of the energy gap and local Hall deflections.

An interesting future direction is the interplay between topology and disorder in periodically-driven systems. In particular the existence of disorder-induced topological phases such as the anomalous Floquet Anderson insulator show the interesting link between topology and disorder.

A 13.17 Tue 16:30 P

Self-organized topological insulator due to cavity-mediated correlated tunneling — Titas Chanda[1], •Rebecca Kraus[2], Giovanna Morigi[2], and Jakub Zakrzewski[1] — [1]Institute of Theoretical Physics, Jagiellonian University in Kraków, Kraków, Poland — [2]Theoretical Physics, Saarland University, Saarbrücken, Germany

Topological materials have potential applications for quantum technologies. Non-interacting topological materials, such as e.g., topological insulators and superconductors, are classified by means of fundamental symmetry classes. It is instead only partially understood how interactions affect topological properties. Here, we discuss a model where topology emerges from the quantum interference between single-particle dynamics and global interactions. The system is composed by soft-core bosons that interact via global correlated hopping in a one-dimensional lattice. The onset of quantum interference leads to spontaneous breaking of the lattice translational symmetry, the corresponding phase resembles nontrivial states of the celebrated Su-Schriefer-Heeger model. Like the fermionic Peierls instability, the emerging quantum phase is a topological insulator and is found at half fillings. Originating from quantum interference, this topological phase is found in "exact" density-matrix renormalization group calculations and is entirely absent in the mean-field approach. We argue that these dynamics can be realized in existing experimental platforms, such as cavity quantum electrodynamics setups, where the topological features can be revealed in the light emitted by the resonator.

A 14: Interaction with strong or short laser pulses

Time: Wednesday 10:45–12:15 Location: H1

Invited Talk A 14.1 Wed 10:45 H1

Improving the scaling in many-electron quantum dynamics simulations — •Michael Bonitz[1], Niclas Schlünzen[1], Jan-Philip Joost[1], and Iva Brezinova[2] — [1]Institut für Theoretische Physik und Astrophysik, Universität Kiel, Leibnizstr. 15 — [2]Technical University Vienna

The accurate description of the nonequilibrium dynamics of correlated electrons in atoms under laser excitation remains a key topic in many fields. Among others, the nonequilibrium Green functions (NEGF) method has proven to be a powerful tool to capture electron-electron correlations [1]. However, NEGF simulations are computationally expensive due to their T^3 scaling with the simulation duration T. With the introduction of the generalized Kadanoff-Baym ansatz [2], T^2 scaling could be achieved for second order Born (SOA) selfenergies [3], which has substantially extended the scope of NEGF simulations. Recently [4], we could achieve linear scaling within SOA and even the GW and dynamically screened ladder approximations which is a breakthrough for simulating the correlated electron dynamics. After demonstrating the linear scaling behavior we will discuss prospects for simulating the laser ionization dynamics in atoms [5].

[1] K. Balzer and M. Bonitz, Lect. Notes Phys. **867** (2013)
[2] P. Lipavský *et al.*, Phys. Rev. B **34**, 6933 (1986)
[3] S. Hermanns *et al.*, Phys. Scripta **T151**, 014036 (2012)
[4] N. Schlünzen *et al.*, Phys. Rev. Lett. **124**, 076601 (2020); Joost *et al.*, Phys. Rev. B **101**, 245101 (2020)
[5] F. Lackner *et al.*, Phys. Rev. A **95**, 033414 (2017)

Invited Talk A 14.2 Wed 11:15 H1

Imaging anisotropic dynamics in superfluid helium nanodroplets — •B. Langbehn[1], K. Sander[2], Y. Ovcharenko[1,3], C. Peltz[2], A. Clark[4], M. Coreno[5], R. Cucini[6], A. Demidovich[6],

M. Drabbels[4], P. Finetti[6], M. Di Fraia[6,5], L. Giannessi[6], C. Grazioli[5], D. Iablonskyi[7], A. C. LaForge[8], T. Nishiyama[9], V. Oliver Álvarez de Lara[4], P. Piseri[10], O. Plekan[6], K. Ueda[7], J. Zimmermann[1,11], K. C. Prince[6,12], F. Stienkemeier[8], C. Callegari[6,5], T. Fennel[2,11], D. Rupp[1,11,13], and T. Möller[1] — [1]TU Berlin — [2]Univ. Rostock — [3]European XFEL — [4]EPFL Lausanne — [5]ISM-CNR Trieste — [6]Elettra-Sincrotrone Trieste — [7]Tohoku Univ. Sendai — [8]Univ. Freiburg — [9]Kyoto Univ. — [10]Univ. di Milano — [11]MBI Berlin — [12]Swinburne Univ. of Tech. — [13]ETH Zürich

Intense short-wavelength light pulses from free-electron lasers (FELs) enable the study of the structure and dynamics of nanometer-sized particles in the gas phase using coherent diffraction imaging methods. In our experiment, we explored the light induced dynamics of xenon doped helium nanodroplets. We used intense near-infrared pulses to ignite a nanoplasma inside the droplets. After a variable time delay of up to 800 ps, we imaged the dynamics triggered by the nanoplasma using extreme ultraviolet pulses from the FERMI FEL. The recorded scattering patterns exhibit pronounced directionalities that can be attributed to anisotropic changes of the droplet surface. A possible connection of these directed dynamics to the droplet's vortex structure will be discussed.

Invited Talk A 14.3 Wed 11:45 H1

Fragmentation of HeH^+ in strong laser fields — •Florian Oppermann[1], Philipp Wustelt[2], Saurabh Mhatre[3], Stefanie Gräfe[3], Gerhard G. Paulus[2], and Manfred Lein[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Deutschland — [2]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Deutschland — [3]Institut für Physikalische Chemie, Friedrich-Schiller-Universität Jena, Helmholtzweg 4, 07743 Jena, Deutschland

Our previous study of ionization and double ionization of HeH^+ in strong 800 and 400nm laser pulses has shown the important role of nuclear motion before and during the electron removal [1]. Here we move our focus to laser parameters where both dissociation and ionization are of comparable probability. According to simulations, this implies wavelengths around 1 to 2μm. For fixed molecular orientation the ratio ionization/dissociation can be controlled (sometimes even reversed) via the relative phase in a collinearly polarized ω-2ω laser pulse.

A Keldysh parameter can be defined not only for the ionization of HeH^+ but also for the dissociation process [2]. The ratio of the two Keldysh parameters is roughly 10, i. e. one pathway can be placed in the multi-photon regime while the other one is in the tunneling regime. Thus by changing the two-color delay on a subcycle scale the dominating process can be switched from multi-photon to tunneling and back.

[1] Wustelt et al., Phys. Rev. Lett. 121, 073203 (2018)
[2] Ursrey et al., Phys. Rev. A 85, 023429 (2012)

A 15: Precision spectroscopy of atoms and ions / Highly charge ions (joint session A/Q)

Time: Wednesday 14:00–16:00 Location: H1

Invited Talk A 15.1 Wed 14:00 H1

Laser spectroscopy of the heaviest actinides — •Premaditya Chhetri[1,2,3], Dieter Ackermann[4], Hartmut Backe[5], Michael Block[1,2,5], Bradley Cheal[6], Christoph Emanuel Düllmann[1,2,5], Julia Even[7], Rafael Ferrer[3], Francesca Giacoppo[1,2], Stefan Götz[1,2,5], Fritz Peter Hessberger[1,2], Mark Huyse[3], Oliver Kaleja[1,5], Jadambaa Khuyagbaatar[1,2], Peter Kunz[8], Mustapha Laatiaoui[1,2,5], Werner Lauth[5], Lotte Lens[1], Enrique Minaya Ramirez[9], Andrew Mistry[1,2], Tobias Murböck[1], Sebastian Raeder[1,2], Fabian Schnieder[2], Piet Van Duppen[3], Thomas Walther[10], and Alexander Yakushev[1,2] — [1]GSI, Darmstadt, Germany — [2]HI Mainz, Mainz, Germany — [3]KU Leuven, Leuven, Belgium — [4]GANIL, Cean, France — [5]JGU, Mainz, Germany — [6]Liverpool University, Liverpool, UK — [7]University of Groningen, KVI-CART, Groningen, Netherlands — [8]TRIUMF, Vancouver, Canada — [9]IPN, Orsay, France — [10]TU Darmstadt, Darmstadt, Germany

Precision measurements of optical transitions of the heaviest elements are a versatile tool to probe the electronic shell structure which is strongly influenced by electron-electron correlations, relativity and QED effects. Optical studies of transfermium elements with Z>100 is hampered by low production rates and the fact that any atomic information is initially available only from theoretical predictions. Using the sensitive RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) technique coupled to the SHIP separator at GSI, a strong optical $^1S_0 \rightarrow ^1P_1$ ground-state transition in the element nobelium (Z=102) was identified and characterized [1]. The isotopes of ^{252,253,254}No were measured [2]. From these measurements, nuclear information on the shapes and sizes were inferred. In addition, several high-lying Rydberg levels were observed, which enabled the extraction of the first ionization potential with high precision [3]. Using an indirect production mechanism, laser spectroscopy was performed on some Fermium isotopes. These results as well as the prospects for future exploration of the atomic structure of the next heavier element, lawrencium (Z=103) will be discussed.

[1] M. Laatiaoui et al., Nature **538**, 495 (2016).
[2] S. Raeder et al., PRL **120**, 232503 (2018).
[3] P. Chhetri et al., PRL **120**, 263003 (2018).

Invited Talk A 15.2 Wed 14:30 H1

Status update of the muonic hydrogen ground-state hyperfine splitting experiment — •A. Ouf and R. Pohl on behalf of the CREMA collaboration — Johannes Gutenberg-Universität Mainz, Institut für Physik, QUANTUM & Exzellenzcluster PRISMA +, Mainz, Germany

The ground state hyperfine splitting (1S-HFS) in ordinary hydrogen (the famous 21 cm line) has been measured with 12 digits accuracy almost 50 years ago [1], but its comparison with QED calculations is limited to 6 digits by the uncertainty of the Zemach radius determined from elastic electron-proton scattering. The Zemach radius encodes the magnetic properties of the proton and it is the main nuclear structure contribution to the hyperfine splitting (HFS) in hydrogen. The ongoing experiment of the CREMA Collaboration at PSI aims at the first measurement of the 1S-HFS in muonic hydrogen (μp) with the potential for a hundredfold improved determination of the proton structure effects (Zemach radius and polarizability), which will eventually improve the QED test using the 21 cm line by a factor of 100. The experiment introduces several novel developments toward the (μp) 1s-HFS spectroscopy. We will present the current efforts of the various developments from the pulsed 6.8 μm laser, to the novel multi pass cavity, and the scintillator detection system.

[1] L. Essen *et al*, Nature **229**, 110 (1971)
[2] R. Pohl *et al.*, Nature **466**, 213 (2010)
[3] A. Antognini *et al.*, Science **339**, 417 (2013)

Invited Talk A 15.3 Wed 15:00 H1

Coupled ions in a Penning trap for ultra-precise *g*-factor differences — •Tim Sailer[1], Vincent Debierre[1], Zoltán Harman[1], Fabian Heisse[1], Charlotte König[1], Jonathan Morgner[1], Bingsheng Tu[1], Andrey Volotka[2], Christoph H. Keitel[1], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Department of Physics and Engineering, ITMO University, St. Petersburg, Russia

Measurements of the electronic magnetic moment (or g factor) of highly charged ions (HCI) in Penning traps have been shown to provide a stringent probe for quantum electrodynamics (QED) in the strongest electromagnetic fields. The isotope shift additionally allows the study of nuclear parameters since many of the common contributions and their uncertainties to the g factor are identical and do not have to be considered. Such measurements become however quickly limited by other factors, for example inherent magnetic field fluctuations. Here, we report on a novel measurement technique based on coupling two ions on a common magnetron orbit to exploit the near-perfect correlation of such magnetic field fluctuations. This has enabled us to directly measure the difference for the isotopes of $^{20}Ne^{9+}$ and $^{22}Ne^{9+}$ to 0.25 parts-per-trillion precision relative to the g factors, which corresponds to an improvement of more than two orders of magnitude compared to conventional techniques. This resolves and verifies a QED contribution to the nuclear recoil for the very first time, while the observed agreement with theory also allows to strengthen the constraints for a potential fifth-force of Higgs-portal-type dark matter interaction.

Invited Talk A 15.4 Wed 15:30 H1

Unraveling the mechanisms of single- and multiple-electron removal in energetic electron-ion collisions: from few-electron ions to extreme atomic systems. — •Alexander Borovik Jr — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Giessen, Germany

For over a half century, electron-impact ionization of ions remains an open topic in atomic physics [1]. While single-electron removal processes in light few-electron systems are currently understood and can be reliably described by theoretical approaches, ionization of many-electron ions, especially multiple ionization, are still not understood completely. In this situation, experiment, where available, is the only reliable source of information [2]. However, as we move to ions in high charge states, requirements on the experimental conditions rise, making new approaches and instrumentation necessary. In the present overview, we describe the current status in the field and report on recent activities that aim at expanding the experimental capabilities by the development of electron guns beyond the state-of-the-art and by employing large heavy-ion accelerator facilities such as FAIR [3].

[1] A. Müller, Adv. At. Mol. Phys. 55, 293 (2008). [2] D. Schury et al. J. Phys. B 53, 015201 (2019). [3] M. Lestinsky et al., Eur. Phys. J. ST 225, 797882 (2016).

A 16: Ultra-cold atoms, ions, and BEC (joint session A/Q)

Time: Wednesday 16:30–18:30 Location: P

A 16.1 Wed 16:30 P

Observation of a universal entropy behaviour for impurities in an ultracold bath — •Silvia Hiebel, Jens Nettersheim, Julian Fess, Sabrina Burgardt, Daniel Adam, and Artur Widera — Physics Department and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany

Nonequilibrium systems usually thermalize by gradually increasing their entropy to a new equilibrium state. For systems very far from equilibrium, however, another pathway has been predicted[1], where rapidly a state of high entropy, close to the maximal entropy possible for this system, is reached. The dynamic following this so-called prethermal memory loss is predicted to be universal.
We experimentally realize such nonequilibrium dynamics in the spin manifold of single Cs impurities undergoing spin-exchange collisions with a large Rb bath. The maximum entropy of the quantum spin distribution is reached after a few spin-exchange collisions starting from a spin-polarized, low entropy state. Rescaling the following spin-distribution dynamics when maximum entropy is reached, we find the trace of each spin state identical, independent of the initially prepared spin state. We analyse and describe these mechanisms in terms of the drift and diffusion of the quantum spin distribution. Our work thus illustrates the existence of universal, prethermal dynamics in open quantum systems far from equilibrium.

[1] Ling-Na Wu and André Eckardt, PRB 101, 220302 (2020)

A 16.2 Wed 16:30 P

Exploring p-Wave Feshbach Resonances in ultracold ^{6}Li and ^{6}Li-^{133}Cs — •Manuel Gerken[1], Kilian Welz[1], Binh Tran[1], Eleonora Lippi[1], Stephan Häfner[1], Lauriane Chomaz[1], Bing Zhu[3], Eberhard Tiemann[2], and Matthias Weidemüller[1,3] — [1]Physikalisches Institut, University of Heidelberg — [2]Institut für Quantenoptik, University of Hannover — [3]University of Science and Technology of China

We report on the observation of spin-rotation coupling in p-wave Feshbach resonances in ultracold mixture of fermionic ^{6}Li and bosonic ^{133}Cs. In addition to the doublet structure in the Feshbach spectrum due to spin-spin interaction, we observe a triplet structure of different m_l states by magnetic field dependent atom-loss spectroscopy. Here, the m_l states are projections of the pair-rotation angular momentum l on the external magnetic field. Through comparison with coupled-channel calculations, we attribute the observed splitting of the $m_l \pm 1$ components to electron spin-rotation coupling. We present and estimation of the spin-rotation coupling by describing the weakly bound close channel molecular state with the perturbative multipole expansion, valid in the range $R > R_{LR}$, where R is the inter nuclear distance and R_{LR} is the LeRoy radius. The underestimation of the coupling reveals a significant contribution of the molecular wave function at short inter-nuclear distances $R < R_{LR}$. We also present measurements of spin-spin coupling in p-wave Feshbach resonances in a ^{6}Li mixture and calculations of collisional cooling close to a ^{6}Li p-wave Feshabch resonance.

A 16.3 Wed 16:30 P

Single-atom quantum otto motor driven by atomic collisions — •Jens Nettersheim[1], Sabrina Burgardt[1], Daniel Adam[1], Eric Lutz[2], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Institute for Theoretical Physics I,University of Stuttgart, Stuttgart, Germany

Recent advances in controlling nanoscopic objects suggest the realizations of machines exploiting quantum properties. However, the increasing importance of fluctuations in quantum systems calls into question whether such devices can combine high efficiency, high output power, and small power fluctuations. Experimentally, we realize a stable quantum-Otto engine by immersing single Cs atoms into an ultracold Rb bath. Employing inelastic spin-exchange interactions, we maximize output power while minimizing power fluctuations owing to the finite quantum spin space forming the machine. We investigate the population fluctuations of the system as a function of its heat exchange and output power. For our system with seven quantum-spin levels, the initial and final states are polarized. They show no population fluctuations, in contrast to an infinite-level harmonic oscillator system at a given temperature. We analyze in which parameter range the quantum-spin engine can outperform harmonic oscillator systems in terms of output power and power fluctuations.

A 16.4 Wed 16:30 P

Long-distance transport of ultracold gases in an optical dipole trap utilizing focus-tunable lenses — •Maximilian Kaiser[1,2], Sian Barbosa[1], Jennifer Koch[1], Felix Lang[1], Benjamin Nagler[1], and Artur Widera[1] — [1]Physics Department, University of Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern — [2]Physics Institute, Heidelberg University, Im Neuenheimer Feld 226, 69120 Heidelberg

In order to integrate novel optical techniques into packed quantum gas experiments, different transport approaches have been developed to bridge the gap between different sections of the experimental vacuum chamber.

We report on the realization of an optical dipole trap (ODT) transport system for ultracold gases based upon [1]. A lens system around a commercially available focus-tunable lens shifts the focus of a red-detuned ODT beam through the vacuum chamber, effectively moving trapped atoms while maintaining constant trapping conditions throughout the entire transport. We have developed a scheme for precise alignment, characterized the focal shift, and studied its spatial stability. We have verified its functionality and found spatial stability of the focus on the micrometer scale. The system is integrated into a lithium-6 quantum-gas experiment, where the transport trap is loaded with efficiencies of more than 90% for both BECs and thermal gases. Ultimately, we demonstrate the transport of an ultracold quantum gas over a distance of 507mm.

[1] Julian Léonard et al., New J. Phys. 16 093028 (2014)

A 16.5 Wed 16:30 P

Exciton-polaron-polariton condensation — •Miguel Bastarrachea-Magnani[1,2], Aleksi Julku[2], Arturo Camacho-Guardian[3], and Georg Bruun[2] — [1]Physics Department, Universidad Autonoma Metropolitana-Iztapalapa, San Rafael Atlixco 186, C.P. 09340 CDMX, Mexico — [2]Center for Complex Quantum Systems, Department of Physics and Astronomy, Aarhus University, Ny Munkegade, DK-8000 Aarhus C, Denmark — [3]T.C.M. Group, Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue,

Cambridge, CB3 0HE, U.K

Exciton-polaritons created in microcavity semiconductors are highly tunable quantum states that, thanks to their hybrid character, allow the transfer of features between light and matter. Polariton interactions make it possible to create quantum fluids, exhibiting macroscopic quantum states like condensation and superfluidity. Because of this they constitute a fruitful field to exchange ideas with atomic physics and to unveil novel no-linear optical effects. Recent experiments have demonstrated that, by doping the semiconductor with itinerant electrons, the exciton-polaritons get dressed in electronic excitations to create polarons, opening a new venue to explore Bose-Fermi mixtures. Here, we describe the condensation of exciton-polaritons in the presence of a two-dimensional electron gas by employing a non-perturbative many-body theory to treat exciton-electron correlations combined with a non-equilibrium theory for the condensate.

A 16.6 Wed 16:30 P

A quantum heat engine driven by atomic collisions — •Sabrina Burgardt[1], Quentin Bouton[1], Jens Nettersheim[1], Daniel Adam[1], Eric Lutz[2], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany. — [2]Institute for Theoretical Physics I, University of Stuttgart, Stuttgart, Germany.

Quantum heat engines are subjected to quantum fluctuations related to their discrete energy spectra. Such fluctuations question the reliable operation of thermal machines in the quantum regime. Here, we realize an endoreversible quantum Otto cycle in the large quasi-spin states of Cesium impurities immersed in an ultracold Rubidium bath.

We employ quantum control to regulate the direction of heat transfer that occurs via inelastic spinexchange collisions. We further use full-counting statistics of individual atoms to monitor quantized heat exchange between engine and bath at the level of single quanta, and additionally evaluate average and variance of the power output. We optimize the performance as well as the stability of the quantum heat engine, achieving high efficiency, large power output and small power output fluctuations.

A 16.7 Wed 16:30 P

Design of high-field coils for Feshbach resonances and rapid ramps in lithium-6 — •Felix Lang[1], Maximilian Kaiser[1,2], Sian Barbosa[1], Jennifer Koch[1], Benjamin Nagler[1], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universitaet Kaiserslautern, Germany — [2]Physics Institute, Heidelberg University, Im Neuenheimer Feld 226, 69120 Heidelberg

Realizing the BEC-BCS crossover in ultracold fermionic gases of lithium-6 requires high magnetic fields to address the Feshbach resonance at 832G [1]. One important tool for the control of such systems is the use of rapid magnetic-field ramps which enables, e.g., the detection of fermionic pair condensates [2].

Here I report on the design of a low-inductance Helmholtz coil pair for high currents up to 400A which complies with these contrary conditions. Numerical calculations of the magnetic field are used to optimize the coil geometry, while complimentary electrical-circuit simulations provide insight into attainable switching times. In addition, I discuss the cooling infrastructure and temperature surveillance, as well as the elaborate manufacturing process of the coils.

[1] R. Grimm, in Proceedings of the International School of Physics "Enrico Fermi", Vol. 164, edited by C. S. M. Inguscio W. Ketterle (2007) pp. 413-462.

[2] M. W. Zwierlein, C. H. Schunck, C. A. Stan, S. M. F. Raupach, and W. Ketterle, Physical Review Letters 94, 180401 (2005).

A 16.8 Wed 16:30 P

Towards Quantum Simulation of Light-Matter Interfaces with Strontium Atoms in Optical Lattices — •Jan Trautmann[1,2], Annie Jihyun Park[1,2], Valentin Klüsener[1,2], Dimitry Yankelev[1,2], Yilong Yang[1,2], Dimitrios Tsevas[1,2], Immanuel Bloch[1,2,3], and Sebastian Blatt[1,2] — [1]MPQ, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]MCQST, 80799 München, Germany — [3]LMU, Schellingstraße 4, 80799 München, Germany

In the last two decades, quantum simulators based on ultracold atoms in optical lattices have successfully emulated strongly correlated condensed matter systems. With the recent development of quantum gas microscopes, these quantum simulators can now control such systems with single site resolution. Within the same time period, atomic clocks have also started to take advantage of optical lattices by trapping alkaline-earth-metal atoms such as Sr, and interrogating them with precision and accuracy at the 2e-18 level. Here, we report on progress towards a new quantum simulator that combines quantum gas microscopy with optical lattice clock technology. We have developed in-vacuum buildup cavities with large mode volumes that will be used to overcome the limits to system sizes in quantum gas microscopes. We imaged the intensity profile of the two orthogonal cavity modes of the in-vacuum buildup cavity by loading ultracold strontium atoms in a lattice created by those modes. By using optical lattices created in this buildup cavity that are state-dependent for the clock states, we aim to emulate strongly-coupled light-matter-interfaces.

A 16.9 Wed 16:30 P

Quantum Gas Magnifier for sub-lattice-resolved imaging of 3D systems — •Luca Asteria[1], Henrik P. Zahn[1], Marcel N. Kosch[1], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]Institut for Laserphysics, Hamburg — [2]The Hamburg Centre for Ultrafast Imaging — [3]Zentrum für Optische Quantentechnologien, Hamburg

Imaging is central for gaining microscopic insight into physical systems, but direct imaging of ultracold atoms in optical lattices as modern quantum simulation platform suffers from the diffraction limit as well as high optical density and small depth of focus. We introduce a novel approach to imaging of quantum many-body systems using matter wave optics to magnify the density distribution prior to optical imaging, allowing sub-lattice spacing resolution in three-dimensional systems. Combining the site-resolved imaging with magnetic resonance techniques for local addressing of individual lattice sites, we demonstrate full accessibility to local information and local manipulation in three-dimensional optical lattice systems. The method opens the path for spatially resolved studies of new quantum many-body regimes including exotic lattice geometries.

A 16.10 Wed 16:30 P

Simulation of the Quantum Rabi Model in the Deep Strong-Coupling Regime with Ultracold Rubidium Atoms — •Stefanie Moll[1], Geram Hunanyan[1], Johannes Koch[1], Martin Leder[1], Enrique Rico[2], Enrique Solano[2], and Martin Weitz[1] — [1]University of Bonn, Bonn, Germany — [2]University of the Basque Country, Bilbao, Spain

When considering light-matter interaction with a magnitude of the coupling strength that approaches the optical resonance frequency, one enters the deep strong-coupling regime, where the approximations of the Jaynes Cummings Model do not hold anymore. Theory has predicted non-intuitive dynamics in the limit of the full QRM-Hamiltonian becoming applicable.

Our experimental implementation of the quantum Rabi model uses ultracold rubidium atoms in an optical lattice potential, with the effective two-level quantum system being realized by different Bloch bands in the first Brillouin zone. The bosonic mode is represented by the oscillations of the atoms in an optical dipole trapping potential.

We observe atomic dynamics in the deep strong-coupling regime, yielding high excitation numbers of the oscillator modes being created out of the vacuum. The current status of experimental results will be presented.

A 16.11 Wed 16:30 P

A high-resolution Ion Microscope to Probe Quantum Gases — •Moritz Berngruber, Nicolas Zuber, Viraatt Anasuri, Yiquan Zou, Florian Meinert, Robert Löw, and Tilman Pfau — Universität Stuttgart, Germany

On our poster, we present a high-resolution ion microscope, which is designed as a versatile tool to study cold quantum gases, ground-state ensembles, Rydberg excitations, and ionic impurities. The ion microscope consists of three electrostatic lenses that allow to image charged particles on a delay-line detector.

The microscope provides a highly tunable magnification, ranging from 200 to over 1500, a spatial resolution better than 200 nm and a depth of field of more than 70 μm. These properties enable the study of bulk quantum gases and phenomena ranging from microscopic few body processes to extended many-body systems. By additionally evaluating the time-of-flight to the detector, it is possible to obtain 3D-images of the cold atomic cloud.

Excellent electric field compensation allows us to study highly excited Rydberg systems and cold ion-atom hybrid systems. We will present recent results in the field of ion-atom hybrid systems, where the interaction between ions and Rydberg atoms results in a novel long-range atom-ion Rydberg molecule.

A 16.12 Wed 16:30 P

All-optical production of K-39 BECs utilizing tunable interactions — •Alexander Herbst, Henning Albers, Sebastian Bode, Knut Stolzenberg, Ernst Rasel, and Dennis Schlippert — Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover

The all-optical production of potassium-39 BECs is of large interest for the field of guided atom interferometry and its application for quantum inertial sensors. Contrary to other setups and atomic species this combination allows for the use of small external magnetic fields to control atomic interactions for the suppression of dephasing effects. However, the negative background scattering length and the narrow hyperfine splitting of potassium-39 pose a major experimental challenge.

We report on the loading of a crossed optical dipole trap at 2 um wavelength and the subsequent generation of a BEC. By using a gray molasses technique on the D1 line we are able to directly load the trap without the need for magnetic trapping as an intermediate step.

For evaporation we utilize time-averaged optical potentials to control the trap frequencies in combination with Feshbach resonances to change the atomic scattering length to positive values. We realize BECs of up to $2 \cdot 10^5$ atoms after a 4 second long evaporation ramp and more than $5 \cdot 10^4$ atoms after less than 1 second. We discuss our experimental sequence, the current limitations of our setup and the perspectives for producing BECs of higher atom number with the fast ramp.

A 16.13 Wed 16:30 P

Trapping Ion Coulomb Crystals in Optical Lattices — •Daniel Hönig[1], Fabian Thielemann[1], Joachim Welz[1], Wei Wu[1], Leon Karpa[2], Amir Mohammadi[1], and Tobias Schätz[1] — [1]Albert-Ludwigs Universität Freiburg — [2]Leibniz Universität Hannover

Optically trapped ion Coulomb crystals are an interesting platform for quantum simulations due to the long range of the Coulomb interaction as well as the state dependence of the optical potential. Optical lattices expand the possible application of this platform by trapping the ions in seperate potential wells as well as giving optical confinement along the axis of the beam. In the past we presented the succesfull trapping of a single ion in a one dimensional optical lattice as well as of ion coulomb crystals in a single beam optical dipole trap.

In this Poster, we present recent advancements in trapping of Ba138+ ions in a one dimensional optical lattice at a wavelength of 532nm and report the first successfull trapping of small ion coulomb crystals ($N \leq 3$) in this lattice. We compare trapping results between the lattice and a single beam optical dipole trap and investigate the effect of an axial electric field on the trapping probability of a single ion to demonstrate the axial confinement of the ion in the optical lattice.

A 16.14 Wed 16:30 P

Quantum droplet phases in extended Bose-Hubbard models with cavity-mediated interactions — •Peter Karpov[1,2] and Francesco Piazza[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]National University of Science and Technology “MISiS”, Moscow, Russia

Extended Bose-Hubbard (eBH) models have been studied for more than 30 years. We numerically found a set of new phases present in generic eBH models with competing long-range attractive and local repulsive interactions [1]. These are different phases of self-bound quantum droplets. We observe a complex sequence of transitions between droplets of different sizes, and of compressible (superfluid or supersolid) as well as incompressible (Mott or density-wave insulating) nature, governed by the competition between the local repulsion and the finite-range attraction.

We propose a concrete experimental implementation scheme based on the multimode optical cavities. The analogous infinite-range model was experimentally realized by the Zürich group [2] using single-mode optical cavities. The recent progress with multimode optical cavities by the Stanford group [3] makes it possible to realize the eBH model with tunable finite-range sign-changing interactions.

[1] P. Karpov, F. Piazza, arXiv:2106.13226 (2021).
[2] R. Landig et al, Nature **532**, 476 (2016).
[3] V. Vaidya et al, Phys. Rev. X **8**, 011002 (2018).

A 16.15 Wed 16:30 P

Density Fluctuations across the Superfluid-Supersolid Phase Transition in a Dipolar Quantum Gas — •Jan-Niklas Schmidt[1], Jens Hertkorn[1], Mingyang Guo[1], Kevin Ng[1], Sean Graham[1], Paul Uerlings[1], Tim Langen[1], Martin Zwierlein[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]MIT-Harvard center for Ultracold Atoms, Research Laboratory of Electronics, and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Supersolidity is a counter-intuitive state of matter that simultaneously shows superfluid flow and crystalline order. Dipolar quantum gases confined in elongated trapping geometries feature an interaction induced modulational instability driven by the softening of a roton excitation that eventually get stabilized by quantum fluctuations. By directly measuring density fluctuation in situ we extract the static structure factor across the transition, identify the roton modes as the dominant cause of the crystallization, and simultaneously observe BEC and crystal phonons on the supersolid side of the transition as a hallmark of supersolidity. An advanced study in circularly symmetric trapping geometries reveals the role of angular roton excitations in the crystallization process to two-dimensional droplet arrays. This understanding forms an important step toward the realization of a two-dimensional dipolar supersolid marking just the starting point to a rich phase diagram of structured patterns including novel exotic phases such as supersolid honeycomb and amorphous labyrinthine phases.

A 16.16 Wed 16:30 P

Formation of spontaneous density-wave patterns in DC driven lattices — •Henrik Zahn, Vijay Singh, Luca Asteria, Marcel Kosch, Lukas Freystatzky, Klaus Sengstock, Ludwig Mathey, and Christof Weitenberg — Universität Hamburg, Hamburg, Deutschland

Driving a many-body system out of equilibrium induces phenomena such as the emergence and decay of transient states. This can manifest itself as pattern and domain formation. The understanding of these phenomena expands the scope of established thermodynamics into the out-of-equilibrium domain. Here, we study the out-of-equilibrium dynamics of a bosonic lattice model subjected to a strong DC field, realized as ultracold atoms in a strongly tilted triangular optical lattice. We observe the emergence of pronounced density wave patterns – which spontaneously break the underlying lattice symmetry – as well as their domains using a novel single-shot imaging technique with single-site resolution in three-dimensional systems. We explain the dynamics as arising from center-of-mass-conserving pair tunneling processes, which appear in an effective description of the tilted Hubbard model. More broadly, we establish the far out-of-equilibrium regime of lattice models subjected to a strong DC field, as an exemplary and paradigmatic scenario for transient pattern formation.

A 16.17 Wed 16:30 P

Quantum gas microscopy of Kardar-Parisi-Zhang superdiffusion — •David Wei[1,2], Antonio Rubio-Abadal[1,2], Bingtian Ye[3], Francisco Machado[3,4], Jack Kemp[3], Kritsana Srakaew[1,2], Simon Hollerith[1,2], Jun Rui[1,2], Sarang Gopalakrishnan[5,6], Norman Y. Yao[3,4], Immanuel Bloch[1,2,7], and Johannes Zeiher[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Germany — [3]University of California, Berkeley, USA — [4]Lawrence Berkeley National Laboratory, California, USA — [5]The Pennsylvania State University, Pennsylvania, USA — [6]College of Staten Island, New York, USA — [7]Ludwig-Maximilians-Universität, Munich, Germany

The Kardar-Parisi-Zhang universality class describes the coarse-grained dynamics of numerous classical stochastic models. Surprisingly, the emergent hydrodynamics of spin transport in the one-dimensional (1D) quantum Heisenberg model was recently conjectured to fall into this class. We test this conjecture experimentally in a cold-atom quantum simulator in spin chains of up to 50 spins by studying the relaxation of domain walls. We find that domain-wall relaxation indeed scales with the superdiffusive KPZ dynamical exponent z=3/2. By probing dynamics in 2D and by adding a net magnetization, we verify that superdiffusion requires both integrability and a non-abelian SU(2) symmetry. Finally, we leverage the single-spin-sensitive detection enabled by our quantum-gas microscope to measure spin-transport statistics, which yields a clear signature of the non-linearity that is a hallmark of KPZ universality.

A 16.18 Wed 16:30 P

Bosonic Continuum Theory of One-Dimensional Lattice Anyons — •Martin Bonkhoff[1], Kevin Jägering[1], Sebastian Eggert[1], Axel Pelster[1], Michael Thorwart[2,3], and Thore Posske[2,3] — [1]Physics Department and Research Center Optimas,Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee149, 22761 Hamburg, Germany

Anyons with arbitrary exchange phases exist on 1D lattices in ultracold gases. Yet, known continuumt heories in 1D do not match. We derive the continuum limit of 1D lattice anyons via interacting bosons. The theory maintains the exchange phase periodicity fully analogous to 2D anyons [1]. This provides a mapping between experiments, lattice anyons, and continuum theories, including Kundu anyons with a natural regularization as a special case. We numerically estimate the Luttinger parameter as a function of the exchange angle to characterize long-range signatures of the theory and predict different velocities for left-and right-moving collective excitations.

[1] M. Bonkhoff, K. Jägering, S. Eggert, A. Pelster, M. Thorwart, and T. Posske, Bosonic continuum theory of one-dimensional lattice anyons, Phys. Rev. Lett. 126, 163201, (2021).

A 16.19 Wed 16:30 P

Dual-species BEC for atom interferometry in space — •Jonas Böhm[1], Baptist Piest[1], Maike D. Lachmann[1], Wolfgang Ertmer[1], Ernst M. Rasel[1], and the MAIUS Team[1,2,3,4,5,6,7] — [1]Institute of Quantum Optics, LU Hanover — [2]Department of Physics, HU Berlin — [3]ZARM, U Bremen — [4]DLR Institute of Space Systems, Bremen — [5]Institute of Physics, JGU Mainz — [6]DLR Simulation and Software Technology, Brunswick — [7]FBH, Berlin

Atom interferometry is a promising tool for measurements of the gravitational constant, universality of free fall and gravitational waves. As the sensitivity scales with the squared interrogation time, conducting atom interferometry in microgravity is of great interest.

The sounding rocket mission MAIUS-1 demonstrated the first BEC and matter wave interferences of it in space. With the follow-up missions MAIUS-2 and -3, we extend the apparatus by another species to perform atom interferometry with Rb-87 and K-41, paving the way for dual-species interferometers on bord of space stations or satellites.

In this contribution, the current status of the scientific payload MAIUS-B is discussed, fulfilling the requirements of generating Rb-87 and K-41 BECs with a high repetition rate in a compact, robust, and autonomously operating setup. The atomic state preparation and the manipulation using Raman double-diffraction processes are highlighted as well.

The MAIUS project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number: 50WP1431.

A 16.20 Wed 16:30 P

Feshbach resonances in a hybrid atom-ion system — •Wei Wu[1], Fabian Thielemann[1], Joachim Welz[1], Thomas Walker[1], Pascal Weckesser[1,2], Daniel Hönig[1], Amir Mohammadi[1], and Tobias Schätz[1] — [1]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

We present the first observation of Feshbach resonances between neutral atoms and ions. [1,2] While Feshbach resonances are commonly utilized in neutral atom experiments, however, reaching the ultracold regime in hybrid traps is challenging, as the driven motion of the ion by the rf trap limits the achievable collision energy. [3] We report three-body collisions between neutral 6Li and 138Ba+, where we are able to resolve individual resonances. We demonstrate the enhancement of two-body interactions through an increase in the sympathetic cooling rate of the ion by the atomic cloud, determined through optical trapping of the ion. and molecule formation evidenced by subsequent three-body losses. This paves the way to new applications such as the coherent formation of molecular ions and simulations of quantum chemistry. [4]

[1] Weckesser P, et al. arXiv preprint arXiv:2105.09382, 2021.
[2] Schmidt J, et al. Physical review letters, 2020, 124(5): 053402.
[3] Cetina M, et al. Physical review letters, 2012, 109(25): 253201.
[4] Bissbort U, et al.Physical review letters, 2013, 111(8): 080501.

A 16.21 Wed 16:30 P

A dipolar quantum gas microscope — •Paul Uerlings, Kevin Ng, Jens Hertkorn, Jan-Niklas Schmidt, Sean Graham, Mingyang Guo, Tim Langen, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We present the progress towards constructing a dipolar quantum gas microscope using dysprosium atoms. This new apparatus combines the long-range interactions found in dipolar quantum gases with the single-site resolution found in quantum gas microscopes. Ultracold dipolar quantum gases are a powerful and versatile platform to study quantum phenomena in and out of equilibrium. The large magnetic moment of dysprosium atoms allows for long-range and anisotropic interactions that give rise to exotic states of matter. By implementing a quantum gas microscope, microscopic details such as site occupation and site correlations will be observable. We plan to do this using magnetic atoms trapped in an ultraviolet optical lattice with a lattice spacing of a $\approx$ 180 nm. Combined with the long-range dipole interaction ($\propto 1/r^3$), the short lattice spacing will significantly increase the nearest-neighbour interaction strength to be on the order of 200 Hz (10 nK). This will allow us to study the regime of strongly interacting dipolar Bose-/and Fermi-Hubbard physics where even next-nearest-neighbour interactions could be visible. Our upcoming dipolar quantum gas microscope will enable further studies relating to quantum simulations and quantum magnetism.

A 16.22 Wed 16:30 P

Imaging the interface of a qubit and its quantum-many-body environment — •Sidharth Rammohan[1], S.K. Tiwari[1], A. Mishra[1], A. Pendse[1], A.K. Chauhan[1,2], R. Nath[3], A. Eisfeld[4], and S. Wüster[1] — [1]Department of Physics, Indian Institute of Science Education and Research, Bhopal, MP, India — [2]Department of Optics, Faculty of Science, Palacky University, 17.listopadu, Czech Republic — [3]Department of Physics, Indian Institute of Science Education and Research, Pune, India — [4]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We show that two major facets of the decoherence paradigm are experimentally accessible for a single impurity atom embedded in a Bose-Einstein condensate when the impurity is brought into an electronic superposition of two Rydberg states. Not only can the electronic decoherence of the Rydberg atom be read out by microwave interferometry, the platform also provides unique access to the accompanying entangled state of the environment. We theoretically demonstrate signatures of the latter in total atom densities during the transient time in which the impurity is becoming entangled with the medium but the resultant decoherence is not complete yet. The Rydberg impurity thus provides a handle to initiate and read-out mesoscopically entangled superposition states of Bose atom clouds affecting about 500 condensate atoms. We find that the timescale for its creation and decoherence can be tuned from the order of nanoseconds to microseconds by choice of the excited Rydberg principal quantum number ν and that Rydberg decoherence dynamics is typically non-Markovian.

A 16.23 Wed 16:30 P

dynamics of atoms within atoms — •Shiva kant Tiwari[1], F. Engel[2], M. Wagner[3], R. Schmidt[3], F. Meinert[2], and S. Wüster[1] — [1]Department of Physics, Indian Institute of Science Education and Research, Bhopal, Madhya Pradesh 462 066, India — [2]Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Recent experiments with Bose-Einstein condensates have entered a regime in which, after the excitation of a single atom into a highly excited Rydberg state, thousands of ground-state condensate atoms fill the Rydberg-electron orbit. Scattering off the electron then sets these into motion, such that one can study the quantum-many-body dynamics of atoms moving within the Rydberg atom. It has been suggested to use these features for tracking the motion, detecting the position and inferring or decohering the the quantum state of isolated Rydberg impurities. Here we numerically model this scenario using Gross-Pitaevskii and truncated Wigner theory. Our focus is on the cumulative effect of multiple sequential Rydberg excitations on the same condensate and the local heating dynamics. We also investigate the impact of details in the electron-atom interaction potential, such as the rapid radial modulation, which is important for the condensate response within the Rydberg orbit but is less relevant for subsequent density waves outside the Rydberg excitation region.

A 16.24 Wed 16:30 P

Collisions of solitary waves in condensates beyond mean-field theory — •Aparna Sreedharan[1], S Choudhury[1], R Mukherjee[1,2], A Streltsov[3,4], and S Wüster[1] — [1]Department of Physics, IISER Bhopal, Madhya Pradesh 462066, India — [2]Department of Physics, Imperial College, SW7 2AZ, London, UK — [3]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Germany — [4]SAP Deep Learning Center of Excellence and Machine Learning Research SAP SE, Germany

A soliton is a self-reinforcing wave packet that maintains its shape despite dispersion, and appears in a large number of natural nonlinear systems including BEC. Solitons with a density maximum are referred to as bright solitons and those in BEC are composed of hundreds or thousands of identical atoms held together by their weak contact interactions. They behave very much like a compound object, with behaviour dictated by the nonlinear wave equation describing the mean field of their many body wave function. Soliton interactions in BEC are strongly affected by condensate fragmentation dynamics which we study using the TWA and MCTDHB. We also show that separate solitary waves decohere due to phase diffusion that depends on their effective ambient temperature, after which their initial mean-field relative phases are no longer well defined or relevant for collisions. In this situation, collisions are predominantly repulsive and can no longer be described within mean-field theory. Using different quantum many body techniques, we present a unified view on soliton fragmentation, phase diffusion and entanglement in their collision dynamics.

A 16.25 Wed 16:30 P

All-Optical Matter-Wave Lens for Atom Interferometry — •Henning Albers[1], Alexander Herbst[1], Ersnt M. Rasel[1], Dennis Schlippert[1], and The Primus-Team[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]ZARM, Universität Bremen

The instability of quantum based inertial sensors highly depends on the center-of-mass motion and the expansion rate of the atomic ensemble. Precise control of these degrees of freedom is essential to perform accurate measurements of inertial effects, such as rotations or accelerations. Using time-averaged potentials in a 2μm crossed dipole trap we realize an all optical matter-wave lens which can be applied at all stages of the evaporative cooling process. By rapid decompression of the trap confinement we induce size oscillations of the trapped ensemble. Turning off the trap at a turning point of this oscillation results in a reduced velocity spread of the atomic cloud and thus a lowered expansion rate. We are able to reduce the transverse expansion temperature of ensembles containing 4×10^5 atoms from 40nK down to 3nK. The current limitations as well as the perspective to lens in transversal and longitudinal direction will be discussed.

A 16.26 Wed 16:30 P

Quantum gas microscopy of Rydberg macrodimers — •Kritsana Srakaew[1], Simon Hollerith[1], David Wei[1], Daniel Adler[1], Antoni Rubio-Abadal[2], Andreas Kruckenhauser[3], Valentin Walther[4], Christian Gross[5], Immanuel Bloch[1,6], and Johannes Zeiher[1] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]The Institute of Photonic Sciences Mediterranean Technology, Castelldefels, Spain — [3]Institute for Quantum Optics and Quantum Information, Innsbruck, Austria — [4]ITAMP, Harvard-Smithsonian Center of Astrophysics, Campridge, USA — [5]Physikalisches Institut, Eberhard Karls Universität, Tübingen, Germany — [6]Ludwig-Maximilians-Universität, Fakultät für Physik, München, Germany

A precise study of molecules is difficult due to a large number of motional degrees of freedom and the presence of an internal quantization axis, the interatomic axis. In the field of quantum simulation, Rydberg atoms recently gained attention due to their large interactions. These interactions also give rise to molecules with bond lengths reaching the micron scale, so-called macrodimers. Their large size allows one to pin atom pairs at a fixed orientation and distance matching the molecular bond length before photoassociation, which gives direct access to the molecular axis. Precise control and exploiting Quantum gas microscopy enables access to study different molecular symmetries and electronic structure tomography of the molecular state.

A 16.27 Wed 16:30 P

Atomic MOT from a buffergas beam source — •Simon Hofsäss[1], Sid Wright[1], Sebastian Kray[1], Maximilian Doppelbauer[1], Eduardo Padilla[1], Boris Sartakov[2], Jesús Pérez Ríos[1], Gerard Meijer[1], and Stefan Truppe[1] — [1]Fritz Haber Institute of the Max Planck Society, Berlin, Germany — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia

A sample of cold atoms is the starting point of many applications in atomic and molecular physics. When trapping atoms from a hot background gas or oven source into a magneto optical trap (MOT), the loading time is usually on the order of seconds and limits the repetition rate of such experiments. Using our pulsed buffer gas beam source - originally designed for the production of diatomic molecules such as Aluminium monofluoride - we can load the MOT with 10^8 Cadmium atoms in less than 10ms. We trap the atoms using the ${}^1P_1 \leftarrow {}^1S_0$ transition at 229nm using light from a frequency-quadrupled Ti:sapphire laser.

A 17: Ultracold atoms, ions, and BEC II / Ultracold plasmas and Rydberg systems (joint session A/Q)

Time: Thursday 10:45–12:15 Location: H1

Invited Talk A 17.1 Thu 10:45 H1

BECCAL - Quantum Gases on the ISS — •Lisa Wörner[1,2], Christian Schubert[1,3], Jens Grosse[1,2], Claus Braxmaier[1,2], Ernst Rasel[1,2], Wolfgang Schleich[1,4], and the BECCAL collaboration[1,2,3,4,5,6,7] — [1]German Aerospace Center, DLR — [2]University of Bremen — [3]Leibniz University Hanover — [4]University Ulm — [5]Humboldt University Berlin — [6]Johannes Gutenberg University — [7]Ferdinand Braun Institute

BECCAL (Bose-Einstein Condensate and Cold Atom Laboratory) is a bilateral NASA-DLR mission dedicated to execute experiments with ultra-cold and condensed atoms in the microgravity environment of the international space station. It builds on the heritage of NASA's CAL and the DLR founded QUANTUS and MAIUS missions. BECCAL aims to enable a broad range of experiments, covering atom interferometry, coherent atom optics, scalar Bose-Einstein gases, spinor Bose-Einstein gases and gas mixtures, strongly interaction gases and molecules, and quantum information. This contribution gives an overview over the current status of BECCAL and its anticipated capabilities for scientific investigations.

BECCAL is supported by DLR with funds provided by BMWi under Grants Nos. 50WP1700-1706.

Invited Talk A 17.2 Thu 11:15 H1

Ultracold polar ^{23}Na^{39}K ground-state molecules — •Kai Konrad Voges[1], Philipp Gersema[1], Mara Meyer zum Alten Borgloh[1], Torsten Hartmann[1], Torben Alexander Schulze[1], Leon Karpa[1], Alessandro Zenesini[1,2], and Silke Ospelkaus[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]INO-CNR BEC Center and Dipartimento di Fisica, Universit 'a di Trento, 38123 Povo, Italy

Heteronuclear ground-state molecules, with their large electric dipole moments, are an excellent platform for the investigation of fascinating dipolar quantum phenomena.

In this talk we present the coherent creation of the light weight bosonic ^{23}Na^{39}K rovibrational ground state molecules by utilizing Feshbach molecule association and subsequent stimulated Raman adiabatic passage (STIRAP) to the ground state. We are able to create rovibrational ground-state ensembles in a single hyperfine state either as a pure ensemble or in a mixture with ultracold atoms. By applying external electric fields we induce electric molecular dipole moments of up to 1 Debye. We further present our investigations of collisional properties of the molecule-atom mixtures and the pure molecular ensemble. For the latter one we investigate the formation of long-lived sticky complexes and their light excitation by the optical dipole trap.

Our measurements put a lower bound on the complex lifetime which is observed to be much larger than predicted by theoretical calculations base on RRKM theory.

Invited Talk A 17.3 Thu 11:45 H1

Anderson localization in a Rydberg composite — •Matthew Eiles, Alexander Eisfeld, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, 38 Noethnitzer Str. Dresden 01187

We demonstrate the localization of a Rydberg electron in a Rydberg composite, a system containing a Rydberg atom coupled to a structured environment of neutral ground state atoms. This localization is caused by weak disorder in the arrangement of the atoms and increases with the number of atoms M and principal quantum number ν. We develop a mapping between the electronic Hamiltonian in the basis of degenerate Rydberg states and a tight-binding Hamiltonian in the so-called "trilobite" basis, and then use this concept to pursue a rigorous limiting procedure to reach the thermodynamic limit in this system, taken as both M and ν become infinite, in order to show that Anderson localization takes place. This system provides avenues to study aspects of Anderson localization under a variety of conditions, e.g. for a wide range of interactions or with correlated/uncorrelated disorder.

A 18: Annual General Meeting

Time: Thursday 12:30–13:30 Location: MVA

Annual General Meeting