Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture halls HS 1010, 1098, and 1015; Poster Tent A, B, and C)

Invited Talks

A 1.1	Mon	11:00–11:30	HS 1010	**Exploring the Supersolid Stripe Phase in a Spin-Orbit Coupled Bose-Einstein Condensate** — •Sarah Hirthe, Vasiliy Makhalov, Rémy Vatré, Craig Chisholm, Ramón Ramos, Leticia Tarruell
A 10.1	Tue	11:00–11:30	HS 1010	**Strong-field coherent control in the extreme ultraviolet domain** — •F. Richter, U. Saalmann, M. Wollenhaupt, E. Allaria, C. Callegari, M. Danailov, L. Gianessi, M. Zangrando, L. Bruder
A 18.1	Wed	11:00–11:30	HS 1010	**Attosecond photoionization dynamics in CO_2 using coincidence spectroscopy** — •Ioannis Makos, David Busto, Dominik Ertel, Jakub Benda, Barbara Merzuk1, Fabio Frassetto, Luca Poletto, Claus Dieter Schröter, Thomas Pfeifer, Zdeněk Mašín, Serguei Patchkovskii, Giuseppe Sansone
A 36.1	Fri	11:00–11:30	HS 1010	**Stringent Test of QED predictions using Highly Charged Tin** — •Jonathan Morgner, Bingsheng Tu, Charlotte M. König, Tim Sailer, Fabian Heisse, Bastian Sikora, Chunhai Lyu, Vladimir Yerokhin, Zoltán Harman, José R. Crespo López-Urrutia, Christoph H. Keitel, Sven Sturm, Klaus Blaum

Invited Talks of the joint Symposium SAMOP Dissertation Prize 2024 (SYAD)

See SYAD for the full program of the symposium.

SYAD 1.1	Mon	14:30–15:00	Paulussaal	**Quantum steering of a Szilárd engine** — •Konstantin Beyer
SYAD 1.2	Mon	15:00–15:30	Paulussaal	**Does a disordered Heisenberg quantum spin system thermalize?** — •Titus Franz
SYAD 1.3	Mon	15:30–16:00	Paulussaal	**Quantum optical few-mode models for lossy resonators** — •Dominik Lentrodt
SYAD 1.4	Mon	16:00–16:30	Paulussaal	**Non-Hermitian topology and directional amplification** — •Clara Wanjura

Invited Talks of the joint Symposium Coulomb Explosion Imaging (SYCE)

See SYCE for the full program of the symposium.

SYCE 1.1	Tue	11:00–11:30	Paulussaal	**Dissociation of halogenated organic molecules induced by soft X-rays – pathways and early stages** — •Edwin Kukk
SYCE 1.2	Tue	11:30–12:00	Paulussaal	**X-ray induced Coulomb explosion imaging with channel-selectivity** — •Rebecca Boll
SYCE 1.3	Tue	12:00–12:30	Paulussaal	**Time-resolved Coulomb Explosion Imaging using X-ray Free-Electron Lasers** — •Till Jahnke
SYCE 1.4	Tue	12:30–13:00	Paulussaal	**Dynamics and control of microsolvated biomolecules studied by Coulomb explosion imaging** — •Sebastian Trippel, Jochen Küpper

Prize Talks of the joint Awards Symposium (SYAS)

See SYAS for the full program of the symposium.

SYAS 1.1	Tue	15:00–15:30	Paulussaal	**Quantum Simulations with Atoms, Molecules and Photons** — •Immanuel Bloch
SYAS 1.2	Tue	15:30–16:00	Paulussaal	**Spectroscopy of molecules with large amplitude motions: a journey from molecular structure to astrophysics.** — •Isabelle Kleiner
SYAS 1.3	Tue	16:00–16:30	Paulussaal	**Quantum x-ray nuclear optics: progress and prospects** — •Olga Kocharovskaya
SYAS 1.4	Tue	16:30–17:00	Paulussaal	**3D printed complex microoptics: fundamentals and first benchmark applications** — •Harald Giessen

Invited Talks of the joint Symposium Controlled Molecular Collisions (SYCC)

See SYCC for the full program of the symposium.

SYCC 1.1	Wed	11:00–11:30	Paulussaal	**Dynamics of CO_2 activation by transition metal ions - The importance of intersystem crossing** — •Jennifer Meyer
SYCC 1.2	Wed	11:30–12:00	Paulussaal	**Angular momentum of small molecules: quasiparticles and topology** — •Mikhail Lemeshko
SYCC 1.3	Wed	12:00–12:30	Paulussaal	**Manoeuvring chemical reactions one degree of freedom at a time** — •Jutta Toscano
SYCC 1.4	Wed	12:30–13:00	Paulussaal	**Cold and controlled collisions using tamed molecular beams** — •Sebastiaan van de Meerakker

Invited Talks of the joint Symposium Size Selected Metal Cluster Spectroscopies (SYMC)

See SYMC for the full program of the symposium.

SYMC 1.1	Thu	11:00–11:30	Paulussaal	**Infrared spectroscopic studies of molecular activation at metal clusters** — •Stuart Mackenzie
SYMC 1.2	Thu	11:30–12:00	Paulussaal	**Dynamic metal-metal cooperation in chemical reactions** — •Jana Roithová
SYMC 1.3	Thu	12:00–12:30	Paulussaal	**A closer look at the electronic structure of simple metal clusters** — •Bernd von Issendorff
SYMC 1.4	Thu	12:30–13:00	Paulussaal	**IR action spectroscopy of metal clusters, complexes and diatomics with free electron lasers** — •André Fielicke

Invited Talks of the joint Symposium Ultrafast Quantum Nano-Optics (SYQO)

See SYQO for the full program of the symposium.

SYQO 1.1	Fri	11:00–11:30	Paulussaal	**Coherent and incoherent dynamics of colloidal plexcitonic nanohybrids** — •Elisabetta Collini
SYQO 1.2	Fri	11:30–12:00	Paulussaal	**Dissipative Many-Body Dynamics in Atomic Subwavelength Arrays in Free Space** — •Stefan Ostermann
SYQO 1.3	Fri	12:00–12:30	Paulussaal	**Quantum dot sources: efficiency, entanglement, and correlations.** — •Ana Predojević
SYQO 1.4	Fri	12:30–12:45	Paulussaal	**Compact chirped fiber Bragg gratings for single-photon generation from quantum dots** — •Vikas Remesh, Ria Krämer, René Schwarz, Florian Kappe, Yusuf Karli, Thomas Bracht, Saimon Covre da Silva, Armando Rastelli, Doris Reiter, Stefan Nolte, Gregor Weihs
SYQO 1.5	Fri	12:45–13:00	Paulussaal	**Observing Ultrafast Coherent Dynamics following Selective Excitation of a Single Quantum Dot** — •Darius Hashemi Kalibar, Philipp Henzler, Ron Tenne, Alfred Leitenstorfer

Sessions

A 1.1–1.7	Mon	11:00–13:00	HS 1010	**Ultra-cold Atoms, Ions and BEC I (joint session A/Q)**
A 2.1–2.8	Mon	11:00–13:00	HS 1098	**Attosecond Physics I (joint session A/MO)**
A 3.1–3.8	Mon	11:00–13:00	Aula	**Bosonic Quantum Gases I (joint session Q/A)**
A 4.1–4.7	Mon	11:00–13:00	HS 3044	**Coulomb-explosion Imaging (joint session MO/A)**
A 5.1–5.8	Mon	17:00–19:00	HS 1010	**Ultra-cold Plasmas and Rydberg Systems I (joint session A/Q)**
A 6.1–6.8	Mon	17:00–19:00	HS 1098	**Atomic Systems in External Fields I**
A 7.1–7.8	Mon	17:00–19:00	Aula	**Bosonic Quantum Gases II (joint session Q/A)**
A 8.1–8.8	Mon	17:00–19:00	HS 1221	**Precision Measurements I (joint session Q/A)**
A 9.1–9.6	Mon	17:00–18:30	HS 3044	**Strong-field Ionization and Imaging (joint session MO/A)**
A 10.1–10.7	Tue	11:00–13:00	HS 1010	**Interaction with Strong or Short Laser Pulses I (joint session A/MO)**
A 11.1–11.8	Tue	11:00–13:00	HS 1098	**Precision Spectroscopy of Atoms and Ions I (joint session A/Q)**
A 12.1–12.8	Tue	11:00–13:00	Aula	**Bosonic Quantum Gases III (joint session Q/A)**
A 13.1–13.7	Tue	11:00–13:00	HS 1221	**Trapping and Cooling of Atoms (joint session Q/A)**
A 14	Tue	13:15–14:15	HS 1010	**Members' Assembly**
A 15.1–15.30	Tue	17:00–19:00	Tent A	**Poster I**
A 16.1–16.6	Tue	17:00–19:00	Tent B	**Poster II**
A 17.1–17.13	Tue	17:00–19:00	Tent C	**Poster III**
A 18.1–18.7	Wed	11:00–13:00	HS 1010	**Attosecond Physics II / Interaction with VUV and X-ray Light (joint session A/MO)**
A 19.1–19.8	Wed	11:00–13:00	HS 1098	**Precision Spectroscopy of Atoms and Ions II (joint session A/Q)**
A 20.1–20.8	Wed	11:00–13:00	HS 1199	**Fermionic Quantum Gases I (joint session Q/A)**
A 21.1–21.8	Wed	14:30–16:30	HS 1010	**Interaction with Strong or Short Laser Pulses II (joint session A/MO)**
A 22.1–22.8	Wed	14:30–16:30	HS 1098	**Highly Charged Ions and their Applications I**
A 23.1–23.8	Wed	14:30–16:30	HS 1015	**Atomic Clusters (joint session A/MO)**
A 24.1–24.8	Wed	14:30–16:30	Aula	**Fermionic Quantum Gases II (joint session Q/A)**
A 25.1–25.30	Wed	17:00–19:00	Tent A	**Poster IV**
A 26.1–26.13	Wed	17:00–19:00	Tent C	**Poster V**
A 27.1–27.8	Thu	11:00–13:00	HS 1010	**Precision Spectroscopy of Atoms and Ions III (joint session A/Q)**
A 28.1–28.8	Thu	11:00–13:00	HS 1098	**Ultra-cold Atoms, Ions and BEC II (joint session A/Q)**
A 29.1–29.8	Thu	14:30–16:30	HS 1010	**Ultra-cold Atoms, Ions and BEC III (joint session A/Q)**
A 30.1–30.7	Thu	14:30–16:15	HS 1098	**Precision Spectroscopy of Atoms and Ions IV (joint session A/Q)**
A 31.1–31.8	Thu	14:30–16:30	HS 1015	**Atomic Systems in External Fields II**
A 32.1–32.8	Thu	14:30–16:30	Aula	**Quantum Gases (joint session Q/A)**
A 33.1–33.30	Thu	17:00–19:00	Tent A	**Poster VI**
A 34.1–34.4	Thu	17:00–19:00	Tent B	**Poster VII**
A 35.1–35.13	Thu	17:00–19:00	Tent C	**Poster VIII**
A 36.1–36.7	Fri	11:00–13:00	HS 1010	**Highly Charged Ions and their Applications II**
A 37.1–37.8	Fri	11:00–13:00	HS 1098	**Ultra-cold Atoms, Ions and BEC IV (joint session A/Q)**
A 38.1–38.7	Fri	11:00–13:00	HS 1199	**Trapped Ions (joint session Q/A)**
A 39.1–39.8	Fri	11:00–13:00	HS 1221	**Precision Measurements II (joint session Q/A)**
A 40.1–40.8	Fri	14:30–16:30	HS 1010	**Ultra-cold Atoms, Ions and BEC V (joint session A/Q)**
A 41.1–41.8	Fri	14:30–16:30	HS 1098	**Precision Spectroscopy of Atoms and Ions V / Ultra-cold Plasmas and Rydberg Systems II (joint session A/Q)**
A 42.1–42.8	Fri	14:30–16:30	HS 1221	**Precision Measurements III (joint session Q/A)**
A 43.1–43.8	Fri	14:30–16:30	HS 3044	**Ultrafast Dynamics III and High-harmonic Generation (joint session MO/A)**

Members' Assembly of the Atomic Physics Division

Tuesday 13:15–14:15 H 1010

A 1: Ultra-cold Atoms, Ions and BEC I (joint session A/Q)

Time: Monday 11:00–13:00 Location: HS 1010

Invited Talk A 1.1 Mon 11:00 HS 1010

Exploring the Supersolid Stripe Phase in a Spin-Orbit Coupled Bose-Einstein Condensate — •Sarah Hirthe, Vasiliy Makhalov, Rémy Vatré, Craig Chisholm, Ramón Ramos, and Leticia Tarruell — ICFO - The Institute of Photonic Sciences, Castelldefels, Spain

Spin-orbit coupled Bose-Einstein condensates, where the internal state of the atoms is linked to their momentum through optical coupling, are a flexible experimental platform to engineer synthetic quantum many-body systems. In my talk, I will present recent work where we have exploited the interplay of spin-orbit coupling and tunable interactions in potassium BECs to observe and characterize the supersolid stripe phase. By optically coupling two internal states of potassium-41 using a two-photon Raman transition, we engineer a single particle dispersion relation with characteristic double-well structure. When the intrawell interactions dominate over the interwell ones, both minima are occupied and their populations interfere, leading to a system with a modulated (striped) density profile. The BEC then behaves as a supersolid: a phase that spontaneously breaks both gauge and translation symmetry, and which combines the frictionless flow of a superfluid and the crystalline structure of a solid. Using a matter-wave lensing technique, we magnify the density profile of the cloud and measure in situ the contrast and spacing of the stripes. Furthermore, we characterize the collective modes of the system and their dependence on interactions and coupling strength.

A 1.2 Mon 11:30 HS 1010

Determination of the dissipative response of a circularly driven atomic erbium quantum Hall system — •Franz Richard Huybrechts, Arif Warsi Laskar, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn

Cold atomic gases are attractive systems for the study of topological states and phases. Here we report on experimental work studying the dissipative response of a synthetic atomic erbium quantum Hall system to two different handed modes of circular shaking. In general, the dissipative response of a topological system, expressed by its circular dichroism, is linked to the transport properties by a Kramers-Kronig relation. In our experiment, for a cold cloud of erbium atoms a quantum Hall geometry is realised in a two-dimensional state space, consisting of one spatial and one synthetic dimension, with the latter being encoded in the Zeeman quantum number of erbium atoms in the ground state. Our measurements give evidence for a difference in the excitation rates between left and right handed driving. The current status of this ongoing experiment will be reported.

A 1.3 Mon 11:45 HS 1010

Drude weight and the many-body quantum metric in one-dimensional Bose systems — •Grazia Salerno[1], Tomoki Ozawa[2], and Päivi Törmä[1,2] — [1]Department of Applied Physics, Aalto University School of Science, FI-00076 Aalto, Finland — [2]Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Sendai 980-8577, Japan

We study the effect of quantum geometry on the many-body ground state of one-dimensional interacting bosonic systems. We find that the Drude weight is given by the sum of the kinetic energy and a term proportional to the many-body quantum metric of the ground state. Notably, the many-body quantum metric determines the upper bound of the Drude weight. We validate our results on the Creutz ladder, a flat-band model, using exact diagonalization at half and unit densities. Our work sheds light on the importance of the many-body quantum geometry in one-dimensional interacting bosonic systems.

A 1.4 Mon 12:00 HS 1010

Shapiro steps in driven atomic Josephson junctions — •Vijay Singh[1], Juan Polo[1], Ludwig Mathey[2], and Luigi Amico[1] — [1]Quantum Research Centre, Technology Innovation Institute, Abu Dhabi, UAE — [2]Zentrum für Optische Quantentechnologien and Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg, Germany

We study driven atomic Josephson junctions realized by coupling two two-dimensional atomic clouds with a tunneling barrier. By moving the barrier at a constant velocity, dc and ac Josephson regimes are characterized by a zero and nonzero atomic density difference across the junction, respectively. Here, we monitor the dynamics resulting in the system when, in addition to the above constant velocity protocol, the position of the barrier is periodically driven. We demonstrate that the time-averaged particle imbalance features a step-like behavior that is the analog of Shapiro steps observed in driven superconducting Josephson junctions. The underlying dynamics reveals an intriguing interplay of the vortex and phonon excitations, where Shapiro steps are induced via suppression of vortex growth. We study the system with a classical-field dynamics method, and benchmark our findings with a driven circuit dynamics.

A 1.5 Mon 12:15 HS 1010

Collisional dynamics between an ion and a Rydberg *S*-state — •Moritz Berngruber[1], Daniel Bosworth[2], Óscar Andrey Herrera Sancho[1], Viraatt Anasuri[1], Jennifer Krauter[1], Nicolas Zuber[1], Frederic Hummel[2], Florian Meinert[1], Robert Löw[1], Peter Schmelcher[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We report on the onset dynamics of a collision between an ion and a Rydberg atom in a highly excited S-state. Due to a large number of avoided crossings in the pair state potential, the dynamics can be quite complex but also provides a lot of possibility to manipulate and control the collision rates by changing the adiabaticity of the system. In our setup we can create Rb^+ ions and highly excited Rydberg sates independently. Owed to a very precise control of electric stray fields, we can conduct our measurements without the need of an additional ion trap, preventing micromotion in our experiments. By using a high-resolution ion microscope, we can directly observe the ions and Rydberg atoms in a cold thermal cloud in real space with a resolution of 200 nm. This allows us not only to directly map out the C4 pair interaction potential but also to directly observe the onset of the collisional dynamics. Finally, the experimental results are compared to a multi-channel model based on a Landau-Zener approach, which agrees very well with the experimental results.

A 1.6 Mon 12:30 HS 1010

Systematic analysis of relative phase extraction in 1D Bose gases interferometry — •Taufiq Murtadho[1], Marek Gluza[1], Nelly Ng[1], Arifa Khatee Zatul[1,2], Sebastian Erne[3], and Jörg Schmiedmayer[3] — [1]Nanyang Technological University, Singapore — [2]University of Wisconsin-Madison, Madison, USA — [3]Technische Universität Wien, Vienna, Austria

Matter-wave interference upon free expansion enables spatially resolved relative phase measurements of two adjacent 1D Bose gases. However, longitudinal dynamics is typically ignored in the analysis of experimental data. We provide an analytical formula showing a correction to the readout of the relative phase due to longitudinal expansion and mixing with the symmetric phase. Furthermore, we assess the error propagation to the estimation of temperature and correlation of the gases with numerical simulation. Our analysis also incorporates experimental systematic errors such as diffraction, recoil, and shot noise from the imaging devices. This work characterizes the reliability and robustness of interferometric measurements, directing us to the improvement of existing phase extraction methods necessary to observe new physical phenomena in cold-atomic quantum simulators.

A 1.7 Mon 12:45 HS 1010

Quantum phases of hardcore bosons with repulsive dipolar density-density interactions on two-dimensional lattices — •Jan Alexander Koziol[1], Giovanna Morigi[2], and Kai Phillip Schmidt[1] — [1]Department of Physics, Staudtstraße 7, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany — [2]Theoretical Physics, Saarland University, Campus E2.6, D-66123 Saarbrücken, Germany

We analyse the ground-state quantum phase diagram of hardcore Bosons interacting with repulsive dipolar potentials. The bosons dynamics is described by the extended-Bose-Hubbard Hamiltonian on a two-dimensional lattice The ground state results from the interplay between the lattice geometry and the long-range interactions, which we account for by means of a classical spin mean-field approach. This extended classical spin mean-field theory accounts for the long-range density-density interaction without truncation. The mean-field analysis is limited by the size of the considered unit cells. We consider three different lattice geometries: square, honeycomb, and triangular. In the limit of zero hopping the ground state is always a devil's staircase of solid (gapped) phases. Such crystalline phases with broken translational symmetry are robust with respect to finite hopping amplitudes. At intermediate hopping amplitudes, these gapped phases melt, giving rise to various lattice supersolid phases, which can have exotic features with multiple sublattice densities. Our results are of immediate relevance for experimental realisations of self-organised crystalline ordering patterns, e.g., with ultracold dipolar atoms in an optical lattice.

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

Time: Monday 11:00–13:00 Location: HS 1098

A 2.1 Mon 11:00 HS 1098

Ultrafast photoelectron spectroscopy with odd and even high-order harmonics — •Marvin Schmoll[1], Barbara Merzuk[1], Samuel Discher[1], Dominik Ertel[1], Ioannis Makos[1], Claus D. Schröter[2], Thomas Pfeifer[2], Robert Moshammer[2], Luca Poletto[3], Fabio Frassetto[3], and Giuseppe Sansone[1] — [1]Universität Freiburg, Physikalisches Institut, Freiburg, Germany — [2]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [3]CNR-Institute of Photonics and Nanotechnologies, Padova, Italy

High-order harmonic generation (HHG) in noble gases produces odd harmonics of the driving field. Adding a weaker second harmonic one can break the underlying symmetry and achieve both odd and even high-order harmonics.

We present an implementation of a collinear setup for such two-color HHG similar to what was first presented in ref. [1], which allows to adjust the relative phase between the fundamental and second harmonic component. Being implemented in combination with a collinear beamline for XUV-IR interferometry [2] we can perform high stability ultrafast photoelectron spectroscopy using these high order harmonics.

Our first results using Argon as a target gas show the viability of the method by demonstrating delay-dependent oscillations in the photoelectron yield for specific energies. These exhibit a period equal to that of the fundamental driving field as opposed to twice that period, which is known from experiments with odd orders only.

[1] N. Dudovich et al., Nature Phys. 2, 781 (2006)

[2] D. Ertel et al., Rev. Sci. Instrum. 94, 073001 (2023)

A 2.2 Mon 11:15 HS 1098

Extreme ultraviolet wave packet interferometry using table-top high harmonic generation — •Sarang Dev Ganeshamandiram, Fabian Richter, Ianina Kosse, Ronak Shah, Mario Niebuhr, Giuseppe Sansone, Frank Stienkemeier, and Lukas Bruder — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

Quantum interference techniques such as wave packet interferometry (WPI) in the extreme ultraviolet (XUV) domain set the basis for establishing advanced nonlinear spectroscopy methods in this wavelength regime [1]. These methods are however very difficult to implement at short wavelengths due to the required high phase stability and sensitivity. We are exploring methods based on acousto-optical phase modulation (PM) to solve these problems. First results from applications in seeded FELs and table-top high-harmonic generation (HHG) are promising [2,3]. Here, we will present an interferometer setup specifically designed for application with table-top HHG and discuss current challenges.

[1] S. Mukamel, et al., Multidimensional Attosecond Resonant X-Ray Spectroscopy of Molecules: Lessons from the Optical Regime, Annu. Rev. Phys. Chem. 64, 101 (2013).

[2] A. Wituschek, et al., Tracking attosecond electronic coherences using phase-manipulated extreme ultraviolet pulses, Nat Commun 11, 883 (2020).

[3] A. Wituschek et al., Phase cycling of extreme ultraviolet pulse sequences generated in rare gases, New J. Phys. 22, 092001 (2020).

A 2.3 Mon 11:30 HS 1098

Controlling Photoabsorption Interferometrically with Intense Laser Pulses from Microscopic to Macroscopic Gases — •Yu He[1], Shuyuan Hu[1], Gergana D. Borisova[1], Yizhu Zhang[1,3], Marc Rebholz[1], Mette B. Gaarde[2], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Louisiana State University, Baton Rouge, USA — [3]Tianjin University, Tianjin, China

Photoabsorption results from the interference between the incident field and the newly generated one radiated by the induced dipole oscillation. This dipole-emitted field can be controlled by the interplay of pulse propagation and intense laser pulses, giving rise to different absorption lineshapes. By temporally confining this new field through emptying the population of the excited state after its excitation, we achieve a local enhancement of absorbance in transient absorption spectroscopy [1,2]. In addition, in tandem with theory, we experimentally demonstrate the transition of absorption profiles from natural Lorentzian to Fano-like, which then become broader with further emergence of spectral bifurcations, finally turning back to near-Lorentzian lines in optically dense helium [3]. The integrated interferometric scenario in ultrafast absorption spectroscopy provides insights into the behavior of ensembles of dipole emitters and their temporal control. Refs: [1] He at al., Phys. Rev. Lett. 129 273201 (2022). [2] He at al., manuscript submitted (2023). [3] He at al., manuscript in preparation.

A 2.4 Mon 11:45 HS 1098

Time- and Frequency-resolved Characterization of Collective Nuclear Dynamics — •Lukas Wolff and Jörg Evers — Max-Planck-Institut für Kernphysik Heidelberg, Germany

Mössbauer nuclei have become an important tool for high precision tests and spectroscopy owing to their extremely narrow linewidths and long coherence times. In recent years, ensembles of nuclei embedded in suitably engineered waveguide structures allowed for the observation of cooperative phenomena such as superradiant decay and collective level shifts. This constituted the field of nuclear quantum optics of collective nuclear excitations. A direct and unambiguous characterization of such level schemes in the time or frequency domain alone is challenging and, thus, new data acquisition and evaluation techniques are of great importance to access the underlying collective dynamics [1]. To this end, we study the time- and frequency-resolved collective behaviour of nuclear ensembles upon x-ray pulses with different temporal and spectral shape to extract signatures for collective and nonlinear dynamics of Mössbauer resonances [2]. We expect our results to help guide future experiments investigating such dynamics using suitably-shaped x-ray pulses and pulse sequences that can be created using time-domain control of nuclear resonances.

[1] L.Wolff and J.Evers, Phys.Rev.Res. **5**, 013071 (2023)

[2] L.Wolff and J.Evers, Phys.Rev.A **108**, 043714 (2023)

A 2.5 Mon 12:00 HS 1098

Designing a Topological Thin-Film X-Ray Cavity — •Hanns Zimmermann[1,2] and Adriana Pálffy[1] — [1]Julius-Maximilians-Universität Würzburg — [2]Universität der Bundeswehr München

A promising platform for the quantum control of high-frequency photons are thin-film cavities, with one or several embedded layers of resonant nuclei such as ^{57}Fe with a Mössbauer transition at 14.4 keV. At grazing incidence, incoming x-rays couple evanescently to the cavity. In turn, the cavity field drives the nuclear transitions. The resulting nuclear response is well described by a recently-developed quantum optical model based on the electromagnetic Green's function [1,2].

Here, we investigate theoretically a thin-film cavity design with multiple embedded ^{57}Fe layers, such that its inter-layer couplings are mostly restricted to the nearest neighbouring layers by intercalating additional layers with high electron densities. Via the geometrical properties of these domains and control of the evanescent field pattern, we implement alternating coupling strengths between the resonant layers. We show that this leads to an x-ray photonic realization of the non-hermitian Su-Schrieffer-Heeger model and investigate how for certain configurations localized nuclear excitations emerge at the edges of the cavity.

[1] X. Kong, et al. Phys. Rev. A 102, 033710 (2020)
[2] P. Andrejić and A. Pálffy, Phys. Rev. A 104, 033702 (2021)

A 2.6 Mon 12:15 HS 1098

Single-shot electron spectroscopy of highly transient matter — •Sara Savio[1], Lars Funke[1], Niclas Wieland[1,3], Lasse Wuelfing[1], Markus Ilchen[2,3], and Wolfram Helml[1] — [1]Fakultät Physik, Technische Universität Dortmund, Maria-Goeppert-Mayer-Straße 2, 44227 Dortmund, Germany — [2]Deutsches Elektronen-Synchroton DESY, Notkestr. 85, 22607 Hamburg, Germany — [3]University of Hamburg, Middle Way 177 , 20148 Hamburg, Germany

Single-shot electron spectroscopy can be used as a tool to investigate photo-ionization processes and the various subsequent relaxation dynamics, ie how the inner shell vacancies are redistributed and filled in atoms and molecules. This work investigates the generation of double-core holes (DCH) in neon atoms with very short lifetimes using the help of intense and tightly focused X-ray pulses at European XFEL at the attosecond frontier. An electron-time-of-flight (e-TOF) spectrometer equipped with a multi-electrostatic lens system followed by a microchannel plate(MCP) based detector is used to specifically collect DCH Auger electrons in single-shot spectroscopy. The wavelength tunability and high X-ray intensity at European XFEL together with this spectroscopic technique enable the study of highly transient systems. Examining the electronic structure of a core-excited system before relaxation can allow for gaining essential insights into ultrafast processes and nonlinear photoabsorption under extreme intensities thus opening a new field of spectroscopy of transient matter.

A 2.7 Mon 12:30 HS 1098

Interatomic Coulombic Decay from Auger final states in aqueous solution — •Andreas Hans[1], Dana Bloss[1], Rémi Dupuy[2], Florian Trinter[3], Uwe Hergenhahn[3], Olle Björneholm[4], and Arno Ehresmann[1] — [1]Universität Kassel und CINSaT, Kassel, Germany — [2]Sorbonne Université, Paris, France — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [4]Uppsala University, Uppsala, Sweden

Interatomic Coulombic decay of resonant Auger final states (RA-ICD) has been discovered about a decade ago. Due to the site-selective character of the resonant excitation and the typically emitted slow electrons, RA-ICD has been envisioned to enhance the efficiency of radiation therapies. So far, the mechanism had only been observed experimentally in prototypical van der Waals dimers. Here, we present the transfer of the idea to the liquid phase. To this end we investigate the decay of $2p \rightarrow 3d$ resonantly excited solvated Ca^{2+} ions. We show, that using multi-electron coincidence spectroscopy increases the contrast for slow electrons drastically and that RA-ICD can be readily observed in the liquid phase.

A 2.8 Mon 12:45 HS 1098

Attoclock, what can or has actually been measured? — •Ossama Kullie — 1 Theoretical Physics, Institute of Physics, University of Kassel

Attoclock is designed to measure the delay time required for a particle to tunnel, or undergo field-ionization, from an atom interacting with a strong laser field. However, some authors claim that the duration the attoclock measures is not a good proxy for tunneling time. In previous works, we showed a model that describes the tunnel- or field-ionization of the attoclock experiment for He- [1] and H-atom [2], in the adiabatic and nonadiabatic field calibrations [3]. In the present talk, we show that it is possible to interpret the attoclock measurement in such a way that real-valued tunnel-time or the delay time due to the barrier region or the classically forbidden region can be determined. Furthermore, we show that in the limit of weak measurement the attoclock provides the interaction time inside the barrier, which is usually measured by the Larmro clock. The limit of thick barrier, the interaction time and the superluminal tunneling are discussed, [1] A. S. Landsman et al, Optica **1**, 343 (2014), U. S. Sainadh et al, Nature **586**, 75 (2019). [2] C. Hofmann et al. J. Mod. Opt. **66**, 1052 (2019). [3] O. Kullie, Phys. Rev. A **92**, 052118 (2015), O. Kullie J. Phys. Commun. **2**, 065001 (2018), O. Kullie and I. A. Ivanov, arXiv:2005.09938v6.

A 3: Bosonic Quantum Gases I (joint session Q/A)

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

A 3.1 Mon 11:00 Aula

Universal Dynamics of Rogue Waves in a Quenched Spinor Bose Condensate — •Ido Siovitz, Stefan Lannig, Yannick Deller, Helmut Strobel, Markus K. Oberthaler, and Thomas Gasenzer — Kirchhoff-Institut für Physik, Universität Heidelberg

Universal scaling dynamics of isolated many-body systems far from equilibrium is a phenomenon documented both in theory and experiment, the mechanisms of which are not yet fully understood. We connect the universal dynamics of a spin-1 gas with rogue-wave like events in the mutually coupled magnetic components of the gas, which propagate in an effectively random potential governed by the nonlinear spin-changing interaction. As a result, real-time instantons appear in the Larmor phase of the spin-1 system as vortices in space and time. We investigate the spatial and temporal correlations of these events to find two mutually related scaling exponents defining the coarsening evolution of length and time scales, respectively.

A 3.2 Mon 11:15 Aula

Nondegenerate two-photon absorption in gaseous xenon for Bose-Einstein condensation of vacuum-ultraviolet photons — •Thilo vom Hövel, Franz Huybrechts, Eric Boltersdorf, Frank Vewinger, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn

Motivated by work with cold atomic ensembles, Bose-Einstein condensation has in recent years also been realized for two-dimensional gases of visible-spectral-range photons. For this, e.g., a dye solution-filled optical microcavity is utilized to thermalize a photon gas via repeated cycles of absorption and emission by dye molecules. In previous work, we proposed to employ a similar platform for the construction of a coherent light source in the VUV (100 - 200 nm wavelength), a spectral range in which it is difficult to operate lasers.

For Bose-Einstein condensation of VUV photons, a thermalization mediator other than the dye system needs to be identified, as the latter is unsuitable in light of the high photon energies. One candidate is the quasimolecular xenon system, with absorption on the $5p^6 \rightarrow 5p^5 6s$ transition at 147 nm and emission on the Stokes-shifted second excimer continuum around 172 nm wavelength. In pure xenon at currently investigated pressures, however, the pronounced spectral gap between absorption and emission impedes efficient contact between photon gas and thermalization mediator. We here report on spectroscopic results of an experimental scheme devised to enhance the (re-)absorption of photons emitted around 172 nm, based on a nondegenerate two-photon process induced by the provision of an auxiliary photon field.

A 3.3 Mon 11:30 Aula

Projection Optimization Method for Open-Dissipative Quantum Fluids and its Application to a Single Vortex in a Photon Bose-Einstein Condensate — •Joshua Krauss[1], Marcos Alberto Gonçalves dos Santos Filho[1,2], Francisco Ednilson Alves dos Santos[2], and Axel Pelster[1] — [1]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]Departamento de Física, Universidade Federal de São Carlos, Brazil

Open dissipative systems of quantum fluids have been well studied numerically. In view of a complementary analytical description we extend here the variational optimization method for Bose-Einstein condensates of closed systems to open-dissipative condensates. The resulting projection optimization method is applied to a complex Gross-Pitaevski equation, which models phenomenologically a photon Bose-Einstein condensate. Together with known methods from hydrodynamics we obtain an approximate vortex solution, which depends on the respective open system parameters and has the same properties as obtained numerically in the literature.

[1] J. Krauß, M.A.G. dos Santos Filho, F.E.A. dos Santos, and A. Pelster, arXiv:2311.10027

A 3.4 Mon 11:45 Aula

Out-of-equilibrium dynamics and phases of an atomic BEC

coupled to an optical cavity — •Gage Harmon[1], Giovanna Morigi[1], and Simon Jäger[2] — [1]Saarland University — [2]University of Kaiserslautern-Landau

We study the pattern formation of a laser-driven atomic Bose-Einstein condensate coupled to a single lossy mode of an optical cavity. In our work, we focus on the regime where the effective cavity detuning depends strongly on the dispersive AC Stark shift, and where the cavity relaxation rate is fast compared to the typical atomic relaxation rate. This results in a feedback between the atomic pattern and cavity field that allows for a parameter regime where the cavity field is unable to stabilize the atomic configuration. Instead, the system enters a dynamical phase where the atomic pattern and cavity field exhibit oscillations. We analyze this behavior using a mean-field approach that describes the coupled dynamics of the atoms and cavity field. In addition, working in the bad-cavity regime allows us to derive equations of motion where the cavity degrees of freedom are eliminated, massively improving the integration time. We benchmark and validate these equations of motion and showcase that the existence of limit cycle phases does not require a treatment of the cavity field and atoms to be on equal timescales. Remarkably, we demonstrate that the presence of non-conservative forces which require both, dissipation and a prominent AC Stark shift, are the key mechanisms that results in limit cycle and chaotic phases.

A 3.5 Mon 12:00 Aula

Bose-Einstein condensation of photons in a vertical-cavity surface-emitting laser — Maciej Pieczarka[1], Marcin Gebski[2], Aleksandra N. Piasecka[1], James A. Lott[3], •Axel Pelster[4], Michał Wasiak[2], and Tomasz Czyszanowski[2] — [1]Department of Experimental Physics, Wrocław University of Science and Technology, Poland — [2]Institute of Physics, Łodź University of Technology, Poland — [3]Institute of Solid State Physics and Center of Nanophotonics, Technical University Berlin, Germany — [4]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany

Here we show the Bose-Einstein condensation of photons in a broad-area vertical-cavity surface-emitting laser with positive cavity mode-gain peak energy detuning. We observed a Bose-Einstein condensate in the fundamental transversal optical mode at the critical phase-space density. The experimental results follow the equation of state for a two-dimensional gas of bosons in thermal equilibrium, although the extracted spectral temperatures were lower than those of the device. This is interpreted as originating from the driven-dissipative nature of the device and the stimulated cooling effect. In contrast, non-equilibrium lasing action is observed in the higher-order modes in a negatively detuned device. Our work opens the way for the potential exploration of superfluid physics of interacting photons mediated by semiconductor optical non-linearities. It also shows great promise for enabling single-mode high-power emission from a large aperture device.

[1] M. Pieczarka, M. Gebski, A.N. Piasecka, J.A. Lott, A. Pelster, M. Wasiak, and T. Czyszanowski, arXiv:2307.00081

A 3.6 Mon 12:15 Aula

Ramsauer Townsend effect and Bragg scattering in an analogue cosmology experiment — •Marius Sparn[1], Elinor Kath[1], Nikolas Liebster[1], Christian F. Schmidt[2], Álvaro Parra-López[3], Mireia Tolosa-Simeón[4], Helmut Strobel[1], Stefan Floerchinger[2], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena — [3]Departamento de Física Teórica and IPARCOS, Universidad Complutense de Madrid — [4]Institut für Theoretische Physik III, Ruhr-Universität Bochum

Cosmological particle production arises when a quantum field is subject to an expanding metric. This phenomenon heavily depends on the details of the cosmological history. Strikingly, this relativistic, time-dependent process can be mapped to a scattering problem, described by a non-relativistic stationary Schroedinger-equation, wherein the scattering potential is determined by the specific form of the expansion. Here we present results from an analogue cosmology experiment with a two-dimensional Bose-Einstein condensate, simulating a scalar quantum field in a FLRW-spacetime [1]. We use the scattering framework to investigate instructive examples, such as a box potential, corresponding to a singular expanding space-time as well as a periodic potential, corresponding to a periodic expansion and contraction. The measured spectra of produced particles reveal features analogue to resonant forward (Ramsauer-Townsend) scattering and Bragg scattering, respectively. [1] Viermann, C. et al. Nature 611, 260-264 (2022)

A 3.7 Mon 12:30 Aula

Dynamics of polaron formation in weakly interacting 1D Bose gases — •Martin Will and Michael Fleischhauer — University of Kaiserslautern-Landau

We discuss the dynamics of the formation of a Bose polaron when an impurity is injected into a weakly interacting one-dimensional Bose condensate. While for small impurity-boson couplings, this process can be described within the Froehlich model as emission, and binding of Bogoliubov phonons, this is no longer adequate if the coupling becomes strong. To treat this regime, we consider a mean-field approach beyond the Froehlich model which accounts for the backaction to the condensate, complemented with Truncated Wigner simulations to include quantum fluctuation. For the stationary polaron we find a periodic energy-momentum relation and non-monotonous relation between impurity velocity and polaron momentum including regions of negative impurity velocity. Consequently, the impurity undergoes Bloch oscillations when subject to a constant force. Studying the polaron formation after turning on the impurity-boson coupling (i) quasi-adiabatically and (ii) in a sudden quench, we find a rich scenario of dynamical regimes. Due to the build-up of an effective mass, the impurity is slowed down even if its initial velocity is below the Landau critical value. For larger initial velocities we find deceleration and even backscattering caused by emission of density waves or grey solitons and subsequent formation of stationary polaron states.

A 3.8 Mon 12:45 Aula

Solitons on the surface of a sphere — •Alexander Wolf[1,2], Vladimir Konotop[3], and Maxim Efremov[2] — [1]Institute of Quantum Physics and Center for Integrated Quantum Science and Technology (IQ^{ST}), Ulm University, D-89081 Ulm, Germany — [2]German Aerospace Center (DLR), Institute of Quantum Technologies, D-89081 Ulm, Germany — [3]Departamento de Física and Centro de Física Teórica e Computacional, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, Ed. C8, Lisboa 1749-016, Portugal

The recent realization of ultracold quantum gases in a shell geometry [1] paves the way towards a Bose-Einstein condensate (BEC) that is trapped tightly onto the surface of a sphere. We investigate the existence and stability of solitons that appear in this system using the two-dimensional (2D) Gross-Pitaevskii equations (GPE). Comparing our results to the 2D plane, we find that the scale invariance of the GPE is broken due to the curvature and compactness of the shell geometry. Consequently, the familiar Townes solitons [2] appear only when the BEC is strongly localized in a small region of the sphere surface.

[1] R. A. Carollo *et al.*, Nature (London) **606**, 281 (2022).
[2] B. Bakkali-Hassani *et al.*, Phys. Rev. Lett. **127**, 023603 (2021).

A 4: Coulomb-explosion Imaging (joint session MO/A)

Time: Monday 11:00–13:00 Location: HS 3044

Invited Talk A 4.1 Mon 11:00 HS 3044

Imaging ultrafast molecular dissociation dynamics; from conventional to surprising paths — •Heide Ibrahim — Advanced Laser Light Source (ALLS) @ Institut National de la Recherche Scientifique (INRS-EMT), Varennes, QC, Canada

Coulomb explosion imaging (CEI) is a powerful tool to track a broad variety of molecular dynamics; even if they occur in a non-concerted manner and require single-molecule detection sensitivity. Upon photoexcitation of a molecule it will break apart. We can see fragments following direct, conventional dissociation paths, as well as fragments deviating from this minimum energy path. The latter are called roaming fragments and explore the potential energy landscape in a statistical manner. At the user facility ALLS we use CEI in combination with high repetition rate laser systems. Dissociating and roaming fragments in formaldehyde are directly captured using CEI, a hard-to-grasp statistically occurring signal. Individual pathways are distinguished based on state-of-the-art theory analysis.

A 4.2 Mon 11:30 HS 3044

Dynamics of H_2-roaming processes, H_3^+ formation in ethanol and aminoethanol initiated by two-photon double-ionization — •Aaron Ngai[1], Sebastian Hartweg[1], Jakob Asmussen[2], Björn Bastian[3], Ltaief Ben Ltaief[2], Matteo Bonanomi[4,5], Carlo Callegari[6], Michele di Fraia[6], Katrin Dulitz[7], Raimund Feifel[8], Sarang Ganeshamandiram[1], Sivarama Krishnan[9], Aaron LaForge[10], Landmesser Friedemann[1], Michelbach Moritz[1], Pal Nitish[6], Plekan Oksana[6], Rendler NicNicolas[1], Richter Fabian[1], Scognamiglio Audrey[1], Sixt Tobias[1], Squibb Richard[8], Sundaralingam Akgash[2], Stienkemeier Frank[1], and Mudrich Marcel[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — [2]Department of Physics and Astronomy, Aarhus University, Aarhus, Denmark — [3]Wilhelm Ostwald Institute for Physical and Theoretical Chemistry, University of Leipzig, Leipzig, Germany — [4]Dipartimento di Fisica Politecnico, Milano, Italy — [5]Istituto di Fotonica e Nanotecnologie (CNR-IFN) Milano, Italy — [6]Elettra - Sincrotrone Trieste S.C.p.A., Basovizza, Trieste, Italy — [7]Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, Innsbruck, Austria — [8]Department of Physics, University of Gothenburg, Göteborg, Sweden — [9]Department of Physics, Indian Institute of Technology Madras, Chennai, India — [10]Department of Physics, University of Connecticut, Storrs, Connecticut, US

The trihydrogen cation (H_3^+) is the simplest and one of the most abundant triatomic cations in the universe. It plays a crucial role in interstellar gas-phase chemistry as it facilitates molecule-forming chemical reactions. Dynamics in simple alcohols that lead to H_3^+ formation typically involve the unusual so-called "roaming"-mechanism of a neutral H_2 moiety. In comparison to previous experiments using strong-field ionization by infrared (IR) pulses [1], we produce dicationic ethanol and 2-aminoethanol molecules using two-photon double-ionization with extreme ultraviolet (XUV) light, and probe the dynamics of H_3^+ formation with a visible (VIS) pulse in a time-resolved pump-probe scheme. We compare results between measurements with XUV photons either below or above the double-ionization threshold, including the lifetimes of intermediate states.

[1] Ekanayake, N. *et al. Nat. Commun.* **9**, 5186 (2018)

A 4.3 Mon 11:45 HS 3044

New endstation for controlled molecule experiments and ultrafast dynamics of OCS — •Wuwei Jin[1,2], Ivo Vinklárek[1], Sebastian Trippel[1,3], Hubertus Bromberger[1], Sergey Ryabchuk[1], Erik Månsson[1], Andrea Trabattoni[1], Vincent Wanie[1], Francesca Calegari[1], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]Department of Physics, Universität Hamburg — [3]Center for Ultrafast Imaging, Universität Hamburg

Imaging ultrafast photochemical reactions with atomic-spatial and femtosecond-temporal resolution is one of the ultimate goals of physical chemistry and the molecular sciences [1]. We present details on our newly established transportable endstation for controlled molecules (eCOMO) and discuss our ultrafast (sub 10 fs) time-resolved study of the photodissociation dynamics of carbonyl sulfide (OCS) after UV-photoexcitation at $\lambda = 267$ nm. OCS was purified and separated from the helium seed gas using the electrostatic deflector [2]. The UV-induced dynamics was probed through strong field ionization using a velocity map imaging spectrometer in combination with a Timepix3 camera [3].

[1] J Onvlee, S Trippel, and J Küpper, *Nat. Commun.* **7462**, 13 (2022)

[2] YP Chang, D Horke, S Trippel, and J Küpper, *Int. Rev. Phys. Chem.* **557**, 34 (2015)

[3] H Bromberger, *et int.* (9 authors), S Trippel, B Erk, and J Küpper, *J. Phys. B.* **144001**, 55 (2022)

A 4.4 Mon 12:00 HS 3044

Complete imaging of the reaction pathways of ionized water dimer — •Luisa Blum[1,2], Ivo S. Vinklárek[1], Hubertus Bromberger[1], Sebastian Trippel[1], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science CFEL, Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]Department of Physics, Universität Hamburg — [3]Center for Ultrafast Imaging, Universität Hamburg

We applied a pure ensemble (92 %) of water dimer $(H_2O)_2$, spatially separated by electrostatic deflection, and subsequently ionized by strong-field ionization, to investigate the ion-radical chemistry of water clusters [1]. The direct observation of fragmentation channels of $(H_2O)_2^+$ and $(H_2O)_2^{+2}$ by multi-mass imaging reveals several yet unknown ion-radical pathways and provides a comprehensive picture of $(H_2O)_2^{+/+2}$, including experimental branching ratios. Furthermore, the ion yields for the Coulomb explosion channels of $(H_2O)_2^{+2}$ indicate electron-recollision-impact ionization as the dominant process, opening the discussion about avenues to control electron recollision and multiple-ionization processes in supramolecular complexes. The study of the $(H_2O)_2^{+/+2}$ ionization fragmentation process is highly relevant to ion-radical heterogeneous chemistry occurring on ice mantles in the Earth's atmosphere and in interstellar space [2].

[1] Vinklárek, I. S., Bromberger, H., Vadassery N., Jin W., Küpper, J., Trippel, S., *submitted*; arXiv:2308.08006 [physics].

[2] Vogt, E., Kjaergaard, H. G., *Annu. Rev. Phys. Chem.*, **73**, 209-231 (2022).

A 4.5 Mon 12:15 HS 3044

Understanding fragmentation dynamics of difluorodiiodomethane — •Nidin Vadassery[1,3], Ivo Vinklárek[1], Sebastian Trippel[1,2], and Jochen Küpper[1,2,3] — [1]Center for Free-Electron Laser Science, Deutches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Department of Physics, Universität Hamburg — [3]Department of Chemistry, Universität Hamburg

Unimolecular photo-fragmentation is prevalent in the many chemical reactions that affect the environment, like ozone depletion, synthesis of oxidative hydrocarbons, formation of aerosol particles, *etc.* [1]. The photo-dissociation of man-made and naturally occuring polyhalohydrocarbons is among the major causes which contribute to such climate-impacting reactions. Difluorodiiodomethane (CF_2I_2) one such example of polyhalohydorcarbon shows unconventional dynamics near dissociative energies [2]. Here, we present our experimental result of exploring the dissociation dynamics of CF_2I_2 using near-infrared laser pulses. A pure sample of CF_2I_2 was produced using the deflector in the eCOMO endstation [3]. We show capability of the end-station to reveal metastable states and unravel the complex quantum-state-specific dynamics during photo-fragmentation.

[1] J. C. G. Martin, *et al.*, *J. Am. Chem. Soc.* **144**, 9240 (2022).

[2] P. Z. El-Khoury, *et al.*, *J. Chem. Phys.* **132**, 124501 (2010).

[3] I. S. Vinklárek, *et int.* (3 authors), J. Küpper, S. Trippel, arXiv:2308.08006 [physics] (2023).

A 4.6 Mon 12:30 HS 3044

Ultrafast photofragmentation studies of $CF_3I{\cdot}I^-$ using mass-selected ion-molecule cluster beam apparatus — •Xiaojun Wang[1,4], Mahmudul Hasan[1], Lin Fan[1], Yibo Wang[1], Hui Li[2], Daniel Slaughter[3], and Martin Centurion[1] — [1]Department of Physics and Astronomy, University of Nebraska-Lincoln, Lincoln, Nebraska 68588, USA — [2]Department of Chemistry, Nebraska Center for Materials and Nanoscience, and Center for Integrated Biomolecular Communication, University of Nebraska-Lincoln, Lincoln, Nebraska 68588, USA — [3]Chemical Sciences Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Rd., Berkeley, California 94720, USA — [4]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany.

We describe an apparatus for investigating the excited-state dissociation dynamics of mass-selected ion-molecule clusters by mass-resolving and detecting photofragment-ions and neutrals, in coincidence, using an ultrafast laser operating at high repetition rates. The apparatus performance is tested by measuring the photofragments: I^-, CF_3I^- and neutrals from photoexcitation of the ion-molecule cluster $CF_3I{\cdot}I^-$ using femtosecond UV laser pulses with a wavelength of 266 nm. The experimental results are compared with our ground state and excited state electronic structure calculations as well as the existing results and calculations, with particular attention to the generation mechanism of the anion fragments and dissociation channels of the ion-molecule cluster $CF_3I{\cdot}I^-$ in the charge-transfer excited state.

Reference: Rev. Sci. Instrum. 94, 095111 (2023)

A 4.7 Mon 12:45 HS 3044

Coulomb explosion imaging of ultrafast photochemistry in molecular photoswitches — Kieran Cheung[1], Claus Peter

Schulz[2], Arnaud Rouzeé[2], Till Jahnke[3], Daniel Rolles[4], Giuseppe Sansone[5], Michael Meyer[3], Mark Brouard[1], Terry Mullins[1], and •Kasra Amini[2] — [1]Chemistry Research Laboratory, Department of Chemistry, University of Oxford, Oxford OX1 3TA, UK — [2]Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany — [3]European XFEL, Schenefeld, Germany — [4]J.R. Macdonald Laboratory, Department of Physics, Kansas State University, Manhattan, KS, USA — [5]Physikalisches Institut, Universität Freiburg, D-79106 Freiburg, Germany

Here, we present an X-ray Coulomb explosion imaging (CEI) study into the photofragmentation and photochemistry of trans-4,4-difluoroazobenzene (DFAB) measured with the COLTRIMS Reaction Microscope at the SQS station of European XFEL. We first provide a systematic study of X-ray fragmentation in DFAB with covariance analysis. We then present pump-probe X-ray CEI measurements of DFAB excited to its first excited state under different visible pump excitation conditions. We discuss the limited ability of trans-DFAB to undergo trans-to-cis isomerization after initial population of its S_1 state, and reveal the onset of a dissociative ionization photodissociation process.

A 5: Ultra-cold Plasmas and Rydberg Systems I (joint session A/Q)

Time: Monday 17:00–19:00 Location: HS 1010

A 5.1 Mon 17:00 HS 1010

Time-reversal in a quantum many-body spin system — •Sebastian Geier[1], Adrian Braemer[1,2], Eduard Braun[1], Maximilian Müllenbach[1], Titus Franz[1], Martin Gärttner[1,2,3], Gerhard Zürn[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Physikalisches Institut, Im Neuenheimer Feld 226 — [3]Institute of Condensed Matter Theory and Optics, Friedrich-Schiller-University Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Time reversal in a macroscopic system is contradicting daily experience. Yet, with the precise control capabilities provided by modern quantum technology, the unitary evolution of a quantum system can be reversed, rendering it a powerful tool for scientific discovery and technological advancements. Here, we implement a time-reversal protocol in a dipolar interacting many-body spin system represented by Rydberg states in an atomic gas. By changing the states encoding the spin, we flip the sign of the interaction Hamiltonian, and demonstrate the reversal of the relaxation dynamics of the magnetization by letting a demagnetized many-body state evolve back-in-time into a magnetized state. We elucidate the role of atomic motion using the concept of a Loschmidt echo. Finally, by combining the approach with Floquet engineering, we demonstrate time reversal for a large family of spin models with different symmetries. Our method of state transfer is applicable across a wide range of quantum simulation platforms and has applications far beyond quantum many-body physics.

A 5.2 Mon 17:15 HS 1010

Exploring the vibrational series of pure trilobite Rydberg molecules — •Markus Exner, Max Althön, Richard Blättner, and Herwig Ott — RPTU Kaiserslautern-Landau, Kaiserslautern, Deutschland

We report on the observation of two vibrational series of pure trilobite rubidium Rydberg molecules. These kinds of molecules consist of a Rydberg atom and a ground state atom. The binding mechanism is based on the scattering interaction between the Rydberg electron and the ground state atom. The trilobite molecules are created via three-photon photoassociation and lie energetically more than 15 GHz below the atomic 22F state. In agreement with theoretical calculations, we find an almost perfect harmonic oscillator behavior of six vibrational states. We show that these states can be used to measure electron-atom scattering lengths for low energies in order to benchmark current theoretical calculations. The molecules have extreme properties: their dipole moments are in the range of kilo-Debye and the electronic wave function is made up of high angular momentum states with only little admixture from the nearby 22F state. This high-l character of the trilobite molecules leads to an enlarged lifetime as compared to the 22F atomic state. Furthermore, our ion pulse spectrometer provides insights into the decay processes.

A 5.3 Mon 17:30 HS 1010

Green's function treatment of Rydberg molecules with spin — •Matthew Eiles[1] and Chris Greene[2] — [1]Max Planck Institut für Physik komplexer Systeme, Nöthnitzer Str 38, 01187 Dresden Germany — [2]Department of Physics and Astronomy and Purdue Quantum Science and Engineering Institute, Purdue University, West Lafayette, Indiana 47907, USA

The determination of ultra-long-range molecular potential curves has been reformulated using the Coulomb Green's function to give a solution in terms of the roots of an analytical determinantal equation. For a system consisting of one Rydberg atom with a fine structure and a neutral perturbing ground state atom with hyperfine structure, the solution yields potential energy curves and wave functions in terms of the quantum defects of the Rydberg atom and the electron-perturber scattering phase shifts and hyperfine splittings. This method provides a promising alternative to the standard currently utilized method of diagonalization, which suffers from problematic convergence issues and nonuniqueness, and can potentially yield a more quantitative relationship between Rydberg molecule spectroscopy and electron-atom scattering phase shifts.

A 5.4 Mon 17:45 HS 1010

Rydberg Atomtronic Devices — •Philip Kitson[1,2], Tobias Haug[1], Antonino La Magna[3], Oliver Morsch[4], and Luigi Amico[1,2,5] — [1]Technology Innovation Institute, Abu Dhabi, UAE — [2]Dipartimento di Fisica e Astronomia and INFN-Sezione di Catania, Catania, Italy — [3]CNR-IMM, Catania, Italy — [4]CNR-INO, Pisa, Italy — [5]Centre for Quantum Technologies, Singapore

Atomtronics realises circuits through the guidance of neutral ultra-cold atoms. However, a recent proposal in the field of atomtronics has been the integration of Rydberg atoms, whereby instead of transporting matter, the established flow is of Rydberg excitations. We take advantage of the blockade and anti-blockade phenomena, resulting from the large dipole moments of such atoms, to prevent or facilitate the flow of excitations throughout networks of Rydberg atoms. In our work, we capitalise on these ideas along with the use of specific atom detunings, in order to create a toolbox of Atomtronics devices. We first formulate a method to control the flow of excitations through a Rydberg network via a detuning upon a gate atom as an analogy to a switch. Second, we generate non-reciprocal flow by using certain conditions of the anti-blockade (the gate atom's detuning and position). Lastly, we devise Rydberg networks to conduct logical decisions. Employing the anti-blockade mechanism we create a classical AND gate and a NOT gate, whereby combining both, we produce a universal logic gate set.

A 5.5 Mon 18:00 HS 1010

Spectral signatures of vibronic coupling in trapped cold atomic Rydberg systems — •Joseph William Peter Wilkinson[1], Weibin Li[2], and Igor Lesanovsky[1,2] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Atoms and ions confined with electric and optical fields form the basis of many current quantum simulation and computing platforms. When excited to high-lying Rydberg states, long-ranged dipole interactions emerge which strongly couple the electronic and vibrational degrees of freedom through state-dependent forces. This vibronic coupling and the ensuing hybridization of internal and external degrees of freedom manifest through clear signatures in the many-body spectrum. In this talk, we briefly discuss the recent results in Ref. [1] wherein we consider the case of two trapped Rydberg ions that realize a quantum Rabi model due to the interaction between the relative vibrations and Rydberg states. We proceed to demonstrate that this hybridization can be probed by radio frequency spectroscopy and discuss observable spectral signatures at finite temperatures and for larger ion crystals.

[1]. J. W. P. Wilkinson, W. Li, and I. Lesanovsky, *Spectral signatures of vibronic coupling in trapped cold atomic Rydberg systems*,

arXiv:2311.16998 (2023)

A 5.6 Mon 18:15 HS 1010

Avalanche terahertz photon detection in a Rydberg tweezer array — •Chris Nill[1,2], Albert Cabot[1], Arno Trautmann[3], Christian Gross[3], and Igor Lesanovsky[1,4] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Institute for Applied Physics, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany — [3]Physikalisches Institut, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [4]School of Physics and Astronomy, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

We propose a protocol for the amplified detection of low-intensity terahertz radiation using Rydberg tweezer arrays [1]. The protocol offers single photon sensitivity together with a low dark count rate. It is split into two phases: during a sensing phase, it harnesses strong terahertz-range transitions between highly excited Rydberg states to capture individual terahertz photons. During an amplification phase, it exploits the Rydberg facilitation mechanism which converts a single terahertz photon into a substantial signal of Rydberg excitations. We discuss a concrete realization based on realistic atomic interaction parameters, develop a comprehensive theoretical model that incorporates the motion of trapped atoms, and study the many-body dynamics using tensor network methods.

[1] C. Nill et al., Avalanche terahertz photon detection in a Rydberg tweezer array, arXiv:2311.16365 (2023).

A 5.7 Mon 18:30 HS 1010

Ultrafast excitation of dense Rydberg gases at the threshold to ultracold plasma — •Jette Heyer[1,2], Mario Grossmann[1,2], Julian Fiedler[1,2], Markus Drescher[1,2], Klaus Sengstock[1,2], Philipp Wessels-Staarmann[1,2], and Juliette Simonet[1,2] — [1]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [2]Center for Optical Quantum Technologies, University of Hamburg, Hamburg, Germany

Ultrashort laser pulses enable the local ionization of a quantum gas on femtosecond time scales. By tuning the central wavelength of a single laser pulse of 166 fs duration across the two-photon ionization threshold of ^{87}Rb, we investigate the transition from ultracold plasma to dense Rydberg gases.

Above this threshold, strong-field ionization triggers the formation of a highly charged ultracold plasma. Below the ionization threshold, we observe the ultrafast formation of dense Rydberg gases as the Rydberg blockade is bypassed by the large bandwidth of the femtosecond pulse. Charge-imbalanced microplasma dynamics prevent Rydberg recombination close to the threshold and leads to ionization of deeply bound Rydberg states even far below the threshold.

Our experimental setup allows us to directly detect the energy distribution of ions and electrons as well as Rydberg atoms. State of the art molecular dynamics simulations give us insight into the underlying dynamics of the many-body system, which is governed by long-range Coulomb interactions.

A 5.8 Mon 18:45 HS 1010

Toward the demonstration of an avalanche THz photon detector with Rydberg atoms — •Fabio Bensch, Lea-Marina Steinert, Philip Osterholz, Shuanghong Tang, Arno Trautmann, and Christian Gross — Eberhard Karls Universität, Tübingen, Germany

Rydberg atoms confined within tweezers demonstrate unique capabilities in realizing strongly interacting and correlated many-body phenomena. The anti-blockade effect, notably, has proven to be an optimal tool for controlling non-linear avalanche Rydberg excitation in both disordered and ordered many-body systems. The integration of optical tweezers with advanced sorting algorithms enables the creation of defect-free arrays with highly precise geometry. In this context, we introduce a novel approach where the combination of defect-free arrays and avalanche facilitated excitation yields a straightforward and fuctional THz photon detector. This opens up an innovative utilization of Rydberg atoms to address the challenging issue of THz photon detection.

A 6: Atomic Systems in External Fields I

Time: Monday 17:00–19:00 Location: HS 1098

A 6.1 Mon 17:00 HS 1098

Characterization of the Field Ionization Laser Ion Source and Trap FI-LIST — •Magdalena Kaja[1], Dominik Studer[2,3], Reinhard Heinke[4], Tom Kieck[2,3], and Klaus Wendt[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [2]Jakob-Steffan-Strasse 3 — [3]Helmholtz Institute Mainz, Germany — [4]STI group, SY department, CERN, Switzerland

We present the development and initial application of the Field Ionization Laser Ion Source and Trap (FI-LIST) at the RISIKO mass separator at Mainz University. Derived from the well-established LIST and PI-LIST units previously developed at Mainz [1,2,3] and successfully implemented at CERN-ISOLDE [4,5,6], the FI-LIST is specifically tailored for field ionization of highly excited atoms within a well-controlled homogeneous electric field. To evaluate its potential for future applications in the field of rare radioactive species, e.g. actinides, we performed ionization potential (IP) measurements on ytterbium, a case where the IP is precisely known. Employing the saddle-point model, we determined the IP value with a relative precision of $3\cdot10^{-6}$, showing perfect agreement with the literature value and confirming the expectations of the device.

[1] K. Blaum, et. al., NIM B 204 (2003) 331-335
[2] K. Wendt, et. al., Nucl. Phys. A 746 (2004) 47-53,
[3] F. Schwellnus, et al., NIM B 266 (19) (2008) 4383-4386
[4]D. Fink, et. al., NIM B 344 (2015) 83-95
[5] D. A. Fink, Phys. Rev. X 5 (2015)
[6] R. Heinke, et. al., NIMB 541 (2023) 8-12

A 6.2 Mon 17:15 HS 1098

A universal method to polarize beams and samples — •Nicolas Faatz[1,2,3], Tarek El-Kordy[1,2,4], Christoph Hanhart[2,5], Chrysovalantis Kannis[6], Lukas Kunkel[1,2,3], Simon Pütz[1,2], Harsh Sharma[1,2,4], Vincent Verhoeven[1,2], Jan Wirtz[1,2,3], and Markus Büscher[6,7] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [2]Institut für Kernphysik, Forschungszentrum Jülich, Jülich, Germany — [3]III. Physikalisches Institut B, RWTH Aachen University, Aachen, Germany — [4]FH Aachen, Campus Jülich, Jülich, Germany — [5]Institute for Advanced Simulation 4, Forschungszentrum Jülich, Jülich, Germany — [6]Institut für Laser- und Plasma-Physik, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany — [7]Peter-Grünberg-Institut 6, Forschungszentrum Jülich, Jülich, Germany

In various applications a high nuclear polarisation, ideally a total alignment of all spins, is favourable, e.g. for sources and targets for fundamental research. The hereby presented method provides an inexpensive, fast, versatile and effective solution to produce highly polarised materials in reasonable amounts based on radio-wave pumping of hyperfine states and quantum interference effects. This method is theoretically understood and was experimentally proven for beams of metastable hydrogen atoms in the keV energy range. Thus, this technique opens the door for new applications as polarised tracers or even low-field MRI with even better spatial resolution in medicine or the production of polarised fuel to increase the energy output.

A 6.3 Mon 17:30 HS 1098

A new polarization method and its applications — •Chrysovalantis Kannis[1], Ralf Engels[2,3], Tarek El-Kordy[2,3,4], Nicolas Faatz[2,3,5], Christoph Hanhart[2,6], Lukas Kunkel[2,3,5], Harsh Sharma[2,3,4], Jan Wirtz[2,3,5], and Markus Büscher[1,7] — [1]Institut für Laser- und Plasma-Physik, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany — [2]Institut für Kernphysik, Forschungszentrum Jülich, Jülich, Germany — [3]GSI, Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [4]FH Aachen, Campus Jülich, Jülich, Germany — [5]III. Physikalisches Institut B, RWTH Aachen University, Aachen, Germany — [6]Institute for Advanced Simulation 4, Forschungszentrum Jülich, Jülich, Germany — [7]Peter-Grünberg-Institut 6, Forschungszentrum Jülich, Jülich, Germany

Since the discovery of nuclear spin, scientific efforts have been focused on the production of non-equilibrium spin distributions, in which one of the possible spin projections prevails. Nuclear spin-polarization is advantageous for several fields of scientific (physics, chemistry, biology) and public (medicine) interest. Recently, our group developed a new polarization method based on radio-wave pumping at small magnetic fields that can be applied to particle beams and potentially to samples. Its advantages compared to conventional methods along with its limitations will be highlighted. Some exemplary applications are polarized sources and targets for the measurement of spin-dependent observables, polarized nuclear fusion, medical imaging diagnostics, etc.. Further developments and our future plans will be discussed.

A 6.4 Mon 17:45 HS 1098

Relativistic strong-field ionization including atomic polarization and Stark-shift — •Michael Klaiber[1], John S Briggs[2], Karen Z Hatsagortsyan[1], and Christoph H Keitel[1] — [1]Max Planck Institute for Nuclear Physics — [2]Universität Freiburg

Relativistic theory of strong-field ionization applicable across the regimes of the deep-tunneling up to the over-barrier ionization (OTBI) is developed, incorporating the effects of the polarization of the atomic bound state and the Stark-shift in an ultrastrong laser field. The theory addresses the order of magnitude discrepancy of the ionization yield at OTBI regime calculated via the numerical solution of the Klein-Gordon equation [1] and the recent experimental result [2] with respect to the state-of-the-art quasiclassical theory of Perelomov-Popov-Terent'ev for strong-field ionization or the relativistic R-matrix theory [3]. While the developed theory employs a simplified Keldysh-like approach describing the ionization as a quantum jump from the bound state to the continuum at a specific transition time, the improved performance is achieved by accounting for the bound state distortion in the laser field. In the nonrelativistic limit, the theory reproduces the well-known fitting formula to numerical calculations for the ionization rate of OTBI.

[1] B. Hafizi et al., Phys. Rev. Lett. 118, 133201 (2017)
[2] A. Yandow et al., arXiv:2306.09620
[3] M. Klaiber et al., Phys. Rev. A 107, 023107 (2023)

A 6.5 Mon 18:00 HS 1098

Dual-comb spectroscopy at high magnetic fields — •Razmik Aramyan[1,2], Oleg Tretiak[1,2], Sushree S. Sahoo[1,2], Arne Wickenbrock[1,2], and Dmitry Budker[1,2,3] — [1]Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, GSI Helmholtzzentrum für Schwerionenforschung, 55128 Mainz, Germany — [3]Department of Physics, University of California, Berkeley, California 94720, USA

The invention of the frequency comb revolutionized metrology and became pivotal in various fields, including astronomy, optical communications, and more. Moreover, it found application in spectroscopy, serving as both a precise reference and the primary tool for sample interrogation. Dual-Comb Spectroscopy (DCS) further advanced this revolution, allowing rapid, high-resolution, and time-resolved analyses.

In various physics fields, atomic data play a pivotal role, especially in exploring 'new physics' beyond the standard model. They furnish essential information for understanding fundamental interactions and designing experiments to probe uncharted scientific fields. Our project aims to develop and use the DCS technique for broad-band spectroscopy of Rare-Earth Elements (REE) under a strong magnetic field (up to 100 T). The data will be used to train a neural network to predict atom-related information accurately. We will present the current state of DCS development and present initial results from our coherent data acquisition and analysis technique. Additionally, we will show the outcomes from various evaporation methods applied to REE, particularly in our first test case, samarium.

A 6.6 Mon 18:15 HS 1098

Structured-light-matter interaction in external fields — •Riaan Philipp Schmidt[1], Shreyas Ramakrishna[2], Anton Peshkov[1], Sonja Franke-Arnold[3], and Andrey Surzhykov[1] — [1]Physikalisch-Technische Bundesanstalt — [2]Helmholtz-Institut Jena — [3]School of Physics and Astronomy, University of Glasgow

During recent years, a number of studies has been performed to investigate the interaction of atomic media with structured light modes. These studies paved the way for the application of structured beams in optical traps and tweezers, classical and quantum communication, and atomic magnetometers. In particular, the latter are based on the analysis of absorption images of such beams in an atomic cloud [1]. In this contribution, we perform a theoretical study for the coupling of atoms and structured light in external fields. In the framework of the density matrix approach and the Liouville-von Neumann equation, we show that experimental observables, i.e. intensity of the transmitted light, are very sensitive to the incident radiation and the external fields. To illustrate this sensitivity we performed detailed calculations for the $5s\,^2\mathrm{S}_{1/2} - 5p\,^2\mathrm{P}_{3/2}$ transition in a rubidium atom induced by various structured light modes. Based on the results of these calculations, we find that the transmission patterns allow for the detection of the alignment of an external magnetic field and the analysis of frequency detuning of the radiation from the atomic resonance. This opens up new opportunities for structured light in atomic magnetometers and polarization spectroscopy experiments.

[1] F. Castellucci et al., Phys. Rev. Lett. 127, 233202 (2021)

A 6.7 Mon 18:30 HS 1098

Ab Initio Dynamics of Orbital Angular Momentum Transfer to Atomistic Systems — •Esra Ilke Albar[1], Franco P. Bonafé[1], Valeriia Kosheleva[1], Heiko Appel[1], and Angel Rubio[1,2,3] — [1]Max Planck Institute for the Structure and Dynamics of Matter — [2]Center for Computational Quantum Physics (CCQ), The Flatiron Institute, 162 Fifth Avenue, New York, NY, 10010, USA — [3]Nano-Bio Spectroscopy Group, Departamento de Física de Materiales, Universidad del País Vasco, 20018, San Sebastian, Spain

Optical vortices are characterized by their orbital angular momentum (OAM) content. Due to their structured wavefront they can induce transitions beyond the dipole approximation. The study of their interaction with atomic and molecular systems in real time, therefore, demand novel computational tools that consider the spatial profile of the incoming fields.

We perform numerical simulations within the time-dependent density functional theory (TDDFT) using the Octopus code, coupling the time-dependent Kohn-Sham equations with Maxwell's equations, to describe self-consistent light and matter dynamics. We account for the spatial structure of optical vortices at different coupling levels beyond dipole using the multipolar expansion as well as the full minimal coupling Hamiltonian. We use atoms as a benchmark system and analyze the validity of the selection rules for different multipolar terms, considering incoming Bessel beams of different order and handedness. We also investigate the effect of other optical vortex parameters on the interaction such as the impact parameter and the envelope function.

A 6.8 Mon 18:45 HS 1098

Semiclassical spin self-organization in non-equilibrium generalized Dicke models — •Marc Nairn[1], Simon Jäger[2], Giovanna Morigi[3], Luigi Giannelli[4], and Beatriz Olmos-Sanchez[1] — [1]Institut für Theoretische Physik, Universität Tübingen, 72076 Tübingen, Germany — [2]Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [3]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [4]Dipartimento di Fisica e Astronomia Ettore Majorana, Università di Catania, 95123 Catania, Italy

Cavity setups serve to probe all to all interactions in many-body spin systems and are intriguing platforms for quantum simulation of exotic states of matter. Motivated by recent experiments with BECs showing the self-organized phase in the non-equilibrium Dicke model, here we study a range of generalized Dicke models and establish the transition into an atomic self-organized state due to spin-motion correlations. We are able to faithfully replicate the dynamics of individual spins in a large atomic ensemble close to the semiclassical limit by taking advantage of the so called discrete Truncated Wigner Approximation (dTWA) and performing an extensive phase-space Monte Carlo sampling. We observe a transition to a spin self-ordered state when the coupling strength is increased beyond a critical value. At this point the atoms align themselves at the cavity field maxima and minima, resulting in an in-phase superradiant emission into the cavity mode. We show the system hosts a rich phase diagram, where the self-ordered state may be finely tuned by means of external lasers.

A 7: Bosonic Quantum Gases II (joint session Q/A)

Time: Monday 17:00–19:00 Location: Aula

A 7.1 Mon 17:00 Aula

Regression theorem and nonlinear response in a photon Bose-Einstein condensate — Alexander Sazhin[1], Vladimir N. Gladilin[2], Andris Erglis[3], Frank Vewinger[1], Martin Weitz[1], Michiel Wouters[2], and •Julian Schmitt[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany — [2]TQC, Universiteit Antwerpen, Universiteitsplein 1, B-2610 Antwerpen, Belgium — [3]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

The quantum regression theorem states that the correlations of a system at two different times are governed by the same equations of motion as the temporal response of the average values. Here we report experiments demonstrating that the two-time second-order correlations of a photon Bose-Einstein condensate inside a dye-filled microcavity exhibit the same eigenvalues of the dynamics as the response of the condensate to a sudden perturbation of the dye molecule bath. This confirms an unconventional form of the regression theorem for a coupled many-body quantum system, where the perturbation acts on the bath and only the condensate response is monitored. For strong perturbations, we observe nonlinear relaxation dynamics well described by microscopic theory, confirming the regression theorem for an optical quantum gas also beyond the regime of linear response.

A 7.2 Mon 17:15 Aula

Bath engineering in atomic quantum gas mixtures — •Lorenz Wanckel, Alexander Schnell, and André Eckardt — Technische Universität Berlin, Institut für Theoretische Physik, 10623 Berlin, Germany

Open quantum many-body systems interacting with their environment can reach interesting non-equilibrium steady states. We want to describe a quantum gas mixture theoretically in the framework of open systems in order to use it for dissipative quantum simulations. We consider a mixture of ultracold atoms of two different species, treating one as the system and the other as the bath, both weakly interacting via contact interaction. The specific model system describes atoms trapped in a one-dimensional optical lattice which is immersed in the cloud of bath atoms. Due to species-selective potentials it is possible that the bath atoms are uneffected by the lattice potential and freely evolve and interact with the system atoms. The bath is treated as an ideal fermionic/bosonic quantum gas. Starting from a microscopic model, we define a spectral coupling density within the Born-Markov approximation scheme and compare it with a simple ansatz describing a local ohmic bath, which is often used in this scenario.

A 7.3 Mon 17:30 Aula

A Coherence Microscope Based on the Matter-Wave Talbot Effect — •Justus Brüggenjürgen, Mathis Fischer, and Christof Weitenberg — Institute for Quantum Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Imaging is crucial for gaining insight into physical systems. In the case of ultracold atoms in optical lattices, quantum gas microscopes have revolutionized the access to quantum many-body systems by detecting and addressing single atoms on single lattice sites. The novel technique of quantum gas magnification uses matter-wave optics to magnify the density distribution before the optical imaging and therefore allows to directly image the Talbot carpet that forms when releasing the atoms from an optical lattice.

We realize this for a BEC of Lithium-7 atoms in a triangular optical lattice and map out the spatial coherence by analyzing the contrast of successive Talbot copies. The technique should also allow to reconstruct the fluctuating phase profile of individual samples imaged at a Talbot copy. This will realize a coherence microscope with spatially resolved access to phase information, which allows to study domain walls, thermally activated vortex-pairs, or to locally evaluate coherence in inhomogeneous quantum many-body systems.

A 7.4 Mon 17:45 Aula

An Optical Quantum Gas Magnifier for Lithium-7 Atoms — •Mathis Fischer, Justus Brüggenjürgen, and Christof Weitenberg — Institute for Quantum Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Ultracold gases in optical lattices are a pristine experimental platform for quantum simulation of complex many-body systems as they come with a high degree of control and a wide range of accessible observables. The advent of quantum gas microscopes has revolutionized the access to quantum many-body systems by detecting and addressing single particles on single lattice sites. The novel complementary approach of quantum gas magnification expands this toolbox to 3D systems and large occupation numbers. Here the atomic density distribution is magnified via matter-wave optics before taking absorption images with effective sub-lattice site resolution.

We report on the realization of an all-optical quantum gas magnifier for ultracold Lithium-7 atoms in triangular optical lattices i.e. using an optical dipole trap as matter-wave lens. The all-optical approach allows us to exploit the broad Feshbach resonance of Lithium to control the interaction strength. With this technique, we can access the coherence properties of the system. In the future, the optical matter-wave lens will also allow to image spin mixtures. Furthermore, the addition of high numerical aperture optics will allow for single-atom sensitivity via free-space fluorescence imaging.

A 7.5 Mon 18:00 Aula

Site-resolved current and kinetic energy measurements using optical superlattices — •Alexander Impertro[1,2,3], Simon Karch[1,2,3], Julian Wienand[1,2,3], SeungJung Huh[1,2,3], Christian Schweizer[1,2,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2,3] — [1]Department of Physics, Ludwig-Maximilians-Universität München, Schellingstr. 4, D-80799 Munich, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80333 Munich — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching, Germany

Quantum gas microscopes naturally realize a measurement of the particle number density in an optical lattice. Further information about the underlying quantum state can only be obtained by measuring additional, complementary observables. Here, we demonstrate how optical superlattice potentials can be used to measure the expectation values of the current and the kinetic energy operator. Our scheme is based on driving programmable rotations in isolated double wells to rotate the measurement basis in an arbitrary direction. Furthermore, we show that a local control enables to perform spatially varying rotations, which can be used both to read out complex correlators as well as to engineer interesting quantum states. The presented scheme will pave the way for a more flexible state tomography and state engineering in optical lattices, and in particular to detect exotic quantum many-body phases that have no signatures in the density.

A 7.6 Mon 18:15 Aula

Interplay of topology and disorder in driven honeycomb lattices — •Johannes Arceri[1,2,3], Alexander Hesse[1,2,3], Christoph Braun[1,2,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2,3] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, München — [2]Munich Center for Quantum Science and Technology (MCQST), München — [3]Max-Planck-Institut für Quantenoptik, Garching

Floquet engineering, i.e., periodic modulation of a system's parameters, has proven as a powerful tool for the realization of quantum systems with exotic properties that have no static analog. In particular, the so-called anomalous Floquet phase displays topological properties even if the Chern number of bulk bands vanishes.

Our experimental platform involves bosonic atoms in a periodically-driven honeycomb lattice. Depending on the driving parameters, several out-of-equilibrium topological phases can be realized, among which an anomalous phase.

Chiral edge modes can be probed by releasing an atomic wavepacket from a tightly focused optical tweezer in proximity of the potential step projected by a digital micromirror device. The additional projection of an optical speckle potential on the honeycomb lattice allows for the realization of disordered systems. We benchmark the robustness of edge modes to disorder across different topological regimes and observe a disorder-driven transition from the Haldane regime to the anomalous regime. Furthermore, we compare edge state dynamics to the expansion of bulk states for increasing disorder strength.

A 7.7 Mon 18:30 Aula

Quantum geometry of bosonic Bogoliubov quasiparticles — •Isaac Tesfaye and André Eckardt — Institut für Theoretische Physik, Technische Universität Berlin Hardenbergstraße 36, 10623 Berlin, Germany

Topological and geometrical features arising bosonic Bogoliubov-de Gennes (BdG) systems have mainly been studied by utilizing a symplectic (generalized) version of the Berry curvature and Chern number. These bosonic topological features may even solely arise due to the non-particle number conserving terms in the corresponding BdG Hamiltonian, making these systems inherently distinct from their non-interacting (fermionic) counterparts. Here, we propose the notion of the symplectic quantum geometric tensor (SQGT) whose imaginary part leads to the previously studied symplectic Berry curvature, while the real part gives rise to a symplectic quantum metric, providing a natural distance measure in the space of bosonic Bogoliubov modes. Moreover, previous proposals to verify the topology of bosonic BdG systems have relied solely on probing topologically protected chiral edge modes. Here, we propose how to measure all components of the SQGT by the use of periodic modulation of the systems' parameters in a linear response regime and connect the symplectic Berry curvature to a generalized anomalous velocity term for Bogoliubov Bloch wave packets.

[1] R. Shindou et al., Phys. Rev. B 87, 174427 (2013).
[2] S. Furukawa and M. Ueda, New J. Phys. 17, 115014 (2015).
[3] T. Ozawa and N. Goldman, Phys. Rev. B 97, 201117 (2018).

A 7.8 Mon 18:45 Aula

Dressed 171Yb+ Hyperfine Qubits in a Multi-layer Planar Ion Trap — •Elham Esteki[1], Bogdan Okhrimenko[1], Amado Bautista Salvador[2,3,4], Christian Ospelkaus[2,3,4], Ivan Boldin[1], and Christof Wunderlich[1] — [1]Dept. Physik, Nat.-Techn. Fak., Universität Siegen, 57068 Siegen (Germany) — [2]Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover (Germany) — [3]Laboratory for Nano - and Quantum Engineering, Schneiderberg 39, 30167 Hannover (Germany) — [4]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig (Germany)

Dressed atomic states - the eigenstates of the Hamiltonian of an atom subject to a near-resonant driving field - protect atomic states against decoherence due to common noise sources. We present a microfabricated ion-trap-chip, designed for quantum information processing based on radiofrequency-dressed qubits using hyperfine states of 171Yb+ ions [1]. The trap-chip consists of multiple layers [2], one of which includes an integrated RF resonator near 12.6 GHz. It creates an axial gradient of the microwave magnetic field amplitude which serves for individual qubit addressing, as well as for qubit-qubit coupling. We experimentally characterize this novel ion-trap-chip and demonstrate preparation, manipulation and detection of RF-dressed single-and two-qubit gates.

References
1. S. Wölk et al., New J. Phys. 19, 083021 (2017)
2. A. Bautista-Salvador et al., New J. Phys. 21, 043011 (2019)

A 8: Precision Measurements I (joint session Q/A)

Time: Monday 17:00–19:00 Location: HS 1221

A 8.1 Mon 17:00 HS 1221

Search for variations of fundamental constants with highly charged ion clocks — •Luis Hellmich[1,2], Ullrich Schwanke[1,2], Steven Worm[1,2], and Lakshmi Kozhiparambil Sajith[2,3] — [1]Humboldt-Universität Berlin — [2]DESY Zeuthen — [3]MPIK Heidelberg

The measurement of the variation of fundamental constants would be strong evidence for new physics. In particular, many different theories predict the variation the fine-structure constant α. Atomic clocks are a highly precise tool of measuring variations of α, as the clock transitions may change with α.

We are aiming to compare a Sr-lattice clock as a reference to a highly charged ion (HCI) clock. HCI clocks are expected to have extremely high sensitivities to α-variations. We show how such a setup could set new limits on variations of fundamental constants. Furthermore, we estimate with Monte-Carlo simulations and real data how those limits translate to constraints on scalar dark matter models and models with Lorentz-invariance violation.

A 8.2 Mon 17:15 HS 1221

A strontium optical clock based on Ramsey-Bordé spectroscopy — •Amir Mahdian[1], Oliver Fartmann[1], Ingmari C Tietje[1], Martin Jutisz[1], Conrad L Zimmermann[2], Vladimir Schkolnik[1,2], Marc Christ[2], and Markus Krutzik[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin

We are developing a Ramsey-Bordé based optical atomic clock where the long-term stability relies on interrogating a stream of strontium atoms. Our choice of the clock transition is the $5s^2\ ^1S_0 \rightarrow 5s5p\ ^3P_1$ intercombination line of Sr at 689 nm, targeting an Allan deviation as low as 2×10^{-15} between 100 s and 1000 s, and 10^{-15} for longer interogation times.

Following an overview of our atom interferometer's current status, the latest developments in the power and frequency stability of the relevant lasers and a different readout mechanism will be presented. Additionally, I showcase the observation of Ramsey-Bordé fringes, accompanied by numerical simulations to aid in interpreting the signal. Moreover, I discuss the stability comparison of our atomic beam clock vs a Rb two-photon frequency reference.

This work is supported by the German Space Agency (DLR), with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) under grant number DLR50WM1852, and by the German Federal Ministry of Education and Research (BMBF) within the program quantum technologies - from basic research to market under grant number 13N15725.

A 8.3 Mon 17:30 HS 1221

Electronic Bridge schemes in ^{229}Th doped LiCAF — •Tobias Kirschbaum[1], Martin Pimon[2], and Adriana Pálffy[1] — [1]Julius-Maximilians-Universität Würzburg, Germany — [2]Technische Universität Wien, Austria

Large band gap crystals such as CaF_2 or $LiCaAlF_6$ (LiCAF) are an ideal inert host for the nuclear clock candidate ^{229}Th. Among others, these crystals are transparent with respect to the clock transition at ≈ 8 eV and a large number of nuclei can be interrogated at the same time [1]. However, DFT calculations indicate that doping of ^{229}Th in these crystals leads to the formation of localized electronic states in the band gap, so-called defect states [2]. Due to their vicinity to the nuclear transition energy, these can be used for effective nuclear excitation via the Electronic Bridge mechanism, as we could show for the case of Th-doped CaF_2 crystals [2,3].

Here, we investigate theoretically different driven Electronic Bridge schemes for ^{229}Th doped LiCAF crystals and present the corresponding excitation rates. These schemes enable a more efficient nuclear excitation/deexcitation compared to direct photoexcitation. The results are discussed in conjuncture with the design of a solid-state nuclear clock.

[1] G. A. Kazakov *et al.*, New J. Phys. **14**, 083019 (2012).
[2] B. S. Nickerson *et al.*, Phys. Rev. Lett **125**, 032501 (2020).
[3] B. S. Nickerson *et al.*, Phys. Rev. A **103**, 053120 (2021).

A 8.4 Mon 17:45 HS 1221

Large ring lasers in geodesy and seismology — •Simon Stellmer[1], Jannik Zenner[1], Andreas Brotzer[2], Jan Kodet[3], Heiner Igel[2], and Karl Ulrich Schreiber[3] — [1]Universität Bonn — [2]LMU München — [3]Geodätisches Observatorium Wettzell und TU München

The rotation of Earth is not as constant as it may seem. On the contrary, it is modulated through various processes at a large range of frequencies. Traditionally, these variations are measured by astronomical techniques such as VLBI, but there is a new kid on the block: large ring lasers have matured to a level that allows for continuous monitoring of variations in the Earth rotation rate at the level of 10^{-8} and below. We will give an overview on the three large ring lasers currently operated in Germany, latest advances and technology development, as well as applications and future perspectives.

A 8.5 Mon 18:00 HS 1221

Quantum Memory Enhanced Velocimetry — •Yagiz Murat[1], Arash Ahmadi[1], Mustafa Gündoğan[1], and Markus Krtutzik[1,2] — [1]Humboldt Universität zu Berlin, Institut für Physik — [2]The Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik

Optical interferometry is crucial in motion sensing. Recent progress has utilized electromagnetically induced transparency (EIT) to measure the velocity of a moving medium, leveraging Fizeau's light-dragging effect. This novel approach opens new possibilities for quantum optical methods in velocimetry, Our work is centered around EIT-based quantum memories. Light storage is realized by tuning a probe and a control field to the Zeeman-split levels of the D1 transition line of cesium atoms ($F = 4 \rightarrow F' = 3$). By monitoring the phase difference of the beating signal of the probe field with a reference field, before and after storage of the probe field, displacement of the cesium vapor cell can be measured down to the nanometer scale. This work contributes to the frontiers of quantum optics and motion sensing, promising advancements in precision measurements. This work has been funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under grant number 448245255.

A 8.6 Mon 18:15 HS 1221

Suppression of scattered light through tunable coherence in Sagnac-Speed-Meters — •Leonie Eggers, Daniel Voigt, and Oliver Gerberding — Universität Hamburg, Institut für Experimentalphysik, Germany

As scattered light noise is a dominating limitation for the sensitivity of gravitational wave detectors, we investigate the use of tunable coherence as a new concept to suppress scattered light.

Tunable coherence is realised by phase modulation following a pseudo-random sequence, which artificially shortens the coherence length of stable continuous wave lasers to the centimeter scale. While Sagnac-Speed-Meter topologies provide a potential alternative for the currently used Michelson-interferometers for future gravitational wave detectors, they suffer from the same limitations through scattered light, as well as the effect of light backscattering from the mirrors and coupling into the counter-propagating beam. We are investigating the use of tunable coherence in Sagnac-Speed-Meters to suppress scattered light through simulations and a tabletop experiment. We are presenting our recent findings on using tunable coherence in Sagnac-Speed-Meters.

A 8.7 Mon 18:30 HS 1221

Investigating a Tensegrity structure as a possible multi DoF inertial sensor — •Ben Becker, Oliver Gerberding, and Artem Basalaev — IExP, Hamburg, Germany

One of the continued challenges for gravitational wave detectors is the advancement of inertial sensors to improve the active isolation of the mirrors. Towards that end we are investigating tensegrity structures as a possible multi degree of freedom inertial sensor. Tensegrity structures are disconnected multi body structures held together by tensioned wires. They offer the option of tuning their mechanical properties by changing the moment of inertial as well as the wire tension. We've simulated a model tensegrity using Ansys multibody dynamics and analyzed its mechanical response to excitation. We compare the direct simulation result with the results of a simulated readout scheme. This readout scheme will be realized on a real tensegrity model for further comparison. We've observed and fitted the transfer functions of the system to get a more thorough understanding with regards to its invertibility and thermal noise. The tensegrity shows distinct transfer function with regimes of linear response for most relevant degrees of freedom. Therefore it should indeed be viable as an inertial sensor.

A 8.8 Mon 18:45 HS 1221

Full spatio-temporal description of Non-linear interference based on cascaded Spontaneous Parametric Down-Conversion. — •Carlos Sevilla[1,2], Purujit Chauhan[1,2], and Fabian Steinlechner[1,2] — [1]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Albert-Einstein-Str. 7, 07745 Jena, Germany — [2]Abbe Center of Photonics, Friedrich-Schiller-University Jena, Albert-Einstein-Str. 6, 07745 Jena, Germany

Non-linear interferometers are a powerful tool for quantum state engineering and applications in quantum sensing with enhanced phase sensitivity [1]. The typical configuration uses a cascade of non-linear processes such as spontaneous parametric down-conversion (SPDC) combined with spatial or spectral dispersion. This architecture has been widely used, but only few studies have addressed the complete spatiotemporal correlations of the output state of a nonlinear interferometer. Here we extend our results on the spatiotemporal description of SPDC based on the spectral dependence of Laguerre-Gauss modes [2] to the output spatio-temporal state of nonlinear interferometers. For this, we take into consideration realistic parameters such as phase difference between the three fields, the optical system which might induce spatial transformation, and polarization rotations inside then nonlinear interferometer. Furthermore, we show experimental results validating our predictions. References:[1] Bernard Yurke et al. Phys. Rev. A 33, 4033 (1986). [2] A. Ferreri et al. Quantum 5,461 (2021). [3] C. Sevilla-Gutiérrez, et.al. Spectral Properties of Transverse Laguerre-Gauss Modes in Parametric Down-Conversion. arXiv:2209.01913

A 9: Strong-field Ionization and Imaging (joint session MO/A)

Time: Monday 17:00–18:30 Location: HS 3044

A 9.1 Mon 17:00 HS 3044

Strong-Field Ionization of Nitrous Oxide Molecule by Short Femtosecond Laser Pulses — •Feras Afaneh — Physics Department, The Hashemite University, P.O. Box 150459, Zarqa 13115, Jordan.

The dissociative photoionization of nitrous oxide molecules, an important atmospheric trace gas, induced by circularly and elliptically polarized laser pulses has been studied by photoelectron photoion coincidence (PEPICO) spectroscopy. PEPICO spectra were used to identify different dissociative photoionization channels. It is observed that the ionized N_2O and its fragments have different correlation trends at different polarization schemes. The relative contributions of different double and triple dissociative ionization channels to the total fragment ion yield are also deduced from the coincident spectra of these channels. The results show that the double dissociative photoionization channels: the denitrogenation (N_2O^{2+} –> N^+ + NO^+) and the deoxygenation (N_2O^{2+} –> O^+ + N_2^+). Furthermore, a considerable contribution of the triple dissociative ionization channels to the total fragment ion yield is also observed. The channels "N^+ + NO^+" and "O^+ + N_2^+" can be explained by dissociation via the $X^3\Sigma^-$ and $1^3\Pi$ states of N_2O^{2+} as the major peaks in the measured kinetic energy release spectra suggested.

A 9.2 Mon 17:15 HS 3044

Theoretical semiclassical modelling of Laser Induced Electron Diffraction (LIED) — •Álvaro Fernández[1,2], Armin Iske[3], Andrey Yachmenev[1,4], and Jochen Küpper[1,2,4] — [1]Deutsches Elektronen-Synchrotron DESY — [2]Department of Physics, Universität Hamburg — [3]Department of Mathematics, Universität Hamburg — [4]Center for Ultrafast Imaging, Universität Hamburg

Experimental techniques for molecular imaging underwent a very fast development in the past decades. From a broad range of novel techniques, laser induced electron diffraction (LIED) [1] stands out because of its high spatiotemporal resolution, high cross section, and lack of structural damage compared to other modern techniques. However, the complexity of this technique causes the necessity of its own theory to understand the results. A general and accurate quantum simulation of the experiment is, to this date, unfeasible and, for this reason, semiclassical models [2] have arised as useful predicting algorithms.

In this talk, a comprehensive analysis of the LIED experiment using a semiclassical model will be given. With this model, we can obtain efficient simulations of the outcome for flexible configurations of molecular geometries. The quality of the results will depend on several factors such as the choice of ionisation theory or electrostatic potential model. An study of the relevance of these factors in the computation of effective cross section for high energy electrons will be presented during the talk.

[1] Karamatskos, E. T, *et al.*, *J. Chem. Phys.*, **150**, 24 (2019)
[2] Wiese, J., *et al.*, *Phys. Rev. Research*, **3**, 013089, (2021)

A 9.3 Mon 17:30 HS 3044

Wavefunction Reconstruction of Excitonic Edge States using Machine Learning — •Aritra Mishra and Alexander Eisfeld — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

A typical problem in quantum mechanics is to reconstruct the eigenstate wave functions from measured data. In the case of molecular aggregates, the information about the excitonic eigenstates is important to understand the optical and transport properties [1]. It has been shown for a linear and a 2D arrangement of the aggregate molecules that such a reconstruction is possible from the spatially resolved near field absorption spectra [2].

Here, we consider the aggregates arranged in two sublattices in a 2D arrangement, each sub lattice having a particular orientation of the molecules as described in [3]. Interestingly, such an arrangement can lead to the formation of topological excitonic edge states. We study the reconstruction of the excitonic wave function of such a system from the near field absorption spectra. The reconstruction is further investigated in the presence of disorder in the Hamiltonian and noise added to the spectra.

[1] X. Gao and A. Eisfeld, J. Phys. Chem. Lett. 9, 6003 (2018)
[2] F. Zheng, X. Gao and A. Eisfeld, Phys. Rev. Lett. 123, 163202 (2019)
[3] J. Yuen-Zhou, S. K. Saikin, N. Y. Yao and A. Aspuru-Guzik, Nature Materials 13, 1026 (2014)

A 9.4 Mon 17:45 HS 3044

Molecular self-probing for the visualisation of vibrational wave-packet dynamics and its laser-induced modification — •Gergana D. Borisova[1], Paula Barber Belda[1], Shuyuan Hu[1], Paul Birk[1], Veit Stooss[1], Maximilian Hartmann[1], Robert Moshammer[1], Alejandro Saenz[2], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Institut für Physik, Humboldt-Universität zu Berlin, 12489 Berlin

We present an all-optical pump-control scheme for molecular wave-packet (WP) visualisation and control, where the molecular ground state acts as an intrinsic self-probe of the system, imprinting the evolution of an excited wave packet onto the coherent dipole emission [1]. In a proof-of-principle experiment, coherent extreme ultraviolet (XUV) light creates a vibrational wave packet in the electronically excited $D\,^1\Pi_u 3p\pi$ state of neutral H_2. Measured XUV absorption spectra of the D-state vibronic resonances provide access to the WP dynamics after reconstruction of the time-dependent dipole response [2], which probes the vibrating wave packet through the molecular ground state. An intense near-infrared (NIR) pulse, applied shortly after the WP excitation, is used to control the wave-packet evolution and through this its revival. With increasing NIR intensity the WP revival shifts to earlier times. We identify state-specific NIR-induced phase shifts as the origin of the observed time shifts, which can be applied even to complex molecular systems to coherently steer the recovery of vibrational wave packets on electronically excited potential-energy curves at a desired time. [1] arXiv:2301.03908 [2] PRL 121 (2018) 173005

A 9.5 Mon 18:00 HS 3044

Ultrafast imaging of rare-gas clusters from their formation to their ionization dynamics — •Alessandro Colombo for the RareGas Clusters at SwissFEL-Collaboration — ETH Zurich, 8049 Zürich, Switzerland

Coherent Diffraction Imaging (CDI) experiments performed at Free-Electron Lasers (FELs) allow to capture femtosecond snapshots of isolated nanosamples, and are a unique tool for spatially and temporally resolve ultrafast electron dynamics at the nanoscale. Isolated atomic clusters represent the perfect prototypical system for such investigations, thanks to their simple electronic structure and their highly tunable size and shape [1]. We present imaging studies performed at SwissFEL on mixed Ar/Xe nanoclusters produced by supersonic expansion into vacuum. Imaging results at 1 keV photon energy reveal fascinating and unexpected shapes at a spatial resolution of few nanometers, which stimulate further research about the thermodynamics and kinematics of these systems. Additionally, the FEL was tuned to photon energies around 0.67 keV, corresponding to the xenon 3d electronic resonance. Fluctuations of the scattering cross-section of Xe can be identified in the CDI reconstructions even several tens of eV away from the 3d edge. The observed behavior can be interpreted as the footprint of ultrafast ionization dynamics happening within the FEL pulse duration, giving insights into the evolution of high charge states, their optical properties and the contribution of transient electronic resonances.

[1] A. Colombo and D. Rupp. (2023) in *Structural Dynamics with X-ray and Electron Scattering*, Royal Society of Chemistry, *in press*

A 9.6 Mon 18:15 HS 3044

High repetition rate ultrafast electron diffraction with direct electron detection — Fernando Rodriguez Diaz, Mark Merö, and •Kasra Amini — Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany

Ultrafast electron diffraction (UED) is a power tool that can monitor the nuclear dynamics of photo-induced gas-phase reactions in real-time with picometre and <250-fs spatiotemporal resolution. However, the temporal resolution of state-of-the-art gas-phase UED setups, often operating at <1-kHz, is insufficient to time-resolve rapidly evolving photo-induced processes (e.g., <350-fs predicted timescale of photoisomerization which plays a crucial role in vision). The limited temporal resolution is due to the severe space-charge dispersion experienced in electron pulses containing 10^4 to 10^5 electrons.

Here, we present a new 30-kHz 100-keV UED setup employing direct electron detection that will be capable of performing time-resolved measurements of photochemical reactions in gas-phase molecules with <100-fs temporal resolution, going beyond the current state-of-the-art in keV and MeV gas-phase UED. This is made possible by operating below the severe space-charge dispersion regime using electron pulses containing very few electrons ($<10^2$) but with sufficient electron flux ($>10^6$ electrons/s) thanks to the high repetition rate of our system. Latest results from the commissioning of our pump-probe UED instrument is presented with details of the current implementation of radiofrequency-compressed electron pulses and the correction of time-of-arrival jitter issues.

A 10: Interaction with Strong or Short Laser Pulses I (joint session A/MO)

Time: Tuesday 11:00–13:00 Location: HS 1010

Invited Talk A 10.1 Tue 11:00 HS 1010

Strong-field coherent control in the extreme ultraviolet domain — •F. Richter[1], U. Saalmann[2], M. Wollenhaupt[3], E. Allaria[4], C. Callegari[4], M. Danailov[4], L. Gianessi[4], M. Zangrando[4], and L. Bruder[1] — [1]Institute of Physics, University of Freiburg — [2]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [3]Institute of Physics, University of Oldenburg — [4]Elettra - Sincrotrone Trieste S.C.p.A., Trieste, Italy

Coherent control drew a lot of interest in recent years spanning over various fields of research regarding the promising abilities for quantum computing and precision measurements. Coherent control extended to the strong-field regime is particularly promising for the manipulation of matter and the control of photochemical reactions. In this work, we develop a scheme to extend strong-field coherent control to the XUV domain. With intense XUV pulses, we induce Rabi oscillations in atoms, leading to Autler-Townes level splittings in the photoelectron spectra [1]. In the near infrared domain, the feasibility to coherently control the population of the Autler-Townes doublet has been shown, based on chirp manipulation of the laser pulses [2,3]. To establish comparable schemes in the XUV domain, we implement chirp control of the XUV pulses from the free electron laser FERMI. By manipulating the chirp of the XUV pulses in a controlled way, we demonstrate strong-field coherent control of Autler-Townes states in the XUV domain.

[1] S. Nandi et al. Nature 608, 488*493 (2022). [2] M. Wollenhaupt et al., Appl. Phys. B 82, 183*188 (2006). [3] U. Saalmann et al., Phys. Rev. Lett. 121, 153203 (2018).

A 10.2 Tue 11:30 HS 1010

Intra-cavity photoelectron tomography and pulsed standing waves at 100 MHz repetition rate — •Jan-Hendrik Oelmann, Tobias Heldt, Lennart Guth, Nick Lackmann, Lukas Matt, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

To get access to multiphoton ionization studies at high laser intensities ($\sim 10^{13}$ W/cm^2) while maintaining the high 100 MHz repetition rate of the driving frequency comb, we have recently developed a novel polarization-insensitive enhancement cavity with an integrated velocity-map imaging (VMI) spectrometer [1, 2]. Polarization-controlled pulse pairs with a variable time delay allow pump-probe experiments. With this polarization control but in single-pulse operation, we were able to tomographically reconstruct 3D photoelectron angular distributions [3] from xenon MPI at 100 MHz repetition rate, revealing resonant Rydberg states during ionization.

Now, we use counter-propagating pulses colliding at the focus to generate intense femtosecond standing waves in the cavity. We probe the phase of these at the nanometer scale using photoemission from a tungsten nanotip. Colliding pulses offer the dual advantage of enabling Doppler-free excitation schemes and of reducing the interaction volume at the focus.
[1] J.-H. Oelmann *et al.*, Rev. Sci. Instrum., 93(12), 123303 (2022). [2] J. Nauta *et al.*, Opt. Lett. 45(8), 2156 (2020). [3] M. Wollenhaupt *et al.*, Appl. Phys. B 95(4), 647-651 (2009).

A 10.3 Tue 11:45 HS 1010

Reconstruction of Three Dimensional Molecular Density from XFEL Scattering Images using Machine Learning — •Siddhartha Poddar, Ulf Saalmann, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems

As the three-dimensional electron density profile recovery technique for a single macro-molecule from a large dataset of coherent diffraction images generated using an X-ray free-electron laser, I have applied an unsupervised machine learning algorithm namely Generative Adversarial Network (GAN). It learns to mimic the high-dimensional distribution of given images by generating its own 'fake' distribution of images with the help of a deep convolutional neural network called the discriminator which distinguishes samples drawn from the original and fake distributions. To generate samples for this fake distribution of images, GAN creates and constantly modifies a three-dimensional structure. This structure is claimed to be unique and an equivalent version of the target electronic density profile of the molecule.

A 10.4 Tue 12:00 HS 1010

Retrieval of the time-dependent bond length in a molecule from photoelectron momentum distributions using deep learning — •Nikolay Shvetsov-Shilovskiy and Manfred Lein — Leibniz Universität Hannover

We apply a convolutional neural network (CNN) to photoelectron momentum distributions produced by strong-field ionization in order to retrieve the time-varying bond length in the dissociating two-dimensional H_2^+ molecule. We consider the pump-probe scheme and treat the motion of the atomic nuclei either classically, semiclassically, or quantum mechanically. In all these cases, the CNN trained on momentum distributions with fixed internuclear distances [1] predicts the time-dependent bond length with a good accuracy. We investigate whether the neural network can also simultaneously retrieve both the internuclear distance and the velocity with which it increases. Therefore, our results show that deep learning can be used not only for static, but also for dynamic molecular imaging.

[1] N. I. Shvetsov-Shilovski and M. Lein, Phys. Rev. A 105 L021102 (2022).

A 10.5 Tue 12:15 HS 1010

Shaped free electron vortices — •Darius Köhnke, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky university Oldenburg, Institute of Physics, Germany

Since their first theoretical proposal [1] and their experimental demonstration [2], free electron vortices have attracted significant attention. Very recently, a novel category of electron spirals, termed ”reversible electron spirals” [3], was introduced. Departing from the conventional approach of employing a constant delay between two subpulses, two chirped subpulses were used. Building on this concept, we introduce tailored free electron vortices in multiphoton ionization (MPI) using two subpulses with circular polarization of opposite handedness, modulated by non-trivial spectral phase functions. Through the utilization of different MPI pathways, the quantum system multiplexes the fields of the subpulses, generating multiple complex spectral phases. These spectral phases are encoded in continuum states characterized by different magnetic quantum numbers. The interference of these continuum states gives rise to multiple interferograms of different symmetry that are multiplexed into a single 3D photoelectron momentum distribution. To demultiplex these interferograms and extract the encoded spectral phases, we perform photoelectron tomography and employ Fourier analysis on the measured wave packet. This approach enables the retrieval of spectral information, both from the input laser fields and signatures of the ionization process, embedded within the interferograms. [1] Phys. Rev. Lett. 115, 113004 (2015), [2] Phys. Rev. Lett. 118, 053003 (2017), [3] Phys. Rev. A 106, 043110 (2022)

A 10.6 Tue 12:30 HS 1010

Coherent control of 6Li multiphoton ionization by a bichromatic laser field — •Silva Mezinska[1], Klaus Bartschat[2], Thomas Pfeifer[1], and Alexander Dorn[1] — [1]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [2]Drake University, Des Moines, Iowa, USA

This work presents a coherent 6Li multiphoton ionization control by a bichromatic laser field at 780/390 nm. In particular, we demonstrate a control of the left-right asymmetry of the photoelectron angular distributions with respect to the plane orthogonal to the laser polarization direction with a subwavelength accuracy. In addition, we also consider a delay scan between the two harmonics extending between the second-harmonic pulse advancing the fundamental pulse and vice versa. Here, we study the delay-dependent features of the photoelectron spectra when the two harmonics are temporally overlapping and non-overlapping. All the experimental results are compared with calculations based on the solution of the time-dependent Schrödinger equation in the single-active electron approximation.

A 10.7 Tue 12:45 HS 1010

Nonspreading relativistic electron wavepacket in a strong laser field — •Andre G. Campos, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics

A solution of the Dirac equation in a strong laser field presenting a nonspreading wave packet in the rest frame of the electron is derived. It consists of a generalization of the self-accelerating free electron wave packet [Kaminer et al. Nature Phys. 11, 261 (2015)] to the case with the background of a strong laser field. Built upon the notion of nonspreading for an extended relativistic wavepacket, the concept of Born rigidity for accelerated motion in relativity is the key ingredient of the solution. At its core, the solution comes from the connection between the self-accelerated free electron wave packet and the eigenstate of a Dirac electron in a constant and homogeneous gravitational field via the equivalence principle. The solution is an essential step towards the realization of the laser-driven relativistic collider [Meuren et al. PRL 114, 143201 (2015)], where the large spreading of a common Gaussian wave packet during the excursion in a strong laser field strongly limits the expectable yields.

A 11: Precision Spectroscopy of Atoms and Ions I (joint session A/Q)

Time: Tuesday 11:00–13:00 Location: HS 1098

A 11.1 Tue 11:00 HS 1098

Implementing a Josephson Voltage Standard on a Penning Trap for the Nuclear Magnetic Moment Measurements of ^{2}D, ^{3}He and ^{7}Li — •Annabelle Kaiser[1], Stefan Dickopf[1], Marius Müller[1], Ralf Behr[2], Ute Beutel[1], Ankush Kaushik[1], Luis Palafox[2], Stefan Ulmer[3,4], Andreas Mooser[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Physikalisch Technische Bundesanstalt, Braunschweig, Germany — [3]RIKEN, Wako, Japan — [4]HHU Düsseldorf, Germany

Penning traps are versatile tools for high-precision measurements of e.g. the hyperfine structure from which atomic masses, binding energies and electron as well as nuclear magnetic moments can be extracted.

For the latter, a spin-flip needs to be resolved with a change in signal that is barely detectable before the background noise, using methods described in [1]. This requires an ultra-stable trapping environment and extremely cold ion temperatures. A new technique will be presented, which reduces the noise originating from the voltage sources generating the electrostatic trapping potential: By implementing a tunable 10 V Josephson voltage standard, the stability of the ion's axial frequency was measured to be twice as stable (10 ppb over 8 minutes, at 800 kHz absolute frequency) as with the typical low-noise voltage sources UM1-14. An environment this stable enables the direct high-precision measurements of the nuclear magnetic moment of ^{2}D, ^{3}He and ^{7}Li. First results of the frequency stability improvement will be presented, along with the status of the project.

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

A 11.2 Tue 11:15 HS 1098

Measurement of the bound-electron *g*-factor in ^{4}He$^+$ for the determination of the electron mass — •Marius Müller[1], Stefan Dickopf[1], Annabelle Kaiser[1], Ute Beutel[1], Ankush Kaushik[1], Stefan Ulmer[2,3], Andreas Mooser[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]RIKEN, Wako, Japan — [3]Heinrich-Heine-Universität, Düsseldorf, Deutschland

The determination of fundamental constants is of great importance for many fields of science and technology. One of these fundamental constants is the atomic mass of the electron, which was previously determined to a fractional uncertainty of 30 ppt by a collaborative effort of high-precision Penning-trap *g*-factor measurements of hydrogen-like carbon-12 and state-of-the-art bound-state QED calculations [1]. Recent measurements of the helium-4 mass at LIONTRAP with a relative precision of 12 ppt [2] allow for an independent cross-check of the electron mass in a different ionic system and further enable an improvement in precision by a factor of 2.5.

At our experimental Penning-trap setup at the MPIK in Heidelberg [3], we are currently conducting high-precision bound-electron *g*-factor measurements of ^{4}He$^+$ in order to improve the precision of the atomic mass of the electron. The current status and first experimental results of the helium-4 measurement campaign will be presented.

[1] S. Sturm *et al.*, Nature 506, 467 (2014)
[2] S. Sasidharan *et al.*, Phys. Rev. Lett. 131, 093201 (2023)
[3] A. Schneider *et al.*, Nature 606, 878 (2022)

A 11.3 Tue 11:30 HS 1098

Precision ground-state hyperfine and Zeeman spectroscopy on ^{9}Be ions — •Stefan Dickopf[1], Bastian Sikora[1], Annabelle Kaiser[1], Marius Müller[1], Stefan Ulmer[2], Vladimir Yerokhin[1], Zoltan Harman[1], Christoph Keitel[1], Andreas Mooser[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Institut für Experimentalphysik, Heinrich-Heine-Universität, Düsseldorf, Germany

Measurements of the Zeeman splitting in systems with nuclear magnetic moments can be used to infer the shielded nuclear and the bound electron *g*-factors, as well as the zero-field hyperfine splitting [1]. We measured the Zeeman splitting of ^{9}Be^{3+} and compare it to measurements on ^{9}Be^{1+} [2] to test the theory of the diamagnetic shielding factor [3] on the parts per billion level. Additionally, we compare our measured zero-field splitting with the value obtained in ^{9}Be^{1+} via the so-called hyperfine specific difference to cancel theoretically intractable nuclear structure contributions. Recent progress and the latest results will be presented.

[1] A. Schneider et al, Nature 606, 878-883 (2022)
[2] D. J. Wineland, J. J. Bollinger, and Wayne M. Itano, Phys. Rev. Lett. 50, 628-631 (1983)
[3] K. Pachucki and M. Puchalski, Optics Communication 283, 641-643 (2010)

A 11.4 Tue 11:45 HS 1098

Isotope shift spectroscopy in ultracold atomic mercury — •Thorsten Groh, Sascha Heider, and Simon Stellmer — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

Low energy beyond standard model theories predict a new boson, that would act as a new force carrier coupling neutrons and leptons via a Yukawa like interaction [Delaunay, PRD 96, 093001; Berengut, PRL 120, 091801]. Precision spectroscopy of atomic isotope shifts could resolve this coupling as an energy shift of electronic levels. New physics signatures would emerge as nonlinearities in King plots of scaled isotope shifts on different electronic transitions.

We cool mercury in a magneto-optical trap. Our results on high resolution deep UV laser spectroscopy show strong deviations from linearity. Our multidimensional King plot analysis indicates that these are dominated by standard model contributions, quadratic field shifts and nuclear deformations. With recent improvements on the machine and spectroscopy results on additional lines we investigate the nonlinearity origins further.

A 11.5 Tue 12:00 HS 1098

Spectroscopy of calcium on an atomic vapor — •Lukas Möller, David Röser, Frederik Wenger, Andreas Reuss, Anica Hamer, and Simon Stellmer — Physikalisches Institut, Universität Bonn

Calcium is an element that posseses multiple desireable qualities that make it suitable for a multitude of applications, including atomic clocks and the search for beyond standard model physics. All of these applications are based on high precision spectroscopy. Spectroscopy on thermal atomic vapor is a straightforward and well-estabished method. By applying a lock-in detection scheme that uses both frequency and amplitude modulation to saturated absorption spectroscopy, we measure the isotope shifts of the 423-nm 1S0 -> 1P1 transition for all stable calcium isotopes.

A 11.6 Tue 12:15 HS 1098

Developments towards quantum logic spectroscopy for high-precision CPT symmetry tests in a cryogenic Penning trap — •Jan Schaper[1], Julia Coenders[1], Moritz von Boehn[1], Nima Hashemi[1], Juan Manuel Cornejo[1], Stefan Ulmer[3,4], and Christian Ospelkaus[1,2] — [1]Leibniz Universität Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Ulmer Fundamental Symmetries Laboratory, Riken, Japan — [4]Heinrich-Heine-Universität Düsseldorf, Germany

High-precision matter-antimatter comparisons allow to test CPT symmetry and to search for new physics beyond the standard model. The BASE collaboration contributes to these tests by measuring the charge-to-mass ratio and *g*-factor of protons and antiprotons in cryogenic Penning traps [1-3]. The BASE experiment at the Leibniz University Hannover is developing measurement schemes based on sympathetic cooling and quantum logic spectroscopy to further increase sampling rates, using ^{9}Be$^+$ both as cooling and logic ion [4].

This talk will present recent advances, including adiabatic transport in the ms-regime [5] and ground-state cooling of a single ^{9}Be$^+$ ion [6]. Furthermore, upcoming changes to the experimental apparatus, including a redesigned Penning trap stack, will be shown.

[1] G. Schneider et al., Science 358, 1081 (2017) [2] C. Smorra et al., Nature 550, 371 (2017) [3] M.J. Borchert et al., Nature 601, 53 (2022) [4] Juan M Cornejo et al 2021 New J. Phys. 23 073045 [5] Meiners et al., arXiv:2309.06776 (2023) [6] Cornejo et at., arXiv:2310.18262 (2023)

A 11.7 Tue 12:30 HS 1098

X-Ray Spectroscopy of the Kα transitions in He-like Uranium — •Philip Pfäfflein[1,2,3], Steffen Allgeier[4], Sonja Bernitt[1,2,3], Andreas Fleischmann[4], Marvin Friedrich[4], Alexandre Gumberidze[2], Christoph Hahn[1,2], Daniel Hengstler[4], Marc O. Herdrich[1,2,3], Felix Kröger[1,2,3], Patricia Kuntz[4], Michael Lestinsky[2], Bastian Löher[2], Esther B. Menz[1,2,3], Uwe Spillmann[2], Sergiy Trotsenko[1,2], Günter Weber[1,2], Binghui Zhu[1,2,3], Christian Enss[4], and Thomas Stöhlker[1,2,3] — [1]HI Jena, Germany — [2]GSI, Darmstadt, Germany — [3]Jena University, Germany — [4]Heidelberg University, Germany

Helium-like ions are the simplest atomic multi-body systems. Their study along the isoelectronic sequence allows for precision tests of the interplay of the effects of electron–electron correlation, relativity and quantum electrodynamics (QED) within a wide range of electromagnetic field strengths. Heavy highly charged ions are ideal for probing higher order QED terms. For the 1s state in uranium, e.g. their contributions are on the 1 eV level at binding energies of above 100 keV.

In spring 2021 an X-ray spectroscopy study of helium-like uranium ions has been performed at the electron cooler of the low-energy storage ring CRYRING@ESR at GSI, Darmstadt using metallic magnetic calorimeter detectors. The achieved spectral resolution reveals the substructure of the Kα_1 and Kα_2 lines for the first time. Using two detectors the Doppler shift was deduced from the recorded spectra. This breakthrough in X-ray spectroscopy enables future precision tests of bound-state QED and many-body effects in extreme field strengths.

A 11.8 Tue 12:45 HS 1098

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

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 single molecular ion, one well-controllable atomic ion is co-trapped, coupling strongly to the molecule via the Coulomb interaction. The shared motional state is used as a bus to transfer information about the internal state of the molecular ion to the atomic ion. Using calcium as a logic ion, we have implemented a quantum logic scheme to detect population transfer on a co-trapped spectroscopy ion. The interaction is driven by a far detuned Raman laser setup. We present the latest progress of our experiment, aiming at high precision spectroscopy of molecular and complex atomic ions.

A 12: Bosonic Quantum Gases III (joint session Q/A)

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

A 12.1 Tue 11:00 Aula

Sub-unity superfluid fraction of a supersolid from self-induced Josephson effect — •Nicolò Antolini[1,2], Giulio Biagioni[2,3], Beatrice Donelli[1,2,4,5], Luca Pezzè[1,2,4], Augusto Smerzi[1,2,4], Marco Fattori[1,2,3], Andrea Fioretti[2], Carlo Gabbanini[2], Massimo Inguscio[1,6], Luca Tanzi[1,2], and Giovanni Modugno[1,2,3] — [1]LENS, University of Florence — [2]CNR-INO — [3]Department of Physics and Astronomy, University of Florence — [4]QSTAR — [5]Università degli Studi di Napoli — [6]Università Campus Bio-Medico di Roma

Many quantum materials in various systems feature a spatially modulated macroscopic wavefunction resulting from spontaneous breaking of gauge and translational symmetries. Their connection with supersolids has only been traced in a few cases since a universal property able to quantify the differences between supersolids, superfluids/superconductors, and crystals has not been established. A key property is the superfluid fraction, measuring the reduction in superfluid stiffness due to spatial modulations, leading to the non-standard superfluid dynamics of supersolids. We employ the Josephson effect to locally measure the superfluid fraction in a supersolid. Even without a physical barrier, the Josephson effect arises spontaneously in a supersolid, and single lattice cells act as self-induced Josephson junctions. We studied a cold-atom dipolar supersolid, revealing a significant subunity superfluid fraction. Our results point to new research directions, like the study of partially quantized vortices and supercurrents, and have an impact on the understanding of other supersolid-like systems.

A 12.2 Tue 11:15 Aula

Supersolidity in a driven quantum gas — •Nikolas Liebster[1], Marius Sparn[1], Elinor Kath[1], Keisuke Fujii[2], Sarah Görlitz[2], Tilman Enss[2], Helmut Strobel[1], and Markus Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, 69120 Heidelberg, Germany

Driven systems are of fundamental scientific interest, as they can display properties that are radically different from similar systems at equilibrium. However, systems out of equilibrium are difficult to describe theoretically, as they are inherently time-dependent and deeply nonlinear. This makes the study of such systems an ideal task for quantum field simulators, in which complex dynamics emerge naturally and can be probed experimentally. Here, we demonstrate the emergence of supersolidity in a driven, two-dimensional superfluid, that only has contact interactions. The self-stabilized system is characterized by simultaneously broken translational and U(1) gauge symmetry, and emerges as a result of large occupations of phononic modes due to driving. We characterize the state by observing collective modes of the lattice as well as lattice phonon propagation. We also show that the system maintains phase rigidity, a key property of superfluidity. This work introduces a novel type of supersolid that is readily experimentally accessible, and establishes a conceptual framework for describing elementary excitations of driven systems.

A 12.3 Tue 11:30 Aula

Strong-coupling expansion for disordered Bose-Hubbard model — •Renan da Silva Souza[1], Axel Pelster[2], and Francisco Ednilson Alves dos Santos[3] — [1]Goethe-Universität, Institut für Theoretische Physik, Frankfurt am Main, Germany — [2]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [3]Departamento de Física, Universidade Federal de São Carlos, Brazil

We identified the different ground states corresponding to the disordered Bose-Hubbard model at zero and finite temperatures and for small tunneling energies. Employing a field-theoretical approach, we constructed a strong-coupling expansion. By utilizing the Poincaré-Lindstedt method, we calculated a renormalized expression for the local density of states, providing clear differentiation between the Mott-insulator and Bose-glass phases. Applying a resummation technique, we computed the expression for the disorder ensemble average of the spectral function. Its analysis shows that disorder leads to an increase in the effective mass of both quasi-particle and -hole excitations of the Mott phase. And it yields the emergence of damped states, which exponentially decay during propagation in space and dominate the whole band when disorder becomes comparable to interactions. We argue that such damped-localized states correspond to single-particle excitations of the Bose-glass phase. Our results for the phase boundary compare well against stochastic and local mean-field numerical predictions.

[1] New J. Phys. **23**, 083007 (2021) and **25**, 063015 (2023)

A 12.4 Tue 11:45 Aula

Dynamical analysis of the chaotic phase in the Bose-Hubbard model — Óscar Dueñas Sánchez[1] and •Alberto Rodríguez[1,2] — [1]Departamento de Física Fundamental, Universidad de Salamanca, E-37008 Salamanca, Spain — [2]Instituto Universitario de Física Fundamental y Matemáticas (IUFFyM), Universidad de Salamanca, E-37008 Salamanca, Spain

We study the dynamical manifestation of the Bose-Hubbard model's chaotic phase [1] by analysing the temporal behaviour of connected two-point density correlations on experimentally accessible time scales up to a few hundred tunneling times. The exact time evolution of initial states with unit density reveals that the chaotic phase can be unambiguously identified from the 'early' time fluctuations of the considered observable around its equilibrium value [2]. The emergence of the chaotic phase is also seen to leave an imprint in the initial growth of the time signals. Specifically, the short time evolution in systems with $L \gtrsim 40$ is scrutinized to investigate the potentially diffusive spreading of density correlations within the chaotic phase.

[1] L. Pausch *et al.*, Phys. Rev. Lett. 126, 150601 (2021)
[2] D. Peña Murillo, MSc Thesis, Universidad de Salamanca (2022)

A 12.5 Tue 12:00 Aula

Emergence of fluctuating hydrodynamics in chaotic quantum systems — •Julian Wienand[1,2,3], Simon Karch[1,2,3], Alexander Impertro[1,2,3], Christian Schweizer[1,2,3], Ewan McCulloch[4], Romain Vasseur[4], Sarang Gopalakrishnan[5], Monika Aidelsburger[1,2,3], and Immanuel Bloch[1,2,3] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [4]Department of Physics, University of Massachusetts, Amherst, MA 01003, USA — [5]Department of Electrical and Computer Engineering, Princeton University, Princeton, NJ 08544, USA

A fundamental principle of chaotic quantum dynamics is that local subsystems eventually approach a thermal equilibrium state. Large subsystems thermalise slower: their approach to equilibrium is limited by the hydrodynamic build-up of fluctuations on extended length scales. We perform large-scale quantum simulations that monitor particle-number fluctuations in tunable ladders of hard-core bosons and explore how the build-up of fluctuations changes as the system crosses over from ballistic to chaotic dynamics. Our results indicate that the growth of large-scale fluctuations in chaotic far-from-equilibrium systems is even quantitatively determined by equilibrium transport coefficients, in agreement with the predictions of fluctuating hydrodynamics. This emergent hydrodynamic behaviour of fluctuations provides a novel test of fluctuation-dissipation relations far from equilibrium.

A 12.6 Tue 12:15 Aula

Extreme wave events and spacetime defects in a spinor Bose-Einstein condensate — •Yannick Deller, Ido Siovitz, Alexander Schmutz, Felix Klein, Helmut Strobel, Thomas Gasenzer, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Ruprecht-Karls Universität Heidelberg, Deutschland

Many-body systems far from equilibrium can exhibit self-similar dynamics characterized by universal exponents. Numerical studies of a quenched ferromagnetic spinor BEC have revealed the appearance of extreme wave events on the way to the universal regime [1]. Furthermore, as a result of these caustics, real-time instanton defects are generated, which take on the form of space-time vortices in the transversal spin order parameter. However, the random appearance of real-time instantons in space and time makes it experimentally challenging to study these excitations in a controlled way. Thus we aim for deterministic preparation of a single instanton event. We employ local spin-dependent phase imprints, which lead to excitations in the transversal spin length. We probe their time evolution and characterize their structure with spatially resolved detection of all relevant spin observables.

[1] Siovitz et. al. , PRL 131, 183402 (2023)

A 12.7 Tue 12:30 Aula

Entrainment of a continuous time crystal — Anton Bölian[1], •Phatthamon Kongkhambut[1], Jim Skulte[1], Ludwig Mathey[1], Jayson G. Cosme[3], Hans Kessler[2], and Andreas Hemmerich[1] — [1]Zentrum für Optische Quantentechnologien and Institut für Quantenphysik, Universität Hamburg, Germany. — [2]Physikalisches Institut der Universität Bonn, Germany. — [3]National Institute of Physics, University of the Philippines, Diliman, Quezon City, Philippines.

Discrete and continuous time crystals are novel dynamical many-body states, that are characterized by robust self-sustained oscillations, emerging via spontaneous breaking of discrete or continuous time translation symmetry. Here, we demonstrate dynamical control of a continuous time crystal by driving it into a discrete time crystalline state. This transition is related to subharmonic entrainment of classical limit cycles, which arises here on the level of many-body quantum systems. Specifically, we prepare a continuous time crystal in a pumped atom-cavity system oscillating at a frequency ω_{CTC} and subsequently modulate the continuous pump intensity with a frequency ω_{dr} close to $2\,\omega_{\mathrm{CTC}}$. For sufficiently large modulation strengths, the emission frequency switches from ω_{CTC} to $\omega_{\mathrm{CTC}} = \omega_{\mathrm{dr}}/2$, which demonstrates the phase transition to a discrete time crystal.

A 12.8 Tue 12:45 Aula

Effects of quantum depletion and gradient corrections on the critical atom number of dipolar droplets — Milan Radonjić[1,2], Axel Pelster[3], and •Antun Balaž[2] — [1]I. Institute of Theoretical Physics, University of Hamburg, Germany — [2]Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Physics Department and Research Center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

The first experimental realization of quantum droplets in dipolar condensates [1] has highlighted the importance of quantum fluctuations [2], which were later shown to be the main source of system's stability against the dipolar collapse. The droplets were predicted and shown to be self-bound beyond the critical atom number even without the trap. However, there is a systematic difference in theoretical estimates of the critical atom number and experimental results [3]. Here we use an approach based on the extended Gross-Pitaevskii equation, which includes quantum depletion and beyond-LDA gradient corrections, to numerically and variationally study their effects on the critical atom number.

[1] H. Kadau et al., Nature **530**, 194 (2016).
[2] A. R. P. Lima and A. Pelster, Phys. Rev. A **84**, 041604(R) (2011); Phys. Rev. A **86**, 063609 (2012).
[3] F. Böttcher et al., Phys. Rev. Research **1**, 033088 (2019).

A 13: Trapping and Cooling of Atoms (joint session Q/A)

Time: Tuesday 11:00–13:00 Location: HS 1221

Invited Talk A 13.1 Tue 11:00 HS 1221

Continuous lasing and pinning of the dressed cavity resonance with strongly-coupled ^{88}Sr atoms in a ring cavity — •Vera Schäfer — JILA, University of Colorado, Boulder, USA — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Superradiant lasers are a promising path for realising a narrow-linewidth, high-bandwidth active frequency reference. They shift the phase memory from the optical cavity, which is subject to technical and thermal vibration noise, to an ultra-narrow optical atomic transition of an ensemble of cold atoms trapped inside the cavity. Our previous demonstration of pulsed superradiance on the mHz transition in ^{87}Sr achieved a fractional Allan deviation of $6.7 * 10^{-16}$ at 1s of averaging. Moving towards continuous-wave superradiance promises to further improve the short-term frequency stability by orders of magnitude. A key challenge in realizing a cw superradiant laser is the continuous supply of cold atoms into a cavity, while staying in the collective strong coupling regime.

We demonstrate continuous loading and transport of cold ^{88}Sr atoms inside a ring cavity, after several stages of laser cooling and slowing. We further describe the emergence of zones of collective continuous lasing of the atoms on the 7.5kHz transition, 7x narrower than the cavity linewidth, and pumped by the cooling lasers via inversion of the motional states. The lasing is supported by self-regulation of the number of atoms inside the cavity that pins the dressed cavity frequency to a fixed value over >2MHz of raw applied cavity frequency. In the process up to 80% of the original atoms are expelled from the cavity.

A 13.2 Tue 11:30 HS 1221

Using multifrequency light for large cold atom traps — •David Johnson, Ben Hopton, Nathan Cooper, and Lucia Hackermüller — University of Nottingham, Nottingham, UK

Magneto-optical trapping (MOT) and Bose-Einstein-Condensates (BECs) are used for a wide range of applications, such as sensors for magnetic or gravitational fields, as well as to test fundamental questions such as Quantum Gravity. Larger atom clouds would allow for more precise sensors and test a larger range of parameters of such theories. One limitation to the size of the trapped cold atom cloud is the range of atom velocities that can be addressed by the trapping beams. By using multiple frequencies each shifted by approximately 5MHz, we expect an increase of the atom loading rate by a factor of 1000 or more, thus leading to trapping 10-100 times more atoms in our MOT. A dark spot MOT can be used to reduce the influence of collisional losses and fully demonstrate the feasibility of our proposal.

A 13.3 Tue 11:45 HS 1221

Dipole trapping of mercury — •Sascha Heider, Thorsten Groh, and Simon Stellmer — Physikalisches Institut, Universität Bonn, Nußallee 12, 53115 Bonn, Germany

Mercury is the heaviest, non-radioactive laser-coolable element in the periodic table. With seven naturally occuring isotopes and deep UV transitions (185 nm) suitable for high resolution imaging, mercury is a promising candidate for realizing a future multipurpose quantum gas machine.

We already achieved laser cooling of all seven isotopes on the $^1S_0 \to {}^3P_1$ (254 nm) transition to sub-Doppler temperatures and high atom numbers [PRA 105, 033106].

For further cooling we currently deploy a high power optical dipole trap (300 W at 1070 nm) to overcome the very low polarizability.

A 13.4 Tue 12:00 HS 1221

Towards light scattering experiments in dense dipolar gases — •Ishan Varma, Marvin Proske, Rhutwik Sriranga, and Patrick Windpassinger — Institute of Physics, JGU Mainz

Dysprosium is a fascinating candidate for studying cooperative and collective effects in dense ultra-cold media. With the largest ground state magnetic moment of all elements in the periodic table (10 Bohrmagnetons), it offers a platform to study light scattering in a system where magnetic dipole-dipole interactions (DDI) and light induced correlations are in mutual competition. At sufficiently high atomic densities, the strong magnetic DDI significantly influence the propagation of light within the sample. In particular, we want to look at signatures of collective light scattering phenomena like super- and subradiance.

This talk reports on the progress made in generating dense samples of ultracold dysprosium atoms. We plan to optically transport atoms into a home-built science cell with high optical access. The creation and imaging of dense atomic samples inside the science cell is achieved using high NA custom objectives, designed and assembled in-house. We present the performance characterization and discuss the development of these objectives in our experimental system. Further, an outlook is given on future measurements exploring collective and cooperative effects in the generated sample.

A 13.5 Tue 12:15 HS 1221

Report on the construction of a new Erbium-Lithium machine — •Alexandre De Martino, Florian Kiesel, Kirill Karpov, Jonas Auch, and Christian Gross — Eberhard Karls Universität Tübingen, Physikalisches Institut, AG Groß, Auf der Morgenstelle 14, 72076 Tübingen

Fermionic gases are notoriously difficult to cool down below 10% of the Fermi temperature with usual methods. Pushing the temperature limit and producing colder gases is becoming essential for the study of strongly correlated systems. Sympathetic cooling with a classical gas as an entropy reservoir may provide a new direction to overcome the current limit.

Here we report on the ongoing development of a new Erbium-Lithium machine, whose purpose is to optimize the cooling of an ultracold Lithium gas with an Erbium reservoir. This mixture has several promising features, that have not yet been utilized for sympathetic cooling in other quantum mixtures.

A 13.6 Tue 12:30 HS 1221

ORKA - Towards a cavity enhanced Optical Dipole Trap for evaporative cooling of Rb87 in microgravity — •Jan Eric Stiehler, Marius Prinz, Marian Woltmann, and Sven Herrmann — Center of Applied Space Technology and Microgravity (ZARM), University of Bremen, Germany

Evaporative cooling in optical traps is a common method to prepare ultra-cold quantum gases and generate Bose Einstein condensates (BEC). This usually comes at the prize of an increased power budget for the trapping laser. For setups that require to be energy efficient e.g. in space, magnetic chip traps are thus often preferred. However, these also come with certain limitations and lack some of the benefits of all-optical trapping and cooling. As an alternative we are investigating the use of a resonantly enhanced optical dipole trap for Rb87 to mitigate the power needs of all-optical evaporative cooling. We plan to employ a bow-tie cavity for evaporative cooling to a BEC, to be used as a matterwave source for interferometry in free fall experiments at the the Bremen Gravitower Pro facility. In this talk we will discuss the trade-off for our trapping scheme and present the resulting experiment design as well as simulation results for the bow-tie cavity trap. The ORKA project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action under grant number DLR 50 WM 2267.

A 13.7 Tue 12:45 HS 1221

Confinement Induced Resonances in Spherical Shell Traps — •C. Moritz Carmesin[1] and Maxim A. Efremov[2,1] — [1]Institute of Quantum Physics and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, 89081 Ulm, Germany — [2]German Aerospace Center (DLR), Institute of Quantum Technologies, 89081 Ulm, Germany

We have computed exactly the energy spectrum and corresponding wave functions of two bosonic particles, which are confined in a spherically symmetric shell-shaped trap of the radius r_0 and interact with each other via a three-dimensional zero-range potential characterized by the s-wave scattering length a_0. Confinement induced resonances (CIRs) are found to occur at certain values of r_0 and a_0 as avoided crossings between the bound (molecular) and trap (nonmolecular) states, as well as between two trap states. The found CIRs originate entirely from the strong coupling of the relative and center-of-mass motions of the two particles. By working close to a CIR, that is at a certain shell radius and a given scattering length, these results offer a new way to increase the atom-atom interaction and even to drive the formation of molecules in the shell-shaped atomic gas.

A 14: Members' Assembly

Time: Tuesday 13:15–14:15 Location: HS 1010

All members of the Atomic Physics Division are invited to participate.

A 15: Poster I

Time: Tuesday 17:00–19:00 Location: Tent A

A 15.1 Tue 17:00 Tent A

Relaxation in dipolar spin ladders — •Gustavo Dominguez[1], Luis Santos[1], Thomas Bilitewski[2], David Wellnitz[3], and Ana Maria Rey[3] — [1]Leibniz University, Hannover, Germany — [2]Oklahoma State University, Oklahoma, USA — [3]University of Colorado, Boulder, USA

Ultracold dipolar particles pinned in optical lattices or tweezers provide an excellent platform for studying out-of-equilibrium quantum magnetism with dipole-mediated couplings. Starting with an initial state in which spins of opposite orientations are prepared in each of the legs of a ladder lattice, we show that spin relaxation displays an unexpected dependence on inter-leg distance and dipole orientation. This dependence, stemming from the interplay between intra- and inter-leg interactions, results in three distinct dynamical regimes: (i) ergodic, characterized by the fast relaxation towards equilibrium of correlated pairs of excitations generated at exponentially fast rates from the initial state; (ii) metastable, in which the state is quasi-localized in the initial state and only decays in exceedingly long timescales, resembling false vacuum decay; and, surprisingly, (iii) partially-relaxed, with coexisting fast partial relaxation and partial quasi-localization. Realizing this intriguing dynamics is at hand of current state-of-the-art experiments in dipolar gases

A 15.2 Tue 17:00 Tent A

Nonlinear interference and electron dynamics: Probing photoelectron momentum distribution in strong-field ionization — •Danish Furekh Dar[1,2] and Stephan Fritzsche[1,2] — [1]Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — [2]Friedrich-Schiller-Universität Jena

Nonlinear interference in the interaction of intense laser pulses with atoms profoundly affects the photoelectron momentum distribution (PMD). We theoretically show that the interference pattern in the PMD arises from the interaction of electron with the fundamental frequencies concealed within the pulse. Nonlinear interference also imprints distinctive features on the ionization spectrum, providing valuable information about electron dynamics and phase relationships within the laser pulse. Additionally, the augmentation of optical cycles induces a distinct confinement in the PMD.

A 15.3 Tue 17:00 Tent A

Photonic Insights into Tissue Thermal Responses: A Numerical Analysis Based on a Two-Temperature Model (TTM) — •Hristina Delibašić Marković[1], Violeta Petrović[1], Konstantinos Kaleris[2,3], and Ivan Petrović[4] — [1]Faculty of Science, University of Kragujevac, Radoja Domanovića 12, 34000 Kragujevac, Serbia — [2]Institute of Plasma Physics and Lasers, Hellenic Mediterranean University, Tria Monastiria, 74100 Rethymo, Greece — [3]Physical Acoustics and Optoacoustics Laboratory, Music Technology and Acoustics Dept., Hellenic Mediterranean University, 74100 Rethymno, Greece — [4]Academy of Professional Studies Šumadija, Department in Kragujevac, Serbia

In this research, we investigate the thermal response of tissue to intense laser pulses using the two-temperature model. This model is pivotal for analyzing heat conduction in both vascular and extravascular regions, crucial in laser-tissue interaction studies. It effectively differentiates between blood and tissue temperatures, incorporating a coupling factor and phase lag times essential for accurate predictions under laser exposure. These parameters are closely linked to the physical properties of blood and tissue, the convective heat transfer coefficient, and the blood perfusion rate. Employing the finite difference method, we address this complex problem, and our findings elucidate the tissue's thermal behavior during laser interaction and its susceptibility to optical breakdown. This work significantly contributes to our understanding of laser-tissue dynamics, offering important insights in the field of atomic and molecular physics.

A 15.4 Tue 17:00 Tent A

Entanglement created in ultracold collisions: a realistic model study — •Yimeng Wang, Karl P. Horn, and Christiane P. Koch — Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Despite being one of the most common and straightforward ways of generating entanglement between two particles, the creation of entanglement in collisions has never been comprehensively studied beyond 1D or toy models. Here, we seek to quantify the degree of entanglement generated in ultracold atomic collisions by computing the inter-particle purity, focusing first on the motional degree of freedom. As the entanglement generated in collisions depends rather sensitively on the initial conditions, we consider two elongated Gaussian wave packets as pre-collision states, whose shapes are determined by the uncertainty of the transverse and longitudinal momenta, to model the realistic experimental settings as possible. Apart from the initial conditions for the particle motion, we study how the partial-wave scattering phase shifts, the energy derivative of which signals a resonance state, influence the degree of entanglement.

A 15.5 Tue 17:00 Tent A

Central energy shift in two-photon ionization process — •Hao Liang and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

In photo-ionization process, the energy of photoelectron is equal to photo energy minus ionization potential. However, if the photon has a finite spectrum width, there would be an additional negative shift for the central energy of photoelectron respect to that of photo spectrum due to the decreasing photo-ionization cross section. Such shift is not easy to be observed in usual scheme. Here we proposed that one can measure it with reconstruction of attosecond harmonic beating by interference of two-photon transition techniques (RABBITT) for two-photon ionization process. By numerically solving the time-dependent Schrödinger equation, we found such central energy shift changes for different phase delays, spectrum width ratios and intensity ratios. With the two-photon perturbative theory, one can understand those phenomenon quantitatively. Finally, we found that the measurement of energy shift provides a way to determine two independent ionization time-delays in two-photon ionization process.

A 15.6 Tue 17:00 Tent A

Towards quantum logic spectroscopy of heavy few-electron ions — •Peter Micke[1,2,3], Zoran Andelkovic[2], and Thomas Stöhlker[1,2,3] — [1]Helmholtz Institute Jena — [2]GSI Helmholtz Center for Heavy Ion Research, Darmstadt — [3]Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena

Heavy highly charged ions (HCI), e.g. hydrogen-like or lithium-like ions, have forbidden optical transitions in their ground-state hyperfine structure and feature the strongest electromagnetic fields to which we have access in a lab on earth. Therefore, these optical transitions are excellent probes for tests of fundamental physics and offer enhanced sensitivities to search for physics beyond the standard models of particle physics and cosmology. Furthermore, many systematic shifts of these transitions are highly suppressed, making heavy HCI ideal systems for the use in novel high-accuracy optical atomic clocks.

Upon recent advances in precision spectroscopy [1] and clock operation [2] with medium-light HCI of intermediate charge state ($^{40}Ar^{13+}$), we are setting up a unique and versatile spectroscopy platform at the HITRAP facility of GSI which combines the powerful heavy-ion accelerators with quantum logic spectroscopy in a cryogenic Paul trap. This will enable frequency metrology of heavy HCI, such as $^{207}Pb^{81+}$ with a clock transition at 1019.7 nm. The state-of-the-art uncertainty can be improved by many orders of magnitude and unprecedented tests of atomic, nuclear, and fundamental physics become available.

[1] P. Micke et al., *Nature* **578**, 60–65 (2020), [2] S. A. King et at. *Nature* **611**, 43–47 (2022). — PhD positions available! —

A 15.7 Tue 17:00 Tent A

Isotope shift measurements in a calcium beam clock — •Andreas Reuss, Anica Hamer, Lukas Möller, David Röser, Frederick Wenger, and Simon Stellmer — Physikalisches Institut, Universität Bonn

In the quest for finding new physics beyond the standard model, the research on isotope shifts in atomic transitions is a promising field for finding potential new interactions between electrons and neutrons, described by a novel force carrier boson.

Calcium is an excellent candidate for finding such new physics interactions with spectroscopic methods, due to its large number of stable isotopes and small nuclear deformations.

In our research we will employ a calcium beam clock using a Ramsey Bordé spectroscopy scheme, utilizing the $S_0 - P_1$ (657nm) and the $S_0 - D_2$ (458nm) clock transitions.

A 15.8 Tue 17:00 Tent A

Multi-Sideband RABBIT in Atoms and Molecules — •Divya Bharti[1], Hemkumar Srinivas[1], Farshad Shobeiry[1], Kathryn Hamilton[2], Robert Moshammer[1], Thomas Pfeifer[1], Klaus Bartschat[3], and Anne Harth[1,4] — [1]Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany — [2]Department of Physics, University of Colorado Denver, Denver, Colorado, USA — [3]Department of Physics and Astronomy, Drake University, Des Moines, USA — [4]Department of Optics and Mechatronics, Hochschule Aalen, Aalen, Germany

We present findings derived from measuring three-sideband (3-SB) RABBIT (Reconstruction of Attosecond Beating by Interference of Two-Photon Transition) in atoms and molecules. RABBIT utilizes an XUV pulse train to induce ionization, while an IR pulse interacts with the subsequent photoelectrons. In the 3-SB RABBIT setup, interactions with IR photons generate three sidebands positioned between consecutive harmonics. This configuration allows us to explore phases resulting from the interference between transitions of different orders in the continuum. These phases remain independent of any chirps in the harmonics, and we investigate this by comparing RABBIT phases extracted from specific sideband groups formed by adjacent harmonics. Additionally, we explore cases where the oscillation in the sidebands involves intermediary resonance states.

A 15.9 Tue 17:00 Tent A

Diffusion of single ultracold atoms in an accelerated optical lattice — •Silvia Hiebel, Daniel Adam, Florian Schall, Sabrina Burgardt, Julian Fess, and Artur Widera — Department of Physics and Research Center optimas, University of Kaiserslautern-Landau, Erwin Schrödinger Str. 46, 67663 Kaiserslautern, Germany

Diffusion is a transport phenomenon that appears as a fundamental process in almost all physical systems, ranging from subdiffusion to hyperballistic diffusion, depending on the external parameters. In addition to the properties of the bath or the diffusing particle, the diffusion in systems subjected to external forces is critical for understanding transport phenomena in complex systems.

Here, we present a system where we can observe the diffusion dynamics of single atoms in tilted optical lattices in the underdamped regime. A one-dimensional optical lattice allows transporting individual cesium atoms with variable lattice depth, constant velocity or acceleration, and thus force. For example, the force exerted on individual atoms can be huge, exceeding standard gravitation by orders of magnitude. Thereby, very different regimes of diffusion can be experimentally accessed. We can tune the system's macroscopic diffusion coefficient by varying the lattice depth and acceleration while applying optical molasses onto the atoms as a "bath of light" for the diffusion. Additionally, the atoms can be transported through a bath of ultracold rubidium atoms. We observe the interplay of the large Rb-bath and the single Cs-atoms trapped in the accelerated lattice and report its effective friction.

A 15.10 Tue 17:00 Tent A

Trap-integrated fluorescence detection with silicon photomultipliers for sympathetic laser cooling in a cryogenic Penning trap — •Markus Wiesinger[1], Florian Stuhlman[2], Matthew Bohman[1], Peter Micke[1,3], Christian Will[1], Hüseyin Yildiz[2], Fatma Abbass[2], Bela Arndt[1,4,5], Jack Devlin[3,5], Stefan Erlewein[1,5], Markus Fleck[5,6], Julia Jäger[1,3,5], Barbara Latacz[3,5], Daniel Schweitzer[2], Gilbertas Umbrazunas[5,7], Elise Wursten[3,5], Klaus Blaum[1], Yasuyuki Matsuda[6], Andreas Mooser[1], Wolfgang Quint[4], Anna Soter[7], Jochen Walz[2,8], Christian Smorra[2,5], and Stefan Ulmer[5,9] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz — [3]CERN, Meyrin, Switzerland — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [5]RIKEN Fundamental Symmetries Laboratory, Japan — [6]Graduate School of Arts and Sciences, University of Tokyo, Japan — [7]Eidgenössische Technische Hochschule Zürich, Switzerland — [8]Helmholtz-Institut Mainz — [9]Heinrich-Heine-Universität Düsseldorf

We present a fluorescence-detection system for laser-cooled $^{9}Be^{+}$ ions based on silicon photomultipliers (SiPM) operated at 4 K and integrated into our cryogenic 1.9 T multi-Penning-trap system. Our approach enables fluorescence detection in a hermetically-sealed cryogenic Penning-trap chamber with limited optical access, where state-of-the-art detection using a telescope and photomultipliers at room temperature would be extremely difficult. We characterize the properties of the SiPM in a cryocooler at 4 K, where we measure a dark count rate below 1/s and a detection efficiency of 2.5(3) %. We further discuss the design of our cryogenic fluorescence-detection trap, and analyze the performance of our detection system by fluorescence spectroscopy of $^{9}Be^{+}$ ion clouds during several runs of our sympathetic laser-cooling experiment.

A 15.11 Tue 17:00 Tent A

Indication of critical scaling in time during the relaxation of an open quantum system — •Julian Fess[1], Ling-Na Wu[2], Jens Nettersheim[1], Alexander Schnell[3], Sabrina Burgardt[1], Silvia Hiebel[1], Daniel Adam[1], André Eckardt[3], and Artur Widera[1] — [1]Department of Physics, RPTU Kaiserslautern, Germany — [2]Center for Theoretical Physics and School of Science, Hainan University, Haikou, China — [3]Institut für Theoretische Physik, Technische Universität Berlin, Germany

Critical scaling occurs in phase transitions corresponding to the singular behaviour of physical systems in response to continuous control parameters. Recently, dynamical quantum phase transitions and universal scaling have been observed in the non-equilibrium dynamics of isolated quantum systems, with time as the control parameter. However, signatures of such critical phenomena in time in open systems were so far elusive. Here, we present results indicating that critical scaling with respect to time can also occur in open quantum systems. We experimentally measure the relaxation dynamics of the large atomic spin of individual Caesium atoms induced by the dissipative coupling to an ultracold Bose gas. For initial states far from equilibrium, the entropy is found to peak in time, transiently approaching its maximum possible value, before eventually relaxing to its lower equilibrium value. Moreover, a finite-size scaling analysis shows that it corresponds to a critical point in the limit of large system sizes. It is signalled by the divergence of a characteristic length, characterized by critical exponents that are found to be independent of system details.

A 15.12 Tue 17:00 Tent A

Quantum light in a finite 1-D slab and its effects on high harmonic generation — •Arlans Juan Smokovicz de Lara — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Deutschland

Since its discovery, high harmonic generation (HHG), as a process non-linear in the number of photons, has been realized with intense "classical" light. Recently, progress has been made towards creating non-classical intense light pulses [1], which promises new quantum effects in the interaction with matter. We will present first results of non-classical light, in particular cat states of linearly polarized light interacting with delocalized electrons, realized in a 1-D slab of atoms [2], investigating the combined effects of the non-classical light and the periodic, crystal-like, yet finite target.

[1] M. Lewenstein, M. F. Ciappina, E. Pisanty, J. Rivera-Dean, P. Stammer, Th. Lamprou & P. Tzallas, Nature Physics volume 17,1104 (2021)

[2] Chuan Yu, Ulf Saalmann, Jan M. Rost, Phys. Rev. A 105, L041101 (2022)

A 15.13 Tue 17:00 Tent A

Measuring the environment of a Cs qubit with dynamical decoupling sequences — •Sabrina Burgardt, Simon Jäger, Julian Fess, Silvia Hiebel, Imke Schneider, and Artur Widera — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, Kaiserslautern 67663, Germany

We report the experimental implementation of dynamical decoupling (DD) on a small, non-interacting ensemble of optically trapped, neutral Cs atoms. We observe a significant enhancement of the coherence time when employing Carr-Purcell-Meiboom Gill (CPMG) DD. A CPMG sequence with ten refocusing pulses increases the coherence time by more than one order of magnitude. In addition, we make use of the filter function formalism and utilize the CPMG sequence to measure the background noise floor affecting the qubit coherence. Our findings point toward noise spectroscopy of engineered atomic baths through single-atom DD in a system of individual Cs impurities immersed in an ultracold Rb-87 bath.

A 15.14 Tue 17:00 Tent A

How to: Mean-field calculations with long-range interactions — •Jan Alexander Koziol[1], Giovanna Morigi[2], and Kai Phillip Schmidt[1] — [1]Department of Physics, Staudtstraße 7, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany — [2]Theoretical Physics, Saarland University, Campus E2.6, D-66123 Saarbrücken, Germany

We introduce an approach to set up mean-field calculations for lattice models with long-range interactions. The basic idea of our method is to perform mean-field calculations on all possible unit cells up to a given extend. The long-range interaction is treated without truncation using resummed couplings. One further advantage of the method we present is that all phases with ordering vectors fitting on any of the considered unit cells can be detected within out framework. We describe in detail the underlying theoretical ideas behind the method, the technicalities on how to implement the unit cell generation, and several results we obtained for (hardcore) bosons on the two-dimensional square and triangular lattice.

A 15.15 Tue 17:00 Tent A

Coincidence experiments on atomic collisions using the TrapREMI. — •Medina Cristian[1], Schotsch F.[1], Zebergs I.[1], Augustin S.[2], Lindenblatt H.[1], Hoibl L.[3], Djendjur D.[3], Schroeter C.D.[1], Pfeifer T.[1], and Moshammer R.[1] — [1]Max-Planck-Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg — [2]Paul Scherrer Institut, Forschungsstrasse 111, 5232 Villigen, Switzerland — [3]Department of Physics and Astronomy, Ruprecht-Karls University , 69120 Heidelberg, Baden-Württemberg, Germany

The reaction dynamics of collisions between atomic argon ions and various atomic projectiles have been investigated using the TrapREMI [1]. This setup combines an electrostatic ion beam trap (EIBT) [2,3] with a reaction microscope (REMI) [4]. Fast argon ions (2 keV) are stored in the EIBT in a linear oscillatory motion while inside the REMI; argon, helium, or neon atomic beams are crossed with the ion bunch. The resulting reaction products are detected in coincidence allowing the reconstruction of their 3D momenta. Additionally, with the implementation of a new ion source that allows higher ion current and an additional gas jet using different noble gasses, Ar+-Atom collisions were performed. Initial results showed that mainly singly-charged argon ion captures an electron, i.e. from the neutral argon beam. Coincidence measurements for all other gasses are similarly shown.

References [1] F. Schotsch, Rev. Sci. Instrum. 92 (2021) [2] D. Zajfman, Phys. Rev. A 55 (1997) [3] M. Lange, Rev. Sci. Instrum. 81 (2010) [4] F. Schotsch, Ph.D. thesis, Heidelberg (2020).

A 15.16 Tue 17:00 Tent A

Towards Ground State Cooling of a Highly Charged Ion - Beryllium Crystal at low Secular Frequency — •Stepan Kokh, Vera M. Schäfer, Elwin A. Dijck, Christian Warnecke, Lukas F. Storz, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Spectroscopy of ions and atoms for generalized King Plot analysis is a rapidly developing field with the potential to identify new physics, such as unknown particles or forces [1]. Using highly charged ions (HCI) for it gives access to previously unavailable transitions. For such an analysis, high precision is required, and suppression of external perturbations is essential. Our superconducting Paul trap shields external fields by 57 dB, a level comparable to dedicated magnetically shielded rooms [2]. However, the current setup limits our secular frequency due to the loss of superconductivity at high RF power. Therefore, we operate only in an intermediate Lamb-Dicke regime. We report on the progress towards ground-state cooling of sympathetically cooled HCI in the given experimental setup.

[1] Nils-Holger Rehbehn, et al., Phys. Rev. Lett. 131, 161803 (2023) [2] Elwin A. Dijck, et al., Rev. Sci. Instrum. 94, 083203 (2023)

A 15.17 Tue 17:00 Tent A

Exploring the vibrational series of pure trilobite Rydberg molecules — •Richard Blättner, Markus Exner, Max Althön, and Herwig Ott — RPTU Kaiserslautern-Landau, Kaiserslautern, Deutschland

We report on the observation of two vibrational series of pure trilobite rubidium Rydberg molecules. These kinds of molecules consist of a Rydberg atom and a ground state atom. The binding mechanism is based on the scattering interaction between the Rydberg electron and the ground state atom. The trilobite molecules are created via three-photon photoassociation and lie energetically more than 15 GHz below the atomic 22F state. In agreement with theoretical calculations, we find an almost perfect harmonic oscillator behavior of six vibrational states. We show that these states can be used to measure electron-atom scattering lengths for low energies in order to benchmark current theoretical calculations. The molecules have extreme properties: their dipole moments are in the range of kilo-Debye and the electronic wave function is made up of high angular momentum states with only little admixture from the nearby 22F state. This high-l character of the trilobite molecules leads to an enlarged lifetime as compared to the 22F atomic state. Furthermore, our ion pulse spectrometer provides insights into the decay processes.

A 15.18 Tue 17:00 Tent A

Quantum Phases from Competing Van der Waals and Dipole-Dipole Interactions of Rydberg Atoms — •Zeki Zeybek[1,2], Rick Mukherjee[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Competing short- and long-range interactions represent distinguished ingredients for the formation of complex quantum many-body phases. Their study is hard to realize with conventional quantum simulators. In this regard, Rydberg atoms provide an exception as their excited manifold of states have both density-density and exchange interactions whose strength and range can vary considerably. Focusing on one-dimensional systems, we leverage the Van der Waals and dipole-dipole interactions of the Rydberg atoms to obtain the zero-temperature phase diagram for a uniform chain and a dimer model. For the uniform chain, we can influence the boundaries between ordered phases and a Luttinger liquid phase. For the dimerized case, a new type of bond-order-density-wave phase is identified. This demonstrates the versatility of the Rydberg platform in studying physics involving short- and long-ranged interactions simultaneously.

A 15.19 Tue 17:00 Tent A

A High-Resolution Ion Microscope to Spatially Observe Ion-Rydberg Interactions — •Jennifer Krauter, Moritz Berngruber, Viraatt Anasuri, Óscar Andrey Herrera-Sancho, Ruven Conrad, Raphael Benz, Florian Meinert, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We report on our recent studies on ion-Rydberg atom interactions performed in the ultra-cold quantum regime using a high-resolution ion microscope. This apparatus provides temporal and spatial imaging of charged particles with a resolution of 200 nm.

Ion-Rydberg atom pair-states on the one hand allow for the observation of collisional dynamics on steep attractive potential energy curves. Avoided crossings with high-l states can cause significant speed up in the dynamics which is dependent on the individual Landau-Zener probabilities. On the other hand, the avoided crossings also lead to potential wells that give rise to bound molecular states. These bound states between an ion and a Rydberg atom feature large bond length, which enable the direct observation of vibrational dynamics. In an effort to further understand the binding mechanism of the Ion-Rydberg atom molecule their lifetime is currently under investigation.

A 15.20 Tue 17:00 Tent A

Precise FEM-solution of Dirac equation and the calculation of the electron bound-g-factor for H_2^+ molecular ion. — •Ossama Kullie — 1 Theoretical Physics, Institute of Physics, University of Kassel

A new generation of experiments is under way aiming at performing high-resolution spectroscopy of molecular hydrogen ions in Penning traps. In some of these traps, the internal state of the molecule is detected via the spin state, using electron spin resonance excitation. In order to perform this excitation, knowledge of the resonance frequency is required. The frequency depends on the bound-g-factor of the electron in the molecule. We calculate this g-factor by perturbatively evaluating the Zeeman energy of the electron in a weak magnetic field. Our FEM-solution of the two-center Dirac equation using 2-spinor minmax method, is highly accurate and the resulting wave function is used to calculate the electron bound-g-factor for H_2^+ molecular ion. We present results for the two (magnetic) field orientations, parallel and perpendicular to the molecule orientation (internuclear axis). [1] O. Kullie and S. tchiller, Phys. Rev. A **105**, 052801 (2022). [2] O. Kullie, J. of Mol. Struc., submitted (2023). [2] O. Kullie and S. Schiller, in progress.

A 15.21 Tue 17:00 Tent A

ATOMIQ: A block based, highly flexible and user friendly extension for ARTIQ — •Christian Hölzl[1], Suthep Pomjaksilp[2], Thomas Niederprüm[2], and Florian Meinert[1] — [1]5th Institute of Physics, Universität Stuttgart, Stuttgart, Germany — [2]Department of Physics and research center OPTIMAS, Technische Universität Kaiserslautern, Germany

The demand for fast and reliable experiment control hardware and software has sharply increased with recent advances in quantum technology. For the fast cycle times required in atom computing and simulation, highly flexible yet nanosecond-precise systems are needed. By providing fully open source software and hardware the ARTIQ/Sinara ecosystem has propelled itself to a leading solution for ion and neutral atom based quantum experiments.

However the out of the box software functionality is heavily limited and requires major time commitment from the end user. Our ATOMIQ extension aims to mitigate this problem by adding a user-friendly abstraction layer, implementing common routines needed for quantum control of neutral atoms. By using a block-based experiment structure, modularity and drastic reduction of boiler plate is achieved without compromising the speed of ARTIQ. Combining simple primitives through multiple inheritance patterns to graspable lab devices like lasers ensures high flexibility and easy extendability. By providing many interfaces to lab infrastructure for data management and non-realtime devices it is also easy to implement ATOMIQ in an already existing system running ARTIQ.

A 15.22 Tue 17:00 Tent A

Towards a Strontium Circular Rydberg Atom Quantum Simulator — •Aaron Götzelmann, Christian Hölzl, Einius Pultinevicius, Moritz Wirth, and Florian Meinert — 5. Physikalisches Institut, Universität Stuttgart

Ensembles of individually trapped highly excited Rydberg atoms have proven to be an excellent platform for quantum simulation of many-body systems. We aim to improve the limited coherence time of state of the art approaches using low-l Rydberg states by using very long lived high-l circular Rydberg states (CRS). We will report on the realization of single atom arrays of individual strontium atoms in an experimental setup which aims to achieve tens of milliseconds lifetimes for CRSs without cryogenic cooling. Specifically, we prepare the array inside a capacitor structure made from indium tin oxide (ITO) thin films, designed to suppress detrimental blackbody decay while providing excellent high-NA optical access. Starting from the preparation of ground-state cooled defect free atom arrays, we will present our path to CRSs via rapid adiabatic passage and coherent microwave coupling between CRSs. With this tool we apply single qubit operations on next-neighboring CRSs. Finally, we will discuss prospects for optical control and imaging of CRS exploiting the second valence electron of strontium.

A 15.23 Tue 17:00 Tent A

Study of Rydberg states in ultra cold ytterbium — •Alexander Miethke, Nele Koch, and Axel Görlitz — Institut für Experimentalphysik, Heinrich-Heine-Universität, Düsseldorf, Deutschland

In recent years Rydberg atoms with their special features, like dipole-dipole interaction or van-der-Waals blockade, have become more and more important for quantum optics. Particularly ultra cold Rydberg atoms are of great interest for the investigation of long range interaction.

A special feature of ytterbium is that due to its two valance electrons atoms in Rydberg states can be easily manipulated and imaged using optical fields. A first step towards studies of ultra cold ytterbium is to gain precise knowledge on the Rydberg states.

Here we present the study of the Rydberg states of ultra cold ytterbium. Using a Micro-Channel-Plate to detect the Rydberg atoms it is possible to measure lifetimes and hyperfine structures of several states. In addition we could measure the energy and polarizability of s, p and d states in the region of high principal quantum numbers n (n=70-90). Using a second stage trap we are able to cool the atoms down to several micro K to reduce their distances and investigate interactions.

A 15.24 Tue 17:00 Tent A

A Dysprosium Dipolar Quantum Qas Microscope — •Fiona Hellstern[1], Kevin Ng[1], Paul Uerlings[1], Jens Hertkorn[1], Lucas Lavoine[1], Ralf Klemt[1], Tim Langen[1,2], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

We present the progress of our dipolar quantum gas microscope, which will enable single particle and single site resolved detection of Dysprosium atoms.

Our optical setup allows for the integration of both square and triangular lattice geometries (utilizing a wavelength of 360 nm), offering the capability to observe and manipulate diverse quantum phase transitions such as the (fractional) mott insulator to supersolid transitions. We present our design of an accordion lattice, a versatile optical trapping system, for loading Dysprosium atoms into the optical lattice. Additionally, our method to efficiently transport ultra-cold atoms from another vacuum chamber into the accordion lattice will be presented.

We will utilise an objective with a high numerical aperture (NA=0.9) and employ a spin- and energy-resolved super-resolution imaging technique, allowing us to achieve single-site detection with 180 nm resolution. The close spacing of the ultraviolet optical lattice significantly amplifies the nearest-neighbor dipolar interactions, reaching approximately 200 Hz (at 10 nK). This places us in the regime of strongly interacting Bose- and Fermi-Hubbard physics.

A 15.25 Tue 17:00 Tent A

Quantum Simulations: Towards EIT ground-state cooling of single trapped ions on a surface electrode trap — •Apurba Das, Deviprasath Palani, Florian Hasse, Ole Pikkemaat, Frederike Dörr, Leon Göpfert, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg i. Br.

Tailored trap configurations for individually confined ions, employing both localized and global control fields, allows us to design and fine-tune intricate quantum systems. Two-photon stimulated Raman transition are typically utilized for individual state control and the coupling of internal and external degrees of freedom within our systems. In forthcoming endeavors, the objective is to incorporate ground state cooling via electromagnetically-induced transparency. This broadband cooling method aims to efficiently cool multiple modes to deterministically prepare the system close to its motional ground state. The poster offers an overview of essential technical advancements, recent progress towards experimental quantum simulations.

A 15.26 Tue 17:00 Tent A

Measurements of the Bound Electron g-factor at ALPHATRAP — •Matthew Bohman[1], Athulya George[1], Fabian Heisse[1], Charlotte König[1], Jonathan Morgner[1], Tim Sailer[1], Kunal Singh[1], Bingsheng Tu[1,2], Klaus Blaum[1], and Sven Sturm[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Institute for Modern Physics, Fudan University, Shanghai 200433

ALPHATRAP [1] is a precision Penning-trap apparatus for high-precision measurements on simple atomic systems. Image current detection enables measurement of the motional frequencies of single particles and, when combined with the Larmor frequency, we extract fundamental properties such as bound-state magnetic moments with high precision. Recent measurements of the bound electron magnetic moment in H-like, Li-like, and B-like tin, for example, tested quantum electrodynamics (QED) at extremely high fields with sub-ppb accuracy [2]. Similarly, we developed a technique to measure direct g-factor differences of co-trapped particles at even higher precision. In a measurement with $^{20,22}Ne^{9+}$, the difference of the two bound electron g-factors was measured to sub-ppt accuracy and set competitive bounds on scalar dark matter candidates [3]. We recently upgraded the apparatus and are building a new electron beam ion trap (EBIT) to produce ions at higher charge states, including H-like lead - testing QED and the Standard Model at even more extreme fields.

[1] Sturm, S. et al. Eur. Phys. J. Spec. Top. 227, 14251491 (2019).
[2] Morgner, J., Tu, B., König, C.M. et al. Nature 622, 5357 (2023).
[3] Sailer, T., Debierre, V. et al. Nature 606, 479483 (2022).

A 15.27 Tue 17:00 Tent A

Magnetic field stability in our ion trap and the ion as a quantum sensor — •Ole Pikkemaat, Apurba Das, Deviprasath Palani, Florian Hasse, Leon Goepfert, Frederike Doerr, Ulrich Warring, and Tobias Schaetz — Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Setting up an ion trap includes well-prepared considerations regarding the choice of both magnetic field strength and stability [1]. For a chosen qubit in the ions energy level structure, in general described by the superposition state $|\Phi\rangle = c_1|0\rangle + c_2 e^{i\varphi}|1\rangle$, magnetic field fluctuations destroy the well-defined phase relation φ between the energy level states, leading to loss of coherence, i.e. lower T_2 times. We want to archive an equivalent hybrid $\overrightarrow{B}$-field setup as in [1] to enhance the stability, i.e. to increase T_2 times for the $^{25}Mg^{+}$ ions we are trapping. In the hybrid setup, permanent magnets are used to create a magnetic field of $\simeq$ 109G to permit $\overrightarrow{B}$-field independent transitions. They replace high-current coils, intending to reduce the related heat which causes instability of the magnetic field. In addition, three small coil pairs in a cartesian setup allow changing minor deviations and establishing active stabilization. Next to the characterization of the magnetic field using 'classical' sensors, the ion will be exploited as a quantum sensor to probe the magnetic field directly. Looking forward to future applications of quantum sensors, turning the 'disadvantage' of the qubits being prone to external influences into a feature for excellent sensors. [1] Hakelberg, F. et al. Sci Rep 8, 4404 (2018)

A 15.28 Tue 17:00 Tent A

QRydDemo - A Rydberg Atom Quantum Computer Demonstrator — •Achim Scholz[1,2], Philipp Ilzhöfer[1,2], Ratnesh Kumar Gupta[1,2], Govind Unnikrishnan[1,2], Jiachen Zhao[1,2], Sebastian Weber[3,2], Hans-Peter Büchler[3,2], Simone Montangero[4], Jürgen Stuhler[5], Tilman Pfau[1,2], and Florian Meinert[1,2] — [1]5th Inst. of Physics, University of Stuttgart — [2]IQST — [3]Inst. for Theoretical Physics III, University of Stuttgart — [4]Inst. for Complex Quantum Systems, University of Ulm — [5]TOPTICA Photonics AG

Within the QRydDemo project, our goal is to realize a neutral atom quantum computer setup using strontium Rydberg atoms trapped in optical tweezers. For this platform we demonstrate a novel fine-structure qubit, encoded in the metastable triplet manifold of ^{88}Sr. First measured single-atom Rabi operations implemented via strong two-photon Raman transitions between the qubit states pave the road towards fast single-qubit gates. Aiming towards the realization of high-fidelity two-qubit gates via single-photon Rydberg transitions, we furthermore investigate a triple magic wavelength, for which not only both qubit states but also the Rydberg state is „magically“ trapped.

Our experimental platform is based on a dynamic, two-dimensional tweezer array of up to 500 qubits, generated by a setup of 20 AODs to allow shuffling operations during the qubit coherence time. The atom array is protected by an electric field control with ITO coated windows. To support the hardware we developed a compiler backend tailored to our Rydberg platform. With an available WebUI this allows emulation and future operation of the quantum computer by public access.

A 15.29 Tue 17:00 Tent A

Acceleration-enhanced Coulomb correlations between free electrons in a transmission electron microscope beam — •Lisa Beimel[1,2], Rudolf Haindl[1,2], Sergey V. Yalunin[1,2], Armin Feist[1,2], and Claus Ropers[1,2] — [1]Department of Ultrafast Dynamics, Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Göttingen, Germany

Correlated electrons are at the heart of many phenomena in condensed matter, as well as atomic and molecular physics. Generally, highly correlated free-electron states are of interest both from a fundamental perspective and for their potential in manifold electron beam applications.

For the generation of free electrons, we employ femtosecond-triggered photoemission from a nanoscale Schottky field emitter in an ultrafast transmission electron microscope [1]. When n electrons are generated by the same laser pulse at the emitter, their initially weak inter-particle Coulomb repulsion is acceleration-enhanced to a strong energy exchange of about 2 eV, as confirmed by trajectory simulations. In our experiment, we measure distinct energy correlations in transverse and longitudinal direction of pair, triple and quadruple free-electron states [2].

In this contribution, we will present recent results on the study of free-electron correlations in an electron microscope beam.

[1] A. Feist *et al.*, *Ultramicroscopy* **176**, 63-73 (2017).
[2] R. Haindl *et al.*, *Nat. Phys.* **19**, 1410-1417 (2023).

A 15.30 Tue 17:00 Tent A

Light-induced correlations in cold dysprosium atoms — •Marvin Proske, Ishan Varma, Rhuthwik Sriranga, and Patrick Windpassinger — Institut für Physik, Johannes-Gutenberg-Universität Mainz

When the average atomic distance in a cloud of ultracold atoms, is below the wavelength of the scattering light, a direct matter-matter coupling is introduced by electric and magnetic interactions. This alters the spectral and temporal response of the sample, where the atoms cannot be treated as individual emitters anymore. We intend to experimentally study light-matter interactions in dense dipolar media with large magnetic moments to explore the impact of magnetic dipole-dipole interactions onto the cooperative response of the sample. With the largest ground-state magnetic moment in the periodic table (10 Bohr-magneton), dysprosium is the perfect choice for these experiments.

This poster reports on the progess made in generating extremely dense cold dysprosium clouds. We discuss the measures taken to optically transport the atoms into a home-built science cell, which serves as a highly accessible platform to manipulate the atomic cloud. The small dimensions of the cell allow for extremely tight dipole trapping, enabled by a self-designed high NA objective. Further, we give a perspective on future measurements exploring collective effects in the generated atom cloud.

A 16: Poster II

Time: Tuesday 17:00–19:00 Location: Tent B

A 16.1 Tue 17:00 Tent B

Orientation dependent ionization yield of molecules — •Paul Winter and Manfred Lein — Leibniz University Hannover

The ionization rate and thus the yield is a central property in strong field ionization of molecules. The ionization rate of a diatomic molecule depends on the relative angle between the electric field and the molecular axis at the moment of ionization.

In simulations it is possible to obtain the orientation dependent quasistatic ionization rate by solving the time-dependent Schrödinger Equation (TDSE) with a static electric field for different molecular orientations and analyzing the emerging steady state. In a typical strong-field experiment, however, finite laser pulses are used and the electron yield is measured for a whole pulse, which raises the question whether the quasistatic rates can be accurately measured. Linearly polarized pulses mix the ionization of two opposite directions, thus they cannot reproduce the quasistatic rate. On the other hand, we show that also circularly polarized fields can lead to qualitatively wrong results.

To solve this problem, we propose using two-color ω-2ω fields with either linear or bicircular polarization. To this end, two-dimensional TDSE solutions for HeH^+ are compared for several different field configurations.

A 16.2 Tue 17:00 Tent B

In-trap laser-ablation ion-source for precision magnetic moment measurements — •Ute Beutel[1,2], Stefan Dickopf[1], Annabelle Kaiser[1], Ankush Kaushik[1], Marius Müller[1], Stefan Ulmer[3,4], Andreas Mooser[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Ruprecht-Karls-Universität, Heidelberg, Germany — [3]Institut für Experimentalphysik, Heinrich-Heine-Universität, Düsseldorf, Germany — [4]RIKEN, Wako, Japan

High-precision measurements of magnetic-moments in Penning traps have been performed to great success for various different systems. For example, measurements of the bound-electron g-factor could be used to determine the electron mass [1] and comparisons of the proton and antiproton magnetic moments set bounds on CPT violations [2].

At our experiment, we have performed measurements of the ground-state Zeeman and hyperfine splitting of $^3He^+$ for the determination of the helion magnetic moment [3]. The equivalent measurement on $^9Be^{3+}$ was recently enabled by in-trap laser-ablation. Future measurements on various ions and isotopes require a more versatile in-trap laser-ablation ion-source which is currently being developed. The recent status and ongoing progress will be presented.

[1] S. Sturm *et al.*, Nature 506, 467 (2014)
[2] C. Smorra *et al.*, Nature, Vol 550, 371 (2017)
[3] A. Schneider *et al.*, Nature 606, 878-883 (2022)

A 16.3 Tue 17:00 Tent B

Towards large-area 256-pixel MMC arrays for high resolution X-ray spectroscopy — •A. Abeln, S. Allgeier, D. Hengstler, D. Kreuzberger, D. Mazibrada, L. Münch, A. Orlow, A. Reifenberger, A. Stoll, A. Fleischmann, L. Gastaldo, and C. Enss — Kirchhoff-Institute for Physics, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Metallic Magnetic Calorimeters (MMCs) are energy-dispersive cryogenic particle detectors. Operated at temperatures below 50 mK, they provide very good energy resolution, high quantum efficiency as well as high linearity over a large energy range. In many precision experiments in X-ray spectroscopy the photon flux is small, thus a large active detection area is desirable. Therefore, we develop arrays with increasing number of pixels. For a cost-effective read-out of a growing number of detector channels we investigate different multiplexing techniques.
In this contribution we present a detector setup comprising a novel dense-packed 16×16 pixel MMC array. The pixels provide a total active area of $4\,\mathrm{mm} \times 4\,\mathrm{mm}$ and are equipped with $5\,\mu$m thick absorbers made of gold. This ensures a stopping power of at least 50 % for photon energies up to 20 keV. The expected energy resolution is $\Delta E = 1.4\,\mathrm{eV}$ (FWHM) at an operating temperature of 20 mK. Furthermore the detector setup features 16 in-house made SQUID chips each with 2×4 flux-ramp modulated dc-SQUIDs which enables us to read out 128 detector channels with 32 read-out channels. We present design considerations and discuss the detector performance.

A 16.4 Tue 17:00 Tent B

Production of C^{4+} in an EBIS for collinear laser spectroscopy — •Emily Burbach[1], Phillip Imgram[2], Kristian König[1], Bernhard Maass[1], Patrick Müller[1], and Wilfried Nörtershäuser[1] — [1]Institut für Kernphysik, TU Darmstadt, Germany — [2]Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium

The Collinear Apparatus for Laser Spectroscopy and Applied Science (COALA) at the Technical University of Darmstadt was used to measure the $1s2s\,^3S_1 \rightarrow 1s2p\,^3P_J$ 227 nm transitions of C^{4+} to improve ab-initio atomic structure calculations [1]. To obtain an ion beam suitable for laser spectroscopy, production of C^{n+} in an electron beam ion source (EBIS) was tested with the gases propane (C_3H_8), methane (CH_4) and carbon dioxide (CO_2).

We present results from collinear laser spectroscopy with differently produced continuous and pulsed C^{4+} ion beams. Wienfilter analyses facilitate understanding the ion production processes for different gas compounds.

This project is supported by DFG (Project-ID 279384907 - SFB 1245).

[1] P. Imgram *et al.*, accepted in Phys. Rev. Lett. (2023)

A 16.5 Tue 17:00 Tent B

Further commissioning and upgrades of the ARTEMIS experiment at HITRAP for high-precision g-factor measurements with highly charged ions — •Bianca Reich[1,2], Arya Krishnan[1,3], Johannes Krempel-Hesse[1,4], K Kanika[1], Jeffrey Klimes[1], Kwaish Anjum[1,5], Patrick Baus[1,3], Gerhard Birkl[1,3], Manuel Vogel[1], and Wolfgang Quint[1,2] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, DE — [2]University of Heidelberg, DE — [3]Technical University of Darmstadt, DE — [4]University of Gießen, DE — [5]University of Jena, DE

The ARTEMIS experiment [Quint et al., Phys. Rev. A **78** 032517 (2008)] at GSI aims to measure the g-factor of the electron bound in heavy highly charged ions. Laser-microwave double-resonance spectroscopy is performed on such ions captured and stored inside a dedicated Penning trap [M. Wiesel et al., Rev. Sci. Inst. **88** 123101 (2017)]. First commissioning has demonstrated successful in-trap ion production, storage, selection and cooling [Kanika et al., J. Phys. B **56** 175001 (2023)]. For access to heavy few-electron ions, ARTEMIS is connected to the HITRAP facility via a beamline that features dedicated ion optics, non-destructive ion detectors, and a cryogenic fast-opening valve [Klimes et al., Rev. Sci. Instrum. **94** 113202 (2023)] which keeps the extreme vacuum of the trap stable while allowing access for ions and laser light. This beamline is constantly being upgraded towards efficient and well-controlled ion injection. We present the status and design updates of this beamline and discuss new spectroscopy candidate ions such as boron-like sulfur S^{11+}.

A 16.6 Tue 17:00 Tent B

An upgraded XUV and soft X-ray split-and-delay unit for FLASH1 — •Matthias Dreimann, Michael Wöstmann, and Helmut Zacharias — Center for Soft Nanoscience, Universität Münster, Germany

A split-and-delay unit (SDU) is upgraded that enables time-resolved pump-probe experiments at FLASH1. With the original design first experiments were performed in 2007 and the SDU was permanently incorporated in the BL2 at FLASH1 in 2010. The planned delay range of this device is -1 ps $< \Delta t <$ +10 ps with a subfemtosecond temporal delay. The upgrade will increase the spectral range of the SDU from hν = 30 eV up to hν = 750 eV. Two different coatings are required achieve a high transmission in this spectral range. Therefore, a design that is based on a three dimensional beam path allows choosing the propagation via two sets of mirrors with these coatings. A C coating will allow a total transmission on the order of T > 0.74 for photon energies between hν * 30 eV and hν = 200 eV at a grazing angle of θ = 3.0° in the variable beam path. A Ni coating can be used to cover a range up to hν = 750 eV at a transmission of T > 0.08.

A 17: Poster III

Time: Tuesday 17:00–19:00 Location: Tent C

A 17.1 Tue 17:00 Tent C

Towards a precision measurement of the XUV-clock transition in highly charged lead — •Antonia Schaffert, Marc Botz, Dominic Hache, Moto Togawa, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Highly charged ions provide electronic transitions in all wavelengths, well suited for next-generation atomic clocks. In order to find stable clocks, metastable states at higher photon energies are needed. Recently, such a metastable electronic state has been found in highly charged, Nb-like lead using mass spectrometry in a Penning-trap [1]. Given its short wavelength, it must be examined with XUV frequency combs. Such an experiment would greatly benefit from further improvements in the precision of its known transition wavelength. We therefore present complementary measurements by measuring decay pathways of the metastable state, which is mostly deexcited to a short-lived state before relaxing to the ground state. These transitions and other adjacent transitions have been identified and accurately determined using an Electron Beam Ion Trap equipped with a high-resolution VUV Grating Spectrometer.

[1] Kathrin Kromer, et al., physics.atom-ph 2310.19365 (2023)

A 17.2 Tue 17:00 Tent C

Symmetry based gate design — •Kaloyan Zlatanov and Nikolay Vitanov — Department of Physics, St. Kliment Ohridski University of Sofia, 5 James Bourchier Boulevard, 1164 Sofia, Bulgaria

One of the main goals of contemporary quantum information is to design faster and more robust gates. We explore a Hamiltonian based approach to tackle this problem in which we design an interaction that yields a specific symmetry that allows the reduction of the system to two and three-level sub-systems in which various control techniques like adiabatic excitation, composite pulses or shaped pulses can be implemented. We illustrate this approach with examples in magnetic systems with Dzyaloshinskii-Moriya interaction as well as in ions for the improvment of the Molmer-Sorensen gate.

A 17.3 Tue 17:00 Tent C

Enhancement of Zeptonewton Force Detection with a Single-Ion Nonlinear Oscillator — •Bo Deng[1], Moritz Göb[1], Benjamin A. Stickler[2,3], Max Masuhr[1,4], Daqing Wang[1,4], and Kilian Singer[1] — [1]Institute of Physics, University of Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Institute for Complex Quantum Systems, Ulm University, Albert-Einstein-Allee 11, 89069 Ulm, Germany — [3]Faculty of Physics, University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany — [4]Institute of Applied Physics, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany

Here we present an anharmonic oscillator implemented with a single atomic ion confined in a funnel-shaped potential [1]. The trapped particle experiences a coupling of radial and axial degrees of freedom that introduces nonlinearity to our system. The bifurcation and hysteresis of the resulting Duffing-type response are characterized. We further demonstrate an axial displacement force detection of $\sim$2.4 zN with a 20-fold enhancement using vibrational resonance effect [2]. The ability to conduct non-resonant low-frequency broadband sensing bears relevance for many fundamental physics studies.

[1] J. Roßnagel, S. T. Dawkins, K. N. Tolazzi, O. Abah, E. Lutz, F. Schmidt-Kaler, and K. Singer, A single-atom heat engine, Science 352, 325 (2016).

[2] B. Deng, M. Göb, B. A. Stickler, M. Masuhr, K. Singer, and D. Wang, Amplifying a zeptonewton force with a single-ion nonlinear oscillator, PRL 131, 153601 (2023).

A 17.4 Tue 17:00 Tent C

Towards Quantum Simulations with Strontium Atoms — Thies Plassmann[1,2], Meny Menashes[1], •Leon Schäfer[1], and Guillaume Salomon[1,2] — [1]Institute for Quantum Physics, Hamburg University, Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Center for Ultrafast Imaging, Hamburg University, Luruper Chaussee 149, 22761 Hamburg

Cold atom platforms with single particle/spin detection and control offer fascinating opportunities for emerging quantum technologies. Among quantum simulators trapped atoms in programmable optical tweezer arrays and excited to Rydberg states are nearly ideal systems to study quantum spin models and opens interesting perspectives for quantum computation. Yet, simulating fermions on such systems remains a long-standing goal and the study of three-dimensional problems on arbitrary lattice structures is still to be explored. A complementary platform for quantum simulation is a quantum gas microscope where large atomic clouds are trapped in optical lattices. Whereas quantum statistics and itinerant models are natively implemented in these experiments, the current lack of programmability and long cycle time are limiting their capabilities. Our vision to overcome these challenges in quantum simulation is to combine atom manipulation using optical tweezers with quantum gas microscopy on a unique quantum simulation platform. We report here on the development of such novel quantum simulator operating with strontium with which we aim to study topological phases in three-dimensional frustrated spin systems as well as the SU(N) Fermi-Hubbard model.

A 17.5 Tue 17:00 Tent C

Optimal time-dependent manipulation of Bose-Einstein condensates — •Timothé Estrampes[1,2], Alexander Herbst[1], Annie Pichery[1,2], Gabriel Müller[1], Dennis Schlippert[1], Ernst M. Rasel[1], Éric Charron[2], and Naceur Gaaloul[1] — [1]Leibniz University Hannover, Institut für Quantenoptik, Germany — [2]Université Paris-Saclay, CNRS, Institut des Sciences Moléculaires d'Orsay, France

Quantum sensing experiments benefit from fast Bose-Einstein Condensate (BEC) generation with small expansion energies. Here, we theoretically find the optimal BEC collimation parameters with painted optical potentials to experimentally achieve 2D expansion energies of 438(77) pK taking advantage of the tunable interactions by driving Feshbach resonances and engineering the collective oscillations. Based on these findings and corresponding simulations, we propose a scenario to realize 3D expansion energies on ground below 16 pK, going beyond the experimental state of the art in microgravity [A. Herbst et al., arXiv:2310.04383 (2023)].

Furthermore, we report on current theoretical studies of the dynamics of space single- and dual-BEC experiments including applications in NASA's Cold Atom Lab aboard the International Space Station or the sounding rocket mission MAIUS-2, paving the way for next-generation quantum sensing experiments, including tests of fundamental physics such as Einstein's equivalence principle.

This work is supported by the "ADI 2022" project funded by the IDEX Paris-Saclay, ANR-1-IDEX-0003-02 and the DLR with funds provided by the BMWi under Grant No. CAL-II 50WM2245A/B.

A 17.6 Tue 17:00 Tent C

Spectroscopy laser setup for isotope shift measurement of highly charged xenon — •Ruben B. Henninger, Vera M. Schäfer, Elwin A. Dijck, Christian Warnecke, Stepan Kokh, Lukas F. Storz, Andrea Graf, Thomas Pfieifer, and José R. Crespo López-Urrutia — Max Planck Institut für Kernphysik, Heidelberg

Exploring the potential existence of a fifth force acting between electrons and neutrons, our research focuses on utilizing transitions in highly charged ions (HCI) as sensitive sensors for such forces. Xenon, with its numerous isotopes, emerges as a promising candidate for this investigation. To achieve the precision required to identify new physics narrow-linewidth lasers in the sub-Hertz regime are essential. This poster introduces a spectroscopy laser setup, which will be implemented in the CryPTEx-SC (Cryogenic Paul Trap Experiment - superconducting) experiment to probe these transitions using quantum logic spectroscopy. The system comprises a 1550 nm fibre laser that is locked to a 10 cm ULE reference cavity, along with two tuneable diode lasers that are locked to the fibre laser through a frequency comb. To enable probing times of order seconds, phase-noise cancellation is implemented for several optical fibres.

A 17.7 Tue 17:00 Tent C

Classifying single-shot diffraction images utilizing machine learning — •Hendrik Tackenberg, Paul Tuemmler, Christian Peltz, and Thomas Fennel — Institute for Physics, University of Rostock, Albert-Einstein-Str. 23-24, D-18059 Rostock, Germany

Single-shot coherent diffractive imaging (CDI) at X-ray free-electron lasers (FELs) has evolved into a well-established method for the structural characterization of unsupported nano-objects with targets ranging from superfluid helium droplets to large biomolecules. Expanding the corresponding experimental setup by additional excitation options, such as short pulse lasers, opens up new routes to study structural dynamics on the femtosecond time and nanometer spatial scale. However, in most scenarios, the dynamics of interest significantly depend on parameters varying on a shot-to-shot basis, such as the objects' orientations, sizes, or positions in the FEL focus. A rigorous quantitative analysis, therefore, critically depends on the evaluation of a sufficiently large data set to sample the relevant parameter space. Recording millions of scattering images in a single experiment is not unusual nowadays and calls for advanced analysis strategies like model-based forward fitting and automated data set classification.

Here, we present a machine-learning-based classification approach that we successfully applied to characterize a recent experiment studying the strong-field induced anisotropic nanoplasma expansion of laser-driven SiO_2 nanospheres at the European XFEL.

A 17.8 Tue 17:00 Tent C

Emulating Rydberg Quantum Computers — •Santiago Higuera-Quintero[1], Sebastian Weber[1], Katharina Brechtelsbauer[1], Nicolai Lang[1], Tilman Pfau[2], Florian Meinert[2], and Hans Peter Büchler[1] — [1]Institute for Theoretical Physics III and IQST, University of Stuttgart, 70550 Stuttgart, Germany — [2]5th Institute of Physics and IQST, University of Stuttgart, 70550 Stuttgart, Germany

Modelling noise processes in noisy intermediate-scale quantum (NISQ) devices plays an important role in designing hardware and algorithms in the journey for scalable quantum computers. In this era, classical emulators of quantum systems can help to better understand typical errors in quantum information processing which arise from coupling to the environment and experimental limitations. Furthermore, it can be used to test error correction schemes towards fault-tolerant quantum computation. In this poster, we present the current state of our gate-based emulator of the Rydberg quantum computer of the QRydDemo project. We provide an overview of our online platform that provides users the opportunity to try out the emulator and get familiar with QRydDemo's native gate operations.

A 17.9 Tue 17:00 Tent C

Laser spectroscopy on sympathetically cooled Th^{3+} alpha-recoil ions — •Gregor Zitzer[1], Johannes Tiedau[1], Maksim Okhapkin[1], Ke Zhang[1], Christoph Mokry[2,3], Jörg Runke[2,4], and Christoph E. Düllmann[2,3,4] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Johannes Gutenberg University Mainz, Mainz — [3]Helmholtz Institute Mainz, Mainz — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

The isotope thorium-229 has a first excited state at only about 8 eV which enables excitation by coherent laser radiation. This unique property promises advantages for future versions of optical clocks. The presented setup is dedicated for high-resolution hyperfine spectroscopy of electronic transitions of nuclear ground and isomeric states in $^{229}Th^{3+}$. Here, the actual status and results of sympathetically cooled Th^{3+} ions are demonstrated in an experiment where ^{229}Th and ^{230}Th are extracted from uranium recoil ion sources and cotrapped with laser-cooled $^{88}Sr^{+}$ ions. The absolute frequencies and isotope shifts of the $5F_{5/2} \to 6D_{5/2}$ transition at 690 nm and the $5F_{7/2} \to 6D_{5/2}$ transition at 984 nm of $^{230}Th^{3+}$ are investigated.

A 17.10 Tue 17:00 Tent C

Modeling controlled sub-wavelength plasma formation in dielectrics — •Jonas Apportin, Christian Peltz, Björn Kruse, Benjamin Liewehr, and Thomas Fennel — Institute for Physics, Rostock, Germany

Laser induced damage in dielectrics due to short pulse excitation plays a major role in a variety of scientific and industrial applications, such as the preparation of 3D structured evanescently coupled wave-guides [1] or nano-gratings [2]. The corresponding irreversible material modifications predominantly originate from higher order nonlinearities like strong field ionization and plasma formation, which makes their consistent description imperative for any kind of theoretical modelling aiming at improving user control over these modifications. In particular the associated feedback effects on the field propagation can have drastic implications.

We developed and utilized a numerical model, that combines a local description of the plasma dynamics in terms of corresponding rate equations for ionization, collisions and heating with a fully electromagnetic field propagation via the Finite-Difference-Time-Domain method, adding self-consistent feedback effects like the sudden buildup of plasma mirrors. Here we present recent numerical results regarding the creation and control of sub-wavelength gratings formed at the rear side of pure and gold-coated fused silica films.

[1] L. Englert et al, Opt. Express 15, 17855-17862 (2007)
[2] M. Alameer et al, Opt. Lett. 43, 5757-5760 (2018)

A 17.11 Tue 17:00 Tent C

Towards laser spectroscopy of molecular hydrogen ions in Alphatrap — •K. Singh[1], A. Kulangara Thottungal George[1], C. M. König[1], I. V. Kortunov[2], J. Morgner[1], T. Sailer[1],

V. Vogt[2], M. Bohman[1], F. Heisse[1], B. Tu[1], K. Blaum[1], S. Schiller[2], and S. Sturm[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Institut für Experimentalphysik, Universität Düsseldorf, 40225 Düsseldorf

Optical spectroscopy on trapped molecular hydrogen ions (MHI), e.g. HD^+ and H_2^+, is one of the most sensitive techniques to probe fundamental physics and to extract fundamental constant such as m_p/m_e, perform tests on Quantum Electrodynamics and look for beyond standard model physics [1].
At Alphatrap [2], we can trap single ions for months in our cryogenic Penning trap. Using sensitive image current detection method and the continuous Stern-Gerlach effect [3], we have recently performed millimeter-wave spectroscopy on the molecular hyperfine structure of HD^+ and we plan to perform optical spectroscopy of the rovibrational structure in HD^+ and H_2^+. The techniques developed here are suitable to be directly applied to the antihydrogen molecular ion $\bar{H}_2^-$ in the future for stringent CPT tests [4]. We will present an overview of the trap and future plans for the laser spectroscopy of MHI at Alphatrap.

[1] S. Schiller, Contemporary Physics **63** (4), 247-279 (2022)
[2] S. Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 1425-1491 (2019)
[3] H. Dehmelt, Proc. Natl. Acad. Sci. USA **83**, 2291 (1986)
[4] E. Myers, Phys. Rev. A **98**, 010101(R) (2018)

A 17.12 Tue 17:00 Tent C

Emergence of Synchronisation in a Driven-Dissipative Hot Rydberg Vapour — •Karen Wadenpfuhl[1,2] and C. Stuart Adams[1] — [1]Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, Durham, DH1 3LE, United Kingdom — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Continuously driven, non-linear systems show interesting behaviours such as bistability and self-oscillations. An interesting question regards the interplay of many self-oscillating entities with coupled dynamics due to an interaction between the individual oscillators. A collective response of a self-oscillating ensemble has been observed in e.g. the applause of audiences, and is theoretically understood within the framework of synchronisation.

Recently, we have observed the emergence of synchronisation in a driven-dissipative hot Rydberg vapour [1]. Synchronisation occurs in a strongly-driven three-level ladder scheme in Rb where we couple the intermediate $5P_{3/2}$ state to a Rydberg state. The synchronised state manifests as oscillations of the transmission of the probe beam through the atomic vapour. The wide tunability of the system parameters as well as fast oscillation frequencies on the order of 10 kHz allow for an exploration of the synchonisation transition over a large parameter space and with many ciooupled oscillators.

[1] K. Wadenpfuhl and C. S. Adams, Emergence of Synchronization in a Driven-Dissipative Hot Rydberg Vapor, PRL 131, 143002 (2023)

A 17.13 Tue 17:00 Tent C

Ab initio MCDHF calculations of transition rates and energy levels of Lr I — •Joseph Andrews[1], Jon Grumer[2], Per Jönsson[3], Jacek Bieroń[4], and Stephan Fritzsche[1,5,6] — [1]Friedrich-Schiller-Universität, Jena, Germany — [2]Uppsala universitet, Uppsala, Sweden — [3]Malmö universitet, Malmö, Sweden — [4]Uniwersytet Jagielloński, Krakow, Poland — [5]Helmholtz-Institut, Jena, Germany — [6]GSI, Darmstadt, Germany

Lawrencium (Z=103), is the heaviest actinide and heaviest element prior to the superheavy region, residing at the forefront of atomic and nuclear physics research. However few experimental results exist for it and theoretical results differ from each other [Phys. Rev. A 104, 052810 (2021), Eur. Phys. J. D 45, 107 (2007)]. To assist their search, experimentalists require precise calculations of transitions with a high Einstein coefficient A. Calculations were initially performed on its lighter homologue Lutetium where experimental results exist to determine the predictive accuracy of our model. Energy levels, transition rates and Landé g-factors of Lr I and Lu I are investigated using the multiconfigurational Dirac-Hartree-Fock (MCDHF) method. Results of both neutral atoms are presented and compared to previous calculations and experiments. Previous calculations of Lr with MCDHF may be considered unreliable due to the small number of correlation orbitals being used, thus it is unclear whether convergence was reached. We report more reliable values than previous MCDHF calculations of the energy levels and Landé g-factors of the $7s^28s\ ^1S_0$, $7s^27p\ ^2P_{1/2,3/2}$, $7s^27d\ ^2D_{3/2,5/2}$ levels and the corresponding transition rates.

A 18: Attosecond Physics II / Interaction with VUV and X-ray Light (joint session A/MO)

Time: Wednesday 11:00–13:00 Location: HS 1010

Invited Talk A 18.1 Wed 11:00 HS 1010

Attosecond photoionization dynamics in CO_2 using coincidence spectroscopy — •Ioannis Makos[1], David Busto[1,2], Dominik Ertel[1], Jakub Benda[3], Barbara Merzuk1[1], Fabio Frassetto[4], Luca Poletto[4], Claus Dieter Schröter[5], Thomas Pfeifer[5], Zdeněk Mašín[3], Serguei Patchkovskii[6], and Giuseppe Sansone[1] — [1]Albert-Ludwigs-Universität Freiburg, Germany — [2]Lund University, Sweden — [3]Charles University, Prague, Czech Republic — [4]IFN-CNR, Padova, Italy — [5]MPIK, Heidelberg, Germany — [6]MBI, Berlin, Germany

Attosecond photoelectron interferometry is used to investigate molecular dynamics upon photoionization, revealing electron correlation effects and electron-nuclear motions interplay. Combining two-color interferometric methods with photoelectron-photoion coincidence spectroscopy enables angle-resolved studies in the recoil frame, providing insights into molecular potential anisotropy. In our study, we investigate carbon dioxide photoionization dynamics using attosecond coincidence spectroscopy. Absorption of an extreme ultraviolet photon, provided by an attosecond pulse train, leads to a superposition of cationic states, coupled to the photoelectron wave packet. Additional infrared photon absorption or emission forms a two-color photoelectron spectrogram. Our work presents CO_2 photoionization time delays, considering the impact of field-induced coupling of ionization channels. Furthermore, we show time-resolved photoelectron angular distributions in the recoil frame by measuring ejected electrons in coincidence with O^+ dissociation fragments.

A 18.2 Wed 11:30 HS 1010

Investigation of Correlated Electronic Dynamics by Nonlinear Attosecond Spectroscopy — •Samuel Kellerer[1], Ioannis Makos[1], Dominik Schomas[1], David Busto[2], Dominik Ertel[1], Robert Moshammer[3], Claus Dieter Schröter[3], Thomas Pfeifer[3], Arjun Nayak[4], Debobrata Rajak[4], Naveed Ahmed[4], Sourin Mukhopadhyay[4], Tamás Csizmadia[4], Balázs Nagyillés[4], Zsolt Divéki[4], Katalin Varjú[4], Jörn Adamczewski-Musch[5], Fabio Frassetto[6], Luca Poletto[6], Paraskevas Tzallas[7], Dimitris Charalambidis[7], and Giuseppe Sansone[1] — [1]Uni Freiburg — [2]Uni Lund — [3]MPIK Heidelberg — [4]ELI ALPS Szeged — [5]GSI Darmstadt — [6]CNR-IFN Padova — [7]IESL-FORTH Hellas

The investigation of ultrafast processes like electronic dynamics in small quantum systems demands for generation and control of laser pulses with durations comparable or even shorter than the timescale of the investigated processes. Combining an attosecond source and a photoelectron/photoion coincidence spectrometer offers the possibility to investigate in detail the photoionization process, returning information on the role played by electronic correlation in multiple ionization of atoms. Despite its conceptual simplicity, the study of the two-photon double-ionization process in helium presents formidable experimental challenges, which we plan to address using the intense attosecond pulses provided by the SYLOS laser system available at ELI ALPS. We will present the attosecond beamline and the photoelectron/photoion apparatus used as an end-station for coincidence spectroscopy as well as first results.

A 18.3 Wed 11:45 HS 1010

Extracting relative dipole moments from a laser-driven two-electron wave packet in helium by combining attosecond streaking and transient absorption spectroscopy — •Shuyuan Hu, Yu He, Gergana D. Borisova, Maximilian Hartmann, Paul Birk, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, 69117 Heidelberg

The electronic structure of atoms and their interaction with light is reflected in complex-valued transition-matrix elements that have a magnitude and phase. In this work, a state-resolved phase of the time-delay dependent modulation of absorption is used to determine the relative signs of transition dipole matrix elements. This measurement relies on precise absolute calibration of the time-delay information, which is achieved by combining attosecond transient absorption and attosecond streaking spectroscopy to simultaneously measure the resonant photoabsorption spectra of laser-coupled doubly excited states in helium, together with the streaked photoelectron spectra. The streaking measurement reveals the absolute time delay zero and the full temporal profile of the interacting electric fields which is then used for a time-dependent few-level simulation of the relevant states. By comparing the 1-fs time-scale modulations across the $2s2p$ (^1P) and $sp_{2,3+}$ (^1P) states between the time-delay calibrated simulation and measurement, we quantify the signs of the transition dipole matrix elements for the laser-coupled autoionizing states $2s2p$-$2p^2$ and $2p^2$-$sp_{2,3+}$ to be opposite of each other.

A 18.4 Wed 12:00 HS 1010

Driving the high harmonic process using a multi-pass cell — •Benjamin Steiner[1], Dominik Ertel[1], Dennis Groschupf[1], Anne-Lise Viotti[2], Mario Niebuhr[1], Barbara Merzuk[1], David Busto[1,2], Ioannis Makos[1], and Giuseppe Sansone[1] — [1]Institute of Physics, University of Freiburg, Freiburg, Germany — [2]Division of Atomic Physics, Lund University, Sweden

The investigation of electronic-correlation driven processes, such as the Auger decay in krypton [1] or single-photon double-ionisation in helium [2], requires photon energies of 100 eV or higher. Using electron-electron-ion coincidence and attosecond pulses in the XUV spectral range obtained by high-order harmonic generation (HHG), these processes can be resolved in time in a pump-probe scheme. The first challenge is to demonstrate an attosecond source operating at high repetition rates (>50kHz) characterised by a cut-off energy well above 100 eV. For this purpose, we developed a temporal pulse compression scheme based on a gas-filled multi-pass cell for high-power throughput driven by a commercially available Yb-based laser system. The achieved pulses lead to high enough peak intensities for driving the HHG process in neon efficiently, maintaining a sufficient photon flux in the desired energy range. The generated attosecond XUV pulses will then be employed in the already existing attosecond coincidence spectrometer in Freiburg [3] for time-resolved investigations of electron dynamics occurring during the above-mentioned processes.

[1] M. Drescher et al, Nature, 419 (2002) [2] C. Ott et al, Nature, 516 (2014) [3] D. Ertel et al, Rev. Sci. Instrum. 94, 073001(2023)

A 18.5 Wed 12:15 HS 1010

Polarization dependence of high-order harmonic generation in the direct measurement of optical waveforms — •Ronak Narendra Shah[1], Jahanzeb Muhammad[1], Ianina Kosse[1], Samuel Bengtsson[2], Riccardo Mori[1], Mario Niebuhr[1], Fabio Frassetto[3], Luca Poletto[3], and Giuseppe Sansone[1] — [1]Physikalisches Institut, Albert-Ludwigs Universitaet Freiburg, Freiburg, 79104, Germany — [2]Department of Physics, Lund University, PO Box 118, SE-221 00 Lund, Sweden — [3]Istituto di Fotonica e Nanotecnologie, CNR, Padova, Italy

We present the polarization effects in an all-optical technique to measure the electric field of a few cycle laser pulse via high harmonic generation (HHG). In our approach, the generation of an isolated attosecond pulse (IAP) and the associated photon yield serves as an ultrashort temporal gate to characterize the electric field of a weak perturbing unknown pulse. Changing the polarization of the unknown laser pulse from parallel to orthogonal polarization with respect to the pulse generating IAP, we report the modulation in the harmonic yield at twice the laser period. The experimental results are in good agreement with simulations based on the strong-field approximations.

A 18.6 Wed 12:30 HS 1010

Towards AI-enhanced online-characterization of ultrashort X-ray free-electron laser pulses — •Thorsten Otto[1,2,4], Kristina Dingel[2], Lars Funke[3], Sara Savio[3], Lasse Wülfing[3], Bernhard Sick[2], Wolfram Helml[3], and Markus Ilchen[4] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]Intelligent Embedded Systems, University of Kassel, Wilhelmshöher Allee 73, 34121 Kassel, Germany — [3]Technische Universität Dortmund, Fakultät für Physik, Maria-Göppert-Mayer-Straße, 44227 Dortmund, Germany — [4]Universität Hamburg, Institut für Experimentalphysik, Luruper Chaussee 149 22761 Hamburg

X-ray free-electron lasers provide ultrashort X-ray pulses with durations typically in the order of femtoseconds, but recently even entering the attosecond regime. The technological evolution of XFELs towards well-controllable light sources for precise metrology of ultrafast processes can only be achieved using new diagnostic capabilities for characterizing X-ray pulses at the attosecond frontier. The spectroscopic technique of photoelectron angular streaking has successfully proven how to non-destructively retrieve the exact time-energy structure of XFEL pulses on a single-shot basis. By using deep learning algorithms, we show how this technique can be leveraged from its proof-of-principle stage towards routine diagnostics at XFELs providing precise feedback in real time.

A 18.7 Wed 12:45 HS 1010

Angular Streaking at 1030 nm – measurement of gigawatt-power attosecond pulses at European XFEL — •Lars Funke[1], Sara Savio[1], Lasse Wülfing[1], Niclas Wieland[1], Kristina Dingel[4], Torsten Otto[2], Ruda Hindriksson[4], Lutz Marder[4], Christopher Passow[2], Rebecca Boll[3], Alberto De Fanis[3], Simon Dold[3], Tommaso Mazza[3], Dirk Raiser[3], Michael Meyer[3], Terence Mullins[3], Markus Ilchen[5], and Wolfram Helml[1] — [1]Technische Universität Dortmund, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]European XFEL GmbH, Schenefeld, Germany — [4]Universität Kassel, Germany — [5]Universität Hamburg, Germany

Angular Streaking can be used as a method for characterizing ultrashort X-ray pulses by overlapping the pulse with a circularly polarized IR laser pulse in a gaseous target. Photoelectron momenta are shifted in a characteristic way for a given spectro-temporal X-ray pulse structure. Measuring the photoelectron energy spectra with multiple time-of-flight spectrometers allows the reconstruction of pulse structure.

A *Cookiebox*-type photoelectron spectrometer array was set up at the SQS instrument of European XFEL to characterize specially tuned sub-femtosecond soft X-ray FEL pulses.

In the measurement, we found intense attosecond X-ray pulses, with pulse durations on the order of 300 as and a peak power in the hundreds of gigawatts. The lower-than-planned streaking laser wavelength of 1030 nm turned out beneficial for characterizing the ultrashort pulses provided.

A 19: Precision Spectroscopy of Atoms and Ions II (joint session A/Q)

Time: Wednesday 11:00–13:00 Location: HS 1098

A 19.1 Wed 11:00 HS 1098

An ultra stable dc voltage source for ion trap experiments — •Dina-C. Rensink[1], Peter Micke[2,5], Markus Wiesinger[2], Christian Will[2], Hüseyin Yildiz[1], Christian Smorra[1,4], Jochen Walz[1,3], and Stefan Ulmer[6,4] — [1]Johannes Gutenberg-Universität Mainz — [2]Max-Planck-Institut für Kernphysik, Heidelberg — [3]Helmholtz-Institut Mainz — [4]RIKEN, Wako, Japan — [5]Helmholtz-Institut Jena — [6]Heinrich-Heine-Universität Düsseldorf

Highly stable voltages are crucial for precision ion traps. We are developing and characterizing a suitable voltage source for the BASE (Baryon-Antibaryon Symmetry Experiment) collaboration at CERN, which operates several Penning traps. These precision traps are used to perform test of the fundamental symmetry (CPT) between matter and antimatter with (anti-)protons, for instance via comparison of the g-factors. The determination of these quantities requires several frequency measurements whose precision can be limited by the stability of the voltages which bias the trap electrodes.

For this purpose, one ultra-stable LTZ1000 voltage reference and five 20 bit DACs have been combined into a programmable 5-channel voltage source. This scalable setup aims at long-term stability, low temperature drift, μV resolution over a $\pm$ 10 V range, and an output current of up to 20 mA per channel. Prior tests with a 2-channel prototype indicate a fractional stability of $< 5\cdot 10^{-8}$ at $\tau = 10^2...10^3$ s (at

7 V). The status of the project will be presented and the performance of the voltage source will be discussed.

A 19.2 Wed 11:15 HS 1098

Atomic level search in lawrencium — •Elisabeth Rickert for the Lawrencium-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — Johannes Gutenberg-Universität Mainz, 55128 Mainz,Germany — Helmholtz-Institut Mainz, 55128 Mainz, Germany

The study of the electronic shell structure of the heaviest elements is a challenging endeavour. A strong influence of relativistic effects, electron-electron correlations, and QED effects, challenge the prediction of the atomic structure. The experimental investigation of elements beyond Z=100 is further complicated by their limited availability and short half-lives as well as their experimentally unknown atomic level structure. Recent laser spectroscopy on nobelium (Z=102) in single-atom-at-a-time quantities with the RAdiation Detection Resonance Ionization Spectroscopy (RADRIS) technique opened the path towards laser spectroscopy experiments of yet heavier elements. For the heaviest actinide, lawrencium (Z=103), two ground-state transitions to the $^2S_{1/2}$ state at around 20420 cm^{-1} and to the $^2D_{3/2}$ state at around 28500 cm^{-1}, are predicted. In 2020 and 2022, over 1000 cm^{-1} around the predicted tranisition wavenumbers have been scanned to search for these transitions. In the talk, the current status of the experiment and the data analysis will be presented.

A 19.3 Wed 11:30 HS 1098

Nuclear Deformation Effects of Highly Charged Ions — •Zewen Sun, Igor A. Valuev, and Natalia S. Oreshkina — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Nuclear shape effects are theoretically investigated in terms of corrections to the electronic binding and transition energies and g factors. The corrections are numerically calculated for the widest possible range of nuclei, consisting over 1100 different samples. By solving the Dirac equation with deformed and non-deformed nuclear shapes, i.e. Fermi and deformed Fermi nuclear charge distributions, we separate the deformation effect in binding energies and wavefunctions. The model parameters for the two charge distributions are determined from experimental data. In addition, the importance of deformation effects for the process of searching for new physics is examined.

A 19.4 Wed 11:45 HS 1098

Towards a direct high-precision measurement of the nuclear magnetic moment of^{3}He^{2+} with 1ppb accuracy. — •Ankush Kaushik[1], Stefan Dickopf[1], Marius Müller[1], Annabelle Kaiser[1], Ute Beutel[1], Stefan Ulmer[2,3], Andreas Mooser[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]RIKEN, Wako, Japan — [3]HHU Düsseldorf, Germany

Accurate magnetic field measurements are of apparent importance in the field of fundamental physics [1]. However, the accuracy of the current standard in magnetometry, water NMR probes, is limited by the complex molecular structure. With a direct parts-per-billion measurement of the nuclear magnetic moment of ^{3}He^{2+} in a Penning trap, we aim to overcome this limitation and establish hyperpolarised ^{3}He probes as the new standard. To this end, spin flips of a single nucleon, indicated by miniature frequency changes, need to be detected over background of frequency fluctuations. Since the latter fluctuations are directly proportional to the motional energy, preparing particles at micro eV energies is essential [2]. To address this constraint we designed a new type of Penning trap that enables fast energy measurements while simultaneously allowing the efficient preparation of particles at the required energies. As such, the new trap will be a key element for a successful measurement. Its design and expected performance will be presented.

[1] Mooser *et al.*, J. Phys.: Conf. Ser. 1138 012004 (2018)
[2] Ulmer *et al.*, Physical Review Letters, 106(25) 253001 (2011)

A 19.5 Wed 12:00 HS 1098

Characterization of an XUV Frequency Comb by Spectroscopy of Rydberg States — •Lennart Guth, Jan-Hendrik Oelmann, Tobias Heldt, Nick Lackmann, Janko Nauta, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We aim to exploit ultra-narrow transitions in highly charged ions (HCIs) for novel frequency standards and fundamental physics studies. Due to the strong binding of electrons to the nucleus, these transitions are in the extreme ultraviolet (XUV), where narrow-bandwidth laser sources are not commercially available. Therefore, we have built an XUV frequency comb that transfers the coherence of a near-infrared (NIR) comb to the XUV by high harmonic generation (HHG) [1]. To achieve the required intensity ($I_{peak} > 10^{13}$ W/cm^2) for HHG, we amplify an NIR comb to 80 W in a chirped pulse fiber amplifier and resonantly overlap them in a passive femtosecond enhancement cavity. Our system generates harmonics up to 40 eV and with μW of power each.

We will give an overview of the current status of our experiment and discuss our plans for resonance-enhanced two-photon ionization to resolve the XUX-comb structure. In our spectroscopy approach, we excite argon with one photon from a referenced comb tooth of the 13$^{\text{th}}$ harmonic, followed by ionization with a narrow-bandwidth NIR cw-laser. We record the momentum of the released electrons using the velocity map imaging technique to ensure the correct Rydberg state.

[1]J. Nauta et al., Opt. Lett. 45, 2156-2159 (2020)

A 19.6 Wed 12:15 HS 1098

A Cryogenic Paul Trap Experiment for Laser Spectroscopy of the ^{229m}Th Nuclear Clock Isomer — •Kevin Scharl[1], Georg Holthoff[1], Mahmood I. Hussain[1], Markus Wiesinger[1], Daniel Moritz[1], Lilli Löbell[1], Tamila Rozibakieva[1], Sandro Kraemer[1,2], Benedict Seiferle[1], Shiqian Ding[3], Florian Zacherl[1], and Peter G. Thirolf[1] — [1]LMU Munich — [2]KU Leuven, Belgium — [3]Tsinghua University, Beijing, China

^{229}Th plays a unique role in the nuclear landscape because of its low-lying isomeric first excited state at 8.338 ± 0.024 eV, thus accessible via modern VUV-laser systems. A nuclear clock based on the thorium isomer holds promise not only to push the limits of high-precision time keeping, but also to contribute to dark matter and other fundamental physics research as a novel type of quantum sensor.

The cryogenic Paul trap experiment currently operated at the LMU Munich is primarily designed for long ion storage times, which allows to measure the still unknown ionic lifetime of the isomer. This quantity is expected to be several thousands of seconds and is essential for the realization of a nuclear frequency standard. In a second step, the setup will be a platform for VUV spectroscopy of the isomer, paving the way towards a first nuclear clock prototype.

In this talk, the building blocks of the experimental setup for trapping and sympathetic laser cooling of ^{229}Th^{3+} by ^{88}Sr$^+$ are presented and the status of first preparatory measurements is discussed.

This work was supported by the European Research Council (ERC) (Grant agreement No. 856415) and BaCaTec (7-2019-2).

A 19.7 Wed 12:30 HS 1098

Tests of QED with hydrogenlike helium and tin ions and high-precision theory of the bound-electron g-factor — •Bastian Sikora, Vladimir A. Yerokhin, Zoltan Harman, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

The g-factor of electrons bound in hydrogenlike ions can be measured and calculated with high accuracy. In recent collaborations, the experimental and theoretical g-factors of the bound electron in hydrogenlike ^{3}He$^+$ and ^{118}Sn^{49+} ions were found to be in excellent agreement [1,2]. We present the theory of the bound-electron g-factor of hydrogenlike ions, as well as the status of two-loop QED calculations aimed to improve the uncertainty of theoretical bound-electron g-factors in the high-Z regime [3]. Such calculations will enable improved tests of QED in planned experiments in the near future and are relevant for the determination of fundamental constants such as the electron mass or the fine-structure constant α as well as searches for physics beyond the standard model.

[1] A. Schneider, B. Sikora, S. Dickopf, et al., Nature **606**, 878 (2022)
[2] J. Morgner, B. Tu, C. M. König, et al., Nature **622**, 53 (2023)
[3] B. Sikora, V. A. Yerokhin, N. S. Oreshkina, et al., Phys. Rev. Research **2**, 012002(R) (2020)

A 19.8 Wed 12:45 HS 1098

Ionization potential evaluation by Rydberg analysis in iron with resonance ionization spectroscopy — •Thorben Niemeyer[1], Sebastian Berndt[1], Christoph E. Düllmann[1,2,3], Tom Kieck[2,3], Jung-Bog Kim[4], Nina Kneip[5], Dominik Studer[1], and Klaus Wendt[1] — [1]Johannes-Gutenberg-Universität, Mainz — [2]GSI Zentrum für Schwerionenforschung, Darmstadt — [3]Helmholtz-Institut, Mainz — [4]Korea National University of Education, Cheongju — [5]Leibniz Universität, Hannover

The energetic position of high-lying Rydberg levels and their convergence limit, defining the ionization potential (IP), are characteristic properties for every element and give insights into its specific atomic structure. As a well suited technique, Resonance Ionisation Mass Spectrometry was applied to develop a new two-step ionization scheme in the atomic spectrum of iron using ti:sa lasers, involving frequency doubling and trippling. Literature data is complemented by numerous newly found even parity Rydberg levels. The IP, obtained through the Rydberg-Ritz formalism, is in perfect agreement with the literature value, which was obtained by three-step resonance ionization with similar precision. This confirms the independence of the IP from parity. A number of Rydberg series above the IP converging to higher-lying continua of the Fe ion were measured and analysed.

The set of data provides the basis for applying RIMS to the EU PrimA-LTD project, for which radioactive Fe-55 ions are implanted into metallic magnetic microcalorimeters for precision studies on the electron-capture decay of this isotope.

A 20: Fermionic Quantum Gases I (joint session Q/A)

Time: Wednesday 11:00–13:00 Location: HS 1199

A 20.1 Wed 11:00 HS 1199

Bulk-boundary correspondence for anomalous Floquet topological insulators: winding number and micromotion area — •Luca Asteria[1,2], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]Institut for Quantum Physics, Hamburg University — [2]Hamburg Centre for Ultrafast Imaging — [3]Center for Optical Quantum Technologies, Hamburg University

Driven Floquet systems can realize topological phases with no static counterparts. So-called anomalous Floquet topological insulators (AFTIs) break the bulk-boundary correspondence based on the Chern number. The winding number, which predicts the number of edge modes instead, is calculated from the time evolution operator of the bulk states within one driving period. While in non-driven system the Chern number also predicts the quantization of the transversal Hall conductance in the systems bulk, for AFTIs so far, no dynamical bulk observable directly connected to the winding number was identified. Here we show that the winding number is directly connected to such an observable, namely the area enclosed by an initially localized particle during a Floquet period. In particular, in the associated fine-tuning limit of the Floquet protocol, we show that the winding number is exactly given by this area in units of half the unit cell area. Such a direct real-space detection of anomalous topology could be realized in several quantum simulation platforms. We also show how, by choice of the associated fine-tuning protocol, the number and the speed of coexisting edge modes could be arbitrarily tuned, which may be of relevance for quantum information and communication applications.

A 20.2 Wed 11:15 HS 1199

Bosonization analysis for a ring of SU(N) fermions with a single impurity — •Andreas Osterloh[1], Wayne Chetcuti[1], Juan Polo[1], and Luigi Amico[1,2] — [1]Technology Innovation Institute, Masdar City & Yas Island, P.O. box 9639 Abu Dhabi, UAE — [2]Dipartimento di Fisica e Astronomia Ettore Majorana, Via S. Sofia 64, 95127 Catania, Italy

We are using a bosonization analysis for handling a ring lattice carrying SU(N) fermions. Similar as for bosons, the impurity results in a boundary sine-Gordon field theory. Their effect on the charge and SU(N)-spin parts of the fields is analyzed and the charge-current is calculated. Its interconnection with the observed fractionalization results is discussed in detail.

A 20.3 Wed 11:30 HS 1199

Heidelberg Quantum Architecture: Fast and modular programmable quantum simulation — •Tobias Hammel[1], Maximilian Kaiser[1], Philipp Preiss[2], Matthias Weidemüller[1], and Selim Jochim[1] — [1]Physikalisches Institut, Heidelberg, Germany — [2]MPQ, Garching, Germany

Heidelberg Quantum Architecture (HQA) is a new ^{6}Li quantum gas experiment providing a fast, versatile, and expandable platform for programmable quantum simulation. In this talk, we report on the realization of these characteristics in our new ^{6}Li experiment and first experimental findings.

Key components of the experiment are easily exchangeable optical modules, which include tweezers, a Digital Mirror Device, optical dipole traps, a tuneable 2D confinement and single atom and spin resolved imaging. Our broad and easy to expand toolbox will enable experimental cycles of up to 10Hz in the near future and allow for fast data collection and on-demand quantum simulation.

The current status of the experiment features a 2D-MOT with loading rates of larger than 10^8atoms/s loaded into a 3D-MOT. From there the atoms are loaded via two optical dipole traps into a tweezer, in which we can rapidly evaporate down to degeneracy.

A 20.4 Wed 11:45 HS 1199

Emergence of a collective excitation in a mesoscopic Fermi gas — •Johannes Reiter, Philipp Lunt, Paul Hill, Maciej Galka, and Selim Jochim — Physikalisches Institut, Univeristät Heidelberg, 69120 Heidelberg, Deutschland

Understanding the elementary excitations of strongly interacting many-body systems in terms of the independent motion of individual particles and their collective behaviour constitutes a pervasive problem in many fields ranging from nuclear physics to cold atoms [1,2].

In this talk, we present the spectroscopic observation of the emergence of the radial quadrupole mode from the confinement dominated excitation spectrum in a mesoscopic Fermi gas trapped in an optical tweezer. By systematically tuning the interparticle interactions across the BEC-BCS crossover we investigate the stability of the mode against single particle excitations and showcase the measurement of its coherent properties. Finally, we discuss the prevailing competition between the confinement and interaction energy delineating constraints on the manifestation of collective behaviour in finite-size quantum systems.

[1] B. Mottelson, Science 193 (4250), 287-294 (1976) [2] S. Giorgini et al., Rev.Mod.Phys. 80, 125 (2008)

A 20.5 Wed 12:00 HS 1199

Observation of pairing in a strongly correlated few-fermion system — •Carl Heintze, Sandra Brandstetter, Karen Wadenpfuhl, Philip Lunt, Keerthan Subramanian, Marvin Holten, Maciej Galka, and Selim Jochim — Universität Heidelberg

Strong correlations and entanglement are crucial for many phenomena of modern physics as high temperature superconductivity and the expansion of the early universe. They pose a challenging task for theorists and experimentalists. We address this problem with few body systems of up to 12 particles. They are large enough to build up complex correlations but are experimentally well controlled, allowing us to extract microscopic observables as atom-atom correlations [1]. We work with quasi 2D systems which are prepared in their quantum mechanical ground state with fixed atom number. We use two different matterwave magnification techniques to measure the momentum or position of every single particle in a spin-resolved way. Recently we observed hydrodynamic behaviour in an expanding few particle system accompanied by the formation of atom pairs [2]. As a next step we aim to gain a deeper understanding of pairing by studying real space correlations in the trapped system. Additionally, we want to use RF-spectroscopy to extract the energy spectrum [3]. In the future we want to measure the contact, prepare repulsively interacting systems and observe interference of identical few body systems.

[1] Holten et al. Nature 606 (2022) [2] Brandstetter et al. arXiv: 2308.09699v1 [cond-mat.quant-gas] [3] Wenz et al. Science 342 (2013)

A 20.6 Wed 12:15 HS 1199

Realisation of a two-particle Laughlin state with rapidly rotating fermions — •Paul Hill[1], Philipp Lunt[1], Johannes Reiter[1], Maciej Galka[1], Philipp Preiss[2], and Selim Jochim[1] — [1]Physikalisches Institut Heidelberg — [2]Max-Planck-Institut für Quantenoptik

The fractional quantum Hall (FQH) effect features remarkable states that due to their strongly correlated nature and exotic topological properties have stimulated a rich body of research going far beyond the condensed matter community, where the effect was originally discovered. One fundamental class of FQH states is described by the celebrated Laughlin wavefunction, which accounts for a large number of plateaus in the Hall resistivity and already exhibits interesting anionic, fractionally charged quasi-particle excitations.

Here we present the direct realisation of the two-particle Laughlin wavefunction by rapid rotation of two interacting spinful fermions in a tight optical tweezer. We owe this result to our newly established experimental tools allowing us to precisely shape and modulate our optical potentials using coherently interfering laser fields.

Our observations reveal distinctive features of the Laughlin wavefunction, including a ground state distribution in the center-of-mass motion, a vortex distribution in the relative motion, correlations in the relative angle of the two particles, and the suppression of interparticle interactions. This achievement represents a significant step towards scalable experiments, enabling the atom-by-atom assembly of fermionic fractional quantum Hall states in quantum simulators.

A 20.7 Wed 12:30 HS 1199

Imaging strongly correlated states of the Fermi-Hubbard model — •Petar Bojović[1,2], Thomas Chalopin[1,2], Dominik Bourgund[1,2], Si Wang[1,2], Titus Franz[1,2], Johannes Obermeyer[1,2], Timon Hilker[1,2], and Immanuel Bloch[1,2,3] — [1]Max Planck Institute of Quantum Optics — [2]Munich Center for Quantum Science and Technology — [3]Ludwig Maximilian University

The Fermi-Hubbard model is a simple yet powerful model that captures much of the essential physics of high-Tc superconductors. It is naturally realized in our Quantum Gas Microscope, where we load fermionic 6Li atoms into optical lattices and conduct site-resolved measurements of their spin and density. Our experiment serves as a powerful tool to explore quantum phases of a Fermi Hubbard diagram.

An example is the pseudogap phase, which exists above the superconducting transition temperature and is suggested to result from preformed dopant pairs. Our experiment allows us to calculate two-point and multi-point correlation functions between spins and/or dopants and explore the phase diagram. Higher-order correlators directly reveal intriguing features about the interaction of dopants or excitations with the antiferromagnetic background.

Here, I will present measurement of multi-point spin and charge correlators as a function of doping and temperature. We observe significant higher order correlations at low temperature and close to half filling, signaling the emergence of strongly correlated states. This formalism opens a new outlook to the characterization of the real-space and low temperature states of the Fermi-Hubbard model.

A 20.8 Wed 12:45 HS 1199

Exploring stripe phase in Fermi-Hubbard model with a quantum gas microscope — •Si Wang[1,2], Dominik Bourgund[1,2], Thomas Chalopin[1,2], Petar Bojović[1,2], Titus Franz[1,2], Sarah Hirthe[4], Immanuel Bloch[1,2,3], and Timon Hilker[1,2] — [1]Max-Planck Institute of Quantum Optics, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany — [3]Ludwig Maximilian University of Munich, Munich, Germany — [4]ICFO - The Institute of Photonic Sciences, Castelldefels, Spain

The Fermi-Hubbard model is crucial for understanding physics in quasi 2D layers of high-Tc cuprate superconductors. Investigating the profound connection between d-wave superconductivity and stripes, essential elements in cuprate ordered phases, promises valuable insights. In the isotropic Fermi-Hubbard model, the interplay between the kinetic energy of the dopants and the magnetic energy of the AFM spin order governs the system and reduces the energy scale for stripe order well beyond the reach of state-of-the-art cold-atom quantum simulators. To address this, we engineered a mixed-dimensional system, selectively suppressing particle tunneling along one direction while maintaining 2D spin interactions. This innovative approach tilts the balance in the competition between kinetic and magnetic energies, and thus elevates characteristic energy scales for collective effects, allowing us to observe signatures of stripes in our quantum simulator. Notably, recent discoveries indicate that mixed-dimensional systems can exhibit a distinct manifestation of high-Tc superconductivity, emphasizing the significance of our research endeavors in advancing this field.

A 21: Interaction with Strong or Short Laser Pulses II (joint session A/MO)

Time: Wednesday 14:30–16:30 Location: HS 1010

A 21.1 Wed 14:30 HS 1010

Focal volume reduction in pulsed standing waves for xenon multiphoton ionization — •Tobias Heldt, Jan-Hendrik Oelmann, Lennart Guth, Nick Lackmann, Lukas Matt, Fiona Sieber, Janko Nauta, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

To study the highly nonlinear light-matter interaction of multiphoton or tunnel ionization, intense light fields are needed. We use a femtosecond enhancement cavity to fulfill this requirement by reaching intensities of $> 10^{13}$ W/cm^2, even at the high 100 MHz repetition rate of a near-infrared frequency comb. The bow-tie cavity supports counter-propagating pulses, leading to a pulsed standing wave when two pulses overlap in the focus. There, we have integrated a gas nozzle and a velocity-map imaging (VMI) spectrometer to study the angular distribution of the emitted photoelectrons [1].

The joint focus of the counter-propagating pulses leads to a doubling of the maximum intensity. In addition, the ionization region along the beam propagation is also reduced because it no longer depends on the Rayleigh length but on the < 200 fs overlap of the pulses. Our experimental data show that this reduction of the focal volume renders the electrostatic focusing in the VMI technique unnecessary. Furthermore, the standing wave influences the emitted electrons over the structured ponderomotive potential, leading to the Kapitza-Dirac effect.

[1] J.-H. Oelmann et al., Rev. Sci. Instrum., 93(12), 123303 (2022).

A 21.2 Wed 14:45 HS 1010

Controlling ionization with chirped circularly-polarized laser pulses — •Ulf Saalmann — Max-Planck-Institut für Physik komplexer Systeme, Dresden/Germany

We show that controlling two-photon ionization with a chirp, originally predicted for linearly-polarized pulses [X], applies to circular polarization as well. In this case the underlying mechanism is particular transparent in the rotating frame. Experimental demonstration of this mechanism for the Helium atom has been achieved at fermi by the Freiburg group and is presented elsewhere.

[X] Saalmann & Giri & Rost, Phys. Rev. Lett. 121 (2018) 153203.

A 21.3 Wed 15:00 HS 1010

Coulomb-correlated multi-electron states generated by femtosecond laser-triggered nanotip photoemission — •Rudolf Haindl[1,2], Armin Feist[1,2], Till Domröse[1,2], Marcel Möller[1,2], John H. Gaida[1,2], Sergey V. Yalunin[1,2], and Claus Ropers[1,2] — [1]Department of Ultrafast Dyamics, Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Göttingen, Germany

Correlations between electrons are at the core of numerous phenomena in atomic, molecular, and solid-state systems. For free particles, detecting inter-particle correlations remains challenging, as ensemble-averaged detection typically conceals few-body effects.

A powerful approach to induce strong electron-electron correlations is spatio-temporally confined photoemission from field emitters employed in ultrafast electron microscopes. When n electrons are generated by the same laser pulse at the emitter, their initially meV-scale inter-particle Coulomb repulsion is acceleration-enhanced in a static electric field to an energy exchange of about 2 eV, as confirmed by trajectory simulations.

In our experiment, we measure distinct energy correlations of pair, triple and quadruple free-electron states in transverse and longitudinal direction [1]. Furthermore, we demonstrate control over the magnitude of Coulomb correlations and discuss how they can facilitate non-Poissonian electron pulse statistics with applications in free-electron quantum optics.

[1] R. Haindl *et al.*, *Nat. Phys.* **19**, 1410-1417 (2023).

A 21.4 Wed 15:15 HS 1010

Strong-field Electron Emission of metal Nanotips with optical Single-Cycle Pulses — •Anne Herzig, Lennart Seiffert, and Thomas Fennel — University of Rostock, Institute of physics, Albert-Einstein-Straße 23, 18059 Rostock

Exposing nanostructures to strong fields enables the emission of energetic electrons via near-field driven elastic backscattering [1]. The availability of intense single cycle or sub-single cycle waveforms [2, 3] enables to explore the formation and propagation of attosecond electron pulses in previously inaccessible regimes of the strong-field interaction. Recent experimental studies [4] have shown promising results on analyzing the short backscattering electron signal. In this talk, the electron emission from tungsten nanotips under intense single-cycle pulses is inspected theoretically via one-dimensional single-active TDSE simulations. The calculated carrier-envelope phase-dependent photoelectron energy spectra reveal prominent signatures with pronounced differences to previous studies performed with many-cycle pulses [5]. The physical origins behind the observed spectral features are disentangled by extending the famous Simple Man's Model of strong-field physics.

[1] M. F. Ciappina et al., Rep. Prog. Phys. 80, 054401 (2017)
[2] A. Wirth et al., Science 334, 195 (2011)
[3] M. T. Hassan et al., Nature 530, 66 (2016)
[4] H. Y. Kim et al., Nature 613, 7945 (2023)
[5] L. Seiffert et al., J. Phys. B 51, 134001 (2018)

A 21.5 Wed 15:30 HS 1010

Observing Laser-Induced Plasma Dynamics by Time-Resolved Coherent-Diffractive-Imaging — •Tom Böttcher, Richard Altenkirch, Christian Peltz, Thomas Fennel, Franziska Fennel, and Stefan Lochbrunner — University of Rostock, Institute of Physics, Albert-Einstein-Str. 23, 18059 Rostock

Resolving the excitation and relaxation dynamics of laser-induced solid state plasmas is crucial for a fundamental understanding of the response of condensed matter targets to intense laser radiation. Knowledge about the influence of laser parameters like the spatial, temporal and spectral pulse structure on the plasma dynamics is essential for taylored laser machining applications. We present a method for observing the plasma dynamics in laser-excited thin gold foils using single-shot pump-probe coherent diffractive imaging. By employing a phase retrieval algorithm, we can reconstruct the 2D-spatial and time resolved complex transmission from recorded diffraction patterns. Our targets are 30 nm thick, free-standing gold foils that are excited by a focused femtosecond (fs)-800 nm pump pulse and subsequently imaged by a low intensity fs-400 nm pulse. The plasma dynamics are monitored on a time scale from 50 fs to 2 ns giving access to the ultrafast excitation (fs-ps regime) as well as the melting and ablation (ps-ns regime) dynamics.

A 21.6 Wed 15:45 HS 1010

Extreme-UV microscopy at ultimate spatial and temporal scales — •Sergey Zayko[1], Hung-Tzu Chang[1], Ofer Kfir[2], Murat Sivis[1], and Claus Ropers[1] — [1]Department of Ultrafast Dynamics, Max-Planck-Institute for Multidisciplinary Sciences, 37077 Göttingen, Germany — [2]School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, 69978Tel Aviv, Israel

Future developments in logic and storage devices heavily rely on versatile research tools operating at the relevant spatio-temporal scales. In applied research fields such as spintronics and strongly correlated electronic materials, these extend into previously unreachable femtosecond-nanometer regimes [1]. In this work, we demonstrate an experimental advance towards such capabilities with femtosecond element-specific, spin-sensitive microscopy at ultimate spatio-temporal scales, achieving simultaneous 18 nm spatial and 35 fs temporal resolution. This allows for a close examination of ultrafast phenomena in real space, providing, deeper insights into the puzzles surrounding ultrafast spin dynamics in the presence of nanoscale magnetic domains [2]. By optimizing the experimental conditions for static imaging, we demonstrate real-space resolutions of 13.5 nm and 12.5 nm for spin and charge scattering, using probe wavelengths close to the m-edges of Co and Ni, respectively. These results from our compact high-harmonic based microscope establish a set of new benchmarks for photon-based imaging techniques.

[1] Zayko et al., Nat. Commun. 12, 6337 (2021)
[2] Koopmans et al., Nat. Materials 9, 259-265 (2010)

A 21.7 Wed 16:00 HS 1010

Tracing attosecond electron emission from a nanometric metal tip — •Lennart Seiffert[1], Philip Dienstbier[2], Timo Paschen[2], Andreas Liehl[3], Alfred Leitenstorfer[3], Thomas Fennel[1,4], and Peter Hommelhoff[2] — [1]University of Rostock — [2]University of Konstanz — [3]Friedrich-Alexander-Universität Erlangen-Nürnberg — [4]Max Born Institute Berlin

Solids exposed to intense electric fields release electrons through tunnelling. This fundamental quantum process lies at the heart of various applications such as petahertz vacuum electronics where electron wavepackets undergoe semiclassical dynamics in an intense laser field, similar to strong-field physics in the gas phase. Recently, we measured the subcycle-dynamics at solids, including the duration of the emission time window [1] and the temporal width of the recolliding wavepacket [2]. Here I present how the suboptical-cycle strong-field emission dynamics from a metallic nanotip is uncovered via two-colour modulation spectroscopy [1,3], where energy spectra of emitted photoelectrons are measured as function of the relative phase between the colors. Projecting the solution of the time-dependent Schrödinger equation onto classical trajectories relates phase-dependent signatures in the spectra to the emission dynamics and yields an emission duration of 710 ± 30 attoseconds.

[1] P. Dienstbier et al., Nature 616, 702-706 (2023)
[2] H. Y. Kim et al., Nature 613, 662-666 (2023)
[3] L. Seiffert et al., J. Phys. B 51, 134001 (2018)

A 21.8 Wed 16:15 HS 1010

Axially Polarized Photoelectrons in Strong-Field Ionization — •Pei-Lun He, Zhao-Han Zhang, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The spin effects in strong-field ionization induced by a linearly polarized laser field are investigated, demonstrating that the photoelectrons exhibit axial polarization relative to the laser polarization axis typically. While the total polarization vanishes upon averaging over the photoelectron momentum, significant momentum-resolved spin polarization is found. The polarization originates from the spin-orbit coupling in the bound state, establishing a correlation between the orbital angular momentum and the spin of the valence shell electron. Consequently, the correlation extends to the spin and the initial transverse velocity of the photoelectron at the tunnel exit. The electron trajectories are thus spin-dependent and are scattered into different directions upon recollisions, resulting in the entanglement of the angular distribution with the electron spin. Furthermore, the interference between direct and rescattered electrons leads to the feasibility of spin-polarized electron holography, offering structural information about the atom.

A 22: Highly Charged Ions and their Applications I

Time: Wednesday 14:30–16:30 Location: HS 1098

A 22.1 Wed 14:30 HS 1098

Quantum-logic based search techniques for highly forbidden transitions in highly charged ions — •Shuying Chen[1], Lukas J. Spiess[1], Alexander Wilzewski[1], Malte Wehrheim[1], Kai Dietze[1], Ivan Vybornyi[2], Klemens Hammerer[2], José R. Crespo López-Urrutia[3], and Piet O. Schmidt[1,4] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Institute of Theoretical Physics, Leibniz Universität Hannover, Hannover, Germany — [3]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany

Optical clocks are the most precise measurement devices, finding application in frequency metrology and fundamental physics. Highly charged ions (HCI) are promising candidates as a reference in optical clocks. To establish a next-generation HCI optical clock at the state-of-the-art precision, an HCI possessing a sub-Hz natural linewidth transition is required. Numerous candidate systems have been explored theoretically but experimental challenges remain due to the considerable uncertainty of the transition frequencies. In this work, we perform experimental and theoretical analysis of search techniques based on a two-ion crystal system confined within a linear Paul trap, with the goal of identifying ultra-narrow transitions in HCI. These techniques include Rabi excitation, the optical dipole force (ODF), and linear continuous sweeping (LCS).

A 22.2 Wed 14:45 HS 1098

Towards optical spectroscopy of highly charged californium ions in preparation for a Cf15+/17+ ion clock — •Lakshmi Priya Kozhiparambil Sajith[1,4], Nils Holger Rehbehn[2], Michael Karl Rosner[2], Kostas Georgiou[3], Leo Prokhorov[3], Aaron Smith[3], Luis Hellmich[4], Ullrich Schwanke[4], Giovanni Barontini[3], José Ramon Crespo López-Urrutia[2], and Steven Worm[1,4] — [1]Deutsches Elektronen Synchrotron (DESY), Platanenallee 6, 15738 Zeuthen , Germany — [2]Max Planck Institut für Kernphysik, Saupfercheckweg 1, Heidelberg, Germany — [3]School of Physics and Astronomy, University of Birmingham, Edgbaston Park Rd, Birmingham B15 2TT, United Kingdom — [4]Humbolt Universität zu Berlin, Unter den Linden 6, 10117 Berlin , Germany

Highly charged Cf ions are a very good candidate for investigating possible variations in fundamental constants owing to its high sensitivity coefficient, in particular, of the fine structure constant. For the construction of a Cf15+ or Cf17+ optical clock, Cf atoms, ablated from a source with a laser, are fed into an electron beam ion trap (EBIT) where highly charged Cf ions are produced, which are then transported through a beam line where they are bunched and pre-cooled and finally trapped in a Coulomb crystal of Ca ions in a cryogenic Paul trap. For the determination of the clock transition for the highly charged Cf ion clock, optical spectroscopy will be performed in an electron beam ion trap. The experimental set-up, including the complexities of the injection of californium atoms, and some preliminary results will be presented.

A 22.3 Wed 15:00 HS 1098

Resistive cooling of ions' center-of-momentum energy in a Penning trap on milli-second time scales — •Markus Kiffer[1], Stefan Ringleb[1], Manuel Vogel[3], and Thomas Stöhlker[1,2,3] — [1]Friedrich Schiller-Universität Jena, 07743 Jena, Germany — [2]Helmholtz-Institut Jena, 07743 Jena, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany

Resistive cooling is a well-established technique to cool the axial motion of ions in a Penning trap. It is especially efficient for large ensembles as the cooling rate scales linearly with the number of ions. Such a fast rate is necessary to quickly create a dense ion cloud for laser experiments at the HILITE experiment. However, this fast rate is only expected for the collective motion of the ion cloud, which decays quickly due to trap anharmonicities.

In our setup the ion bunches are produced by a dedicated ion source and trapped directly in a harmonic potential. This means the ions have a significant collective motion and are immediately in resonance with the cooling circuit, which allows the prompt measurement after trapping. We present measured cooling curves of the collective cloud motion for a controlled ion number and verify that the measured rate is proportional to the number of trapped ions. Using an effective energy model we model the measured curve and extract both the resistive cooling rate and the dephasing rate. Currently, we trap several thousand Ne^{8+} ions, which results in a collective cooling time on the order of 10 ms.

A 22.4 Wed 15:15 HS 1098

Laser spectroscopy of hydrogen-like $^{208}Bi^{82+}$ — •Rodolfo Sánchez for the LIBELLE-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

We report the first successful measurement of the 1s hyperfine splitting of the high-Z radioactive ion $^{208}Bi^{82+}$. The experiment was performed at GSI, the facility for heavy ion research, where these exotic ions were produced in flight and stored in the experimental storage ring (ESR) at a velocity of 72% of the speed of light. At this speed, the Doppler shift transforms the visible laser light into the far ultraviolet range required to drive the hyperfine-transition in $^{208}Bi^{82+}$.

The observation of this hyperfine line is a very important step towards the determination of the so-called "specific difference", a weighted difference between the hyperfine transition energies in hydrogen-like and lithium-like ions that eliminates uncertainties due to the nuclear magnetic moment distribution [1]. At this point, only the specific difference provides the means to test QED in the strongest magnetic fields available in the laboratory and has been determined so far exclusively for the stable isotope ^{209}Bi [2,3].

[1] V. M. Shabaev, et al., Phys. Rev. Lett. 86, 3959 (2001).
[2] J. Ullmann, et al., Nature Comm. 8, 15484 (2017).
[3] L. V. Skripnikov, et al. Phys. Rev. Lett. 120, 093001 (2018).

A 22.5 Wed 15:30 HS 1098

S-EBIT II, first commissioning results — •Tino Morgenroth[1,2,3], Sonja Bernitt[1,2,3], Rex Simon[1,2,3], Sergiy Trotsenko[2], Reinhold Schuch[1,4], and Thomas Stöhlker[1,2,3] — [1]Helmholtz Institute Jena, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]IOQ, Friedrich-Schiller-University Jena, 07743 Jena, Germany — [4]Department of Physics, Stockholm University, 106 91 Stockholm, Sweden

The demand for beamtime at GSI facilities like ESR, CRYRING or HITRAP has increased over the last years and can not be fully covered by the GSI accelerator infrastructure. Local ion sources play an important role in closing this gap and allowing for *offline operation* of experiments at GSI.

Electron Beam Ion Traps (EBITs) are widely known as a versatile tool for spectroscopic studies of partially ionized atomic systems. Furthermore, they can be used as small stand-alone ion sources, capable of producing beams of heavy highly-charged ions of a certain charge state at reasonable intensities.

The S-EBIT II is currently under commissioning for operation as a facility for x-ray spectroscopy and as a standalone ion source for HITRAP. This will provide new opportunities for local experiments independently from the GSI accelerator infrastructure. Examples are the ARTEMIS experiment and the upcoming cryogenic paul trap for quantum logic spectroscopy. As a first step towards completing commissioning, we carried out DR measurements with argon.

A 22.6 Wed 15:45 HS 1098

Precision spectroscopy of highly charged ions in the ARTEMIS Penning trap for electron g-factor measurements at HITRAP — •Arya Krishnan[1,2], Bianca Reich[1,3], Johannes Krempel-Hesse[4], Kanika Kanika[1,3], Jeffrey W. Klimes[1], Khwaish K. Anjum[1,5], Patrick Baus[2], Gerhard Birkl[2], Manuel Vogel[1], and Wolfgang Quint[1,3] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Germany — [2]Technical University of Darmstadt, Germany — [3]University of Heidelberg, Germany — [4]University of Giessen, Germany — [5]University of Jena, Germany

The ARTEMIS experiment at the HITRAP facility situated at GSI focuses on precision measurements of electron magnetic moments in highly charged ions. Ions are currently produced inside the cryogenic Penning trap of the experiment [Kanika et al., J. Phys. B 56, 175001 (2023)] and are prepared and cooled using non-destructive techniques [Ebrahimi et al., Phys. Rev. A 98, 023423 (2018)]. Electron magnetic moments (g-factor) will be measured using the laser-microwave double-resonance spectroscopy on the desired few-electron ions stored in the trap. The connection to the HITRAP beamline and upgrades for dynamic capture and storage of ions from external sources enables this method to be applied to hydrogen-like heavy species such as Bi82+ and other lighter species such as S11+. The half-open design of the trap allows optical access which in turn facilitates microwave probing of the Larmor frequency through laser spectroscopy of fine/hyperfine structure of the ions. We present the current status of the experiment.

A 22.7 Wed 16:00 HS 1098

Analyzing heavy elemental polyatomic molecular ions for tests of fundamental physics — •Carsten Zülch, Konstantin Gaul, Steffen M. Giesen, and Robert Berger — Fachbereich Chemie, Philipps-Universität Marburg, Hans-Meerwein-Straße 4, 35032 Marburg, Germany

Recently, we proposed diatomic highly charged molecular ions for precision tests of fundamental physics [1]. These provide unique, compressed electronic spectra — an effect which can be exploited in the search for a spatio-temporal variation of fundamental constants —, long trapping times and sympathetical coolability [2]. Polyatomic molecules possess more internal degrees of freedom and can exhibit internal comagnetometer states as well as internally broken symmetries [3,4]. Thus, polyatomic molecular ions promise to advance quantum information sciences, cold chemistry and collisions, high precision spectroscopy and therewith the search for symmetry violation beyond the Standard Model. In this contribution we investigate a multitude of polyatomic molecular ions in respect of their electronic structure, spectroscopic constants and enhancement factors of symmetry violating properties in a broken-symmetry quasirelativistic mean-field ansatz such as $PaNC^{3+}$ or $PaNCS^{3+}$. We subsequently account for electron correlation using two-component many-body perturbation theory.

[1] Zülch, Gaul, Giesen, Garcia Ruiz, Berger, *arXiv* 2203.10333.
[2] Zülch, Gaul, Berger, *Isr. J. Chem.* 2023, 63, e202300035.
[3] Isaev, Berger, *PRL* 2016, 116; Kozyryev et al., *JPB* 2016, 49.
[4] Isaev et al., *JPB* 2017, 50; Kozyryev et al., *PRL* 2017, 119.

A 22.8 Wed 16:15 HS 1098

Cooling of heavy highly charged ions: The HITRAP-Penning Trap — •Dimitrios Zisis for the Hitrap-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, Germany — Technical University of Darmstadt, Germany

For conducting high-precision experiments at low energies and small energy distributions, heavy and highly charged ions (HCI) need to be decelerated and cooled, which is the aim of the HITRAP facility. It is situated at the GSI Helmholtzzentrum für Schwerionenforschung, where a wide range of HCI can be provided. Its unique capability to decelerate and cool HCI, not only enables easier ion storage and manipulation but also further transport towards attached experiments.

At HITRAP, HCI are decelerated in a two-step process from 4 MeV/u to 6 keV/u before being captured in a Penning trap for electron cooling. This cooling process precedes the subsequent ejection of ions, facilitating their transport to various precision experiments.

We present the latest successful outcomes in electron cooling of HCI. Despite the observed reduction in ion energy, a detailed investigation of systematic effects has yet to be carried out. Future steps involve the optimization of the cooling process including more advanced detection methods and further systematic studies.

A 23: Atomic Clusters (joint session A/MO)

Time: Wednesday 14:30–16:30 Location: HS 1015

A 23.1 Wed 14:30 HS 1015

Experimental studies on core-level interatomic Coulombic decay in heterogeneous rare gas clusters — •Catmarna Küstner-Wetekam[1], Lutz Marder[1], Dana Bloss[1], Christina Zindel[1], Uwe Hergenhahn[2], Arno Ehresmann[1], Přemysl Kolorenč[3], and Andreas Hans[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [3]Institute of Theoretical Physics, Charles University, V Holesovickach 2, 180 00 Prague, Czech Republic

To understand the fundamental mechanisms of radiation chemistry in realistic environments, it is crucial to examine prototypical systems where molecules or atoms interact with their surroundings. Weakly bound van der Waals clusters serve as promising model systems for investigating novel relaxation pathways. In contrast to isolated atoms, electronically excited states may now decay via different interatomic processes such as interatomic Coulombic decay (ICD) or radiative charge transfer (RCT). Due to the relatively low probability of ICD following inner-shell ionization in rare gas clusters, multicoincidence spectroscopy is essential for its detection. Here, we present the observation of changes in branching ratios when going from homogeneous Ar and Kr clusters to heterogeneous ArKr clusters. This transition effectively introduces a distinct environment for the excited atom in each cluster, providing valuable insights into the influence of cluster composition on interatomic decay pathways.

A 23.2 Wed 14:45 HS 1015

Self-organized supersolidity in ion doped Helium droplets — •Juan Carlos Acosta Matos, Panagiotis Giannakeas, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

It is well known that crystallized shells, of Helium atoms, a so called snowball, forms around the ion in the otherwise (super-)fluid Helium droplet [1]. Here, we show that for sufficiently large droplets a third regime appears between the snowball and the liquid one with a supersolid structure where the Helium density exhibits a periodic modulation of the particle density on a spherical shell. The periodic modulation emerges due to the inner shell snowball structure that provides a lattice substrate for the outer droplet shells yielding an accumulation of superfluid particles. To identify supersolidity in a geometrically confined scenario of a droplet we combine modified density functional theory (DFT), allowing us to describe large enough droplets, with a Gaussian Imaginary Time Dependent Hartree (G-ITDH)[2] method which traces the emergence of crystallized structures. Our approach works well as a comparison to Quantum Monte Carlo results [3] for smaller droplets reveals. [1] D. E. Galli etal, J. Phys. Chem. A 2011, 115, 7300-7309 [2] W. Unn-Toc etal, J. Chem. Phys. 137, 054112 (2012) [3] M. Rastogi etal, Phys. Chem. Chem. Phys. 2018, 20, 25569

A 23.3 Wed 15:00 HS 1015

Disentangling the decay cascade of inner-shell vacancies in krypton clusters — •Lutz Marder, Catmarna Küstner-Wetekam, Niklas Golchert, Johannes Viehmann, Emilia Heikura, Nils Kiefer, Arno Ehresmann, and Andreas Hans — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

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

Our state-of-the-art experiment, where electrons and photons are detected in coincidence, allows for investigation of multi-particle decay pathways after ionization with synchrotron radiation. Upon introduction of an inner-shell vacancy in a homogeneous Kr cluster, the well-known atomic relaxation pathways – consisting of Auger-Meitner decays and fluorescence – is altered significantly by the opening of new interatomic relaxation mechanisms such as interatomic Coulombic decay (ICD), electron-transfer mediated decay (ETMD) and radiative charge transfer (RCT), all of which have been observed and are presented here.

A 23.4 Wed 15:15 HS 1015

Measurements of Electron-Photon Coincidences from Local and Non-Local Electronic Relaxation Processes in Rare-Gas Clusters after Excitation with Synchrotron Radiation from Multi-Bunch Operation Mode — •Johannes Viehmann[1], Andreas Hans[1], Christian Ozga[1], Nils Kiefer[1], Emilia Heikura[1], Lutz Marder[1], Catmarna Küstner-Wetekam[1], Uwe Hergenhahn[2], and Arno Ehresmann[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Fritz Haber Institute of the Max Planck Society, Faradayweg 4-6 14195 Berlin Germany

Investigating interatomic (or intermolecular) processes in dense media is of interest for understanding the emergence of new properties in conglomerates of interacting particles. This is a stepping stone in bottom up approaches to describe complex environments like biological relevant systems. Our group has used electron-photon coincidence measurements to investigate local and non-local electronic relaxation processes after inner-valence excitation with synchrotron radiation of rare gas clusters. Coincidence measurements at synchrotrons have been restricted to single bunch operation modes of the facilities due to necessities of proper time references. Here, we suggest a technique to expand the use of such electron-photon-coincidence measurements to arbitrary synchrotron filling patterns and show first benchmark results.

A 23.5 Wed 15:30 HS 1015

Extreme shift of Auger cascade energies after deep inner-shell ionization in rare-gas clusters — •Niklas Golchert[1], Nils Kiefer[1], Catmarna Küstner-Wetekam[1], Lutz Marder[1], Minna Patanen[2], Christina Zindel[1], Arno Ehresmann[1], and Andreas Hans[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Nano and Molecular Systems Research Unit, Faculty of Science, P.O. Box 3000, FI-90014, University of Oulu, Oulu, Finland

Closing the gap between isolated atoms and macroscopic objects, clusters serve as ideal prototype systems for fundamental research of local and non-local processes in dense media. By investigating their electron emission spectra after photoionization, detailed insights about the interactions between the constituents of a medium are gained.

Here, we present recent experimental results obtained by multi-electron coincidence spectroscopy showing the strong dependence of Auger cascade energies in clusters on the charge state of the emitting ion caused by the polarization of its surrounding. These findings will deliver valuable information for future spectroscopic experiments on dense media such as clusters or liquids using high-energetic light sources.

A 23.6 Wed 15:45 HS 1015

Reconstructing the anisotropic expansion of a laser driven nanoplasma — •Paul Tuemmler[1], Felix Gerke[2], Christian Peltz[1], Hendrik Tackenberg[1], Björn Kruse[1], Bernhard Wassermann[2], Thomas Fennel[1], and Eckart Rühl[2] — [1]University of Rostock, D-18059 Rostock, Germany — [2]Freie Universität Berlin, D-14195 Berlin, Germany

Coherent diffractive imaging (CDI) at X-ray free-electron lasers (FELs) has evolved into a well-established method for the structural investigation of unsupported nanoparticles. This inherently static method can be readily adopted to time-dependent studies by incorporating a second pulse in a pump-probe scheme.

In a recent experiment at LCLS, we utilized this method to study the fundamental process of free plasma expansion into vacuum using the example of laser-pumped SiO_2 nanospheres. The resulting plasma expansion rapidly and isotropically softens the initial surface density step. This, in turn, increases the radial decay of the scattering signal eventually precluding meaningful measurements due to a diminishing signal-to-noise ratio within only a few hundred femtoseconds [1].

Here, we present the results of a follow-up experiment at the European XFEL where we revisited SiO_2 as a target, but operated in a weaker excitation regime. This approach allowed us to record images over far longer timescales and revealed a strong anisotropic expansion dynamic, as predicted by theory [2].

[1] C. Peltz *et al.*, New J. Phys. **24**, 043024 (2022).
[2] C. Peltz *et al.*, Phys. Rev. Lett. **113**, 133401 (2014).

A 23.7 Wed 16:00 HS 1015

Superradiant parametric Mössbauer radiation — •Ze-An Peng, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Mössbauer nuclei facilitate a broad range of applications based on their spectrally narrow resonances at energies of hard X-rays. However, the narrow resonances render a strong excitation via intense X-ray beams challenging. This motivates a search for alternative excitation sources.

Parametric X-ray radiation (PXR) is a well-known mechanism for generating high-quality x-ray beams, which is based on intense relativistic electron beams passing through crystals. If the crystal contains Mössbauer nuclei, then under suitable conditions spectrally narrow parametric Mössbauer radiation (PMR) can be emitted [1]. Recently, a new scheme of superradiant PXR was proposed which employs coherently modulated electron bunches produced in X-ray free-electron laser accelerators [2]. This boosts the PXR intensity generated from the crystal by orders of magnitude.

Here, we construct a superradiant parametric Mössbauer radiation source, which is rendered possible by an extended configuration in which the conditions for superradiant PXR and the Mössbauer resonance condition can be satisfied simultaneously. After illustrating the operation principle of the source, the properties of the generated X-ray beam and possible applications will be discussed.

[1] O. D. Skoromnik, I. D. Feranchuk, J. Evers, and C. H. Keitel, Phys. Rev. Accel. Beams 25, 040704 (2022). [2] I. D. Feranchuk, N. Q. San, and O. D. Skoromnik, Phys. Rev. Accel. Beams 25, 120702 (2022).

A 23.8 Wed 16:15 HS 1015

Nonlinear effects in the charge fractionalization of critical chains — •Flávia Braga Ramos[1], Imke Schneider[1], Sebastian Eggert[1], and Rodrigo Pereira[2] — [1]University of Kaiserslautern-Landau, Kaiserslautern, Germany — [2]International Institute of Physics, Natal, Brazil

Using the density matrix renormalization group we investigate how a single particle excitation is accommodated in a strongly correlated chain using an out-of-equilibrium protocol. By creating an initial Gaussian wave packet with fixed momentum, we are able to control the regime of energy excitations. Remarkably, the late-time dynamics of the wave packet comprises up to three descendent humps: two counter-propagating low-energy modes and an additional high-energy contribution, whose existence depends on the energy scale set in the initial state. We interpret this unconventional charge fractionalization in terms of the nonlinear Luttinger liquid theory which has attracted great theoretical interest in recent years. Our results provide a new perspective to observe the dynamics of critical chains in the whole range of energy excitations which could potentially be realized in ultracold atomic gases.

A 24: Fermionic Quantum Gases II (joint session Q/A)

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

A 24.1 Wed 14:30 Aula

Exact one-particle density matrix for SU(N) fermionic matter-waves in the strong repulsive limit — •Andreas Osterloh[1], Wayne Chetcuti[1], Juan Polo[1], and Luigi Amico[1,2] — [1]Technology Innovation Institute, Masdar City and Yas Island, P.O. box 9639Abu Dhabi, UAE — [2]Dipartimento di Fisica e Astronomia Ettore Majorana, Via S. Sofia 64, 95127 Catania, Italy

We consider a gas of repulsive N-component fermions confined in a ring-shaped potential, subject to an effective magnetic field. For large repulsion strengths, we work out a Bethe ansatz scheme to compute the two-point correlation matrix and then the one-particle density matrix. Our results holds in the mesoscopic regime of finite but sufficiently large number of particles and system size that are not accessible by numerics. We access the momentum distribution of the system and analyse its specific dependence of interaction, magnetic field and number of components N. In the context of cold atoms, the exact computation of the correlation matrix to determine the interference patterns that are produced by releasing cold atoms from ring traps is carried out.

A 24.2 Wed 14:45 Aula

Universal Entropy Transport in Fermionic Superfluids across the BEC-BCS Crossover — Jeffrey Mohan, •Simon Wili, Philipp Fabritius, Mohsen Talebi, Meng-Zi Huang, and Tilman Esslinger — ETH Zürich, Otto-Stern-Weg 1, 8093 Zürich, Switzerland

Particle transport between two superfluids is often associated with reversible, entropy-free supercurrents, such as in the Josephson and fountain effects. However, this only applies to weakly-coupled superfluids in the linear response regime. Here, we experimentally investigate particle and entropy flow within a ballistic channel, strongly coupling two superfluids across the BEC-BCS crossover. Our observations reveal large currents of both particles and entropy. While these currents depend on the channel's geometry, the entropy transported per particle appears constant across different geometries. Instead, it is influenced by the interaction strength and reservoir degeneracy. This suggests that the non-equilibrium currents flowing through the channel inherit the universal equilibrium properties from the reservoirs. Moreover, when distinguishing advective and diffusive entropy currents, we find that the Wiedemann Franz law, which describes the relation of these currents in Fermi liquids, is strongly violated at unitarity but partially restored on the BCS side. The present observations raise fundamental questions about transport in strongly interacting, non-equilibrium Fermi systems.

A 24.3 Wed 15:00 Aula

Unravelling Interaction and Temperature Contributions in Unpolarized Trapped Fermionic Atoms in the BCS Regime — •Sejung Yong, Sian Barbosa, Jennifer Koch, Felix Lang, Axel Pelster, and Artur Widera — Physics Department and Research Center OPTIMAS, Kaiserslautern-Landau, Germany

In the BCS limit density profiles for unpolarized trapped fermionic clouds of atoms are largely featureless. Therefore, it is a delicate task to analyze them in order to quantify their respective interaction and temperature contributions. Temperature measurements have so far been mostly considered in an indirect way, where one sweeps isentropically from the BCS to the BEC limit. Instead we suggest here a direct thermometry, which relies on measuring the column density and comparing the obtained data with a Hartree-Bogoliubov mean-field theory combined with a local density approximation. In case of an attractive interaction between two-components of ^{6}Li atoms trapped in a tri-axial harmonic confinement we show that minimizing the error within such an experiment-theory collaboration turns out to be a reasonable criterion for analyzing in detail measured densities and, thus, for ultimately determining the sample temperatures. The findings are discussed in view of various possible sources of errors.

[1] S. Yong, S. Barbosa, J. Koch, F. Lang, A. Pelster, and A. Widera, arXiv:2311.08853

A 24.4 Wed 15:15 Aula

A quantum engine in the BEC-BCS crossover — •Jennifer Koch[1], Keerthy Menon[2], Eloisa Cuestas[2,3], Sian Barbosa[1], Eric Lutz[4], Thomás Fogarty[2], Thomas Busch[2], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]OIST Graduate University, Onna, Japan — [3]Enrique Gaviola Institute of Physics, Córdoba, Argentina — [4]Institute for Theoretical Physics I, University of Stuttgart, Germany

Heat engines convert thermal energy into mechanical work both in the classical and quantum regimes. However, quantum theory offers genuine nonclassical forms of energy, different from heat, which so far have not been exploited in cyclic engines to produce useful work. In this talk, I will discuss a recently realized quantum many-body engine fuelled by the energy difference between fermionic and bosonic ensembles of ultracold particles that follows from the Pauli exclusion principle [1]. We employ a harmonically trapped superfluid gas of ^{6}Li atoms close to a magnetic Feshbach resonance, which allows us to effectively change the quantum statistics from Bose-Einstein to Fermi-Dirac by tuning the gas between a Bose-Einstein condensate of bosonic molecules and a unitary Fermi gas (and back) through a magnetic field. The talk will focus on the quantum nature of such a Pauli engine. Additionally, I will present the pressure-volume diagram of the new kind of engine and show how the engine behaves after multiple cycles. Our findings establish quantum statistics as a useful thermodynamic resource for work production. [1] J. Koch et al., Nature 621, 723 (2023)

A 24.5 Wed 15:30 Aula

A generalized formalism to describe multi-channel Hartree-Fock-Bogoliubov interactions in fermionic systems — •Nikolai Kaschewski[1], Axel Pelster[1], and Carlos A. R. Sá de Melo[2] — [1]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]School of Physics, Georgia Institute of Technology, Atlanta, USA

A simplified description of fermionic systems relies on the Hartree-Fock-Bogoliubov (HFB) approximation, where the interaction is decomposed into distinct channels. However, an major issue with this procedure is that the separation between the channels is somewhat arbitrary. In some cases, only one interaction channel is considered, e.g the pairing channel in the BCS theory and the BCS-BEC crossover, or in other cases, two different interaction channels are artificially separated like in the Jellium model. In this talk, we present a generalized self-consistent theory by using weighting parameters for each channel. Our approach removes the arbitrariness of channel separation and provides a minimization principle for the optimal partitioning. We present this formalism for any type of spatially non local potentials without memory and derive the respective HFB self-consistency equations on a mean-field level and show how inter-channel interactions arise. We illustrate the power of our technique with a simple example before showing on a formal level how to include pairing, density, and exchange fluctuations simultaneously without miscounting or double-counting states.

A 24.6 Wed 15:45 Aula

The role of particle-hole interactions and effective ranges in homogeneous Fermi fluids — Nikolai Kaschewski[1], Axel Pelster[1], and •Carlos A. R. Sá de Melo[2] — [1]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]School of Physics, Georgia Institute of Technology, Atlanta, USA

The standard theoretical method for studying fermionic superfluidity is based on the description of interactions in terms of pairing and on the identification of a superfluid order parameter. Only particle-particle (pp) processes are included that form Cooper pairs which then perform Bose-Einstein condensation. Particle-hole (ph) processes are only sparsely considered. One example are the ph fluctuations of Gor'kov and Melik-Barkhudarov that lowers the condensation temperature [1]. On this poster, we present a self-consistent mean-field theory for BCS superfluidity that includes pp and ph processes simultaneously through a weighted partitioning of states that produce and inhibit pairing. We obtain non-perturbative corrections due to ph scattering, which require an effective range expansion [2] in order to get physical results. The theory generalizes the BCS mean field theory, makes connections to effective-range mean-field effects [3]. Our preliminary results set the stage for the simultaneous exploration of fluctuations in the pp and ph channels [1] in the BCS-BEC crossover.

[1] L.P. Gor'kov, T.K. Melik-Barkhudarov, Sov. Phys. JETP **13**, 1018 (1961) [2] H. A. Bethe, Phys. Rev. **76**, 38 (1949) [3] S. Mal and B. Deb, J. of Phys. B **55**, 035301 (2022)

A 24.7 Wed 16:00 Aula

Topological pumping induced by interactions — konrad viebahn[1], anne-sophie walter[1], eric bertok[2], •zijie zhu[1], marius gächter[1], armando a. aligia[3], fabian heidrich-meisner[2], and tilman esslinger[1] — [1]Institute for Quantum Electronics & Quantum Center, ETH Zurich, 8093 Zurich, Switzerland — [2]Institute for Theoretical Physics, Georg-August-Universität Göttingen, 37077 Göttingen, Germany — [3]Instituto de Nanociencia y Nanotecnologia CNEA-CONICET, Centro Atomico Bariloche and Instituto Balseiro, 8400 Bariloche, Argentina

A topological 'Thouless' pump represents the quantised motion of particles in response to a slow, cyclic modulation of external control parameters. The Thouless pump, like the quantum Hall effect, is of fundamental interest because it links physically measurable quantities, such as particle currents, to geometric properties which can be robust against perturbations and thus technologically useful. Here we observe a Thouless-type charge pump in which the particle current and its directionality inherently rely on the presence of strong interactions. Experimentally, we utilise fermionic atoms in a dynamical superlattice which traces a pump trajectory that remains trivial in the non-interacting limit. Remarkably, the transferred charge in the interacting system is half of its usual value in the non-interacting case, in agreement with matrix-product-state simulations. Our experiments suggest that Thouless charge pumps are promising platforms to gain insights into interaction-driven topological transitions and topological quantum matter.

A 24.8 Wed 16:15 Aula

Kapitza-Dirac scattering of strongly interacting Fermi gases — •Max Hachmann[1], Yann Kiefer[1,2], and Andreas Hemmerich[1] — [1]Universität Hamburg, Hamburg, Deutschland — [2]ETH, Zürich, Schweiz

We experimentally probe properties of interacting spin-mixtures of fermionic (40K) atoms by studying their interaction with light. An elementary scattering scenario is resonant Bragg diffraction, also referred to as Bragg spectroscopy, where matter is diffracted from a onedimensional (1D) optical standing wave. A Feshbach resonance is used to tune the interactions across the entire BEC-BCS crossover regime, including the point of unitarity. With the preparation schemes available in our experiment, the scattering lengths can be dynamically tuned, such that either repulsively bound molecular dimers (Feshbach molecules) or pairs of unbound fermions can be studied. To benchmark our scattering protocol, we apply it to a sample of spin-polarized non-interacting fermionic atoms and study the dynamical behaviour. In this case, a simple model using a time-dependent Schrödinger equation yields surprisingly accurate results, well matching the experimental observations. For spin-mixtures in the unitarity regime, the higher order diffraction peaks are observed to disappear with no conclusive theoretical description presently available.

A 25: Poster IV

Time: Wednesday 17:00–19:00 Location: Tent A

A 25.1 Wed 17:00 Tent A

Analysing Single Particle Trajectories Of Ultracold Atoms With Artificial Intelligence — •Marco Mohler, Silvia Hiebel, Dennis Wagner, Sabrina Burgardt, Julian Fess, Marius Kloft und Artur Widera — University of Kaiserslautern-Landau, Kaiserslautern, Germany

Artificial Intelligence can be a helpful tool in analysing large datasets. In the presented work, we analyze the diffusion of Cs atoms, which are trapped in a far-detuned optical dipole trap and driven by an optical molasses. As the atoms absorb and reemit photons from the molasses laser beams they receive small momentum kicks in a random direction. This fluctuating force together with Doppler damping due to the laser beams detuning results in diffusive behaviour and is similar to Brownian motion. A small imbalance in the power of the counterpropagating molasses beams results in a small drift away from the stronger beam. This is to be avoided as it is a disturbance to experiments. Here, we present a neural network trained to learn the underlying force field behind the diffusive cesium trajectory which originates from the details of the laser setup. Applying the network to experimental data might reduce everyday readjustment time by telling which parameters to adjust to negate the drift from a reduced number of recorded trajectories. Initial training is carried out on simulated data because producing this data requires less ressources. Therefore trajectories are calculated for different laser imbalances and presented to the neural network so that it learns how the imbalance affects the atoms‘ movement. Currently the simulation is being tested before the neural network is set up.

A 25.2 Wed 17:00 Tent A

High Fidelity transport of trapped-ion qubits in a multilayer array — •Deviprasath Palani, Florian Hasse, Apurba Das, Leon Goepfert, Ole Pikkemaat, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Universitaet Freiburg, Freiburg, Germany

Trapped ion arrays, facilitated by Radio-Frequency surface electrode traps, offer a promising platform for extending analog quantum simulations in size and dimension. Our prototype, fabricated by Sandia National Laboratories, creates a three-dimensional potential landscape housing 13 strongly confined ion storage sites alongside intermittently weakly confined areas featuring transport channels. An equilateral triangular array, situated closer to the surface with a side length of 40 μm, enables local site control, 2D inter-site coupling, and Floquet-engineering coupling via motional degrees of freedom[1-3]. Extending these methods, we enable deterministic ion redistribution using an ancilla site approximately 13 μm above the array. Ramsey spectroscopy confirms the preservation of electronic degree-of-freedom information during ion transport. Our current focus lies in addressing noise predominantly arising from surface contaminants using argon-ion bombardment and tackling other technical limitations[5].

[1] Mielenz, M. et al. Nat. Commun. 7, 11839 (2016). [2] Hakelberg, F. et al. Phys. Rev. Lett. 123, 100504 (2019). [3] Kiefer, P. et al. Phys. Rev. Lett. 123, 213605 (2019). [4] Palani, D. et al. Phys. Rev. A. 107, L050601 (2023). [5] Warring, U. et al. Adv. Quantum Technol. 1900137 (2020).

A 25.3 Wed 17:00 Tent A

Construction of a versatile platform for Rydberg atom experiments — •Aaron Thielmann, Mirza Akbar Ali, Sven Schmidt, Suthep Pomjaksilp, Thomas Niederprüm, and Herwig Ott — Department of Physics and research center OPTIMAS, RPTU Kaiserslautern-Landau

In recent years, atomic arrays emerged as a ground-breaking platform in quantum physics. These setups do not only feature single-atom control, additionally exciting addressable atoms to Rydberg states introduces further possibilities to study physical problems in different geometric configurations.

Using a metallic vacuum-chamber, our aim is to get a versatile platform for research on arrays of single atoms or small samples while having as much control over sorrounding parameters as possible. Through a high resolution objective not only tweezer trap generation and observation but also site-selective (de-)excitation will be possible. This will enable us to investigate different phenomena like transport with dissipation in arbitrarily arranged arrays of Rubidium atoms. Additional features include electric and magnetic field control as well as the ability for global application of microwave and optical fields. Furthermore a second species of Rubidium could enable even more possibilities.

A 25.4 Wed 17:00 Tent A

Ultracold LiCr Feshbach dimers: prospects for doubly-polar ground-state molecules — •Maximilian Schemmer[1,2], Stefano Finelli[1,2], Alessio Ciamei[1,2], Beatrice Restivo[1,2], Antonio Cosco[1,2], Andreas Trenkwalder[1,2], and Matteo Zaccanti[1,2] — [1]Istituto Nazionale di Ottica del Consiglio Nazionale delle Ricerche (CNR-INO), 50019 Sesto Fiorentino, Italy — [2]European Laboratory for Nonlinear Spectroscopy (LENS), 50019 Sesto Fiorentino, Italy

We report the creation and study of ultracold ^{6}Li^{53}Cr Feshbach molecules. Leveraging on the Fermi statistics of the parent atomic mixture, we adiabatically associate up to 50×10^3 LiCr at a peak phase-space density of about 0.1, thereby populating a weakly-bound rotationless level of the electronic ground-state $^6\Sigma^+$. We directly observe the paramagnetic nature of $^6\Sigma^+$ by measuring the magnetic dipole moment of closed-channel dimers, and we show precise control of the open-channel fraction close to the Feshbach resonance pole. We characterize the loss mechanisms induced by trap light and inelastic collisions. We show that a pure molecule sample trapped at a convenient wavelength of 1560nm features lifetimes exceeding 0.2 s. According to recent ab-initio calculations, efficient and coherent transfer to the absolute ground-state will deliver doubly-polar molecules for novel quantum simulation and computation as well as ultracold chemistry.

A 25.5 Wed 17:00 Tent A

Optical tweezer for immersion of single Cs impurities in an ultracold Rb bath — •Levi Geier, Sabrina Burgardt, Silvia Hiebel, Julian Fess, and Artur Widera — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, Kaiserslautern 67663, Germany

Optical tweezers, i.e. tightly focussed laserbeams, have evolved into versatile tools in the study of many-body quantum systems with control on the single-particle level. Their range of application is very broad since devices such as spatial light modulators and acousto-optical deflectors allow arbitrary and time-dependent optical potentials. In the scope of this work an optical tweezer setup based on an acousto-optical defletor is presented, which will be used to control single Caesium atoms dynamically inside a 3-dimensional Rubidium BEC. As optical tweezers rely on the optical dipole force only, manipulation of the atomic states is enabled, and coherence is preserved. We aim to investigate the coherence dynamics of a single Caesium qubit when immersed in a Rubidium BEC.

A 25.6 Wed 17:00 Tent A

Collisional energy effects on atom-ion Feshbach resonances — •Joachim Siemund[1], Fabian Thielemann[1], Daniel Hönig[1], Wei Wu[1], Krzysztof Jachymski[2], Thomas Walker[1,3], and Tobias Schätz[1] — [1]Physikalisches Institut, Albert-Ludwigs Universität Freiburg — [2]Faculty of Physics, University of Warsaw — [3]Blackett Laboratory, Imperial College, London

We investigate the inelastic loss dynamics around Feshbach resonances between neutral atoms and ions depending on the collision energy. By immersing a single ^{138}Ba$^+$ ion in an ultracold cloud of ^{6}Li, we have demonstrated the enhancement of two- and three-body interactions through changes in the ion's electronic state and radial kinetic energy. We probe the atom-ion interaction rate while tuning the ion's kinetic energy and atomic cloud temperature. We observe the enhancement and suppression of inelastic loss processes depending on the collision energies and specific Feshbach resonance. This energy dependence could provide insight into the fundamental nature of the interaction dynamics, which also will be discussed in a parallel talk by Fabian Thielemann.

A 25.7 Wed 17:00 Tent A

Theoretical study of radio-frequency induced Floquet-Feshbach resonances in ultracold Lithium-6 gases — •Alexander Guthmann, Felix Lang, and Artur Widera — RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Feshbach resonances play a crucial role in the exploration of ultracold atoms. The magnetic field position of these resonances is determined by the point at which the energy of a dimer-bound state intersects the asymptotic atomic threshold. This contribution discusses the utilization of an oscillating magnetic field in the radio frequency range to couple colliding atom pairs to the dimer state, generating new resonances at different magnetic field values. Employing Floquet theory, we transform the time-dependent problem into a time-independent equivalent, yielding a Hamiltonian suitable for coupled-channel calculations. Using Lithium-6 as an example, which exhibits a notably broad s-wave resonance at 832G due to a weakly bound halo state, our results from coupled-channel calculations reveal that this halo state enables the creation of radio frequency-induced resonances with significant widths and tunability at modulation strengths achievable in practice. Theoretical findings will be presented, and the feasibility of experimental observation, along with associated technical challenges, will be explored.

A 25.8 Wed 17:00 Tent A

Topological pumping of vortices through Bloch-like oscillations of a magnetic soliton — Franco Rabec, Guillaume Chauveau, •Guillaume Brochier, Sylvain Nascimbene, Jean Dalibard, and Jérôme Beugnon — Laboratoire Kastler Brossel, Collège de France, France

Bloch oscillations are a striking feature of the counterintuitive motion of particles created by a lattice potential. However, one can reproduce such an effect with a system that is translationally invariant, provided that the dispersion relation remains periodic. An example is realized by a magnetic soliton which can be mapped onto an immiscible spin mixture in a quasi-1D Bose gas. We report on the observation of such Bloch-like oscillations. We experimentally investigate this phenomenon with both strict boundary conditions and periodic boundary conditions, the latter revealing the presence of a backflow and the formation of a topological vortex pump in this system.

A 25.9 Wed 17:00 Tent A

Hundreds of atoms in an array of optical tweezers in a cryostat — Etienne Bloch[1], Gert-Jan Both[1], Lilian Bourachot[1], •Davide Dreon[1], Thierry Lahaye[2], Desiree Lim[1], Gregoire Pichard[1], and Julien Vaneecloo[1] — [1]Pasqal SAS, 7 Rue Léonard de Vinci, 91300 Massy, Francee — [2]Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, 91127 Palaiseau Cedex, France

We will present the work done on a new generation of quantum processors that we are developing at PASQAL, a spin-off company of the Institut d'Optique, which is building neutral atom quantum computers. This machine incorporates optical tweezer technology in a cryogenic environment. We have recently incorporated high numerical aperture optics that allow us to trap hundreds of single atoms in the tweezer array. In addition to that, we are demonstrating improved vacuum-limited lifetime compared to room temperature setups. This prototype represents a significant milestone, bringing us closer to the realisation of a neutral atom processor with more than a thousand qubits.

A 25.10 Wed 17:00 Tent A

Quantum-gas microscopy of the Bose-Hubbard model with ^{84}Sr — Sandra Buob[1], Jonatan Höschele[1], Vasiliy Makhalov[1], •Antonio Rubio-Abadal[1], and Leticia Tarruell[1,2] — [1]ICFO - Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain — [2]ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain

Atomic species with two-valence electrons, such as alkaline-earth atoms, offer exciting spectroscopic tools that can bring quantum simulation with ultracold atoms into new directions.

Here we present an experimental setup capable of preparing ultracold bosonic strontium in a two-dimensional optical lattice. By performing fluorescence imaging of a 2D quantum gas with site-resolved resolution, we realize a strontium quantum-gas microscope. In this poster, we discuss the main technical features of our setup, its current status, and possible future directions.

A 25.11 Wed 17:00 Tent A

Characterisation of Drifts and Non-Linearity of Data Acquisition Electronics for Metallic Magnetic Calorimeter Detectors — •Daniel A. Müller[1,3], Philip Pfäfflein[1,2,3], Marc O. Herdrich[1,3], Christoph Hahn[1,2], Felix M. Kröger[1,2,3], Bastian Löher[2], Günter Weber[1,2], and Thomas Stöhlker[1,2,3] — [1]HI-Jena, Jena, Germany — [2]GSI, Darmstad, Germany — [3]Friedrich-Schiller-Universität Jena, Jena, Germany

Recent experiments employing novel metallic magnetic calorimeter detectors have shown the excellent spectral resolution (better than 100 eV FWHM at 100 keV) and timing capability of those detectors. The measurement principle of this detector is based on a temperature rise of an absorber by stopping an incident x-ray photon resulting in a change of the magnetisation of a paramagnetic sensor. With a superconducting quantum interference device those changes can be measured with high sensitivity. While providing a wide energy acceptance (0.1 - 100 keV), the entire spectral range can only be fully utilised, if drifts and non-linear effects of the data acquisition electronics are under control. Otherwise precision spectroscopy is only possible if a well-known x-ray or gamma line is close to the line of interest for establishing an absolute energy scale. In the present work, we report on the characterisation of STRUCK SIS3316 digitizer modules in terms of integral non-linearity and temperature-dependent drifts. It has been shown that these effects have a sizeable impact on the spectral performance of the detectors. Furthermore, a calibration and correction method to mitigate these effects on the recorded spectrum was developed.

A 25.12 Wed 17:00 Tent A

Polarization Phenomena of Compton Scattering in the Hard X-Ray Regime Revealed by Compton Polarimetry — •Tobias Over[1,2,3], Alexandre Gumberidze[1], Marc O. Herdrich[2,3], Thomas Krings[4], Wilko Middents[1,2,3], Philip Pfäfflein[1,2,3], Uwe Spillmann[1], Günter Weber[1,2], and Thomas Stöhlker[1,2,3] — [1]GSI GmbH, Planckstraße 1, 64291 Darmstadt — [2]HI Jena, Fröbelstieg 3, 07743 Jena — [3]FSU Jena, Leutragraben 1, 07743 Jena — [4]FZ Jülich, Wilhelm-Johnen-Straße, 52425 Jülich

For photon energies from several tens of keV up to a few MeV, Compton polarimetry is an indispensable tool to gain insight into subtle details of fundamental radiative processes in atomic physics. Within the SPARC collaboration several segmented semiconductor detectors have been developed that are well suited for application as efficient Compton polarimeters. For electron-photon and photon-photon scattering processes in the hard x-ray regime these kind of detectors enable revealing photon polarization effects in great detail. Particular emphasis is given to processes common in astrophysical objects. For processes such as radiative recombination, electron bremsstrahlung, Rayleigh and Compton scattering where spin-effects and polarization transfer phenomena are of great importance. In our presentation, an overview of recent results obtained for inelastic scattering in the hard x-ray regime as well as ongoing experimental projects will be presented. In particular, we will discuss the extension to photon energies of several hundreds of keV, using a novel Compton telescope detector.

A 25.13 Wed 17:00 Tent A

Wigner vs. Smith: Time delays in anisotropic potentials — •Ulf Saalmann and Jan M Rost — Max-Planck-Institut für Physik komplexer Systeme, Dresden/Germany

Scattering properties and time delays for non-symmetric potentials are discussed paradigmatically in one dimension in comparison to symmetric ones. Only for the latter the Wigner and Smith time delays coincide. We further discuss the importance of the potential position and give a criterion how to identify a potential with intrinsic symmetry which behaves like an asymmetric one if it is merely offset from the scattering center. [arxiv.org/abs/2309.02059]

A 25.14 Wed 17:00 Tent A

The attoclock and its interpretation, real-valued tunneling time and superluminal tunneling — •Ossama Kullie — 1 Theoretical Physics, Institute of Physics, University of Kassel

Tunneling is a quantum mechanical phenomena. The time required for the tunneling or field-ionization of an electron from an atom through a laser field can be measured using the so-called attoclock. However, some authors claim that the time delay measured by the attoclock is not an indicator of the tunneling time. We present a model that describes the tunnel- or field-ionization of the attoclock experiment for He- [1] and H-atom [2], in the adiabatic and nonadiabatic field calibrations [3]. And we show that one can interpret the attoclock measurement in such a way that it is possible to determine the tunneling time or the time delay due the barrier region or the classically forbidden region. We also show that for the weak measurement [4], in which the time is usually measured by the Larmor clock [5], the attoclock offers a possibility to measure the interaction time for thick barrier and even superluminal tunneling is possible [6].

[1] A. S. Landsman et al, Optica **1**, 343 (2014), U. S. Sainadh et al, Nature **586**, 75 (2019). [2] C. Hofmann et al. J. Mod. Opt. **66**, 1052 (2019). [3] O. Kullie, Phys. Rev. A **92**, 052118 (2015), O. Kullie and I. A. Ivanov, arXiv:2005.09938v6. [4] Y. Aharonov, Phys. Rev. A. **65**, 052124 (2002). [5] R. Ramos, Nat. 538, 529 (2020). [6] Work in preparation.

A 25.15 Wed 17:00 Tent A

A Coincidence Unit for Ultracold Quantum Gases combining Electron Velocity-Map-Imaging and Ion-Microscopy — •Lasse Paulsen[1], Jette Heyer[1,2], Julian Fiedler[1,2], Mario Grossmann[1,2], Klaus Sengstock[1,2], Markus Drescher[1,2], Juliette Simonet[1,2], and Philipp Wessels-Staarmann[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

By combining femtosecond laser pulses with ultracold quantum gases, new states of matter ranging from atom-ion hybrid sytems over dense Rydberg gases to ultracold microplasma can be created using local strong-field excitation and ionization.

In order to access the dynamics of these complex systems, a high spatial, spectral and angular resolution of the generated electrons and ions is necessary. Therefore, a coincidence unit consisting of a velocity-map-imaging spectrometer for electrons and an ion microscope will be implemented in the experimental setup. This allows mapping the electron momenta with a simulated energy resolution of $\Delta E/E \leq 10\%$ over a range of 0.05 meV - 3.2 eV and imaging of the ions with a spatial resolution of 100 nm. Furthermore, coincidence detection is enabled via pulsed extraction allowing to study the dynamics and correlations in many-body-systems with long-range interaction.

A 25.16 Wed 17:00 Tent A

Probing Axions and Axion Like Particles through Cosmic Axion Spin Precession Experiment- High-field — •Malavika Unni for the CASPEr-Collaboration — Helmholtz-Institut, GSI Helmholtzzentrum fuer Schwerionen-forschung, 55128 Mainz, Germany

Cosmic Axion Spin Precession Experiment (CASPEr) [1,2] investigates pseudoscalar bosons, axions, and axionlike particles (ALPs), through their interactions with standard model particles. Axions offer a solution to the formidable strong CP problem and provide a compelling link to Dark Matter. In this work, we study the coupling of the axion and ALP field with fermions. Utilizing Nuclear Magnetic Resonance (NMR) spectroscopy, we search for the coupling between Axions (and ALPs) and nuclear spins. In the CASPEr high-field setup featuring a 14.1 T magnet, we explore the frequency range of 70 to 600 MHz using tunable LC circuits cooled to cryogenic temperatures. In conjunction with a shim coil integrated into the cryostat, we employ an additional shim stack to ensure field homogeneity. We also examine various hyperpolarization techniques and identify the most suitable samples for achieving high sensitivity. Further details on our experimental setup and the NMR-detection system will be elaborated in the presentation. [1]. P. W. Graham, S. Rajendran, Phys. Rev. D 88, 035023 (2013) [2]. D. Budker, P. W. Graham, M. Ledbetter, S. Rajendran, A.O.Sushkov, Phys. Rev. X 2014.

A 25.17 Wed 17:00 Tent A

Automated loading of Highly Charged Ions in a Paul Trap — •Lukas Fabian Storz — Max-Planck-Institut für Kernphysik, Heidelberg

Automatizations for experiments are crucial to maximize productivity and accuracy. We have implemented an algorithm using the fluorescence of Be-Ions detected on a CCD camera to automatically load large Be-Crystals. The presence of an HCI causes a void of Be^+ in the crystal, which shows as a hole in the image. Its radius depends on the HCI charge state, and HCI recombination with residual gas changes it, allowing us to monitor the density at the trap over several months. Simultaneously the secular frequencies also yield the charge state. Our algorithm is applicable to similar ion trapping experiments and serve for their optimization.

A 25.18 Wed 17:00 Tent A

Automated loading of Highly Charged Ions in a Paul Trap — •Lukas Fabian Storz, Vera M. Schäfer, Elwin A. Dijck, Stepan Kokh, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Automatizations for experiments are crucial to maximize productivity and accuracy. We have implemented an algorithm using the fluorescence of Be-Ions detected on a CCD camera to automatically load large Be-Crystals. The presence of an HCI causes a void of Be^+ in the crystal, which shows as a hole in the image. Its radius depends on the HCI charge state, and HCI recombination with residual gas changes it, allowing us to monitor the density at the trap over several months. Simultaneously the secular frequencies also yield the charge state. Our algorithm is applicable to similar ion trapping experiments and serve for their optimization.

A 25.19 Wed 17:00 Tent A

Catalyzation of supersolidity in binary dipolar condensates — •Daniel Scheiermann[1], Luis Ardila[1], Thomas Bland[2,3], Russell Bisset[3], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Quantenoptik and Quanteninformation, Innsbruck, Austria — [3]Institut für Experimentalphysik, Universität Innsbruck, Austria

Breakthrough experiments have newly explored the fascinating physics of dipolar quantum droplets and supersolids. The recent realization of dipolar mixtures opens further intriguing possibilities.

We show that under rather general conditions, the presence of a second component catalyzes droplet nucleation and supersolidity in an otherwise unmodulated condensate. For miscible mixtures, droplet catalyzation results from the effective modification of the relative dipolar strength, and may occur even for a surprisingly small impurity doping. We show that different ground-states may occur, including the possibility of two coexisting interacting supersolids. The immiscible regime provides a second scenario for double supersolidity in an array of immiscible droplets.

Further we will discuss how the superfluidity of this mixture can be tested.

A 25.20 Wed 17:00 Tent A

A cavity-microscope for micrometer-scale control of atom-photon interactions — •Ekaterina Fedotova, Francesca Orsi, Rohit Bhatt, Jonas Faltinath, Gaia Bolognini, Nick Sauerwein, and Jean-Philippe Brantut — Institute of Physics and Center for Quantum Science and Engineering, EPFL, Lausanne, Switzerland

Cavity quantum-electrodynamics enables measurements of atoms with sensitivity limited by quantum backaction. Over the last decade, the possibility to observe and control the motion of few or individual atoms using cavity-enhanced light-matter coupling has been exploited to realize various quantum technological tasks. A principle limitation of these experiments lies in the mode structure of the cavity, which is hard-coded in the distance and geometry of the mirrors, effectively trading spatial resolution for enhanced sensitivity.

In this poster, I will present our cavity-microscope device allowing for spatio-temporal programming of the light-matter coupling of atoms in a high finesse cavity. This is achieved through local Floquet engineering of the atomic structure, imprinting a corresponding light-matter coupling. We illustrate this capability by engineering micrometer-scale coupling, using cavity-assisted atomic measurements and optimization. Our system has the same footprint and complexity as a standard Fabry-Perot cavities or confocal lens pairs, and can be used for any atomic species. This technique opens a wide range of perspectives from ultra-fast, cavity-enhanced mid-circuit readout to the quantum simulation of fully connected models of quantum matter such as the Sachdev-Ye-Kitaev model.

A 25.21 Wed 17:00 Tent A

Towards measurements of axionic Dark Matter with the CASPEr-gradient low-field experiment — •Julian Walter and Yuzhe Zhang for the CASPEr-Collaboration — Helmholtz-Institut, GSI Helmholtzzentrum fuer Schwerionenforschung, 55128 Mainz, Germany

Axions and other light pseudoscalar bosons (< 1 eV$/c^2$) which are collectively referred to as axion-like particles (ALPs) have become well-motivated dark matter candidates. The Cosmic Axion Spin Precession Experiment (CASPEr) [1] aims at detecting ALPs with nuclear magnetic resonance techniques. CASPEr-Gradient in Mainz probes the hypothetic coupling of nuclear spins to the gradient of the ALP field [2]. The experimental apparatus was designed to scan ALPs with Compton frequencies of up to 600 MHz, corresponding to a mass range of approximately up to 10^{-6} eV. We performed a test measurement on a thermally polarized liquid methanol sample at a 317 G leading field, which corresponds to searching for ALP fields at 1.348568 MHz within a 238-Hz bandwidth. The data analysis strategy and preliminary results are presented.

[1] D. F. J. Kimball et al. "Overview of the Cosmic Axion Spin Precession Experiment (CASPEr)". In: *Microwave Cavities and Detectors for Axion Research.* Cham: Springer International Publishing, 2020, pp. 105-121. ISBN: 978-3-030-43761-9
[2] P. W. Graham and S. Rajendran. "New observables for direct detection of axion dark matter". In: *Phys. Rev. D* 88 (3 Aug. 2013), p. 035023. DOI: 10.1103/PhysRevD.88.035023.

A 25.22 Wed 17:00 Tent A

Probing resonant absorption in helium using intense XUV FEL pulses — •Arikta Saha[1], Alexander Magunia[1], Harijyoti Mandal[1], Muwaffaq Ali Mourtada[1], Carlo Kleine[1], Yu He[1], Marc Rebholz[1], Gergana D. Borisova[1], Hannes Lindenblatt[1], Florian Trost[1], Robert Moshammer[1], Stefan Düesterer[2], Tino Lang[2], Ulrike Fruehling[2], Christina Papadopoulou[2], Christina Böemer[2], Dietrich Krebs[2], Skirmantas Alisaukas[2], Christoph Heyl[2], Ingmar Hartl[2], Steffen Palutke[2], Markus Braune[2], Elisa Appi[3], Doriana Vinci[4], Milutin Kovacev[5], Philip Mosel[5], Peer Biesterfeld[5], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Deutsches Elektronen Synchrotron DESY, 22607 Hamburg, Germany — [3]Lund University, 22100 Lund, Sweden — [4]European XFEL, 22869 Schenefeld, Germany — [5]Universität Hannover, 30167 Hannover, Germany

We studied excited state dynamics of helium using intense XUV FEL pulses. The XUV-driven nonlinear dynamics was measured by transient absorption spectroscopy. In the absorption spectrum, we look at 1s4p lineshape modifications in helium. The absorption lineshape is first excited by XUV pulses from high harmonic generation(HHG) and further modified by intense XUV FEL pulses, which leads to a change in the absorption feature. We observe absorption line shape modifications in the 1s4p line in time-resolved measurements on the femtosecond and picosecond timescale, as well as a function of FEL photon energy, FEL intensity, and helium target gas pressure.

A 25.23 Wed 17:00 Tent A

Nuclear photoabsorption in ^{229}Th using twisted light — •Tobias Kirschbaum and Adriana Pálffy — Julius-Maximilians-Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Twisted light refers to light beams that carry orbital angular momentum. The past decade has witnessed several studies of the interaction of these beams with matter, in particular with atomic systems. Among others, twisted light beams are used in quantum metrology to minimize the unwanted light shift in atomic clock transitions [1]. A compelling alternative for these atomic clocks, hardly affected by such shifts, is the ^{229}Th nucleus which has a long-lived first excited state at ≈ 8 eV [2].

Here, we investigate new avenues for the photoexcitation of the ^{229}Th nuclear isomer using vortex beams. We focus on spatial and temporal excitation patterns induced by the twisted light field for the magnetic dipole and electric quadrupole channels of the nuclear transition. Nuclear excitation in both solid-state targets presenting nuclear hyperfine splitting as well as single ions is investigated and the advantages compared to plane wave driving are highlighted.

[1] R. Lange *et al.*, Phys. Rev. Lett. **129**, 253901 (2022).
[2] E. Peik *et al.*, Quantum Sci. Technol. **6**, 034002 (2021).

A 25.24 Wed 17:00 Tent A

Two-colour cooling for 40K-87Rb quantum gas mixtures — •Yann Hendrick Kiefer[1,2], Max Hachmann[2], and Andreas Hemmerich[2] — [1]ETH Zürich, Zürich, Schweiz — [2]Universität Hamburg, Hamburg, Deutschland

We present an efficient cooling scheme for fermionic 40-potassium atoms, using laser light red and blue detuned with respect to the D2 and D1 principle flourescence lines, respectively. The cooling scheme is found to significantly increase the saturation level for loading of a 40-potassium magneto-optical trap (MOT), resulting in increased atom numbers or decreased cycle times. While the attainable 40-potassium atom number is approximately doubled if exclusively 40-potassium atoms are cooled, the scheme is particularly powerful for dual-species MOTs, for example, if 40-potassium and 87-rubidium atoms are cooled simultaneously in the same MOT configuration. The typical atom losses due to light-assisted hetero-nuclear collisions between 40-potassium and 87-rubidium seem to be reduced giving rise to a threefold improvement of the 40-potassium atom number as compared to that in a conventional dual-species MOT, operating merely with D2 light. Our scheme can be a useful extension to most dual-species experiments, aiming to reach simultaneous degeneracy of both species.

A 25.25 Wed 17:00 Tent A

Cost Effective Modernization of the Aging Computerized Control System of the Buffergas-Cell Setup for Studies of the ^{229m}Th Isomer — •Georg Holthoff, Daniel Moritz, Lilli Löbell, and Peter G. Thirolf — LMU, Munich, Germany

We discuss the ever more prevalent issue of aging and failing computers used for the control of long running experimental setups, which, in the worst-case scenario, can lead to complete loss of operation of an experiment and necessitate immense recovery efforts. How these systems can be modernized at low cost, either by virtualization and adaption of existing hardware, or by complete replacement using customized microcontroller based solutions, is the main focus. Both paths are compared and possible advantages and disadvantages laid out, which may offer guidance for the proper choice in similar situations.

As example, the modernization of a system, built in the early 2000s to run an experimental setup for the identification and characterization of the low-energy nuclear clock thorium isomer ^{229m}Th as part of the LMU Nuclear Clock Project, is presented. This system originally was run by an Intel Pentium4 based computer using proprietary PCI-cards (PCI is a now deprecated interface standard) to communicate with an elaborate Siemens Simatic S7 SPS, running multiple pumps, ion optics and a buffer-gas stopping cell. It is assumed that this age range and complexity make it a representative example for the challenges generally faced in such an upgrade scenario. Both routes for replacement are explored as developments for both were undertaken at our setup. Supported by the European Research Council (ERC): Grant 856415.

A 25.26 Wed 17:00 Tent A

Development of multi-wavelength cavity ring-down spectroscopy for radiocarbon analysis — •Erik Thiel[1,2], Naoki Matsumoto[2], Momo Mukai[2], Keisuke Saito[2], Yuta Suzuki[2], Hideki Tomita[2], Kota Tsuge[2], and Klaus Wendt[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz — [2]Department of Applied Energy, Nagoya University, Japan

Cavity ring-down laser spectroscopy provides a highly sensitive method for detection of elements and even individual isotopes in gas samples. Combined with a multichannel laser source, as provided e.g. by a frequency comb, environmental or technical samples can be analysed with the highest efficiency, rapidly and with high significance. Aside of presenting the technique and its capabilities for ultratrace determination of ^{14}C the presentation focusses specifically on the data acquisition procedure and electronics for the ringdown signal which is adapted and optimized for the multiple laser frequency excitation. It is providing a proof of concept for the determination of ring-down decay rate based on time interval analysis which utilizes the discrete recording and processing of two or more timing signals.

A 25.27 Wed 17:00 Tent A

Trapping Ion Coulomb Crystals in an Optical Lattice — •Daniel Hoenig[1], Fabian Thielemann[1], Wei Wu[1], Thomas Walker[1], Leon Karpa[2], Amir Mohammadi[1], and Tobias Schaetz[1] — [1]Albert-Ludwigs Universität Freiburg — [2]Leibniz Universität Hannover

We present recent advancements in trapping $^{138}Ba^{+}$ ions in a one-dimensional optical lattice at a wavelength of 532 nm and the first successful trapping of linear ion Coulomb crystals ($N \leq 3$) in such a trap array. The observed eigenfrequencies of the ions in the lattice and the increased robustness of the trapping probability against axial electric fields provide evidence for confinement of the ions at individual lattice sites.

As optical lattices are extendable in size and dimension, they might allow for the realization of ion-microtrap structures in 2D and 3D. This could enable new pathways towards analog quantum simulation of systems incorporating long-range interactions. Additionally, the absence of micromotion in optical traps could give them an edge over rf-traps in applications, where heating and decoherence induced by micromotion become limiting factors. This includes the study of atom-ion interactions at ultracold temperatures, as well as the creation and study of coherent superpositions of structural crystal phases and their entanglement.

A 25.28 Wed 17:00 Tent A

Enhancing spectroscopic resolution for coherent control of photoionization with a novel XUV photon spectrometer — •Harijyoti Mandal[1], Muwaffaq Ali Mourtada[1], Alexander Magunia[1], Weiyu Zhang[1], Yu He[1], Hannes Lindenblatt[1], Florian Trost[1], Lina Hedewig[1], Cristian Medina[1], Arikta Saha[1], Marc Rebholz[1], Ulrike Frühling[2], Carlo Kleine[1], Gergana D. Borisova[1], Steffen Palutke[2], Evgeny Schneidmiller[2], Mikhail Yurkov[2], Stefan Düsterer[2], Rolf Treusch[2], Chris H. Greene[3], Yimeng Wang[3], Robert Moshammer[1], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Deutsches Elektronen Synchrotron DESY, 22607 Hamburg, Germany — [3]Purdue University, West Lafayette, IN 47907, USA

Extreme-ultraviolet (XUV) free-electron lasers (FELs) can be used for nonlinear multiphoton excitation or ionization of atoms and molecules. Interfering pathways of the second harmonic of the FEL pulses can be used for coherent control experiments, however their spectral content is typically not measured, which is particularly important for stochastic FEL pulses with spectral fluctuations from shot to shot. We present a novel XUV photon spectrometer capable of simultaneously measuring fundamental (ω) and second harmonic (2ω) of FEL spectra. The spectrometer is installed at FLASH, Hamburg, and operates at a repetition rate of 100 kHz. We use phosphor screens and out-of-vacuum imaging onto two GOTTHARD detectors, allowing us to resolve the intrinsic spectral pulse structure of both ω and 2ω FEL pulses. Using a reaction microscope we measured the three-dimensional momentum distributions of helium recoil ions by tuning FLASH in the vicinity of intermediate singly excited states.

A 25.29 Wed 17:00 Tent A

Partial-wave representation of the strong-field approximation: length versus velocity gauge — Fang Liu[1,2,3], •Kefei Zou[1,2,3], and Stephan Fritzsche[1,2,3] — [1]Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich- Schiller-Universität Jena, 07743 Jena, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany

The strong-field approximation (SFA) is a commonly used method to study ionization of atoms by intense laser field. Recently, a reformulation of the SFA in terms of partial waves expansion has been presented in [Phys. Rev. A 102, 053108 (2020)]. In this contribution, we investigate the above threshold ionization of the atom driven by elliptically polarized light pulse. In addition, we calculate the angular distribution of photoelectrons in both velocity and length gauge. Our results show differences between the two gauges. Moreover, we find that the angular distribution of the photoelectrons calculated in length gauge are in better agreement with the experimental data than those from velocity gauge. This highlights the importance of choosing the gauge to perform theoretical calculations in SFA.

A 25.30 Wed 17:00 Tent A

Active stabilization of a standing wave in a femtosecond enhancement cavity with a cw laser interferometer — •Lukas Matt, Tobias Heldt, Lennart Guth, Jan-Hendrik Oelmann, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

To study the strong field emission of electrons from metallic nanotips or noble gases, we have developed a passive enhancement cavity for a frequency comb at 1039 nm [1]. Two different coupling arms into the ring cavity allow counter-propagating pulses to be timed to collide at the focus of the cavity forming a standing wave. Different thermal fluctuations and vibrations of the two coupling paths limit the stability of the standing wave. To maintain a stable phase relationship between the standing wave and the nanotip target we designed an active stabilization system using a narrow-band cw laser at 976 nm forming a Michelson interferometer. The interference signal allows to lock the length difference using Pancharatnam's phase via a piezo-actuated mirror [2]. We present the technical realization of this system.

[1] J.-H. Oelmann et al., Rev. Sci. Instrum., 93(12), 123303 (2022).
[2] M. U. Wehner et al., Opt. Lett., 22(19), (1997)

A 26: Poster V

Time: Wednesday 17:00–19:00 Location: Tent C

A 26.1 Wed 17:00 Tent C

Experiments on highly charged ions from S-EBIT II — •Rex Simon[1,2,3], Tino Morgenroth[1,2,3], Sonja Bernitt[1,2,3], Sergiy Trotsenko[2], Reinhold Schuch[1,4], and Thomas Stöhlker[1,2,3] — [1]Helmholtz Institute Jena, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]IOQ, Friedrich-Schiller-University Jena, 07743 Jena, Germany — [4]Department of Physics, Stockholm University, 106 91 Stockholm, Sweden

Exploring electron-ion interaction reveals fundamental insights into atomic structures and plasma behaviours. Dielectronic recombination (DR) is one of the crucial processes determining ion charge state balance. This knowledge not only enhances theoretical understanding but is vital for accurate plasma diagnostics[1]. The electron beam ion trap S-EBIT II at the HITRAP ion trapping and cooling facility will serve not only as an exceptional ion source but also operate autonomously, making it a versatile tool for various experiments such as cutting-edge experiments with extracted highly charged ions for measurements of charge-changing processes, notably DR. Integration with the HITRAP beam line, addresses the dynamic requirements of evolving experimental research.

References [1] Beilmann, C. et al. (2013). Multielectronic K-L intershell resonant recombination in Ar, Fe, and Kr ions. Phys. Rev. A, 88(6), 062706.

A 26.2 Wed 17:00 Tent C

Towards a potassium quantum gas miscroscope — •Scott Hubele[1,2], Martin Schlederer[1,2], Alexandra Mozdzen[1,2], Guillaume Salomon[1,2], and Henning Moritz[1,2] — [1]Institute for Quantum Physics, University of Hamburg, Hamburg, Germany — [2]Hamburg Centre for Ultrafast Imaging, University of Hamburg, Hamburg, Germany

Understanding many-body quantum systems, both in and out of equilibrium, is often computationally challenging due to the large Hilbert space of the systems of interest. This makes quantum simulation very attractive, especially when the relevant observables and their correlations can be measured directly. The Bose-Hubbard model for instance, which describes interacting bosons in lattices, can be well simulated using ultracold atoms loaded into optical lattices. High-resolution imaging can then be used to resolve the occupation of each lattice site, in what is known as a quantum gas miscroscope.

Here, we present our progress towards building a quantum gas microscope using ultracold potassium-39, to study the Bose-Hubbard model in 2D. We create an interfering 2D optical lattice by sending a single 1064nm beam twice through the science chamber at orthogonal angles, and retroreflecting it. A shallow angle vertical lattice is used to confine the atoms along the z direction. After some time evolution, a high-NA objective will then used to collect fluorescence from the atoms using Raman sideband imaging. Characterization of our optical lattices is presented as well as progress towards single-site resolved imaging.

A 26.3 Wed 17:00 Tent C

Microwave control of Rydberg pair states — •Shuanghong Tang, Fabio Bensch, Philip Osterholz, Lea-Marina Steinert, Arno Trautmann, and Christian Gross — Eberhard Karls Universität, Tübingen, Germany

Quantum simulator based on Rydberg atoms is a powerful tool to study quantum many-body behaviors. An experimental system with single potassium-39 atoms placed in 2D arrays of optical tweezers with sophisticated resorting algorithm allows us to use microwave to control the interactions of defect-free Rydberg atom array. Here, we present our two-photon excitation scheme and the microwave engineering potential of Rydberg states. With the implementation of the microwave, we are able to couple the different Rydberg states and engineer the potential between them.

A 26.4 Wed 17:00 Tent C

Penetration of s-holes via VU-LVa light — •Annbuhlika kom

Fan, Claire Anlage, Andi Macht, and Balude Erbeer — Mahatma University of Fake, Chennai Street 5

In past VU-LVa light as shown great performance of stripping s-holes of various elements from light metals to heavy interacting species. Compared to UV its complicated but more successful in penetrating s-holes as will be presented. Generation, propagation and annhilation of VU-LVa light is discussed in the progress of s-holes penetration is shown via an Iron-Y2-system. Possibillity of use in Gl0-RY hole mechanism is discussed.

A 26.5 Wed 17:00 Tent C

The way towards low-energy, heavy, highly charged ions: the Hitrap deceleration facility — •Nils Stallkamp for the Hitrap-Collaboration — GSI Helmholtzentrum für Schwerionenforschung GmbH, Darmstadt — Institut für Kernphysik, Goethe Universität Frankfurt am Main

The HITRAP facility, located at the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, is designed to decelerate and cool heavy, highly charged ions (HCI) created by the GSI accelerator complex and make them accessible at low energies for precision experiments. The system consists of a two-stage deceleration structure, an interdigital H-type linac (IH) and a radio-frequency quadrupole (RFQ), followed by a cryogenic Penning-Malmberg trap for subsequent ion cooling. The deceleration stages reduce the ion energy from 4 MeV/u to 500 keV/u and to 6 keV/u respectively, before forwarding a slow, but hot ion bunch towards the cooling trap. The trap is operated in a so-called nested configuration, in which the electrons, created by an external photoelectron source, are stored simultaneously with the HCI and serve as cold thermal bath.
Recently, the first indications of electron cooling of locally-produced HCI in a Penning trap could be achieved, a major milestone towards heavy HCI at eV and sub-eV energies. We will present the current status of those measurements as well as upcoming steps for further systematic studies of the cooling process.

A 26.6 Wed 17:00 Tent C

ORKA - Design of a cavity enhanced optical dipole trap for the preparation of a Rb87 BEC — •Marius Prinz, Jan Eric Stiehler, Marian Woltmann, and Sven Herrmann — Center of Applied Space Technology and Microgravity (ZARM), University of Bremen, Germany

The LASERs commonly used in optical traps for evaporative cooling to prepare ultra-cold atoms and generate BECs usually come with the downside of a high power budget. A more energy efficient and compact solution for optical dipole traps is to resonantly enhance a low-power trapping laser in a bow tie cavity. In the ORKA project we aim to exploit this to generate a crossed optical dipole trap for preparation of a Rb87 BEC with an input laser power <50 mW. This allows for an experimental setup with a reduced space- and power-budget as compared to commonly used dipole traps, so it can be used for matter-wave-interferometry and microgravity experiments at the Bremen Gravitower Pro. Here we present the properties of our bow tie cavity and the experiment design compatible with the constraints of operation in a drop tower capsule. Our simulations predict an optical dipole trap suitable for BEC preparation with an input power <10 mW using a bow tie cavity with a finesse of >15k for both 780nm and 1064nm. The ability to manipulate the atoms with near resonant light inside the cavity opens up a further avenue for interesting future research. The ORKA project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action under grant number DLR 50 WM 2267.

A 26.7 Wed 17:00 Tent C

Data analysis solution for axion dark matter research — •Yuzhe Zhang[1], Julian Walter[1], and Declan Smith[2] for the CASPEr-Collaboration — [1]Helmholtz-Institut, GSI Helmholtzzentrum fuer Schwerionenforschung, 55128 Mainz, Germany — [2]Department of Physics, Boston University, Boston, MA 02215, USA

Axions, originally proposed as a solution to the strong-CP problem, have become a dark matter candidate. Theory predicts that the axion field has three kinds of non-gravitational couplings to standard-model particles: the axion-photon, axion-gluon and axion-fermion couplings. These couplings will generate characteristic signals in axion haloscopes. Here, we present the data analysis procedure used in two experiments: Search for Halo Axions with Ferromagnetic Toroids (SHAFT) [1] and Cosmic Axion Spin Precession Experiment (CASPEr) [2]. The analysis not only includes commonly-used signal processing techniques, but also takes advantage of the expected axion lineshape to further increase the signal-to-noise ratio. This work is of potential interest to general axion and other exotic physics research since the data analysis procedure can be tailored to different experiments by specifying the expected signal*s spectral signature.

[1] A. V. Gramolin, D. Aybas, D. Johnson, J. Adam, A. O. Sushkov, Nature Physics 2021, 17, 1 79.

[2] D. Budker, P. W. Graham, M. Ledbetter, S. Rajendran, A. O. Sushkov, Phys. Rev. X 2014, 4.

A 26.8 Wed 17:00 Tent C

Rymax one: A neutral atom quantum processor to solve optimization problems — Tobias Ebert[1], •Jonas Witzenrath[2], Benjamin Abeln[1], Silvia Ferrante[1], Kapil Goswami[1], Jonas Gutsche[2], Hendrik Koser[1], Rick Mukherjee[1], Jens Nettersheim[2], Jose Vargas[1], Niclas Luick[1], Thomas Niederprüm[2], Dieter Jaksch[1], Henning Moritz[1], Herwig Ott[2], Peter Schmelcher[1], Klaus Sengstock[1], and Artur Widera[2] — [1]University of Hamburg, 22761 Hamburg, Germany — [2]RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

From efficient distribution of workload in industrial manufacturing plants to short vehicle routes for parcel delivery - computationally hard optimization problems are a crucial part of our modern society. While finding solutions using classical solvers requires substantial computational resources, quantum processors promise to yield better solutions in less time.

To explore the potential of quantum computing for real-world applications we are building Rymax One (www.rymax.one), a quantum processor specifically designed to solve hard optimization problems. By using ultracold neutral Ytterbium atoms trapped in arbitrary arrays of optical tweezers, we aim for hardware-efficient encoding of optimization tasks. The level structure of ^{171}Yb provides qubit realizations with long coherence times, Rydberg-mediated interactions and high-fidelity gate operations, allowing us to realize a scalable platform for quantum processing. On that we will explore the performance of novel quantum algorithms to tackle real-world problems.

A 26.9 Wed 17:00 Tent C

Towards Spin-Resolved Single Atom Detection in Disordered Many-Body Rydberg Systems — •Valentina Salazar Silva, Eduard Braun, Sebastian Geier, Gerhard Zürn, and Matthias Weidemüller — Physikalisches Institut, Heidelberg, Deutschland

Rydberg systems remain a key tool in many areas of research due to their unique properties arising from highly excited electronic states. The mapping of many-body spin systems onto tunable Rydberg states has so far allowed for the observation of unique phenomena, such as the stretched relaxation dynamics of disordered spin systems on intermediate timescales, which cannot be accurately described by mean-field theory. These findings could be explained by an emergent integrability, where the dynamics are governed by pairs composed of nearest neighbor spins. Until now, all the diagnostics have been based on measuring average quantities like densities and magnetization. The next step, building upon our latest results, is to study this emergence of integrability at a microscopic level by enabling local access to pair-correlations. The spatial and spin resolution of single atoms can be achieved by adapting a standard fluorescence imaging scheme, as it has been demonstrated for localized Lithium atoms in a two-dimensional plane. In the case of the heavier Rubidium atoms and under similar conditions, we expect a significant performance improvement. Here we discuss the theoretical calculations and first considerations for the designing of an efficient fluorescence imaging setup, taking direct advantage of the Rydberg-manifold, as well as necessary adaptations for the resolving of correlation functions.

A 26.10 Wed 17:00 Tent C

High-performance optical clocks based on ^{171}Yb$^+$ — Martin Steinel, Melina Filzinger, •Saaswath JK, Jian Jiang, Ekkehard Peik, and Nils Huntemann — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Optical clocks based on narrow-linewidth electronic transitions of trapped ions are employed in various high-precision experiments probing the limits of our current understanding of physics. The ^{171}Yb$^+$ ion is particularly suited to these measurements, because it provides two transitions with large sensitivity to variations of fundamental constants and low sensitivity to external perturbations. Comparisons of its $^2S_{1/2} - {}^2D_{3/2}$ electric quadrupole (E2) and $^2S_{1/2} - {}^2F_{7/2}$ electric octupole (E3) transition currently provide most stringent limits on potential variations of the fine structure constant and constrain the coupling between normal matter and ultra-light dark matter.

The systematic uncertainty of high-performance $^{171}Yb^+$ optical clocks operated at room temperature has so far been limited by the uncertainty in the sensitivity of the transitions to thermal radiation $\Delta\alpha$. For the $^{88}Sr^+$ ion, $\Delta\alpha$ has been measured with significant lower uncertainty. We employ this by using the $^{88}Sr^+$ as a temperature sensor and determine it's clock transition frequency with record accuracy. In addition, we calibrate the intensity of an infrared laser with a single $^{88}Sr^+$ ion. Measurements of the induced frequency shift of an $^{171}Yb^+$ ion at the same position in the beam provides the corresponding $\Delta\alpha$. This way, we largely reduce the uncertainty achievable with $^{171}Yb^+$ ion clocks.

A 26.11 Wed 17:00 Tent C

Quantum Monte Carlo simulations of hardcorde bosons with repulsive dipolar density-density interactions on two-dimensional lattices — •Robin Rüdiger Krill[1,2], Jan Alexander Koziol[2], Calvin Krämer[2], Anja Langheld[2], Giovanna Morigi[1], and Kai Phillip Schmidt[2] — [1]Theoretical Physics, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 7, Germany

We apply stochastic series expansion quantum Monte Carlo simulations to determine ground-state properties of frustrated long-range hardcore Bose-Hubbard lattice models in two dimensions. Recent investigations of such systems with mean-field approaches indicate rich quantum phase diagrams including a devil's staircase of solid phases and a plethora of exotic lattice supersolids [1,2]. The quantum Monte-Carlo approach allows us to extend this mean-field study by fully incorporating quantum fluctuations, and thus to analyse the interplay among frustration, long-range interactions, and quantum fluctuations.

[1] J.A Koziol, A.Duft, G.Morigi, K.P. Schmidt, SciPost Phys. 14, 136 (2023)
[2] J.A Koziol, G.Morigi, K.P. Schmidt, arXiv:2311.10632 (2023)

A 26.12 Wed 17:00 Tent C

Signatures of IR-laser dressing in coherent diffractive imaging — •Tom von Scheven, Björn Kruse, Bjarne Mergl, Christian Peltz, and Thomas Fennel — Institute of Physics, University of Rostock, Albert-Einstein-Str. 23-24, D-18059 Rostock, Germany

Single-shot coherent diffractive imaging (CDI) enables the capture of a full diffraction image of a nanostructure using a single flash of XUV or X-ray light. The resulting scattering image encodes both the geometry and the optical properties of the target. So far, this method has mainly been employed for ultrafast structural characterization [1]. However, CDI can also be utilized to resolve ultrafast optical property changes caused by e.g. transient excitation from nonlinear scattering [2], or by illumination with a second ultra-short laser pulse.

Here, we explore the expected signatures for the latter case theoretically, where simultaneous exposure to a strong IR field can induce transient optical properties. To this end, the effective optical properties emerging from the laser dressing must be determined and used to describe the resulting scattering process, which we model using the well-known Mie-solution. We extract the effective optical properties from the dipole response of a local quantum description based on an atom-like solution of the time-dependent Schrödinger equation. The identification of the states and processes responsible for these properties and the corresponding features in the diffraction image is performed by a systematic comparison with results for a few-level system.

[1] I. Barke *et al.*, Nat. Commun. **6**, 6187 (2015)
[2] B. Kruse *et al.*, J. Phys.: Photonics **2**, 024007 (2020)

A 26.13 Wed 17:00 Tent C

Exploration of Supersolidity in Spin-Orbit Coupled Bose-Einstein Condensates — •Sarah Hirthe, Vasiliy Makhalov, Rémy Vatré, Craig Chisholm, Ramón Ramos, and Leticia Tarruell — ICFO - The Institute of Photonic Sciences, Castelldefels, Spain

A Supersolid is an exotic phase of matter that combines seemingly opposing characteristics of solids and superfluids. It displays spontaneous translational symmetry breaking manifesting in crystalline order, while also possessing superfluid properties like frictionless flow. Although originally predicted over fifty years ago in the context of solid Helium, supersolidity was first observed only few years ago using ultracold atoms. In these systems, various approaches like cavity-mediated interactions, dipolar interactions, or optically induced spin-orbit coupling can cause the spontaneous breaking of translational symmetry. Here, we characterize supersolidity in a spin-orbit coupled Bose-Einstein condensate of potassium. This dressed system displays an engineered single-particle dispersion relation with two minima at distinct momenta. Matter-wave interference between the condensates in the two minima gives rise to a density modulation, thus realizing the so-called supersolid stripe phase. We are able to observe this spontaneous stripe pattern in-situ, by employing a matter-wave lensing technique to magnify the density. Furthermore, we characterize the collective modes of our system. In particular, we observe a softening of the spin dipole mode for increasing coupling strength.

A 27: Precision Spectroscopy of Atoms and Ions III (joint session A/Q)

Time: Thursday 11:00–13:00 Location: HS 1010

A 27.1 Thu 11:00 HS 1010

Resolved sideband spectroscopy of cold mixed ioncystals of Ca^+ and Th^+ — •Azer Trimeche[1], Can Leichtweiss[1], Jonas Stricker[2,3], Valerii Andriushkov[1,2], Dmitry Budker[1], Christoph E. Düllmann[2,3,4], and Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [2]Helmholtz-Institut Mainz, Germany — [3]Department Chemie - Standort TRIGA, Johannes Gutenberg-Universität Mainz, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Thorium isotopes became of high interest in the search for new physics, and fundamental physics tests, because of their unique nuclear and atomic properties. The **T**rapping **A**nd **C**ooling of **T**horium **I**ons in **Ca**lcium crystals (TACTICa) project develops ion trapping and spectroscopic techniques for a precise determination of the nuclear moments, hyperfine intervals, and isotope shifts with different Th isotopes. For the production, we use two different sources: a recoil ion source [1] and a laser ablation source [2]. $^{232}Th^+$ ions are trapped in a $^{40}Ca^+$ crystal [2], and cooled down sympathetically by polarization gradient cooling [3]. We implement resolved sideband spectroscopy of mixed Ca-Th ion crystals as a starting point for resolved sideband ground state cooling of crystals with extreme charge-to-mass ratio difference and quantum logic spectroscopy of Th ions.

[1] R. Haas et al., Hyperfine interactions 241 (2020) 25.
[2] K. Groot-Berning et al., *PRA* 99 (2019) 023420.
[3] W. Li et al., *NJP* 24(4) (2022) 043028.

A 27.2 Thu 11:15 HS 1010

High-resolution spectroscopy of fermium-255 at the RISIKO mass separator — •Mitzi Urquiza-González for the Fermium-Collaboration — Division HÜBNER Photonics, Hübner GmbH & Co KG, 34123 Kassel, Germany

Laser spectroscopy measurements can provide information about fundamental properties of both atomic and nuclear structure. Such measurements are of particular importance for the heaviest actinides and superheavy elements, where data is sparse. During the last measurement campaign at the RISIKO mass separator facility in the Institute of Physics in the Johannes Gutenberg University Mainz (JGU), nine successive samples, consisting of 108 to 109 atoms, were used to study the atomic and nuclear structure of ^{255}Fm (Z=100).

This presentation will focus on the hyperfine structure (HFS) of ^{255}Fm for two different excited levels, from which the hyperfine coupling constants have been determined.

A 27.3 Thu 11:30 HS 1010

Hyperfine Spectroscopy of Single Molecular Hydrogen Ions in a Penning Trap at Alphatrap — •C. M. König[1], M. Bohman[1], V. Hahn[1], F. Heisse[1], I. V. Kortunov[2], A. Kulangara Thottungal George[1], J. Morgner[1], F. Raab[1], T. Sailer[1], K. Singh[1], B. Tu[1,3], V. Vogt[2], K. Blaum[1], S. Schiller[2], and S. Sturm[1] —

[1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg — [2]Institut für Experimentalphysik, Univ. Düsseldorf, 40225 — [3]Institute of Modern Physics, Fudan University, Shanghai 200433

Molecular hydrogen ions (MHI) are a simple system allowing the comparison of high-precision measurements to state-of-the-art QED theory, testing the validity of the latter. At ALPHATRAP [1], we can isolate and confine a single MHI for months and perform high-precision spectroscopy using non-destructive quantum state detection.
I will present the results of hyperfine structure measurements on a single HD^+ ion. From these, the bound g factor of the constituent particles, as well as coefficients of the hyperfine Hamiltonian can be extracted. The latter are important for a better understanding of rovibrational spectroscopy performed on this ion, from which fundamental constants, such as $m_\mathrm{p}/m_\mathrm{e}$ are determined to highest precision [2].
We are currently upgrading our trap for single-ion rovibrational laser spectroscopy of MHI. The development of these techniques is one of the required steps towards spectroscopy of an antimatter $\overline{\mathrm{H}}_2^-$ ion [3].

[1] S. Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 1425*1491 (2019)
[2] I. V. Kortunov, *et al.*, Nature Physics vol **17**, 569*573 (2021)
[3] E. Myers, Phys. Rev. A **98**, 010101(R) (2018)

A 27.4 Thu 11:45 HS 1010

MMC Array to Study X-ray Transitions in Muonic Atoms — •DANIEL UNGER, ANDREAS ABELN, THOMAS ELIAS COCOLIOS, OFIR EIZENBERG, CHRISTIAN ENSS, ANDREAS FLEISCHMANN, LOREDANA GASTALDO, CESAR GODINHO, MICHAEL HEINES, DANIEL HENGSTLER, PAUL INDELICATO, DANIEL KREUZBERGER, KLAUS KIRCH, ANDREAS KNECHT, JORGE MACHADO, BEN OHAYON, NANCY PAUL, RANDOLF POHL, KATHARINA VON SCHOELER, STERGIANI MARINA VOGIATZI, and FREDERIK WAUTERS — for the QUARTET Collaboration

The QUARTET collaboration aims to improve the accuracy of absolute nuclear charge radii of light nuclei from Li to Ne. A proof-of-principle measurement with lithium, beryllium and boron has recently been performed at the Paul Scherrer Institute. Conventional solid-state detectors do not provide sufficient accuracy in the relevant energy range. We use a low temperature Metallic Magnetic Calorimeter (MMC) array for high-precision X-ray spectroscopy of low-lying states in muonic atoms. MMCs are characterized by a high resolving power of several thousand and a high quantum efficiency in the energy range of interest. We present the experimental setup and the performance of the detector used. We discuss the first preliminary spectra and systematic effects in this first measurement. The obtained data in combination with the achieved energy resolution and calibration should allow a more precise characterization of the muonic X-ray lines. With the knowledge gained, a significant improvement in the determination of nuclear charge radii is expected.

A 27.5 Thu 12:00 HS 1010

Advancing RAdiation Detected Resonance Ionization towards more exotic nuclei — •KENNETH VAN BEEK FOR THE RADRIS COLLABORATION — TU Darmstadt

Experimental data on atomic and nuclear properties for exotic nuclei in the heavy actinide region ($Z \geq 100$) remains scarce up to date. The RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) apparatus, located at GSI, Darmstadt, Germany, is employed to determine such quantities — such as energy levels, ionization potentials, moments, mean-square charge radii, and isotope shifts. Past measurements at RADRIS encompassed the study of $^{245,246,248-250,254}$Fm and $^{251-255}$No. In the current design of the setup the detection of laser ions via their α-decay for nuclei with half-lives in the order of several hours to tens of hours becomes impractical. This presentation will show already obtained results by RADRIS and how future improvements will increase the methods reach towards longer-lived nuclei. This will allow accessing, e.g., ^{246}Cf (35.7 h) and ^{252}Fm (25.39 h). The latter is of special interest, as it lies directly at the $N = 152$ shell gap in the fermium isotopic sequence, thus closing the gap between already studied isotopes on the neutron-rich and on the neutron-poor side.

A 27.6 Thu 12:15 HS 1010

Electron Optical Systems for High-Resolution Electron Time-of-Flight Spectrometer — •NICLAS WIELAND[1], LARS FUNKE[2], LASSE WÜLFING[2], ARNE HELD[2], SARA SAVIO[2], MARKUS ILCHEN[1], and WOLFRAM HELML[2] — [1]Universität Hamburg, Insitut für Experimentalphysik — [2]Technische Universität Dortmund, Fakultät Physik

Angular streaking allows resolving the sub-femtosecond temporal structure of SASE free-electron laser pulses. A circularly polarized infrared laser imprints a phase-dependent momentum shift onto the photoelectron spectra of a gas target. Angle-resolving time-of-flight spectrometers can be used to resolve these. The latter devices typically consist of electron optics, a drift section, and a detector. Parameters such as energy resolution and energy-dependent transmission for the whole system can be determined by simulation. In this talk, we present the finalized simulation-supported spectrometer design used inside our new chamber for the SpeAR_XFEL project. Furthermore, we will introduce the possibility of adaptive electron optics in our spectrometer using the popular open-source computing platform FEniCSx to further increase the achievable resolution and transmission by applying optimizer-determined voltage sets to our optics. Gaining insight into electron trajectories using precise simulations appears to be an efficient way to improve the overall performance of such experiments-We present our progress in terms of electrode design and applied voltages for a 0-3 keV electron energy spectrum to further develop spectrometer research in this field.

A 27.7 Thu 12:30 HS 1010

Calorimetric wire detector for monitoring atomic hydrogen beam — CHRISTIAN MATTHÉ, •ALEC LINDMAN, and SEBASTIAN BÖSER for the Project 8-Collaboration — Johannes Gutenberg Universität, Mainz

The Project 8 collaboration aims to determine the absolute neutrino mass with a sensitivity of 40 meV by measuring the tritium decay spectrum around the endpoint energy. For this level of precision it is necessary to use atomic tritium, since molecular tritium sensitivity is limited by the molecular final state distribution to about 100 meV.

A flux of $\approx 10^{19}$atoms/s from the source will be required to inject a beam with $\approx 10^{15}$atoms/s into the detection volume after cooling and state selection inefficiencies. For monitoring this beam, we have built a detector that uses a wire with a micrometer-scale diameter intersecting the beam on which a small fraction of the beam's hydrogen atoms recombine into molecules. The energy released heats the wire and produces a measurable change in its resistance. Such a detector is suitable for both development work and for minimally disruptive online monitoring in the final experiment. In this talk results will be presented on measurements of the atomic hydrogen fraction as well as the shape of the produced beam.

A 27.8 Thu 12:45 HS 1010

Comparison of Sr lattice clocks from Japan, UK, and Germany — •TIM LÜCKE[1], CLOCK TEAMS[1,2,3,4,8], and LINK TEAMS[1,2,5,6,7] — [1]PTB, Braunschweig, Deutschland — [2]NPL, London, UK — [3]RIKEN, Tokyo, Japan — [4]University of Tokyo, Tokyo, Japan — [5]LNE-SYRTE, Paris, France — [6]LPL, Paris, France — [7]RENATER, Paris, France — [8]University of Birmingham, Birmingham, UK

We present a measurement campaign investigating the agreement of state-of-the-art optical clocks from Japan and Europe. Two transportable Sr lattice clocks from RIKEN in Japan [1] and PTB in Germany were compared with the stationary Sr clocks at NPL in London [2] and PTB in Braunschweig. In addition to local comparisons an interferometric fiber [3] link was used to compare the clocks remotely. The data will also be analyzed with respect to chronometric leveling as a geodetic application.

[1] M. Takamoto *et al.*, Nat. Photonics **14**, 411-415 (2020).
[2] R. Hobson *et al.*, Metrologia **57** 065026 (2020).
[3] M. Schioppo *et al.*, Nat. Commun. **13**, 212 (2022).

A 28: Ultra-cold Atoms, Ions and BEC II (joint session A/Q)

Time: Thursday 11:00–13:00 Location: HS 1098

A 28.1 Thu 11:00 HS 1098

Realization of the ^{88}Sr fine-structure qubit: The building block for a 500-qubit quantum computer demonstrator (QRydDemo) — •Govind Unnikrishnan[1], Jennifer Krauter[1], Philipp Ilzhöfer[1], Ratnesh Kumar Gupta[1], Jiachen Zhao[1], Achim Scholz[1], Christian Hölzl[1], Aaron Götzelmann[1], Sebastian Weber[2], Nastasia Makki[2], Hans Peter Büchler[2], Jürgen Stuhler[3], Florian Meinert[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]Toptica Photonics AG, 82166 Gräfelfing, Germany

The QRydDemo project aims to realize a quantum computer demonstrator with 500 qubits based on the novel fine-structure qubit encoded in the metastable triplet manifold of ^{88}Sr, which enables fast gates (100 ns) and a long coherence time (10 ms). Here, we demonstrate the first step towards this goal by realizing preparation, readout and coherent operations on the fine-structure qubit. In addition to driving Rabi oscillations bridging an energy gap of 17 THz, we also carry out Ramsey spectroscopy with which we extract the coherence time T_2 in our system. A full quantum mechanical model is used to simulate our experiments by including noise sources to identify the main constraints limiting our coherence time and project improvements to our system in the immediate future.

A 28.2 Thu 11:15 HS 1098

Dysprosium Quantum Gas Microscope — •Kevin Ng, Fiona Hellstern, Jens Hertkorn, Paul Uerlings, Lucas Lavoine, Ralf Klemt, Tim Langen, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

With quantum gas microscopy providing access to study particle interactions and correlations on the microscopic scale, engineering analogues to simulate and understand solid state systems with a high degree of control has become possible. Although single atoms can be trapped and imaged in optical lattices, most existing quantum gas microscopes trap and image atoms using light with relatively long wavelengths, and where only short-range contact interactions exist between atoms. Here, we present our progress toward building a quantum gas microscope with dysprosium atoms that will be trapped in lattices using ultraviolet ($\sim$ 360nm) light, where enhanced anisotropic dipolar interactions compete with tunable inter-site particle tunnelling and on-site interactions. Owing to the enhanced dipolar interaction strength between dysprosium atoms in optical lattices of such a short wavelength, our quantum gas microscope opens up the possibility to observe novel phases of matter in a variety of lattice geometries. Our planned experimental setup and initial steps toward characterising the trapping properties of dysprosium at 360nm will be presented.

A 28.3 Thu 11:30 HS 1098

Stabilization of a paramatrically driven BEC: an open quantum system approach — •Larissa Schwarz, Simon B. Jäger, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany

We theoretically analyze the effects of periodically modulated repulsive interactions in a Bose-Einstein condensate (BEC) that features intrinsic damping mechanisms. We derive a master equation describing the dynamics of the momentum modes of the BEC in the parameter regime of weak driving strengths. Above a threshold for the modulation strength we find that the BEC becomes unstable. Below this threshold the combination of damping and periodic driving guides the system into a stationary state that shows an enhancement of fluctuations for specific momentum modes that can be controlled by the driving frequency. We analyze the stationary state of these fluctuations, quantify the condensate depletion and analyze the squeezed and anti-squeezed quadratures generated by the parametric driving, emphasizing the possibility to generate non-classical states of matter.

A 28.4 Thu 11:45 HS 1098

Collisional energy effects on atom-ion Feshbach resonances — •Fabian Thielemann[1], Joachim Siemund[1], Daniel Hönig[1], Wei Wu[1], Krzystof Jachymski[2], Thomas Walker[1,3], and Tobias Schaetz[1] — [1]Physikalisches Institut, Albert-Ludwigs Universität Freiburg — [2]Faculty of Physics, University of Warsaw — [3]Blackett Laboratory, Imperial College, London

Collisions between particles are at the heart of many physical and chemical processes. The ability to control them down to the single quantum level is crucial to understanding the constituents and their interaction. We use our hybrid setup to combine a single Ba^+_{138} ion with a cloud of ultra-cold, spin-polarized Li_6 near degeneracy. We investigate the transition from the classical to the quantum regime of collisions and show to what extent individual atom-ion Feshbach resonances of this combination depend on the collisional energy. With the help of a quantum recombination model, we make first steps towards distinguishing between resonances that occur due to different open-channel partial-wave contributions.

A 28.5 Thu 12:00 HS 1098

A quantum-gas microscope for ultracold strontium atoms — Sandra Buob[1], Jonatan Höschele[1], Vasiliy Makhalov[1], •Antonio Rubio-Abadal[1], and Leticia Tarruell[1,2] — [1]ICFO - Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain — [2]ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain

Quantum-gas microscopes offer novel observables to study quantum many-body systems, but have so far been mostly restricted to alkali atoms. Alkaline-earth species, like strontium, offer a range of desirable features, due to their electronic structure, which can significantly expand the toolbox of Hubbard-type quantum simulation.

In this talk, I will present the realization of site-resolved imaging of a quantum gas of bosonic strontium in a clock-magic optical lattice. We realize fluorescence imaging via the blue 461-nm transition and simultaneous attractive Sisyphus cooling via the narrow 689-nm intercombination line. From the raw fluorescence images, we are able to reconstruct the atomic occupation with fidelities above 95%. Our experiment opens the door to future microscopic studies of the dissipative Bose-Hubbard model, as well as SU(N) fermions.

A 28.6 Thu 12:15 HS 1098

Phase-Stable Traveling Waves Stroboscopically Matched for Super-Resolved Observation of Trapped-Ion Dynamics — •Florian Hasse, Deviprasath Palani, Apurba Das, Frederike Doerr, Leon Goepfert, Ole Pikkemaat, Ulrich Warring, and Tobias Schaetz — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

We introduce an approach, creating and maintaining the coherence of four oscillators: a global microwave reference field, a polarization-gradient traveling-wave pattern of light, and the spin and motional states of a single trapped ion. The features of our method are showcased by probing the 140-nm periodic light pattern and stroboscopically tracing dynamical variations in position and momentum observables with noise floors of 1.8(2) nm and 8(2) zμNs, respectively.

We are currently expanding our methods towards non-classical squeezed states to realize the transfer of spatial entanglements, present in multimode squeezed states, into the robust electronic degrees of freedom (DOF) of multiple ions. For this we switch the trapping potential of two $^{25}Mg^+$ ions fast enough to induce a non-adiabatic change of the ions' motional mode frequencies, preparing the ions in a squeezed state of motion, accompanied by the formation of entanglement in the ions' motional DOF. This is a promising ansatz to study analogs of physics of the early universe, as particle pair creation during cosmic inflation, and relativistic quantum effects, e.g., Hawking radiation.

A summary of our previous work is published on Arxiv: https://arxiv.org/abs/2309.15580

A 28.7 Thu 12:30 HS 1098

Fractional angular momentum quantization in Atomtronic circuits — •Wayne Jordan Chetcuti[1], Juan Polo[1], Andreas Osterloh[1], and Luigi Amico[1,2,3] — [1]Quantum Research Center, Technology Innovation Institute, P.O. Box 9639 Abu Dhabi, UAE — [2]Dipartimento di Fisica e Astronomia and INFN-Sezione di Catania, Via S. Sofia 64, 95127 Catania, Italy — [3]Centre for Quantum Tech-

nologies, National University of Singapore 117543, Singapore

In this talk, I showcase the latest results for bosonic and fermionic matter-wave circuits in the context of Atomtronics. For attractively interacting bosons, the system sees the formation of bound states, which are the quantum analogs of bright solitons found in the mean-field regime. Considering the full many-body regime allows us access to a new phenomenology arising from the strong correlations in the system. Specifically, for a ring geometry pierced by a synthetic gauge field, we find that the angular momentum quantization per particle acquires fractional values depending on the number of particles constituting the bound state. The phenomenon of fractionalization manifests as new plateaus in the angular momentum and presents potentially important applications in the field of metrology and sensing. Analogous phenomenology is found in SU(N) fermionic systems in similar configurations. However, the physical origin of the angular momentum quantization present in these systems depends on the nature of the interactions, be they repulsive or attractive. The feature of fractionalization has promising applications to interferometry using these massive bound states in fermionic and bosonic systems.

A 28.8 Thu 12:45 HS 1098

Magnetic field shielding and rotation stabilisation in the Einstein-Elevator — •Alexander Heidt — Institut für Transport- und Automatisierungstechnik, Hannover, Deutschland

There is an increasing focus on the exploration of space, its potential colonisation and the use of its advantages for fundamental physical research. To make this possible, technologies are required that work in microgravity. The Einstein-Elevator was developed and built out of the motivation to research technologies suitable for space. It is also able to simulate various gravity conditions. Numerous projects from various disciplines are currently being worked on, such as from mechanical engineering to develop new production processes and from physics to carry out basic research into atomic interferometry. One of these is the INTENTAS project, which aims to measure the entanglement of atoms in microgravity. The "spin-exchange collisions" method is used here, whereby weak magnetic field fluctuations can prevent such entanglement of atoms. In order to ensure this entanglement reliably, a magnetic field fluctuation of a few nanotesla is required. For this reason, a magnetic shield was designed as part of the project that suppresses magnetic field fluctuations in the Einstein-Elevator (10 *T) to a few nanotesla. On the other hand, the DESIRE project aims to find evidence of dark energy. However, the setup is sensitive to rotations, so the Einstein-Elevator has been extended with reaction wheels to compensate for any rotations that occur.

A 29: Ultra-cold Atoms, Ions and BEC III (joint session A/Q)

Time: Thursday 14:30–16:30 Location: HS 1010

A 29.1 Thu 14:30 HS 1010

ATOMIQ: An easy-to-use abstarction layer for ARTIQ — •Suthep Pomjaksilp[1], Christian Hölzel[2], Florian Meinert[2], Herwig Ott[1], and Thomas Niederprüm[1] — [1]Department of Physics and research center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Kaiserslautern, Germany — [2]5th Institute of Physics, Universität Stuttgart, Stuttgart, Germany

In recent years, the emergence of a vast landscape of quantum technology experiments created a still growing demand for high perfomance experiment control systems. In contrast to proprietary systems, the Sinara hardware and ARTIQ software ecosystem are fully open-source while reaching nanosecond timing performance. Yet, the subset of Python commands used by ARTIQ predominantly describes hardware like digital frequency synthesizers, DACs and ADCs, making it time-consuming to implement experimental sequences.

The ATOMIQ framework aims to bridge the gap between this hardware and entities familiar to experimental physicists like AOM controlled lasers, coils and cameras. In addition, ATOMIQ consolidates common routines (loading a magneto-optical trap, load and evaporate a dipole trap) into building blocks which can be transported in between experiments while preserving the possibility to leverage the high-perfomance primitives of ARTIQ. Finally, we demonstrate how ATOMIQ can be seamlessly integrated into a non-realtime data acquisition and control system.

A 29.2 Thu 14:45 HS 1010

Circular Rydberg qubits of alkaline earth atoms in optical tweezers — •Einius Pultinevicius, Christian Hölzl, Aaron Götzelmann, Moritz Wirth, and Florian Meinert — 5th Institute of Physics, Universität Stuttgart, Stuttgart, Germany

We report the first demonstration of trapped circular Rydberg states of an alkaline-earth metal atom (Strontium) in an optical tweezer array. Circular Rydberg states promise orders of magnitude longer lifetimes compared to their low-L counterparts, which allows for overcoming fundamental limitations in the coherence properties of Rydberg atom based quantum simulators and quantum computers. In our experiments, we utilize tweezer trapped Strontium atoms and demonstrate efficient transfer into high-n circular Rydberg atoms with n=79 via rapid adiabatic passage. We implement a qubit between circular states of closeby hydrogenic manifolds coupled via a two-photon microwave transition and study its coherence via Rabi and Ramsey measurements. We also demonstrate trapping of the circular state enabled via the second available valence electron of the Sr atom. Our results open exciting prospects for exploiting unique properties of long-lived circular states of two-valence electron atoms, comprising coherent core excitation, for quantum technologies.

A 29.3 Thu 15:00 HS 1010

Universal Self-Organization Dynamics in a Strongly Interacting Fermi Gas — •Timo Zwettler[1,2], Tabea Bühler[1,2], Aurélien Fabre[1,2], Gaia Bolognini[1,2], Victor Helson[1,2], Giulia del Pace[1,2], and Jean-Philippe Brantut[1,2] — [1]Institute of Physics, EPFL, Switzerland — [2]Center of Quantum Science and Engineering, EPFL, Lausanne, Switzerland

Cavity-coupled many-body systems constitute a new emergent field in condensed matter systems, where complex quantum materials are combined with cavity quantum electrodynamics (cQED) to substantially modify material properties by strong light-matter coupling.

We realize a prototypical cavity quantum material by combining cQED with a strongly interacting Fermi gas, providing an ideal, microscopically controllable platform for the study of collective light-matter coupling in strongly correlated matter. We explore the interplay of strong, short-range collisional interactions in the Bose-Einstein condensate to Bardeen-Cooper-Schrieffer (BEC-BCS) crossover and engineered, long-range cavity-mediated interactions, which arise from a two-photon scattering process in the transversally pumped atom-cavity system.

In recent experiments, we advance our understanding of density-wave ordering by investigating the out-of-equilibrium dynamics following a quench across the quantum phase transition. By observing the photons leaking from the optical cavity, we reveal the universal behaviour of the order parameter dynamics in this driven-dissipative system.

A 29.4 Thu 15:15 HS 1010

Repulsively-bound pair states in the 1D extended Hubbard model — •Pascal Weckesser[1,2], Kritsana Srakaew[1,2], David Wei[1,2], Daniel Adler[1,2], Suchita Agrawal[1,2], Immanuel Bloch[1,2,3], and Johannes Zeiher[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany

The binding between two particles is usually mediated by attractive forces. Operating in an external confinement however, one can observe pair-binding despite having repulsive interactions. The existence of such bound states has been conjectured for the one-dimensional extended Hubbard model, yet so far their observation remained elusive.

In this talk, we present our recent findings on realizing one-dimensional extended Hubbard systems for ^{87}Rb atoms trapped in optical lattices and explore the emerging exotic bound states. Here, the long-range repulsion between two adjacent lattices sites is engineered using stroboscopic Rydberg dressing. We probe the presence of the bound state by monitoring the out-of-equilibrium dynamics of two particles using our quantum gas microscope, giving us direct access to the evolution of the density and the underlying correlations. As a final measurement, we explore multiparticle binding between three atoms. Our results path the way to study complex extended Hubbard models and string breaking in spin chains.

A 29.5 Thu 15:30 HS 1010

Josephson effect in a double-well potential and its generalization for finite temperatures — •Kateryna Korshynska[1,2] and Sebastian Ulbricht[2,3] — [1]Department of Physics, Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska Street, Kyiv 01601, Ukraine — [2]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, D-38116 Braunschweig, Germany — [3]Technische Universität Braunschweig, D-38106 Braunschweig, Germany

In modern cold atom physics the study of many-particle bosonic systems gives insight into fundamental quantum processes and lays the foundation for powerful tools in precision metrology. The quantum nature of a bosonic system manifests itself in the Josephson effect, when the particles are placed in a double-well potential. In this potential one can define time-dependent probabilities of a single particle to be in the left or the right well. From that we develop the description of a many-particle system in the regime of global coherence (BEC) and in the case when the system is partially non-coherent. Focusing on the latter case we address the changes in many-particle dynamics, giving rise to a generalization of Josephson equations, which describe the system in non-equilibrium at finite temperatures. In this regime they predict deviations from the standard Josephson effect, which become more pronounced for high temperatures and a small number of bosons. For low temperatures, moreover, we find that the amplitude of Josephson oscillations is restricted. This prediction can be used to test the principles of statistics of a many-particle quantum system.

A 29.6 Thu 15:45 HS 1010

Investigating interference with phononic bright and dark states in a trapped ion — •Robin Thomm[1], Harry Parke[1], Alan C. Santos[2], André Cidrim[2], Gerard Higgins[1], Marion Mallweger[1], Natalia Kuk[1], Shalina Salim[1], Romain Bachelard[2,3], Celso J. Villas-Boas[2], and Markus Hennrich[1] — [1]Department of Physics, Stockholm University, Stockholm, Sweden — [2]Departamento de Física, Universidade Federal de São Carlos, São Carlos, Brazil — [3]Institut de Physique de Nice, Université Côte d'Azur, Valbonne, France

Interference underpins some of the most unusual and impactful properties of both the classical and quantum worlds, from macroscopic systems down to the level of single photons. In this work a new description of interference, based on the formation of collective bright and dark states, is investigated experimentally. We employ a single trapped ion, whose electronic states are coupled to two of its motional modes in order to simulate a multi-mode light-matter interaction. We observe the emergence of phononic bright and dark states for both a single phonon and a superposition of coherent states. The collective dynamics of these systems demonstrate that a description of interference based solely on bright and dark states is sufficient to explain the light-matter coupling of any initial state in both the quantum and classical regimes.

A 29.7 Thu 16:00 HS 1010

Fermi-liquid-like thermal and spin diffusion between unitary superfluids by dissipation — •Meng-Zi Huang, Philipp Fabritius, Jeffrey Mohan, Mohsen Talebi, Simon Wili, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland

Dissipation engineering in strongly correlated systems is an emerging territory of nontrivial interplay between coherent and incoherent dynamics. With direct particle and entropy measurements in a two-terminal setting, we show that the Seebeck response of a strongly-interacting Fermi gas can be enhanced by particle dissipation. This enhancement is robust when changing the dimensionality of the connection between the reservoirs and even the nature of the dissipation mechanisms, namely from spin-selective to pairwise losses. The dissipation also enhances thermal diffusion and spin diffusion, restoring the Fermi-liquid thermal and spin conductance which is initially strongly suppressed in this non-Fermi liquid. Although a microscopic theory is still missing, we provide a phenomenological model that can describe the observations.

A 29.8 Thu 16:15 HS 1010

A Fermionic Quantum Gas Microscope for the Continuum — •Joris Verstraten, Maxime Dixmerias, Kunlun Dai, Shuwei Jin, Bruno Peaudecerf, Tim de Jongh, and Tarik Yefsah — Ultracold Fermi Gases, Laboratoire Kastler Brossel, Paris, France

Quantum gas microscopes have emerged as powerful tools to investigate the microscopic details of ultracold many-body systems. It enables the imaging of dilute quantum gases with single atom resolution and has shed light on the properties of various systems such as the Bose- and Fermi-Hubbard models. As it relies on optical lattice potentials, this method was restricted to periodic systems, in which atoms are already constrained to move between lattice sites. On the other hand, using a deep optical lattice to pin atoms initially prepared in a continuous trap leads to a non-trivial projection on discrete positions.

Here we report on the realization of a Lithium 6 based quantum gas microscope intended to study the microscopic characteristics of ultracold Fermi gases inside the continuum regime. We investigate the fidelity of the pinning process through a dynamical study of individually prepared non-interacting atoms in free space, and are able to experimentally reconstruct the wavefunction of single atoms expanding from a locally harmonic trap. Imaging fidelity as high as 99% can also be achieved under the right experimental conditions, proving that single-atom imaging of bulk systems is not only technically possible but also a reliable method of measuring the microscopic properties of continuous sytems. This opens up the path for the study of correlations in continuous, strongly interacting systems of fermions.

A 30: Precision Spectroscopy of Atoms and Ions IV (joint session A/Q)

Time: Thursday 14:30–16:15 Location: HS 1098

A 30.1 Thu 14:30 HS 1098

Laser-spectroscopic determination of the nuclear charge radius of ^{13}C — •Patrick Müller[1], Emily Burbach[1], Phillip Imgram[2], Kristian König[1], Wilfried Nörtershäuser[1], and Julien Spahn[1] — [1]Institut für Kernphysik, TU Darmstadt, 64289 Darmstadt, Germany — [2]Instituut voor Kern- en Stralingsfysica, KU Leuven, 3001 Leuven, Belgium

Collinear laser spectroscopy (CLS) has proven to be a powerful method to benchmark nuclear and atomic structure calculations. Light heliumlike systems are ideal test cases for both worlds as they exhibit a greatly varying nuclear structure and are accessible for high-precision ab-initio calculations. In an ongoing effort, it is planned to determine absolute and differential nuclear charge radii, R_{C} and $\delta\langle r^2\rangle$, of the light elements Be to N by purely using CLS and ab-initio nonrelativistic quantum electrodynamics calculations in the helium-like ions. As a first step, the $1s2s\,^3\mathrm{S}_1 \rightarrow 1s2p\,^3\mathrm{P}_J$ transitions in $^{12,13}\mathrm{C}^{4+}$ were determined using the Collinear Apparatus for Laser Spectroscopy and Applied Science (COALA) at the Technical University of Darmstadt. We present results for $\delta\langle r^2\rangle^{12,13}$ and the hyperfine structure of $^{13}\mathrm{C}^{4+}$, which is modulated by significant hyperfine-induced mixing, and compare them to ab-initio nuclear and atomic structure calculations. In both cases, our model independent results can be used to improve theory and help quantifying theoretical uncertainties. A comparison to the model-dependent results from elastic electron scattering and muonic atom spectroscopy will help to improve these experimental methods.
This project is supported by DFG (Project-ID 279384907 - SFB 1245).

A 30.2 Thu 14:45 HS 1098

Coherent excitation of a Sub-mHz optical magnetic quadrupole transition — •Valentin Klüsener[1,2], Sebstian Pucher[1,2], Dimitry Yankelev[1,2], Felix Spriestersbach[1,2], Jan Trautmann[1,2], Immanuel Bloch[1,2,3], and Sebastian Blatt[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology, 80799 München, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-

Universität München, 80799 München, Germany

Ultranarrow clock transitions to metastable states are fundamental for many applications in quantum metrology, simulation and information. We report on the first coherent excitation of the $^1S_0$-$^3P_2$ magnetic quadrupole (M2) transition in ^{88}Sr. By confining atoms in a state insensitive three-dimensional optical lattice, we achieve excitation fractions of 97 % and observe Fourier limited linewidths as narrow as 55 Hz. We characterize the coherence of the prepared states by performing Ramsey spectroscopy and find coherence times of 10 ms, which can be extended to 250 ms with a spin-echo sequence. Finally, we use our spectroscopic results to determine the decay rate of the M2 transition to $154(32) \times 10^{-6}\,s^{-1}$ in agreement with longstanding theoretical predictions. These results establish an additional clock transition in neutral strontium and pave the way for applications of the metastable $^3P_2$ state in precision quantum metrology, simulation and information processing.

A 30.3 Thu 15:00 HS 1098

Multi-Cubic-Meter Atom Trapping for Project 8 — •Alec Lindman for the Project 8-Collaboration — Institute for Physics and Excellence Cluster PRISMA+, Johannes Gutenberg University Mainz

The Project 8 direct neutrino mass experiment will achieve its next-generation sensitivity of 40 meV by improving precision (with its Cyclotron Radiation Emission Spectroscopy method), statistics (which scale with active volume in Project 8 rather than area), and control of systematics (by replacing molecular tritium with atomic tritium).

Since atomic tritium recombines on contact with surfaces, a large, static magneto-gravitational trap will hold the tritium atoms in free space. To achieve its sensitivity, Project 8 requires a density of about 10^{17} atoms per m^3 at about 1 mK and a total volume of about 100 m^3, divided among ten identical 10 m^3 traps.

Keeping such a trap full over the multi-year runtime of the experiment requires producing a high flux of atoms (10^{19} atoms/s) with a hot atom source, continuously cooling them (first on surfaces, and then using magnetic fields and gas-gas collisions), and finally injecting the cold beam into the trap. This talk will describe the intended trap design, the difficulties and advantages of a large trap, plans for the cooling system, and experimental progress on a high-flux tritium-compatible atom source.

A 30.4 Thu 15:15 HS 1098

Sensitivity of Project 8's wire detector for an atomic tritium beam — •Darius Fenner and Martin Fertl — Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Deutschland

The Project 8 experiment aims to achieve a sensitivity of 40 meV on the neutrino mass through precise measurements of the tritium beta spectrum near its endpoint. To achieve the required energy resolution, the production of atomic tritium is imperative because it has no molecular final state distribution. Such a distribution, caused by vibrational and rotational modes of the molecules, smears the energy spectrum. At the setup in Mainz the thermal dissociation of hydrogen instead of tritium is studied. The efficiency of this process is quantified using a wire detector equipped with three 5μm tungsten wires. As atomic hydrogen recombines on the wire surface and releases the recombination energy, the temperature change of the wire is measured as a resistance change. However, the measured signal depends on the position along the wire, as heat can more readily dissipate near the mountings. In this work, the wire's sensitivity curve is determined as a function of wire position. The measurement process involves a 2D scan of the wire while performing pointwise heating with a laser. Moreover, the sensitivity is simulated in a COMSOL heat transfer simulation to complement the experimental findings.

A 30.5 Thu 15:30 HS 1098

Using Non-linear Dissociation Processes of BeH+ for the Alignment of the Laser Pulse Overlap in XUV Frequency Comb Spectroscopy of He+ — •Florian Egli, Jorge Moreno, Theodor Wolfgang Hänsch, Thomas Udem, and Akira Ozawa — Max-Planck-Institut für Quantenoptik, Garching, Deutschland

The energy levels of hydrogen-like atoms and ions are accurately described by bound-state quantum electrodynamics (QED). With spectroscopic measurements of hydrogen and hydrogen-like atoms, the Rydberg constant and the proton charge radius can be determined. The comparison of the physical constants obtained from different combinations of measurements serves as a consistency check for the theory. The hydrogen-like He^+ ion is an interesting spectroscopic target for QED tests. Due to their charge, He^+ ions can be held nearly motionless in the field-free environment of a Paul trap, providing ideal conditions for high-precision measurements. The 1S-2S two-photon transition in He^+ can be directly excited by an extreme-ultraviolet frequency comb at 60.8 nm generated by a high-power infrared frequency comb using high-order harmonic generation (HHG). In order to perform Doppler-free spectroscopy on the 1S-2S transition, the frequency comb is split into double pulses which are overlapped at the ions. As a signal for the pulse overlap alignment, we investigate non-linear dissociation processes of BeH^+. The processes discussed here are using 204 nm and 255 nm light, which can be generated from our infrared frequency comb.

A 30.6 Thu 15:45 HS 1098

An optical clock for robust operation and remote comparisons — •Saaswath JK, Martin Steinel, Melina Filzinger, Jian Jiang, Ekkehard Peik, Nils Huntemann, and the Opticlock consortium — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

We report on a transportable and easy-to-operate optical clock that uses the $^2S_{1/2} - {}^2D_{3/2}$ transition of a single trapped $^{171}Yb^+$ ion at 436 nm as the reference. The system has been developed within a pilot project for quantum technology in Germany led by industry and is set up in two 19" racks [1]. In this way, transportation can easily be realized, and the large degree of automatization allows for robust operation. Comparisons to existing high-accuracy optical clock systems at PTB enabled verification of the clock's uncertainty budget at the low 10^{-17} level. During these tests, operation with 99.8% availability over more than 14 days has been achieved. Furthermore, the system has been operated for a significant fraction of the year 2023, enabling a very accurate determination of its frequency and contributions to timescales. We are currently improving the robustness of the setup and reducing uncertainties of shifts from thermal radiation and electric field gradients. This prepares Opticlock well for transportation to Finnland and Czechia, where it will be compared to other high-performance optical clocks. This will demonstrate a novel approach for key comparisons in time and frequency.

[1] J. Stuhler, et al. Measurement: Sensors 18, 100264 (2021)

A 30.7 Thu 16:00 HS 1098

Laser spectroscopy of Fermium-255 at the RISIKO mass separator facility — •Matou Stemmler for the Fermium-Collaboration — Johannes Gutenberg Universität Mainz, 55099 Mainz, Germany

Laser spectroscopy can provide information about fundamental properties of both atomic and nuclear structure. Such measurements are of particular importance for the heaviest actinides and superheavy elements, where data is sparse. During the last measurement campaign at the RISIKO mass separator facility in the Institute of Physics at Johannes Gutenberg University Mainz (JGU), nine successive samples of the artificially produced ultra-rare isotope ^{255}Fm (Z=100) of 10^8 to 10^9 atoms each, were used to study the atomic and nuclear structure of fermium. The samples originate from an initial ^{254}Es sample that was produced at the Oak Ridge National Laboratory high flux nuclear reactor (USA). The sample was subsequently re-irradiated at the Institut Laue-Langevin reactor in Grenoble (F) with thermal neutrons to produce ^{255}Es (half-life: 39.8 d), which decays to ^{255}Fm (20.07 h) via β^- decay. This presentation will focus on the atomic structure studies of ^{255}Fm, for which a new three-step laser ionization scheme was developed. Rydberg convergences were studied and the accuracy of the ionization potential was improved [1].

[1] J. Am. Chem. Soc. 44, 14609-14613 (2018)

A 31: Atomic Systems in External Fields II

Time: Thursday 14:30–16:30 Location: HS 1015

A 31.1 Thu 14:30 HS 1015

Search for new physics with spin-based magnetometry — •Wei Ji[1,2], Kai Wei[3], Jia Liu[4], Changhao Xu[1,2], and Dmitry Budker[1,2,5] — [1]Helmholtz Institut Mainz — [2]Staudingerweg 18 — [3]Beihang University — [4]Peking University — [5]University of California, Berkeley

Spin-based magnetometry has made remarkable progress in recent years, allowing for precise measurements of fundamental physics and the exploration of new physics beyond the standard model. In this talk, I will introduce the alkali-noble gas hybrid spin magnetometry and its applications in searching for exotic spin-dependent interactions and axion dark matter. I will also briefly introduce a new type of magnetometry that is being developed based on levitated ferromagnetic particles.

A 31.2 Thu 14:45 HS 1015

Measuring nuclear spin qubits by qudit-based spectroscopy using the V2 color center in Silicon Carbide — •Pierre Kuna[1], Erik Hesselmeier[1], Istvan Takacs[2], Viktor vady[2,4], Wolfgang Knolle[3], Nguyen Tien Son[4], Misagh Ghezellou[4], Jawad Ul-Hassan[4], Durga Dasari[1], Florian Kaiser[5], Vadim Vorobyov[1], and Jörg Wrachtrup[1] — [1]3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany — [2]Eötvös Loránd , Egyetem tér 1University-3, H-1053 Budapest, Hungary — [3]Department of Sensoric Surfaces and Functional Inter- faces, Leibniz-Institute of Surface Engineering (IOM), Leipzig, Ger- many — [4]Department of Physics, Chemistry and Biology, Linköping University, Linköping, Sweden — [5]Materials Research and Technology (MRT) Department, LIST, 4422 Belvaux, Luxembourg

Nuclear spins with hyperfine coupling to single electron spins are highly valuable quantum bits. In this work [1] we probe and characterise the particularly rich nuclear spin environment around single silicon vacancy color-centers (V2) in 4H-SiC. By using the electron spin-3/2 qudit as a 4 level sensor, we identify several sets of 29Si and 13C nuclear spins through their hyperfine interaction. We extract the major components of their hyperfine coupling via optical detected nuclear resonance, and assign them to shells in the crystal via the DFT simulations. We utilise the ground state level anti-crossing of the electron spin for dynamic nuclear polarization and achieve a nuclear spin polarization of up to 98(6)% and demonstrate coherent control of single nuclear spins. [1] Preprint Arxiv: 2310.15557

A 31.3 Thu 15:00 HS 1015

A Gravitational Analogon of the Metrological Triangle — •Sebastian Ulbricht[1,2] and Claus Lämmerzahl[3] — [1]Physikalisch-Technische Bundesanstalt PTB, Braunschweig, Germany — [2]Technische Universität Braunschweig, Braunschweig, Germany — [3]Center of Applied Space Technology and Microgravity ZARM, University of Bremen, Bremen, Germany

Before the 2019 revision of SI, the quantum metrological triangle provided a tremendously precise measurement scheme for the electron charge e and the Planck constant h based on the Josephson effect, the quantum Hall effect, and the counting of single electrons. Now, after the SI-redefinition, this triangle is used to realize electric standards and offers substantial options for consistency checks, testing our understanding of the electromagnetic interaction of quantum particles. In this talk, we consider a gravitational analogue of the quantum metrological triangle, giving rise to analoga of the Josephson effect and the quantum Hall effect for neutral quantum particles in a gravitational field. This parallels between electromagnetic and gravitational interaction can be drawn, since the weak field limit of General Relativity resembles the mathematical structure of electrodynamics. The gravitational metrological triangle provides a testing field for our understanding of quantum systems in gravity. We in particular discuss its feasibility for quantum tests of the Weak Equivalence Principle and tests of the universality of quantum mechanics.

A 31.4 Thu 15:15 HS 1015

Resonant photon scattering by highly-charged ions exposed to external fields — •Jan Richter — PTB, Braunschweig, Germany — Leibniz Universität, Hannover, Germany

The elastic photon scattering process is a fundamental aspect of atom-light interactions and has been the subject of numerous experimental and theoretical studies. In this talk, we want to revisit the theory of resonant elastic scattering of photons on ions. Hereby, special attention is paid to the influence of external electric and magnetic fields on the scattering process such as the Hanle effect. The impact of this effect is discussed in the framework of different experimental scenarios.

A 31.5 Thu 15:30 HS 1015

Geometric post-Newtonian description of massive spin-half particles in curved spacetime — •Ashkan Alibabaei[1,2], Philip Schwartz[1], and Domenico Giulini[1,3] — [1]Institute for Theoretical Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany — [3]Center of Applied Space Technology and Microgravity, University of Bremen, Am Fallturm 1, 28359 Bremen, Germany

The equivalence principle requires matter to universally couple to gravity, encoded in spacetime geometry. For quantum fields, this leads to the framework of quantum field theory in curved spacetime. This framework, however, is quite far detached from the practical description of low-energy quantum systems in terms of Galilei-symmetric Schrödinger equations plus special- and general relativistic corrections. We aim to close this gap by considering the one-particle sector of the respective quantum field theory described effectively by a classical field, for this purpose we apply a systematic low energy approximation scheme. In my talk, I will describe a Hydrogen-like atom coupled to gravity and external electromagnetic field in a twofold expansion scheme, first implementing a weak-gravity approximation, and second a slow velocity post-Newtonian expansion. This yields to a systematic and complete generation of general-relativistic correction terms for spin-half quantum systems. We find new terms that were overlooked in the literature and extend the level of approximation.

A 31.6 Thu 15:45 HS 1015

Wave Packet Propagation and the Quantum to Classical Transition — •John S. Briggs — Physikalisches Inst. Universitaet Freiburg, Germany

The free propagation of wave packets is the oldest problem of continuum quantum mechanics. A brief historical review of the theory is given. In contradistinction to text book treatments, the spreading of a wave packet in time is proposed as the paradigm of the quantum to classical transition. Using the Gaussian wave packets as example, the trajectories of normals to the wave fronts (identical to Bohm trajectories) emerge as the dominant feature. Along such trajectories the momentum space wave function is invariant. The trajectories become straight-line line classical trajectories asymptotically.

The complete analogy to the propagation of Hermite-Gauss wave packets in classical optics is demonstrated. In particular the Gouy phase of optics is shown to be a dynamic phase involving the instantaneous harmonic oscillator eigenfunction. Transition to a frame moving along the trajectory gives a simple form where the Gouy phase appears as the proper time in this frame. As example, in the moving frame the propagation of two interfering Gaussian slits is shown to be simply the propagation of two quantum coherent states.

Finally the quantum to classical transition for macroscopic objects is examined . It is argued that the assignment of a wave function to the universe, as in quantum cosmology, is not a valid concept.

A 31.7 Thu 16:00 HS 1015

Vortex electron scattering by atomic targets — •Sophia Strnat[1,2], Lalita Sharma[3], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Institut für Mathematische Physik, Technische Universität, Braunschweig — [3]Indian Institute of Technology, Roorkee

Since the first twisted electrons have been produced, special attention has been paid to these vortex matter waves. Such electrons, characterized by an additional intrinsic angular momentum beyond spin, find applications in transmission electron microscopy (TEM). Notably, their use has been proposed and experimentally demonstrated for determining the chirality of crystals [1]. In electron energy loss spectra, vortex electron beams have the capability to discern the occupation of atomic sublevels, providing a general insight into electronic configurations and offering a powerful tool for probing local properties of nanomaterials and biomolecules [2]. Despite these advancements, a comprehensive and fully relativistic depiction of the inelastic scattering of vortex electrons by atoms remains absent. Our contribution closes this gap by describing the scattering process with quantities such as total excitation rates, alignment and orientation parameters of atomic states for a diverse range of scenarios. Furthermore, we will emphasize the study of scattering on a bare atom versus an atom confined within a potential.

[1] A. Asenjo-Garcia, F.J. Garcia de Abajo, Phys. Rev. Lett. **113** (2014) 066102
[2] R. Juchtmans, J. Verbeeck, Phys. Rev. B **92** (2015) 134108

A 31.8 Thu 16:15 HS 1015

Compton polarimetry of elastic scattering of highly linearly polarized hard x-rays — •Wilko Middents[1,2,3], Günter Weber[1,2], Alexandre Gumberidze[2], Thomas Krings[4], Tobias Over[1,2,3], Philip Pfäfflein[1,2,3], Uwe Spillmann[2], and Thomas Stöhlker[1,2,3] — [1]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena — [2]GSI GmbH, Planckstraße 1, 64291 Darmstadt — [3]FSU Jena, Leutragraben 1, 07743 Jena — [4]FZ Jülich, Wilhelm-Johnen-Str., 52425 Jülich

Elastic scattering of photons off matter is a fundamental light-matter interaction process. Precise polarization-dependent measurements provide a sensitive test of the underlying theory. For photon energies from several tens of keV up to a few MeV, efficient polarimetry is based on the polarization-sensitive pattern of Compton scattering.

I will report on the technique of Compton polarimetry in the hard x-ray regime via detectors based on a double-sided segmented semiconductor crystal [1]. Furthermore, I will show the results of an experiment on the polarization transfer in elastic scattering of 175 keV x-rays off a gold target and provide an outlook on future possibilities for polarization measurements of elastic scattering.

[1] Vockert, M. et al., (2017), NimB 313-316. https://doi.org/10.1016/j.nimb.

A 32: Quantum Gases (joint session Q/A)

Time: Thursday 14:30–16:30 Location: Aula

A 32.1 Thu 14:30 Aula

Braiding Laughlin quasi-holes in ultracold atoms using Ramsey interferometry — •Felix Palm[1,2], Nader Mostaan[1,2], Nathan Goldman[2], and Fabian Grusdt[1] — [1]LMU Munich & MCQST, Munich, Germany — [2]CENOLI, Université Libre de Bruxelles, Brussels, Belgium

Braiding non-Abelian anyons in topologically ordered systems has been proposed as a possible route towards topologically protected quantum computing. While recent experiments based on various platforms have made significant progress towards this goal, coherent control over individual anyonic excitations has still not been achieved today. At the same time, progress in cold-atom quantum simulators resulted in the realization of a two-boson $\nu = 1/2$-Laughlin state, a paradigmatic fractional quantum Hall state hosting Abelian anyonic quasi-holes.

Here we show that cold atoms in quantum gas microscopes are a suitable platform to create and manipulate these quasi-holes. First, we show that a Laughlin state of eight bosons can be realized by connecting small patches accessible in experiments. Next, we demonstrate that two cross-shaped pinning potentials are sufficient to create two quasi-holes in this Laughlin state. Starting with these two quasi-holes we numerically perform an adiabatic exchange procedure, and reveal their semionic braiding statistics for various exchange paths, thus clarifying the topological nature of these excitations. Finally, we propose an experimentally feasible interferometry protocol to probe the braiding phase in quantum gas microscopes, using a two-level impurity immersed in the fractional quantum Hall fluid.

A 32.2 Thu 14:45 Aula

Adiabatic Preparation of a Chiral Spin Liquid — •Moritz Schlechtriem, Francesco Petiziol, and André Eckardt — Technische Universität Berlin, Institut für Theoretische Physik, Hardenbergstraße 36, 10623 Berlin, Germany

Efficient protocols to prepare spin-liquid states are essential for exploring these phases of matter and harnessing their potential for applications. The goal of this study is to investigate the adiabatic preparation of a chiral spin liquid ground state on the Kagome lattice. Considering different easily-realizable initial Hamiltonians and different system sizes, the minimal duration for a high-fidelity adiabatic transition into the spin-liquid phase is determined and optimal adiabatic paths are explored. In a second step, the analysis is extended to the case in which the spin-liquid Hamiltonian is realized via Floquet engineering.

A 32.3 Thu 15:00 Aula

The anyon-Hubbard model: From few to many-body — •Martin Bonkhoff — I. Institut für Theoretische Physik, Universität Hamburg

Recent experimental progress in the engineering of density-dependent Peierls phases has rekindled the interest in one-dimensional anyonic lattice models of the Hubbard type. We review specific ground-state properties of such anyons on hand of the single-species anyon-Hubbard model. Thereby we focus primarily on the distinction between few-particle systems, or very small system sizes, and a real many-body setting [2,3]. For the former case we use integrable techniques to study the properties of the model, which is contrasted then with field-theoretical methods for long-wavelengths. The emphasis is thereby on the coherence properties of the model that are intrigiungly modified by the statistical interactions in contrast to ordinary, local inter-particle interactions. We find a quite different phenomenology for the two regimes and discuss related experimental challenges.

[1] Martin Bonkhoff, Simon B. Jäger, Imke Schneider, Axel Pelster, and Sebastian Eggert, Phys. Rev. B 108, 155134 (2023)
[2] Martin Bonkhoff, Kevin Jägering, Sebastian Eggert, Axel Pelster, Michael Thorwart, and Thore Posske, Phys. Rev. Lett. 126, 163201 (2021)

A 32.4 Thu 15:15 Aula

Bogoliubov theory of 1D anyons in a lattice — •Binhan Tang[1], Axel Pelster[1], and Martin Bonkhoff[2] — [1]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]I. Institute for Theoretical Physics, Universität Hamburg, Germany

In a one-dimensional lattice anyons can be defined via generalized commutation relations containing a statistical parameter, which interpolates between the boson limit and the pseudo-fermion limit. The corresponding anyon-Hubbard model is mapped to a Bose-Hubbard model via a fractional Jordan-Wigner transformation, yielding a complex hopping term with a density-dependent Peierls phase. Here we work out a corresponding Bogoliubov theory. To this end we start with the underlying mean-field theory, where we allow for the condensate a finite momentum and determine it from extremizing the mean-field energy. With this we calculate various physical properties and discuss their dependence on the statistical parameter and the lattice size. Among them are both the condensate and the superfluid density as well as the equation of state and the compressibility. Based on the mean-field theory we then analyse the resulting dispersion of the Bogoliubov quasi-particles, which turns out to be in accordance with the Goldstone theorem. In particular, this leads to two different sound velocities for wave propagations to the left and the right, which originates from parity breaking.

A 32.5 Thu 15:30 Aula

Hamiltonian learning for quantum field theories — Robert Ott[1,2], Torsten Zache[1,2], •Maximilian Prüfer[3], Sebastian Erne[3], Mohammadamin Tajik[3], Hannes Pichler[1,2], Jörg Schmiedmayer[3], and Peter Zoller[1,2] — [1]Institute for Theoretical Physics, University of Innsbruck — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences — [3]Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien

Synthetic quantum systems, such as those based on bosonic quantum gases, offer an excellent opportunity to study complex phenomena arising in quantum many-body physics. Recently, a set of efficient tools called Hamiltonian learning (HL) has been developed to uncover the underlying microscopic interactions in quantum systems from experiments. While HL is well developed for discrete lattice-based many-body systems, its application to continuous quantum systems faces a challenge due to the absence of a lattice scale. In this work, we propose a protocol that capitalizes on the locality of effective field theories to extract their Hamiltonians from experimental data. By varying the resolution scale of the measurements, our protocol gives access to the scale dependence of coupling parameters reminiscent of the running of couplings with the renormalization group flow. To demonstrate the effectiveness of our method, we apply it to theoretical studies of both classical and quantum fields. We furthermore showcase its application in an ultracold quantum gas experiment, learning the Hamiltonian underlying its classical statistical description.

A 32.6 Thu 15:45 Aula

Towards simulation of lattice gauge theories with ultracold ytterbium atoms in hybrid optical potentials — •Rene Villela[1,2], Tim Höhn[1,2], Etienne Staub[1,2], Leonardo Bezzo[1,2], Ronen Kroeze[1,2], and Monika Aidelsburger[1,2,3] — [1]Ludwig-Maximilians-Universität, München, Germany — [2]Munich Center for Quantum Science and Technology, München, Germany — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany

Gauge theories play a fundamental role in our understanding of nature, ranging from high-energy to condensed matter physics. Their formulation on a regularized periodic lattice geometry, so-called lattice gauge theories (LGTs), has proven invaluable for theoretical studies, as numerical studies on, e.g., their real-time dynamics are computationally challenging. We report progress on developing a quantum simulator for LGTs using neutral ytterbium atoms. Ytterbium's internal level structure provides a ground and metastable clock state pair, and fermionic isotopes further host nuclear spin degrees of freedom. We combine optical lattice and optical tweezers technology that can enable robust and scalable implementation of LGTs. To realize state-selective control, which is key for our approach to simulate LGTs, we exploit magic and tune-out wavelengths. We present the first measurements of such wavelengths near the narrow cooling transition at 556 nm and discuss prospects in implementing local gauge invariance.

A 32.7 Thu 16:00 Aula

Fast preparation of cold Ytterbium gases for Rydberg quantum optics experiments — •Xin Wang, Thilina Muthuarachchige, Tangi Legrand, Ludwig Müller, Wolfgang Alt, Eduardo Uruñuela, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons paves the way to realize and control high optical nonlinearities at the level of single photons. Demonstrations of photon-photon gates or multi-photon bound states based on this concept have so far exclusively employed ultracold alkali atoms. Two-valence electron species, such as Ytterbium, offer unique novel features namely narrow-linewidth laser-cooling, optical detection and ionization or long-lived nuclear-spin memory states.

In this talk, we present our experimental progress towards the realization of strong photon-photon interactions, mediated by the Yb-174 Rydberg polaritons formed in a 1-D ultracold Ytterbium gas. Specifically, we discuss our compact two-chamber experimental design enabling fast production of ultracold Yb-174 gases at high density. Instead of an oven and Zeeman slower, we use a fast-loading two-stage hybrid MOT sequence to prepare and load the atoms in an elongated dipole trap, where we generate Rydberg polaritons under Rydberg electromagnetically induced transparency. Owing to the zero nuclei spin of Yb-174 and singlet spin state in bivalent structure, longer coherent times are expected compared to experiments with alkali atoms.

A 32.8 Thu 16:15 Aula

Borromean states in a one-dimensional three-body system — •Tobias Schnurrenberger[1], Lucas Happ[2], and Maxim Efremov[1] — [1]German Aerospace Center (DLR), Institute of Quantum Technologies, 89081, Ulm, Germany — [2]Few-body Systems in Physics Laboratory, RIKEN Nishina Center for Accelerator-Based Science, Wako, Saitama 351-0198, Japan

We show the existence of Borromean states in a one-dimensional quantum three-body system composed of two identical, heavy bosons and a different, lighter particle. It is assumed that there is no interaction between the two bosons, while the heavy-light subsystems do not have a bound state. Within the framework of the Faddeev equations, the three-body spectrum and the corresponding wave-functions are computed numerically. In addition, we identify the parameter-space region of the heavy-light interaction, where the Borromean states occur, investigate their dependence on the mass ratio, and evaluate their geometric properties.

A 33: Poster VI

Time: Thursday 17:00–19:00 Location: Tent A

A 33.1 Thu 17:00 Tent A

Building neutral-atom quantum processors — •Pierre-Antoine Bourdel for the Pasqal-Collaboration — Pasqal SAS, 7 rue Léonard de Vinci, 91300 Massy, France

In the past years, neutral atoms have entered the quantum computing race. Quantum startup PASQAL has stemmed from the group of A. Browaeys and T. Lahaye, who pioneered trapping single atoms in arbitrary, defect-free and reconfigurable tweezer patterns. In this highly scalable platform, excitation to Rydberg states enables controlled interactions between atoms, and entanglement generation. Such platform has already demonstrated quantum simulations in a regime out of reach with current classical approaches. Regarding quantum computation, applications have been proposed and demonstrated for solving hard combinatorial optimisation problems, non-linear differential equations and classifying sets of graphs using machine learning. We will give an overview of the technical building blocks of our platform at PASQAL, discuss its capabilities for digital and analog-based quantum computing in the NISQ era, and present the last results that we have achieved with our neutral atoms quantum processors.

A 33.2 Thu 17:00 Tent A

FermiQP - A Fermionic Quantum Processor — •Yu Hyun Lee[1,3], Frank Hermann[1,4], Janet Qesja[1,2], Robin Groth[1,2], Andreas von Haaren[1,2], Luca Muscarella[1,2], Liyang Qiu[1,2], Immanuel Bloch[1,2,3], Timon Hilker[1,2], and Philipp Preiss[1,2] — [1]Max-Planck Institute of Quantum Optics, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany — [3]Ludwig Maximilian University Munich, Munich, Germany — [4]Karlsruhe Institute of Technology, Karlsruhe, Germany

FermiQP is a demonstrator experiment for a lattice based fermionic quantum processor with neutral Li-6 atoms. The experiment aims to combine the versatility of digital quantum gates with the power of analogue Fermi-Hubbard simulators. Single qubit gates will be implemented as Raman rotations between hyperfine states, while controlled collisions between atoms in a bichromatic lattice will constitute two-qubit gates. Tweezer-based resorting techniques will enable all-to-all connectivity of the qubits. This also allows robust control of the starting configuration for investigating the Fermi-Hubbard phase diagram. We present the status of the experiment, including progress on the implementation of single qubit addressing, single-site and spin resolved quantum gas microscopy, and new cooling schemes for fast degenerate Fermi gas preparation.

A 33.3 Thu 17:00 Tent A

Experimental Observation of Time-Dependent Energy-Level Renormalization near Ultrastrong Couplings in Quantum-Rabi Systems — •Frederike Doerr, Florian Hasse, Alessandra Colla, Ulrich Warring, Heinz-Peter Breuer, and Tobias Schaetz — Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

A novel theory, extending beyond perturbation theory, elucidates the thermodynamic behavior of open quantum systems interacting with thermal baths: predicting a time-dependent frequency shift, $\Delta\omega(t)$, arising from the interaction with the environmental mode, dependent on the system-environment coupling (g) and temperature (T) [1]. We investigate changes in the electronic energy levels of a trapped ion strongly connected to a single motional degree of freedom. Employing Ramsey interferometry and analyzing the oscillation frequencies of the system's coherences, we observe a clear and time-dependent effective shift in the ion's energy levels, consistent with the theoretical predictions. These findings provide direct evidence of dynamic energy level renormalization in strongly coupled quantum systems, emphasizing the role of memory effects in shaping the system's energy landscape.

[1] A. Colla and H.-P. Breuer, Phys. Rev. A 105, 052216 (2022).

A 33.4 Thu 17:00 Tent A

Coherent control of electron emission direction in helium with ω-2ω SASE FEL pulses — •Muwaffaq Ali Mourtada[1], Harijyoti Mandal[1], Alexander Magunia[1], Weiyu Zhang[1], Yu He[1], Hannes Lindenblatt[1], Florian Trost[1], Lina Hedewig[1], Cristian Medina[1], Arikta Saha[1], Marc Rebholz[1], Ulrike Frühling[2], Carlo Kleine[1], Gergana D. Borisova[1], Steffen Palutke[2], Evgeny Schneidmiller[2], Mikhail Yurkov[2], Stefan Düsterer[2], Rolf Treusch[2], Chris H. Greene[3], Yimeng Wang[3], Robert Moshammer[1], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Deutsches Elektronen Synchrotron DESY, 22607 Hamburg, Germany — [3]Purdue University, West Lafayette, IN 47907, USA

Measurements of the photoelectron angular distribution of two-photon single-ionisation in the vicinity of singly excited intermediate states in helium are presented. Using extreme-ultraviolet pulses generated at the high-repetition-rate free-electron laser in Hamburg (FLASH), helium atoms are ionized and the recoil ion momenta are measured with a reaction microscope. In a previous experiment [1], first indications for interfering pathways between FEL fundamental and its second harmonic have been observed. Here we present new measurements to further investigate the possibility of directional asymmetry in the photoelectron angular distribution of interfering one-photon and two-photon single ionization in helium. In this poster we will discuss the ongoing data analysis and show first results.

[1] Straub et al., PRL 129, 183204 (2022)

A 33.5 Thu 17:00 Tent A

Experimental investigation of strongly interacting quantum fluids of light in rydberg atoms — •Amar Bellahsene — Université de Strasbourg CESQ-ISIS, Strasbourg, France

Photons are effectively perfect quantum systems as they can be easily and efficiently generated, manipulated and detected, except they have one major drawback: they are inherently non-interacting. If we could engineer strong and tunable interactions between photons it would be a great leap forward for numerous fields, especially in many-body physics, quantum simulation and quantum computing. One of the most promising methods to simultaneously realize strong light-matter couplings and strong effective photon-photon interactions is in ultracold gases which are laser coupled to strongly-interacting Rydberg states under an electromagnetically induced transparency (EIT) resonance. My experimental PhD project consists of investigating the relatively unexplored regime where strongly interacting photons with exotic properties (long-range and nonlocal interactions) propagate inside spatially structured ultracold 39K atoms with optical tweezers.

A 33.6 Thu 17:00 Tent A

Acquisition and analysis of RABBIT measurements — •Muhammad Jahanzeb, Narendra Shah Ronak, Cristian Manzoni, Devkota Diwaka, and Giuseppe Sansone — Institute of Physics, University of Freiburg, Freiburg, Germany

The Reconstruction of Attosecond Beating by Interference of Two-Photon Transitions (RABBIT), is a technique used to measure time delays in photoionization on an attosecond scale [1-2]. In the RABBIT technique, the photoionization delays measured in atoms can be decomposed in a Wigner delay, related to the photoionization process induced by the absorption of a single extreme ultraviolet photon, and a continuum-continuum delay, due to the absorption of additional infrared photons by the freed photoelectron [2].

I will report on the development of an experimental setup aiming at the investigation of the continuum-continuum delay in photoionization. In the experimental setup, high-order harmonics will be generated using a 800 nm driving laser that will be then recombined with a synchronized 1200 nm pulse obtained using a non-collinear optical parametric amplifier [3]. Using this combination of parameters, two sidebands are expected between the each pair of photoelectron peaks associated to the absorption of a single XUV photon. By comparing the oscillations of adjacent sidebands, we are aiming to investigate the contribution of the continuum-continuum phase in the photoionization process. [1] Paul et al, Science, 292 (2001) [2] Dahlström et al, Journal of Physics, 45 (2012) [3] Manzoni et al, Journal of Optics, 18 (2016)

A 33.7 Thu 17:00 Tent A

Variable Multiphoton Lattices for Ultracold Rubidium Atoms — •Stefanie Moll[1], Geram Hunanyan[1], Johannes Koch[1], Enrique Rico[2,3,4,5], Enrique Solano[6], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany — [2]Department of Physical Chemistry, University of the Basque Country UPV/EHU, Box 644, 48080 Bilbao, Spain — [3]Donostia International Physics Center, 20018 Donostia-San Sebastián, Spain — [4]EHU Quantum Center, University of the Basque Country UPV/EHU, P.O. Box 644, 48080 Bilbao, Spain — [5]IKERBASQUE, Basque Foundation for Science, Plaza Euskadi 5, 48009 Bilbao, Spain — [6]Kipu Quantum, Greifswalder Straße 226, 10405 Berlin, Germany

Optical lattices are versatile tools to confine atoms in tuneable periodic potentials, with applications ranging from quantum simulation to the realization of atomic clocks. Usual standing wave lattices are realized by utilizing the ac Stark shift induced by red detuned standing waves to trap cold atoms in the antinodes of the periodic intensity pattern. In a quantum picture the induced potential arises due to virtual two-photon processes. We are exploring lattice potentials created by the dispersion of multiphoton Raman processes, which allows to achieve higher spatial periodicities as well as a state-dependency of the lattice potential. Using a four-photon lattice potential to create a suitable Bloch-band structure, we have performed a quantum simulation of the quantum Rabi model. We are currently exploring the applicability of multiphoton lattices to synthesize a larger variability of potentials.

A 33.8 Thu 17:00 Tent A

Accuracy and efficiency of Particle-in-Cell schemes simulating ultrafast laser-induced plasma dynamics — •Richard Altenkirch[1], Graeme Bart[2], Christian Peltz[1], Thomas Fennel[1], and Thomas Brabec[2] — [1]Universität Rostock, Germany — [2]uOttawa, Canada

Particle-in-cell (PIC) algorithms have been developed since the 1970s and since grown into one of the most widely used tools for studying intense light-matter interactions and the associated plasma kinetics on a macroscopic scale. Lately, the introduction of the microscopic Particle-in-Cell scheme [1] has even allowed for the simulation of strongly coupled plasmas by incorporating the essential short-range interactions that are neglected in typical PIC routines. However, the need to resolve individual particles causes MicPIC to become very computationally expensive for spatial regimes above 1 micron [2]. Therefore, in order to capture effects of the spatial laser beam shape at optical frequencies on ablation processes, macroscopic PIC approaches are needed. However, MicPIC results still function as a very helpful guideline for gauging to what extent these different routines are suitable for simulating specific scenarios. Using MicPIC as a reference, we analysed the efficiency and the accuracy of PIC as well as collisional PIC schemes in the ablation scenario of a laser-induced plasma in a thin gold film.

[1] C.~Varin, C.~Peltz, T.~Brabec, T.~Fennel, Ann. Der Phys., 526 (2014), pp. 135-156

[2] G. Bart, C. Peltz, N. Bigaouette, T. Fennel, T. Brabec, C. Varin, Computer Physics Communications 219 (2017), pp. 269-285

A 33.9 Thu 17:00 Tent A

The scaling method for the numerical solution of the relativistic ionization problem — •Aleksandr V. Boitsov, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The coordinates scaling method, previously applied to the numerical solution of the time-dependent Schrodinger equation (TDSE), is generalized for the numerical solution of the problem of an atom ionization in a relativistically strong laser field. As a first step, we focus on a one-dimensional implementation of the general idea. To facilitate the use of the scaling method, Foldy-Wouthuysen transformation is applied in Silenko's form within the quasiclassical approximation, reducing time-dependent Dirac equation (TDDE) to the square-root Klein-Gordon-like equation. The problems related to the use of nonuniform grid in the scaling method are analyzed. Comparison with known solutions of TDDE is provided.

A 33.10 Thu 17:00 Tent A

A dedicated angular streaking setup for attosecond photoionization experiments — •Lasse Wülfing[1], Niclas Wieland[2], Lars Funke[1], Arne Held[1], Wolfram Helml[1], Sara Savio[1], and Markus Ilchen[2] — [1]Technische Universität Dortmund — [2]Universität Hamburg

Angular streaking represents a scheme to resolve photoionization processes down to the attosecond regime, reaching even the natural time frame of fundamental electronic interactions in atomic and molecular systems. This is done by the reconstruction of superfast SASE free-electron laser pulses for use in photoionization experiments. A circularly polarized laser is superimposed onto the X-ray pulses, generating a birth time correlated kick for photoelectrons produced in a given target gas. By using multiple electron spectrometers in one plane around the interaction point, the initial pulses can be reconstructed.

Our group developed a dedicated detector for angular streaking, incorporating two planes of newly designed electron time of flight spectrometers for broad energy-acceptance into a mu-metal shielded vacuum chamber. The setup is meant as a versatile basis for angular streaking experiments realized in different scenarios. This poster presents an overview of the derived design and current status in the construction of the dedicated setup at FLASH (DESY).

A 33.11 Thu 17:00 Tent A

Towards machine learning optimized time-averaged potentials to generate a Bose-Einstein condensate — •Max Schlösinger[1], Victoria Henderson[1], Simon Kanthak[1], Oliver Anton[1], Elisa Da Ros[1], and Markus Krutzik[1,2] — [1]Humboldt-Universität zu Berlin, Institute of Physics & IRIS Adlershof, Newtonstraße 15, 12489 Berlin — [2]Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Strasse 4, 12489 Berlin

Time-averaged potentials (TAPs) are a versatile tool for the generation and manipulation of ultracold atom clouds. In order to fully take advantage of this techniques, we investigate machine learning routines with a setup based on acousto-optic deflectors.

Our aim is to mitigate non-linearities in the electro-optical system and effects due to frequency modulation which restricts predictability of shape and smoothness as well as to counteract temporal and spatial instabilities. In particular we focus on identifying the most suitable fitness function associated with the optimisation of different optical potential geometries using images based on a CCD camera.

In the future, we would like to rely on TAP's capabilities to improve the evaporative cooling routine and to enhance the efficiency of a ^{87}Rb Bose-Einstein condensate-based quantum memory.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) under grant numbers No. 50WM2247.

A 33.12 Thu 17:00 Tent A

XUV Frequency Comb driven Velocity Map Imaging of Argon — •Nick Lackmann[1], Jan-Hendrik Oelmann[1], Tobias Heldt[1], Lennart Guth[1], Janko Nauta[2], Thomas Pfeifer[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Swansea University, UK

Atomic clocks offer potential for fundamental physics studies due to their remarkable precision [1,2]. Opting for clock transitions in the extreme ultraviolet (XUV) not only increases achievable precision but also facilitates spectroscopy on systems such as highly charged ions and the thorium-229m nuclear transition. To realize this, an extreme-ultraviolet frequency comb was constructed using cavity-enhanced high-harmonic generation, driven by a 100 MHz near-infrared frequency comb [3]. This approach generates harmonics up to 42 eV. The resulting harmonics are employed in a resonant ionization protocol, where the comb excites the transition of interest, followed by ionization with a narrow NIR laser. The electron momenta are captured using the velocity map imaging technique to simultaneously record multiple transitions.

[1] M. G. Kozlov et al., Rev. Mod. Phys. 90, 045005 (2018)
[2] Safronova et al., Phys. Rev. Lett. 113, 030801 (2014)
[3] J. Nauta et al., Opt. Express 29, 2624 - 2636 (2021)

A 33.13 Thu 17:00 Tent A

Towards Multidimensional XUV Spectroscopy Combined with Spectral Interferometry — •Lina Hedewig, Carlo Kleine, Alexander Magunia, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, Heidelberg 69117, Germany

Using two infrared (IR) and two extreme ultraviolet (XUV) ultrashort pulses we are currently implementing a method for multidimensional XUV spectroscopy combined with spectral interferometry to gain further insight into gas-phase quantum dynamics of atoms and molecules.

The setup is based on a four quadrant split-and-delay mirror which allows independent time delay control of each beam with attosecond precision, similar to [1]. One XUV pulse excites an electronic wavepacket in the target generating a coherent dipole response. This wavepacket is strong-field coupled by the two intensity-tunable IR pulses, allowing selective control of state-specific quantum dynamics. Due to phase-matching requirements, the IR-modified response can be diffracted towards the remaining fourth beam, comparable to [2], and creates a nearly background-free signal, partially still overlapping with the initial XUV beam. Spatially resolving the signals in our XUV spectrometer, both collinear and non-collinear pathways are recorded. To additionally extract the phase of the dipole response, the second XUV beam serves as local oscillator for heterodyned spectral interferometry. The poster presents the experimental setup and first measurements.

[1] Zhang et al., Opt. Lett. 38, 356-358 (2013)
[2] Bengtsson et al., Nature Photon 11, 252-258 (2017)

A 33.14 Thu 17:00 Tent A

Fundamental physics tests with an optical clock based on Ca^{14+} — •Malte Wehrheim[1], Lukas J. Spiess[1], Alexander Wilzewski[1], Shuying Chen[1], Jan Richter[1], Agnese Mariotti[4], Elina Fuchs[4], Andrey Surzhykov[1,5], Erik Benkler[1], Melina Filzinger[1], Nils Huntemann[1], José R. Crespo Lopez-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 — [4]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [5]Technische Universität Braunschweig, Universitätsplatz 2, 38106 Braunschweig, Germany

We conduct quantum logic spectroscopy on highly charged ions enabling us to measure atomic parameters which are compared to ab-initio calculations. Clock operation is performed by stabilizing a laser to the $^3P_0 \rightarrow {}^3P_1$ fine structure transition in Ca^{14+}. Its absolute frequency is determined by comparing it to the atomic clock based on the Yb^+ octupole transition at PTB. Measurements of the five stable isotopes of calcium with even number of nucleons to 2 parts in 10^{16} yield the isotope shifts with a fractional uncertainty of $2 * 10^{-10}$. By combining this result with spectroscopy data in singly charged calcium and precise measurements of the nuclear masses, bounds can be placed on a hypothetical fifth force.

A 33.15 Thu 17:00 Tent A

The LSYM experiment — •Andreas Thoma, Daniel Rubin, Lukas Holtmann, Fabian Raab, Maria Pasinetti, Sangeetha Sasidharan, and Sven Sturm — Max Planck Institut für Kernphysik

One of the currently most important and unsolved questions in physics is the unbalance in quantity of matter and antimatter in the universe, which is in contradiction to Quantum Electrodynamics (QED), the most successful quantum field theory in the Standard Model.

LSym is a cryogenic Penning trap experiment being developed to measure mass, charge and g-factor of positrons and electrons at a precision of 10e-14 magnitude, that could possibly falsify CPT symmetry.

To achieve such accuracy the particles have to be cooled down to 300mK to ensure finding the positron in the ground state where spin-flips can be accessed via excitations of the Larmor mode.

Here, the experimental setup and methods as well as challenges of cooling to cryogenic temperatures will be presented.

A 33.16 Thu 17:00 Tent A

Pairing dome from an emergent Feshbach resonance in a strongly repulsive bilayer model — •Hannah Lange[1,2,3], Lukas Homeier[1,3], Eugene Demler[4], Ulrich Schollwöck[1,3], Annabelle Bohrdt[3,5], and Fabian Grusdt[1,3] — [1]LMU Munich, Germany — [2]MPI for Quantum Optics, Garching, Germany — [3]Munich Center for Quantum Science and Technology, Germany — [4]ETH Zurich, Switzerland — [5]University of Regensburg, Germany

A key to understanding unconventional superconductivity lies in unraveling the pairing mechanism of mobile charge carriers in doped antiferromagnets, giving rise to an effective attraction between charges even in the presence of strong repulsive Coulomb interactions. In this talk, I will consider a mixed-dimensional t-J ladder, a system that has recently been realized with ultracold atoms [1], and show how it can be extended with a nearest neighbor Coulomb repulsion. With repulsion turned off, the system features tightly bound hole pairs and large binding energies (closed channel). When the repulsion strength is increased, a crossover to more spatially extended, correlated pairs of individual holes (open channel) can be observed. In the latter regime, we still find robust binding energies that are strongly enhanced in the finite doping regime. The effective model in the strongly repulsive regime reveals that the attraction is mediated by the closed channel, in analogy to atomic Feshbach resonances between open and closed channels [2].

[1] Hirthe et al., Nature 2023
[2] Lange et al., arXiv:2309.15843, 2309.13040

A 33.17 Thu 17:00 Tent A

ARPES spectroscopy of an extended Majumdar-Ghosh model — •Simon M. Linsel[1,2], Nader Mostaan[1,2,3], Annabelle Bohrdt[2,4], and Fabian Grusdt[1,2] — [1]LMU Munich, Germany — [2]Munich Center for Quantum Science and Technology, Germany — [3]Université Libre de Bruxelles, Brussels, Belgium — [4]University of Regensburg, Germany

Experimental and numerical spectroscopy have revealed novel physics in anti-ferromagnets, in particular in frustrated and doped systems. The Majumdar-Ghosh (MG) model has an analytically known spin-disordered ground state of dimerized singlets as a result of magnetic frustration. Here we study the single-hole angle-resolved photoemission spectroscopy (ARPES) spectrum of an extended MG model, where we introduce a spin-density interaction that is experimentally accessible with ultracold molecules. We report a bound spinon-holon ground state and clear signatures of a spinon-holon molecule state and polarons in the ARPES spectrum at different magnetizations. We also apply a Chevy ansatz to gain analytical insights into the molecule spectrum. Our results provide new insights into the physics of dopants in frustrated t-J models.

A 33.18 Thu 17:00 Tent A

Advances in microfabrication of Metallic Magnetic Calorimeters — •Daniel Kreuzberger, Andreas Reifenberger, Andreas Abeln, Alexander Orlow, Daniel Hengstler, Andreas Fleischmann, and Christian Enss — Heidelberg University

Metallic Magnetic Calorimeters (MMCs) are low temperature particle detectors which can reliably be produced with multilayer microfabrication techniques. Moreover, the consequent use of these techniques allows for the fabrication of thousands of virtually identical detectors as required for large, dense packed arrays. Using various examples of current MMC detectors which are actively used for high resolution x-ray spectroscopy, we present the status of our microfabrication processes. This includes the fabrication of overhanging x-ray absorbers made of gold with a thickness up to $100\,\mu$m. For this, a newly developed fabrication process is presented, preventing almost all athermal phonons from escaping in the substrate without thermalization in the sensor. We also discuss copper filled Through-Silicon-Vias (TSV) used to heatsink the detector pixels to the wafer backside.

A 33.19 Thu 17:00 Tent A

Tests of QED and determination of nuclear parameters with the hydrogenlike beryllium-9 ion — •Bastian Sikora, Vladimir A. Yerokhin, Zoltan Harman, and Christoph H. Keitel — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

In an external magnetic field, the ground state of the ^{9}Be^{3+} ion is split into multiple sublevels due to hyperfine and Zeeman effect. The bound electron's g-factor, the ground-state hyperfine splitting as well as the shielded magnetic moment of the nucleus can be determined by measurements of transition frequencies between these sublevels [1].

We present theoretical calculations of the nuclear shielding constant, the ground-state hyperfine splitting and the bound-electron g-factor [2]. The nuclear shielding constant is used to extract the magnetic moment of the bare nucleus with unprecedented precision, enabling a first test of multi-electron shielding calculations performed for the lithiumlike ^{9}Be$^+$ ion. Furthermore, we improve the accuracy of the effective nuclear Zemach radius using the theory of hyperfine splitting. We also present the contributions of muonic and hadronic vacuum polarization to hyperfine splitting, calculated for different nuclear models [3]. We also study a weighted difference of hyperfine splittings of the hydrogenlike and ithiumlike Be ions which is found to be in excellent agreement with experimental results.

[1] A. Schneider, B. Sikora, S. Dickopf, et al., Nature **606**, 878 (2022)
[2] S. Dickopf, B. Sikora, et al., in preparation
[3] J. Heiland and B. Sikora, in preparation

A 33.20 Thu 17:00 Tent A

Off-resonant measurements of trapped ions using a dual hot-end resonator — •Stefan Ringleb[1], Markus Kiffer[1], Manuel Vogel[2], and Thomas Stöhlker[1,2,3] — [1]Friedrich Schiller-Universität Jena, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany — [3]Helmholtz-Institut Jena, 07743 Jena, Germany

Ion detection in Penning traps is typically done using resonant circuits which consist of a wound coil connected to one electrode. The oscillating ions induce a current via mirror charges which drives the resonator resulting in a voltage for ion detection. Using such configurations in combination with superconducting coils, also single ions can be detected. This technique also allows for fast resistive ion cooling to reduce the centre-of-momentum energy of an ion or an ion ensemble with a correlated ion motion.
In our setup, we have investigated another approach - a normal-conducting resonator connected to two opposing electrodes. In this configuration, we are able to detect ion ensembles with a considerably high centre-of-momentum motion both in resonance and off resonance. This allows for ion detection without concurrent ion cooling opening new possibilies to characterise the ion bunch properties - in particular the transfer of ion energy from the centre-of-mass motion to the uncorrelated axial motion.
We will present our experimental setup and will give insight into the methods we can apply to determine the dephasing behaviour of the ion bunch.

A 33.21 Thu 17:00 Tent A

Quantum orbit simulations of above-threshold ionization (ATI) on nanometric tips with few-cycle pulses — •Timo Wirth and Peter Hommelhoff — Lehrstuhl für Laserphysik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen

When nanometric tips are exposed to light in the strong field regime, electrons in the tip are ionized through tunnel ionization (step 1). The free electrons are then driven in the laser field (step 2). While most of these electrons will not return to the tip (direct electrons), a fraction is driven back to the tip and elastically scatters at the tip surface (step 3). This rescattering process can be understood classically within the three-step model. Classical simulations can give insights into the rescattering process, but a quantum-mechanical approach allows deeper insights. This can be done with the time-dependent Schrödinger equation (TDSE). However, TDSE simulations often do not allow a good qualitative understanding of the results. Such an understanding can be gained from quantum orbit simulations. The quantum orbit theory is based on the strong-field approximation (SFA) and includes the crucial quantum mechanics ab initio. We discuss the results of quantum orbit simulations of the ATI process at nanometric needle tips.

A 33.22 Thu 17:00 Tent A

Momentum induced tunneling of Bose-Einstein Condensates — •Daida Thomas[1], Knut Stolzenberg[1], Dustin Lindberg[2], Sebastian Bode[1], Denys Bondar[2], Ernst M Rasel[1], Naceur Gaaloul[1], and Dennis Schlippert[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, 30167 Hannover — [2]Tulane University, 6823 St. Charles Avenue, New Orleans, LA 70118

Quantum tunneling of BEC's in a double well potential has been explored in the realm of entanglement generation and Josephson tunneling. Traditional approaches for creating a double well mostly involved inserting barriers in a single well leading to the creation of a double-well system. We accelerate atoms towards a barrier in a double-well system, inducing momentum driven tunneling and envision testing our technique with asymmetric barriers. This is done in optical dipole traps, incorporating acousto-optical deflectors, thereby allowing versatile control over the trapping potentials with respect to position and trap depth. The sample used is a ^{87}Rb Bose-Einstein condensate, prepared in a magnetically insensitive state, with a sample size of up to 300×10^3 atoms. We report on preliminary implementation prospects of tunneling to study the preferential tunneling direction of BEC's and quantum correlations stemming from the nonlinear dynamics of atomic interactions.

A 33.23 Thu 17:00 Tent A

Ion microscope as a versatile tool for probing Rydberg physics, ultracold ions and hybrid systems — •Viraatt

S.V. Anasuri[1], Moritz Berngruber[1], Jennifer Krauter[1], Ruven Conrad[1], Raphael Benz[1], Óscar Andrey Herrera Sancho[1,2,3,4], Florian Meinert[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Escuela de Física, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica — [3]Centro de Investigación en Ciencia e Ingeniería de Materiales, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica — [4]Centro de Investigación en Ciencias Atómicas, Nucleares y Moleculares, Universidad de Costa Rica, San José, Costa Rica

The long-range interactions in ion-atom hybrid systems lead to fascinating phenomena that can be spatially and temporally studied using our high-resolution ion microscope. Our recent studies on a cold ion-Rydberg system with rubidium atoms include observation of novel bound molecular states. Owing to the nature of the long range interactions, the s-wave scattering regime for ion-atom hybrid systems has thus far been elusive. Our proposed initialization of the scattering event via photo-ionization of an ultra-long range Rydberg molecule of lithium atoms combined with the excellent resolution and electric field stability of our ion microscope makes it possible to enter the few partial wave regime.

A 33.24 Thu 17:00 Tent A

A dedicated 2-dimensional array of metallic magnetic microcalorimeters to resolve the 29.18keV doublet of ^{229}Th — •A. Striebel, A. Abeln, S. Allgeier, A. Brunold, J. Geist, D. Hengstler, D. Kreuzberger, A. Orlow, L. Gastaldo, A. Fleischmann, and C. Enss — Heidelberg University

The isotope ^{229}Th has the nuclear isomer state with the lowest presently known excitation energy, which possibly allows to connect the fields of nuclear and atomic physics with the potential application as a nuclear clock. In order to excite this very narrow transition with a laser a precise knowledge of the transition energy is needed. Recently the isomer energy (8.338±0.024) eV [Kraemer et al., arXiv:2209.10276, 2022] could be precisely determined. To get valuable insights, we will improve our high-resolution measurement [Sikorsky et al., PRL 125, 2020] of the γ-spectrum following the α-decay of ^{233}U. This decay partially results in excited ^{229}Th with a nuclear state at 29.18 keV. Resolving the doublet, that in turn results from de-excitation to the ground and isomer state, respectively, would allow an independent measurement of the isomer energy as well as the branching ratio of both transitions. To resolve this doublet, a 2D detector array consisting of 8×8 metallic magnetic calorimeters (MMCs) was fabricated. MMCs are operated at mK temperatures and convert the energy of a single incident γ-ray photon into a temperature pulse which is measured by a paramagnetic temperature sensor. We discuss the detector properties, including an energy resolution of 3.1 eV (FWHM) at 5.9 keV and present first spectra of ^{229}Th taken with this detector.

A 33.25 Thu 17:00 Tent A

Progress towards a novel apparatus for unit testing of ion trap prototypes and development of ion transport protocols — •Ludwig Krinner[1,2], Christian Joohs[1,2], Tobias Pootz[1], Emma Vandrey[1], Nila Krishnakumar[2], and Friederike Giebel[2] — [1]Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We report on progress towards an apparatus for testing and characterization of an in-house fabricated surface-electrode ion-trap chip [1], for realization of the QCCD-architecture [2, 3]. The apparatus will mount the combination of trap-chip and chip-interposer on a socket made from PEEK and copper, which also house various ablation-targets for loading beryllium, calcium and strontium. The apparatus has an integrated system for in-situ surface cleaning using argon ions [4], to enable low heating rates.

We will present the current status of the the setup, specifically the characterization of imaging optics, progress on the beam-delivery setup as well as a realization of transport waveforms to be tested on the trap chip currently in micro-fabrication.

[1] A. Bautista-Salvador et al., N. J. Phys., Vol. 21, 043011 (2019)
[2] D.J. Wineland et al., J. Res. Natl. Inst. Stand. Technol. 103, 259 (1998)
[3] D. Kielpinski, C. Monroe, and D. J. Wineland, Nature 417, 709 (2002)
[4] D. A. Hite et al., Phys. Rev. Lett., Vol. 109, 103001 (2012)

A 33.26 Thu 17:00 Tent A

Nonlinear Pulse Compression Multi-Pass Cell characterized by Frequency-Resolved Optical Gating for Extreme-Ultraviolet Frequency Comb Generation — •Fiona Sieber[1], Lennart Guth[1], Jan-Hendrik Oelmann[1], Tobias Heldt[1], Prachi Nagpal[1], Nick Lackmann[1], Simon Angstenberger[1], Stepan Kokh[1], Hannah Unold[1], Lukas Matt[1], Janko Nauta[2], Thomas Pfeifer[1], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut for Nuclear Physics, Heidelberg, Germany — [2]Department of Physics, Swansea University, Singleton Park, SA2, United Kingdom

To conduct precision spectroscopy beyond the optical regime, we transfer a near-infrared frequency comb with 100 MHz repetition rate via high harmonic generation to the Extreme-Ultraviolet [1]. We aim to increase the yield of the harmonics by further compressing the 80 W pulses in a Herriott-type Multi-Pass Cell (MPC). In the MPC the pulses are focused into a nonlinear medium where they undergo self-phase modulation. Multiple passes stepwise broaden the spectrum implying a decreased fourier transform limit for the pulse duration [2]. Using a post-compression set-up with chirped mirrors, we decreased our pulse length of 200 fs to 100 fs. A Frequency-Resolved Optical Gating set-up is used to evaluate the pulse shape and duration.

[1] J. Nauta et al., Optics Express, Vol. 29, No. 2, 2624 (2018)
[2] A.-L. Viotti et al., Optica, Vol. 9, No. 2, 197 (2022)

A 33.27 Thu 17:00 Tent A

Multi-Pass Process Tomography: precision and accuracy enhancement — •Stancho Stanchev — Department of Physics, St Kliment Ohridski University of Sofia, 5 James Bourchier blvd, 1164 Sofia, Bulgaria

In this work, we introduce an alternative method to enhance the precision and accuracy of Quantum Process Tomography (QPT) by mitigating the errors caused by state preparation and measurement (SPAM), readout and shot noise. Instead of conducting QPT solely on a single gate, we propose performing QPT on a pulse train (multi-pass) consisting of multiple identical instances of the gate. By obtaining the Pauli transfer matrix of the multi-pass process, we outline a post-processing procedure for a more precise and accurate characterization of the single process. We demonstrate the effectiveness of this approach through simulation on the IBM Quantum - ibmq qasm simulator and experimental implementation on the processor ibmq manila, Falcon r5.11L.

A 33.28 Thu 17:00 Tent A

On The Generation Of Arbitrary Tweezer Geometries For Neutral Atom Quantum Computing — •Jakob Wüst[1], Stefan Boschmann[1], Jonas Gutsche[1], Jens Nettersheim[1], Jonas Witzenrath[1], Niclas Luick[2], Thomas Niederprüm[1], Dieter Jaksch[2], Henning Moritz[2], Herwig Ott[1], Peter Schmelcher[2], Klaus Sengstock[2], and Artur Widera[1] — [1]RPTU Kaiserslautern-Landau, Kaiserslautern, Germany — [2]University of Hamburg, Hamburg, Germany

The advent of commercially viable quantum computation will critically improve our ability to solve hard optimization problems. This requires an easily scalable and stable platform, for which neutral atom based systems are a promising candidate. As core components of such quantum computers, the generation and control of homogeneous trapping arrays as well as their deterministic loading are of particular interest.

Here, we report on the generation of large arrays of optical tweezers with a Spatial Light Modulator (SLM). We characterize the tweezer array and quantify the limitations imposed on the patterns by our experimental conditions. Furthermore, we present a method for characterizing a sorting beam controlled by two separate acousto-optic deflectors and the response of the beam to different forms of radio frequency ramps and different ramping speeds.

A 33.29 Thu 17:00 Tent A

Tracking XUV strong couplings with absorption line-shape changes and underlying population transfer with a convolutional neural network — •Alexander Magunia, Daniel Richter, Marc Rebholz, Christian Ott, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

The electronic states within an atom or molecule determine their properties, also while interacting with their environment. As shown recently in helium atoms, electronic population can be effectively transferred from the ground state to valence states with intense extreme-ultraviolet (XUV) free-electron laser pulses via Rabi cycling (1). The underlying strong-field coupling of states during the Rabi dynamics also leads to changes in the absorption line shape (2,3).

In our contribution, we will describe methods to model and understand ultrafast strong couplings in a two-level system and resulting absorption line-shape changes. Furthermore, we extend the system by including two excited bound states or an ionization continuum. We also present a convolutional neural network, which can predict time-resolved electronic bound-state populations from the (simulated) absorption spectra.

(1) S.N. et al., Nature 608, 488-493 (2022)
(2) Phys. Rev. Lett. 123, 163201 (2019)
(3) Appl. Sci. 10, (18) 6153 (2020)

A 33.30 Thu 17:00 Tent A

All-optical matter-wave lensing to pK energie — •Alexander Herbst[1], Timothé Estrampes[1,2], Robin Corgier[3], Wei Liu[1], Knut Stolzenberg[1], Eric Charron[2], Ernst Rasel[1], Naceur Gaaloul[1], and Dennis Schlippert[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, 30167 Hannover, Germany — [2]Université Paris-Saclay, CNRS, Institut des Sciences Moléculaires d'Orsay, 91405 Orsay, France — [3]LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université 61 avenue de l'Observatoire, 75014 Paris, France

We report on an all-optical collimation method for matter-waves, utilizing time-averaged potentials and tunable interactions. By rapid decompression of an optical dipole trap, we induce size oscillations to a BEC, which are then used to minimize the momentum spread of the ensemble with a well-timed release. Additionally, we choose ^{39}K as atomic species which allows to tailor the atomic scattering length by means of magnetic Feshbach resonances. Minimizing interactions, we show an enhancement of the collimation compared to the strong interaction regime, realizing ballistic 2D expansion energies of 438 ± 77 pK in our experiment. We analyze the individual contributions to the ensemble dynamics, using an accurate simulation of our results. Based on our findings we present an advanced scenario which allows for 3D expansion energies below 16 pK by implementing an additional pulsed delta-kick collimation directly after release from the trapping potential.

A 34: Poster VII

Time: Thursday 17:00–19:00 Location: Tent B

A 34.1 Thu 17:00 Tent B

Narrow-Linewidth Laser System for Optical Trapped Barium Ion Coulomb Crystals — •Wei Wu, Daniel Hoenig, Andreas Weber, and Tobias Schaetz — University of Freiburg, Institut of Physics, Hermann-Herder-Strasse 3, Freiburg 79104, Germany

We designed and implemented a 1762 nm laser system, specifically for driving the electric quadrupole transition from S1/2 to D5/2 states in Ba138 ions. The laser is locked to an 100 mm ULE cavity using PDH circuits and its wavelength is determined using a Michelson interfereometer. The laser system permits to discern the motional energy levels of ions within a optical dipole trap or Paul trap, which subsequently facilitates the implementation of Raman side-band cooling, enabling us to exert precise control over the ion temperature. Such presicion will significantly help us enhancing the understanding of the dynamics of the barium ion influenced by its colissions with ultracold lithium or rubidium atoms. Moreover it can be used to populate ions in a superposition of elecronic states, allowing for in-depth investigation of electronic state dependence of optical potential towards conditional stimulated phase transitions and their related superpositions.

A 34.2 Thu 17:00 Tent B

Towards fermionic weakly-bound open-shell RbSr molecules — •Noah Wach[1,2], Digvijay Digvijay[1], Premjith Thekkeppatt[1], Klaasjan van Druten[1], and Florian Schreck[1] — [1]Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, The Netherlands — [2]Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Our goal is to produce ultracold RbSr polar, open-shell molecules, to extend the range of possibilities offered by ultracold molecular physics. Unlike in alkali atoms, Feshbach resonances in alkali-alkaline earth atoms are extremely narrow due to the non-magnetic ground state of alkaline earth atoms. The creation of weakly bound molecules of alkali-alkaline earth atoms is strongly hindered by the very weak coupling of the Feshbach resonances. Here we present our novel approach, utilizing confinement-induced resonances (CIR) in a strongly interacting Bose-Fermi mixture to create weakly bound RbSr molecules. We plan to take advantage of CIR, which strongly couples an excited trapped state of a very weakly bound molecule to the atomic pair state in a strongly interacting Rb-Sr mixture. We also observe the protection against 3-body collisional losses in a strongly interacting Bose-Fermi mixture in the quasi-2D regime.

A 34.3 Thu 17:00 Tent B

multiply charged ions from highly-charged helium droplets — •shaimaa Habib — 1Universität Innsbruck, Institut für Ionenphysik und Angewandte Physik, Technikerstr. 25, A-6020 Innsbruck, Austria

Helium droplets have been demonstrated to pick up dopants from the gas phase, and evaporative cooling enables experiments at temperatures below 1 K [1]. Massive doping of neutral droplets leads to the formation of nanoparticles and quantum wires which were studied after deposition with high resolution microscopy [2] and in situ via coherent X-ray diffraction [3]. Recently, we discovered that large helium droplets can become highly-charged [4]. The charge centers self-organize as two-dimensional Wigner crystals at the surface of the droplets and act as seeds for the growth of dopant clusters [5]. Cluster ions and charged nanoparticles of a specific size and composition can be formed by this technique with unprecedented efficiency. Dopant cluster ions can be extracted by collision induced evaporation of the host droplet [6,7] or by splashing of the droplet upon surface impact [8]. Both methods are suitable to form high yields of He tagged ions of both polarities which enables messenger type spectroscopy of all kinds of cold ions. The location of charge centers in multiply charged He droplets close to the surface makes them accessible for subsequent interactions with metastable He atoms which leads to Penning ionization and the formation of cold multiply-charged dopant ions. For many dopant clusters, we obtain critical sizes of di- and trications that are well below the values obtained by conventional techniques.

A 34.4 Thu 17:00 Tent B

multiply charged ions from highly-charged helium droplets — •shaimaa Habib[1,2], S Bergmeister[1], L Ganner[1], F Foitzik[1], I Stromberg[1], F Zappa[1], O Echt[1], P Scheier[1], and E Gruber[1] — [1]1Universität Innsbruck, Institut für Ionenphysik und Angewandte Physik, Technikerstr. 25, A-6020 Innsbruck, Austria — [2]Faculty of Science, Damnhour University, Egypt

Helium droplets have been demonstrated to pick up dopants from the gas phase, and evaporative cooling enables experiments at temperatures below 1 K [1]. Massive doping of neutral droplets leads to the formation of nanoparticles and quantum wires which were studied after deposition with high resolution microscopy [2] and in situ via coherent X-ray diffraction [3]. Recently, we discovered that large helium droplets can become highly-charged [4]. The charge centers self-organize as two-dimensional Wigner crystals at the surface of the droplets and act as seeds for the growth of dopant clusters [5]. Cluster ions and charged nanoparticles of a specific size and composition can be formed by this technique with unprecedented efficiency. Dopant cluster ions can be extracted by collision induced evaporation of the host droplet [6,7] or by splashing of the droplet upon surface impact [8]. Both methods are suitable to form high yields of He tagged ions of both polarities which enables messenger type spectroscopy of all kinds of cold ions.

A 35: Poster VIII

Time: Thursday 17:00–19:00 Location: Tent C

A 35.1 Thu 17:00 Tent C

Narrow and Ultranarrow transitions of highly charged Xe as probes for fifth forces — •Nils-Holger Rehbehn[1], Michael Karl Rosner[1], Julian C. Berengut[2,1], Piet O. Schmidt[3,4], Thomas Pfeifer[1], Ming Feng Gu[5], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut for Nuclear Physics, 69117 Heidelberg, Germany — [2]School of Physics, University of New South Wales, Sydney, New South Wales 2052, Australia — [3]Physicalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [4]Leibniz-Universität Hannover, 30167 Hannover, Germany — [5]Space Science Laboratory University of California, 94720 Berkeley, California, USA

A hypothetical fifth force acting between constituents of an atom could lead to a New Physics Model beyond the Standard Model. Such a model could potentially explain several phenomenon categorized under Dark Matter. To this end, we measured thirteen optical transitions in highly charged xenon which can be used in future quantum logic spectroscopy method measurements. Its anticipated precision is used to evaluate theoretical King-plots to reveal the most sensitive pairs. The sensitivity to a fifth force will be improved by four orders of magnitude compared the the most recent King-plot analyses, while overcoming higher orders of the Standard Model and isotope mass uncertainties via the generalized King-plot.

A 35.2 Thu 17:00 Tent C

Characterization of a radiofrequency trap for electrons — •Vladimir Mikhailovskii[1], Natalija Sheth[1], Hendrik Bekker[1], Guofeng Qu[2], Yuzhe Zhang[1], Ferdinand Schmidt-Kaler[3], Christian Smorra[3], Hartmut Häffner[4], and Dmitry Budker[1,3,4] — [1]Helmholtz-Institut Mainz, GSI Helmholtzzentrum für Schwerionenforschung, Mainz, Germany — [2]Institute of Nuclear Science and Technology, Sichuan University, Chengdu, China — [3]Johannes Gutenberg-Universität, Mainz, Germany — [4]Department of Physics, University of California, Berkeley, USA

We demonstrate trapping of electrons in a radiofrequency trap. The low charge-to-mass ratio of electrons puts special requirements on the experiment. First, we need electrons at low energies. Since electrons lack internal structure, which is commonly used to laser cool ions, it is necessary to produce them at low energies at the trap center. This is achieved by two-step photoionization of a Ca beam [1], where the atoms are ionized only slightly above the ionization threshold. Second, the trap must be operated at high frequencies. We have realized such a trap, consisting of three PCBs described in [2], and are currently characterizing its performance at 1.6 GHz in a UHV system. After loading the trap, the electrons are detected after a variable waiting time by extraction and subsequent detection with an electron multiplier tube. The results on the trap depth and the lifetime of the trapped electrons are presented.

[1] S. Gulde et al, Appl. Phys. B; 73, 861(2001)
[2] C. Matthiesen et al, Phys. Rev. X; 11, 011019 (2021)

A 35.3 Thu 17:00 Tent C

Characterization of electron-production efficiency in ^{40}Ca two-step photoionization for loading electrons into a radiofrequency trap — •Natalija Sheth[1], Vladimir Mikhailovskii[1], Hendrik Bekker[1], Guofeng Qu[2], Yuzhe Zhang[1], Ferdinand Schmidt-Kaler[3], Christian Smorra[3], and Dmitry Budker[1,3,4] — [1]Helmholtz-Institut Mainz, GSI Helmholtzzentrum für Schwerionenforschung, Mainz, Germany — [2]Institute of Nuclear Science and Technology, Sichuan University, Chengdu, China — [3]Johannes Gutenberg-Universität, Mainz, Germany — [4]Department of Physics, University of California, Berkeley, USA

Radiofrequency (RF) traps are widely used for trapping ions, molecules, and even nanoparticles [1], while confining of electrons remains a challenging task. Within the AntiMatter On a Chip project we are characterizing an RF trap for electrons keeping in mind future possibility of trapping positrons. Loading electrons into the RF trap is realized by two-step photoionization (PI) of neutral Ca atoms [2]: excitation 4^1S_0 - 4^1P_1 with a 423 nm laser, and ionization from 4^1P_1 to continuum with a 393 nm laser. This approach allows production of cold electrons within the effective volume of the trap. A Ca atomic beam is produced by thermal evaporation of Ca. PI signal detection is realized by an electron-multiplier tube. Dependence of the PI signal on the lasers power and the detection efficiency are discussed.

[1].D. Bykov, et al. Rev. Sci. Inst; 93 (7), 073201 (2022)
[2].S. Gulde, et al. Appl Phys B; 73, 861 (2001).

A 35.4 Thu 17:00 Tent C

Theory of Bloch-oscillation-enhanced atom interferometry — •Ashkan Alibabaei[1,2], Florian Fitzek[1,2], Jan-Niclas Kirsten-Siemss[1,2], Klemens Hammerer[1], and Naceur Gaaloul[2] — [1]Institute for Theoretical Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany

We investigate the fundamental limits of Large Momentum Transfer (LMT) Atom Interferometry by using the Bloch oscillations of atoms in optical lattices. A thorough theoretical framework for Bloch-oscillation-enhanced atom interferometry is presented and validated through a comparison with numerical solutions of the Schrödinger equation. This establishes design criteria to reach the fundamental efficiency and accuracy limits of large momentum transfer using Bloch oscillations. We apply our findings to current state-of-the-art experiments and make projections for the next generation of quantum sensors. Finally, we outline future steps to include the effects of the lattice potential in transverse direction towards a more realistic description. This will facilitate our ability to perform comprehensive analyses of the statistical and systematic errors for future Bloch-enhanced LMT atom interferometers.

A 35.5 Thu 17:00 Tent C

Proposal for a series of experiments on autonomous running and starting of an ion trap micro engine — •Diego Fieguth[1,2], Peter Stabel[1,2], and James Anglin[1,2] — [1]RPTU Kaiserslautern — [2]Landesforschungszentrum OPTIMAS

A minimal realization of a combustion engine, in the sense of a system that enables secular energy transfer across a large difference in dynamical time scales, can be achieved with only two or three degrees of freedom evolving as a closed dynamical system. We propose implementing a minimal engine model using only the three-dimensional motion of a single trapped ion. The transverse vibrational modes of the ion in the trap will be analogous to fuel or heat baths, to power work in the form of axial motion against an opposing force. We propose a step-by-step sequence of trapped ion experiments that involve launching the ion with some initial velocity in the axial direction. In all cases, the microscopic engine runs autonomously, in the sense that it evolves under a time-independent Hamiltonian with no external power and no external control. In addition, the proposed experiments demonstrate the non-trivial constraints which must be obeyed if the microscopic engine is to be able not only to run autonomously, but also to start autonomously. We explain how these constraints arise from unitarity, through the Kruskal-Neishtadt-Henrard (KNH) theorem of classical adiabatic theory and its recently proven quantum analog.

A 35.6 Thu 17:00 Tent C

Formation and Decay of Charged Rydberg Dimers and Trimers — •Neethu Abraham and Matthew Travis Eiles — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The preparation and detection of various types of Rydberg molecules, ranging from Rydberg macrodimers to Rydberg atom-ion molecules is a major advancement in the field of ultracold atomic physics. The lifetimes of these molecules are typically shorter than those of bare Rydberg atoms, indicating the involvement of non-radiative decay processes in their dynamics. Specifically, the presence of non-adiabatic coupling between electronic potential energy curves could be a significant factor in their decay. We explore this mechanism here in the Rydberg atom-ion molecule system, where a vibrational bound state can hop onto a repulsive potential curve and decay. We employ the streamlined version of the multichannel R-matrix method to compute the positions and widths of the resonance states, revealing notable alterations arising from the influence of this coupling. An extended version of the Rydberg atom-ion dimer is a Rydberg atom-atom-ion trimer system, and we investigate the prospect of its formation. The interaction between the two Rydberg atoms leads to interesting phenomena influencing the overall molecular configuration. Our primary objective is to provide a detailed exploration of the electronic and vibrational structure of this tri-atomic molecule.

A 35.7 Thu 17:00 Tent C

cryogenic strontium quantum processor — •Valerio Amico, Jackson Angonga, Roberto Franco, Xintong Su, and Christian Gross — University of Tuebingen

Optical tweezers lattices hosting neutral Rydberg atoms are a promising platform for quantum computing and simulation. However, the most demanding challenge consists in mitigating noise due to environmental coupling. In our ongoing project, we propose a pioneering approach that involves creating optical tweezer lattices, based in fermionic strontium 87, in a cryogenic environment at 4K. The use of a closed-cycle cryostat will provide an extremely high vacuum (XHV) environment of 1e-12 mbar which will reduce atom loss due to background gas and increase the atom lifetime in trap beyond 10 min thus enabling the assembly of larger arrays. Furthermore, operating at cryogenic temperatures will markedly reduce black-body radiation (BBR) and consequently reduce BBR-induced transitions between Rydberg levels. This will increase Rydberg lifetime and improve the fidelity of entangling gates and qubit coherence. In addition to shielding provided by the 4K copper case, the cryogenic environment enables the usage of superconducting coils, which offer outstanding passive stability of the magnetic field and thereby increases the qubit coherence. In this presentation we will showcase initial trapping and cooling of Sr-87 in our vacuum chamber, the design and construction of our cryogenic chamber and our current efforts towards cooling and transport of atoms into the cryostat.

A 35.8 Thu 17:00 Tent C

Realisation of a two-particle Laughlin state with rapidly rotating fermions — •Philipp Lunt, Paul Hill, Johannes Reiter, Maciej Galka, Philipp Preiss, and Selim Jochim — Physikalisches Institut, Universität Heidelberg

The fractional quantum Hall (FQH) effect features remarkable states that due to their strongly correlated nature and exotic topological properties have stimulated a rich body of research going far beyond the condensed matter community, where the effect was originally discovered. One fundamental class of FQH states is described by the celebrated Laughlin wavefunction, which accounts for a large number of plateaus in the Hall resistivity and already exhibits interesting anionic, fractionally charged quasi-particle excitations.

Here we present the direct realisation of the two-particle Laughlin wavefunction by rapid rotation of two interacting spinful fermions in a tight optical tweezer. We owe this result to our newly established experimental tools allowing us to precisely shape and modulate our optical potentials using coherently interfering laser fields.

Our observations reveal distinctive features of the Laughlin wavefunction, including a ground state distribution in the center-of-mass motion, a vortex distribution in the relative motion, correlations in the relative angle of the two particles, and the suppression of interparticle interactions. This achievement represents a significant step towards scalable experiments, enabling the atom-by-atom assembly of fermionic fractional quantum Hall states in quantum simulators.

A 35.9 Thu 17:00 Tent C

High fidelity quantum gates between electronic and nuclear spins in diamond — •Simon Gregor Walliser, Philipp Vetter, and Fedor Jelezko — Institut für Quantenoptik, Universität Ulm, Deutschland

Quantum computing is a rapid developing field which takes advantage of quantum mechanical phenomena to efficiently solve complex problems.

A potential candidate, for a small-scale proof-of-principle quantum computer, is the nitrogen vacancy (NV) center in diamond, a point defect in the diamond lattice. It allows manipulation and optical readout of its electron spin state at room-temperature and can control surrounding nuclear spins.

We implement several two-qubit gates between the electron spin of the NV center and surrounding, weakly coupled carbon spins, based on dynamical decoupling sequences. The performance of the gates is planned to be evaluated through several protocols, which take state and measurement errors into account, to ensure a fair comparison with other systems.

A 35.10 Thu 17:00 Tent C

Applying machine learning optimization to a transfer beamline for highly charged ions — •Elwin A. Dijck, Vera M. Schäfer, Stepan Kokh, Lukas F. Storz, Christian Warnecke, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max Planck Institute for Nuclear Physics, Heidelberg

We optimize the production and transport of highly charged ions (HCIs) through a low-energy beamline that serves to decelerate and inject HCIs produced by an electron beam ion trap (EBIT) into a cryogenic radiofrequency trap for precision spectroscopy experiments [1]. The parameters to be optimized include EBIT settings, several dozen electrode voltages of electrostatic ion optics, as well as the timing of voltage pulses for deceleration, charge state selection and re-capture of HCI bunches. The online optimization is implemented using the open-source software package M-LOOP, which includes the machine learning methods of Gaussian process regression and a gradient-based approximator using an artificial neural network. The automated procedure allows faster optimization, as well as the investigation of apparatus stability over time. We discuss defining appropriate cost functions and the results obtained.

[1] Dijck et al., Rev. Sci. Instrum. **94**, 083203 (2023)

A 35.11 Thu 17:00 Tent C

Dynamics of melting linear mixed-species Coulomb crystals — •Elwin A. Dijck[1], Luca A. Rüffert[2], Lars Timm[3], José R. Crespo López-Urrutia[1], and Tanja E. Mehlstäubler[2,3] — [1]Max Planck Institute for Nuclear Physics, Heidelberg — [2]Physikalisch-Technische Bundesanstalt, Braunschweig — [3]Leibniz University, Hannover

We investigate the disappearance of ordered structure with increasing system temperature of linear ion Coulomb crystals trapped in a linear radiofrequency trap using molecular dynamics simulations. Understanding these dynamics is valuable for optimizing the operation of multi-ion optical clocks and experiments using highly charged ions for tests of fundamental physics. The thermal motion at higher temperature causes ions to swap places at increasing rates, depending on ion properties and trapping parameters. In particular, we study how the melting dynamics are affected by the presence of ion species with differing charge and/or mass. We support the simulation results with experimental data of small Be^+ ion crystals with and without a highly charged ion, controlling the ion temperature using Doppler cooling/heating. We discuss different criteria for defining the melting point and how the increased Coulomb repulsion by a highly charged ion alters the crystal structure such that these mixed-species ion crystals exhibit localized melting.

A 35.12 Thu 17:00 Tent C

Compact high precision electronics in space applications — •Alexandros Papakonstantinou, Thijs Wendrich, Christian Reichelt, Matthias Koch, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Atom interferometers with two species of cold degenerate quantum gases have been used to measure the Eötvös ratio. Ground-based experiments face limitations due to the trajectory of atoms within the confined space of the science chamber, which impacts the improvement of the Eötvös ratio in the interferometer due to the limitation of the free-fall time. However, employing a microgravity environment, provided for example by a sounding rocket or the ISS, presents advantages as it bypasses the constraints imposed by the apparatus size. In order to achieve interferometers for such conditions, the development of high-precision, compact electronics that meet the required standards and safety regulations for both the ISS and unmanned sounding rockets is essential. The electronics presented in this poster were developed with our experience in the QUANTUS family projects and proved their qualification by driving the lasers and magnetic fields to create degenerate quantum gases of two species during the MAIUS-2 sounding rocket mission.

A 35.13 Thu 17:00 Tent C

Synthetic dimension-induced pseudo Jahn-Teller effect in one-dimensional confined fermions — •André Becker[1,2], Georgios M. Koutentakis[3], and Peter Schmelcher[1,2] — [1]Center for Optical Quantum Technologies, Department of Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg Germany — [2]The Hamburg Centre for Ultrafast Imaging, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Institute of Science and Technology Austria (ISTA), am Campus 1, 3400 Klosterneuburg, Austria

We demonstrate the failure of the adiabatic Born-Oppenheimer approximation to describe the ground state of a quantum impurity within an ultracold Fermi gas despite substantial mass differences between the bath and impurity species. Increasing repulsion leads to the appearance of non-adiabatic couplings between the fast bath and slow impurity degrees of freedom which reduce the parity symmetry of the latter according to the pseudo Jahn-Teller effect. The presence of this mechanism is associated to a conical intersection involving the impurity position and the inverse of the interaction strength which acts as a synthetic dimension. We elucidate the presence of these effects via a detailed ground state analysis involving the comparison of ab initio fully-correlated simulations with effective models. Our study suggests ultracold atomic ensembles as potent emulators of complex molecular phenomena.

A 36: Highly Charged Ions and their Applications II

Time: Friday 11:00–13:00 Location: HS 1010

Invited Talk A 36.1 Fri 11:00 HS 1010

Stringent Test of QED predictions using Highly Charged Tin — •Jonathan Morgner, Bingsheng Tu, Charlotte M. König, Tim Sailer, Fabian Heisse, Bastian Sikora, Chunhai Lyu, Vladimir Yerokhin, Zoltán Harman, José R. Crespo López-Urrutia, Christoph H. Keitel, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, Heidelberg

Quantum electrodynamics (QED) is one of the pillars of the Standard Model. Its success in describing the fundamental interactions of charged particles, including non-classical effects such as self-energy and vacuum polarisation, is demonstrated in weak fields by the precise measurement of the electron magnetic moment (or $g-2$) [1]. Testing this in strong fields is of similar importance, as it allows exploring the boundaries of validity of the theory.

Here we present our recent measurement of the bound-electron magnetic moment of hydrogen-like tin [2]. The highly charged ions are produced in an electron beam ion trap and ejected into the Alphatrap apparatus, where we store a few single ions for months to perform high-precision Penning-trap spectroscopy on them. A comparison with the *ab initio* theory prediction shows agreement, and is therefore a precise test of the underlying theory at the highest Z so far. We additionally present measurements and first results of the lithium-like and the boron-like tin system [3].

[1] X. Fan, *et al.*, PRL **130**, 071801 (2023),
[2] J. Morgner, *et al.*, Nature **622**, 53*57 (2023),
[3] J. Morgner, *et al.*, in preparation.

A 36.2 Fri 11:30 HS 1010

Sympathetic cooling of ions using electron cyclotron radiation at the ELCOTRAP experiment — •Jost Herkenhoff, Sergey Eliseev, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

The evolution of precision in recent Penning-trap experiments is driving the need for ever-improving cooling techniques. In this talk, the prospect of a new sympathetic cooling technique using an electron-plasma coupled to a single ion is presented.

The cyclotron mode of electrons in a strong magnetic field and cryogenic environment decays to very low quantum numbers by emission of cyclotron radiation, causing this mode to end up predominantly in its ground state. Driving the motional sideband allows the axial motion to thermalize with the cyclotron motion to its ground state, which can then be coupled to a single ion stored in a spatially separated Penning trap using a common-resonator, allowing sympathetic cooling of all motional degrees of the ion. The extremely low expected temperatures in the millikelvin range open up an exciting new frontier of measurements in Penning traps.

The first implementation of this technique is currently being developed at the dedicated ELCOTRAP experiment at the Max-Planck Institute for Nuclear Physics, whose current status and prospects will be presented in this talk.

A 36.3 Fri 11:45 HS 1010

Metastable state detection with Penning-trap mass spectrometry — •Kathrin Kromer[1], Menno Door[1], Pavel Filianin[1], Zoltán Harman[1], Jost Herkenhoff[1], Paul Indelicato[2], Christoph H. Keitel[1], Daniel Lange[1], Chunhai Lyu[1], Yuri N. Novikov[1], Christoph Schweiger[1], Sergey Eliseev[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, — [2]Laboratoire Kastler Brossel, Sorbonne Université, CNRS, Paris, France

The construction of clocks in the XUV has recently become possible due to the extension of the frequency comb method to this frequency range. In combination with the vast landscape of transitions in highly charged ions (HCIs) a next generation of ultra precise clocks has come within reach. However, the search for suitable clock transitions, e.g. involving long-lived metastable electronic states, usually relies heavily on complicated atomic structure calculations.

With the Penning-trap mass spectrometer Pentatrap, we can discover long-lived metastable states and measure their energies without actively driving the transition and therefore being independent of theoretical predictions. With this method we have measured a metastable state energy in Pb as a mass difference of just 31.2(0.8) eV on top of the mass of the lead nuclei of ≈194 GeV, making it one of the most precise mass determination to date with a relative uncertainty of 4×10^{-12} [K. Kromer *et al.*, Phys. Rev. Lett., in print (2023)]. It is thereby possible to benchmark atomic structure calculations in open-shell HCI.

A 36.4 Fri 12:00 HS 1010

Developments of microwave filters for the LSym experiment — •Fabian Raab, Maria Pasinetti, Lukas Holtmann, Daniel Rubin, Andreas Thoma, Sangeetha Sasidharan, and Sven Sturm — MPIK Heidelberg

LSym is a new cryogenic Penning trap experiment that intends to test the symmetry of matter and antimatter in the lepton sector. In particular, the experiment will test for differences in mass, charge and g-factor of the positron and electron to achieve the most precise test for a hypothetical CPT violation so far.

In the experiment the positron has to be cooled to its ground state of motion. Therefore, the trap assembly is cooled to about 300 mK, where the trap cavity is largely depleted from black-body photons around the cyclotron frequency of 140 GHz. However, for the sideband cooling and the spin-manipulation we need drives very close to the cyclotron frequency, which can cause adverse heating far above the ground state if not accounted for.

This can be counteracted by implementing a microwave filter structure, which allows the two drives to enter the trap almost unhindered, while blocking almost all of the power close to the cyclotron frequency. Challenges that arise from the close proximity of the drive modes to the cyclotron mode and some ideas to overcome them will be presented here.

A 36.5 Fri 12:15 HS 1010

Positron source in the LSym experiment — •Maria Pasinetti, Fabian Raab, Lukas Holtmann, Daniel Rubin, Andreas Thoma, Sangeetha Sasidharan, and Sven Sturm — Max-Planck-Institut für Kernphysik

The goal of LSym is to conduct a stringent CPT test by comparing the properties of matter and antimatter with unprecedented sensitivity by simultaneously comparing the spin precession frequencies of a single positron and an electron in a millikelvin-cooled Penning trap. One of the challenges in this project is to trap one or a few positrons from a rather weak (about 1MBq) radioactive ^{22}Na source. Furthermore, an efficient detection method for the positrons needs to be designed and implemented. As the positrons follow a β^+ decay spectrum, they have to be moderated before entering the trap, a process with low efficiency requiring careful execution. The trapped positron is then cooled to the ground-state of motion in the center of the trap. This presentation illustrates the principles and techniques that will be used for the positron source at LSym.

A 36.6 Fri 12:30 HS 1010

Hyper-EBIT: The development of a source for very highly charged ions — •Athulya Kulangara Thottungal George, Matthew Bohman, Fabian Heisse, Charlotte Maria König, Jonathan Morgner, Kunal Singh, José Ramon Crespo López-

Urrutia, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, Heidelberg

Precision tests of quantum electrodynamics (QED) in strong fields can be performed using highly charged ions (HCI). Here, only a few or even a single one of the innermost electrons are left, experiencing the strong fields originating from the nucleus. The Alphatrap experiment is a cryogenic Penning trap experiment which is dedicated to perform strong-field QED tests by measuring the bound electron magnetic moment (or g factor).

Recently, we have measured the bound electron g factor of hydrogen-like tin with Alphatrap to sub parts-per-billion precision. Our ultimate goal is to further advance such tests into the strongest fields by performing similar measurements on the heaviest HCI such as $^{208}Pb^{81+}$. For the production of $^{208}Pb^{81+}$ an electron beam ion trap called "Hyper-EBIT" is being constructed at the Max-Planck-Institut für Kernphysik with planned beam energies of 300 keV and up to 500 mA of beam currents. This contribution presents the recent developments of Hyper-EBIT.

A 36.7 Fri 12:45 HS 1010

King Plots: Constraining New Physics using Isotope Shift Spectroscopy — •Agnese Mariotti[1], Erik Benkler[2], Julian Berengut[8], Shuying Chen[2], Jose R. Crespo Lopez-Urrutia[3], Melina Filzinger[2], Elina Fuchs[1,2,4], Nils Huntemann[2], Steven A. King[2], Fiona Kirk[2], Nils H. Rehbehn[3], Jan Richter[2], Matteo Robbiati[4,6,7], Micheal K. Rosner[3], Piet O. Schmidt[2,5], Lucas J. Spiess[2], Andrey Surzyhkov[2], Anna Viatkina[2], Malte Wehrheim[2], Alexander Wilzewski[2], Diana A. Craik[9], Jeremy Flannery[9], Jonathan Home[9], Luca Huber[9], Roland Matt[9], Menno Door[3], Klaus Blaum[3], and Martin R. Steinel[2] — [1]LUH-ITP — [2]PTB — [3]MPI — [4]CERN — [5]LUH-IQ — [6]TIF Lab — [7]TII — [8]UNSW — [9]ETH/TBD

With 95% of the universe's content still unexplained by modern physics, the motivations for new physics searches are becoming more and more evident. The approach used in our work exploits the high precision of low-energy experiments to identify deviations from the theoretical predictions of the Standard Model. We utilize a combination of isotope shift measurements and King plots, which allows to minimize the required theoretical input and is sensitive to a new interaction that couples electrons and neutrons. A wise combination of experimental data enables us to set strong constraints on such coupling. Here, we show how we improve the previous bounds by building King plots with the recent measurement of isotope shift in Ca14+, carried out at PTB. Additionally, we present two ways of utilizing the available data: a geometrical approach and a fitting method.

A 37: Ultra-cold Atoms, Ions and BEC IV (joint session A/Q)

Time: Friday 11:00–13:00 Location: HS 1098

A 37.1 Fri 11:00 HS 1098

Accurate and efficient Bloch-oscillation-enhanced atom interferometry — •Florian Fitzek[1,2], Jan-Niclas Kirsten-Siemss[2], Ernst M. Rasel[2], Naceur Gaaloul[2], and Klemens Hammerer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Bloch oscillations of atoms in optical lattices offer a powerful technique to significantly enhance the sensitivity of atom interferometers by orders of magnitude. To fully exploit the potential of this method, an accurate theoretical description of losses and phases beyond current treatments is essential. In this work, we introduce a comprehensive theoretical framework for Bloch-oscillation-enhanced atom interferometry [Fitzek *et al.*, arXiv:2306.09399]. We confirm its accuracy through comparison with an exact numerical solution of the Schrödinger equation [Fitzek *et al.*, Sci Rep 10, 22120 (2020)]. Using our approach, we define the fundamental efficiency and accuracy limits of Bloch-oscillation-enhanced atom interferometers and establish design criteria to achieve their saturation. We compare these limits to current state-of-the-art atom interferometers and formulate requirements for the improvement of future quantum sensors.

This work is supported through the Deutsche Forschungsgemeinschaft (DFG) under EXC 2123 QuantumFrontiers, Project-ID 390837967 and under the CRC1227 within Project No. A05 as well as by the VDI with funds provided by the BMBF under Grant No. VDI 13N14838 (TAIOL).

A 37.2 Fri 11:15 HS 1098

Quantum fluctuations in one-dimensional supersolids — •Chris Bühler, Tobias Ilg, and Hans Peter Büchler — Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart

In one dimension, quantum fluctuations prevent the appearance of long-range order in a supersolid, and only quasi-long-range order can survive. We derive this quantum critical behavior and study its influence on the superfluid response and properties of the solid. The analysis is based on an effective low-energy description accounting for the two coupled Goldstone modes. We find that the quantum phase transition from the superfluid to the supersolid is shifted by quantum fluctuations from the position where the local formation of a solid structure takes place. For current experimental parameters with dipolar atomic gases, this shift is extremely small and cannot be resolved yet, i.e., current observations in experiments are expected to be in agreement with predictions from mean-field theory based on the extended Gross-Pitaevskii formalism.

https://journals.aps.org/prresearch/abstract/10.1103/PhysRevResearch.5.033092

A 37.3 Fri 11:30 HS 1098

Realizing freely programmable passively phase-stable 2D optical lattices — David Wei[1,2], •Daniel Adler[1,2], Kritsana Srakaew[1,2], Suchita Agrawal[1,2], Pascal Weckesser[1,2], Immanuel Bloch[1,2,3], and Johannes Zeiher[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany

Ultracold atoms in optical lattices have become a vital platform for experimental quantum simulation, enabling the precise study of a variety of quantum many-body problems. For most experiments, the layout of the lattice beams restricts the accessible lattice configurations and thus the underlying physics. Here, we present a novel tunable lattice, which provides programmable unit cell connectivity and in principle allows for changing the geometry mid-sequence. Our approach builds on the phase-stable realization of a square or triangular lattice combined with microscopically projected repulsive local potential patterns. We benchmark the performance of this system through single-particle quantum walks in the square, triangular, kagome, and Lieb lattices. In the strongly correlated regime, we microscopically characterize the geometry dependence of the quantum fluctuations.

A 37.4 Fri 11:45 HS 1098

Phase diagram of the extended anyon Hubbard model in one dimension — •Imke Schneider[1], Martin Bonkhoff[2], Kevin Jägering[1], Shijie Hu[3], Axel Pelster[1], and Sebastian Eggert[1] — [1]University of Kaiserslautern-Landau, Landesforschungszentrum OPTIMAS — [2]Universität Hamburg — [3]Beijing Computational Science Research Center

Anyons with arbitrary exchange angle can be realized using ultracold atoms in optical lattices. Here, we study the anyonic extended Hubbard model in one dimension. At unit filling a repulsive next-nearest neighbor interaction generally leads to gapped phases but it is far from trivial which correlations are the dominant ones as a function of topological exchange angle and on-site interaction U. We find that a careful derivation of all terms in the Luttinger liquid theory predicts an intermediate phase between a Mott insulator for large repulsive U and a charge density wave at negative U. As a function of exchange angle the intermediate phase changes from Haldane insulator for pseudo bosons to a dimerized phase for pseudo fermions at an interesting multicritical point. Our results are confirmed by extensive numerical simulations.

A 37.5 Fri 12:00 HS 1098

Spontaneous ignition of an ion trap engine — •Peter Stabel, D[illegible]ieguth, and James Anglin — RPTU Kaiserslautern

Do the microscopic roots of thermodynamics extend even before the onset of chaotic ergodization, into the integrable Hamiltonian mechanics of small, isolated systems? Here we propose a set of experiments on the three-dimensional motion of a single ion in a linear Paul Trap, in which the focus is not on any form of thermalization, but on the engine-like secular transfer of energy between fast and slow degrees of freedom, analogous to the rapid motions of hot gas particles slowly lifting a weight. The ion's three motional degrees of freedom constitute the entire system, which is isolated and undriven; a high-frequency transverse vibrational mode of the ion plays the role of a battery or fuel tank, or hot reservoir to power steady axial motion against an opposing force. We show that this combustion engine-like system can generically run autonomously, but that only under a certain more stringent condition can the engine also start autonomously. This non-trivial condition for autonomous starting of the engine-like process can be derived from unitarity, via the classical Kruskal-Neishtadt-Henrard theorem and its recent quantum extension. Although these post-adiabatic theorems do not involve ergodization, they do involve a certain increase of phase space areas, or subspace dimensions, and may play a role similar to that played macroscopically by thermodynamics, in constraining the design of microscopic autonomous machines.

A 37.6 Fri 12:15 HS 1098

Emergence of a Bose polaron in a small ring threaded by the Aharonov-Bohm flux — •Fabian Brauneis[1], Areg Ghazaryan[2], Hans-Werner Hammer[1,3], and Artem Volosniev[2] — [1]Technische Universität Darmstadt, Department of Physics, 64289 Darmstadt, Germany — [2]Institute of Science and Technology Austria (ISTA), 3400 Klosterneuburg, Austria — [3]ExtreMe Matter Institute EMMI and Helmholtz Forschungsakademie Hessen für FAIR (HFHF), 64291 Darmstadt, Germany

The model of a ring threaded by the Aharonov-Bohm flux underlies our understanding of a coupling between gauge potentials and matter. The typical formulation of the model is based upon a single particle picture, and should be extended when interactions with other particles become relevant. Here, we illustrate such an extension for a particle in an Aharonov-Bohm ring subject to interactions with a weakly interacting Bose gas. Our findings demonstrate that the system's ground state can be effectively characterized using the Bose polaron concept – a particle dressed by interactions with a bosonic environment. Our results suggest the Aharonov-Bohm ring as a platform for the few-to many-body crossover of quasi-particles that arise from an impurity immersed in a medium.

This work has received funding from the DFG Project no. 413495248 [VO 2437/1-1].

A 37.7 Fri 12:30 HS 1098

Effective Theory for the Gaudin-Yang model — •Timothy George Backert[1], Hans-Werner Hammer[1,3], Artem Volosniev[2], Fabian Brauneis[1], Joachim Brand[4], and Matija Čufar[4] — [1]Technische Universität Darmstadt, Department of Physics — [2]Institute of Science and Technology Austria (ISTA) — [3]ExtreMe Matter Institute EMMIand Helmholtz Forschungsakademie Hessen für FAIR (HFHF) — [4]New Zealand Institute for Advanced Study, Massey University, New Zealand

We investigate the crossover from a Bardeen-Cooper-Schrieffer superfluid with loosely bound Cooper pairs to a Bose-Einstein condensate of tightly bound dimers (molecules) for a one-dimensional spin-1/2 Fermi gas (Gaudin-Yang model [GY]) on a ring. We obtain exact Bethe-Ansatz solutions which describe the BCS-BEC crossover in the form of a transition from a (BCS-like) gas of loosely bound fermion pairs to a Tonks-Girardeau gas of tightly bound dimers. For the experimentally relevant case of an external potential only numerical solutions can be obtained. In order to obtain analytical insights into the case with an external potential, we set up an effective theory with fermions and dimers as degrees of freedom and determine the coupling constants by matching to the Bethe-Ansatz results. We find good agreement with the numerical results for small particle numbers. This paves the way for the exploration of many-body systems using this effective theory. Supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) * Project-ID 279384907 * SFB 1245.

A 37.8 Fri 12:45 HS 1098

Three-charged-particle systems in the framework of coupled coordinate-space few-body equations — •Renat Sultanov — Odessa College, Department of Mathematics, 201 W. University Blvd. Odessa, TX USA

We study *three-charged-particle* low-energy elastic collision and particle-exchange reaction with special attention to the systems with Coulomb and an additional nuclear interaction employing a close-coupling expansion scheme to a set of coupled two-component few-body equations [1]. First we apply our formulation to compute low-energy elastic scattering phase shifts for the $d+(t\mu^-)_{1s}$ collision, which is of significant interest for the muon-catalyzed-fusion D-T cycle. Next, we study the particle-exchange reaction $d+(pX^-)\to p+(dX^-)$ with the long-lived elementary heavy lepton stau X^- which can play a critical role in the understanding of the Big-Bang nucleosynthesis and the nature of dark matter. We also study the total cross sections and rates for two particle-exchange reactions involving antiprotons ($\bar{p}$), deuteron (d) and triton (t), e.g., $\bar{p}+(d\mu^-)_{1s}\to(\bar{p}d)_{1s}+\mu^-$ and $\bar{p}+(t\mu^-)_{1s}\to(\bar{p}t)_{1s}+\mu^-$, where μ^- is a muon. The effect of the final state short-range strong ($\bar{p}d$) and ($\bar{p}t$) nuclear interactions is significant in these reactions, which increases the reaction rates by a factor of ≈ 3. Additionally (if time permits), a 3-body $\bar{p}+Mu$ collision will be discussed, where Mu is a muonium atom [2].

1. R. A. Sultanov and S. K. Adhikari, Phys. Rev. C 107, 064003 (2023).
2. R. A. Sultanov and D. Guster, J. Phys. B 46, 215204 (2013).

A 38: Trapped Ions (joint session Q/A)

Time: Friday 11:00–13:00 Location: HS 1199

Invited Talk A 38.1 Fri 11:00 HS 1199

Photonic integration for trapped-ion quantum metrology — •Elena Jordan[1], Guochun Du[1], Carl-Frederik Grimpe[1], Fatemeh Salahshoori[1], Markus Kromrey[1], Atasi Chatterjee[1], Anastasiia Sorokina[2,3], Steffen Sauer[1,2,3], Anton Peshkov[1,2], Gillenhaal Beck[4], Karan Mehta[5], Stefanie Kroker[1,2,3], Andrey Surzhykov[1,2,3], and Tanja Mehlstäubler[1,6,7] — [1]PTB, Braunschweig, Germany — [2]Technische Universität Braunschweig, Germany — [3]Laboratory for Emerging Nanometrology Braunschweig, Germany — [4]Institut für Quantenelektronik ETH Zürich, Switzerland — [5]School of Electrical and Computer Engineering Cornell University, Ithaca, NY 14850, USA — [6]Institut für Quantenoptik Leibniz Universität Hannover, Germany — [7]Laboratorium für Nano- und Quantenengineering Leibniz Universität Hannover, Germany

Integrated photonics make ion trap setups scalable to large numbers of ions, help to compactify the setup and improve the robustness against vibrations for portable optical clocks and quantum sensors. We are developing ion traps with integrated photonics for quantum metrology. With photonic design structured light can be generated that, combined with improved pointing stability, enables the excitation of forbidden transitions in trapped ions. For the cooling and addressing of Yb^+ ions wavelengths from UV to NIR are required. The light is coupled in from optical fibers, distributed via waveguides, and coupled out through the surface of the chip via gratings. Our aim is to employ the traps in portable optical clocks that can be used for geodetic measurements.

A 38.2 Fri 11:30 HS 1199

Apparatus design for scalable cryogenic trapped-ion quantum computing experiments — •Tobias Pootz[1], Lukas Kilzer[1], Celeste Torkzaban[1], 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

Future applications for trapped ion quantum computers require a signicant increase in the number of ion qubits and excellent interconnectivity. In my talk I will describe the design of cryogenic demonstrator machines for this task, implementing surface-electrode ion traps mounted on a universal interchangeable socket. The apparatus design is based on a vibration-isolated cold head to cool a cryogenic vacuum system to temperatures below 10 K. The system features several hundred DC control lines to support transport of qubits through dedicated trap structures including junctions, storage, detection and manipulation registers. Multi-qubit quantum gates will be implemented through the use of chip-integrated microwave lines. The system has been designed to accommodate the integration of new components for scaling as the development of the underlying enabling technologies progresses, such as chip integrated waveguides. Multiple setups were built. One setup is based on 9Be+ qubits and 40Ca+ ions for sympathetic cooling; a second setup will be based on 43Ca+ qubits and 88Sr+ cooling ions.

A 38.3 Fri 11:45 HS 1199

Fabrication of multisegmented ion traps in a specialized cleanroom — •Alexander Müller[1], Jan Müller[1], Björn Lekitsch[1], and Ferdinand Schmidt-Kaler[1,2] — [1]QUANTUM, Institut für Physik, 55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, 55099 Mainz, Germany

Trapped ions are among the leading platforms in quantum computing. We aim to scale up to 50 ions by taking advantage of versatile linear multi-segmented ion traps which combine qubit register reconfigurations [1] and individual addressing of ions in these registers. A fully three-dimensional shaping of electrodes, a homogeneous well-conducting high quality metallic coverage, the precise alignment of trap structures, an excellent optical access, and a fully reliable and repeatable fabrication process are required.

For this we established a special purpose cleanroom. By Selective Laser-induced Etching (SLE) a 3D structure is formed out of fused silica [2]. Metallic sputter deposition results in functional trap chips, which are assembled using a die-bonder, finally fixed on a carrier PCB, and wirebonded for electrical connection of the electrodes. All fabrication steps can be performed in-house and without leaving the cleanroom in a rapid prototyping fashion (<10 days). We report the testing of devices and the trapping of Ca+ ions.

[1] V. Kaushal et al., AVS Quantum Sci.; 2 (1):014101.
[2] S. Ragg et al., Rev. Sci. Instrum.; 90 (10):103203.

A 38.4 Fri 12:00 HS 1199

Microfabrication of surface ion traps for operation with Strontium Rydberg ions — •Simon Schey[1,2], Michael Pfeifer[1,3], Marion Mallweger[2], Natalia Kuk[2], Ivo Straka[2], Clemens Rössler[1], Yves Colombe[1], and Markus Hennrich[2] — [1]Infineon Technologies Austria AG, Villach, Austria — [2]Stockholm University, Stockholm, Sweden — [3]University of Innsbruck, Innsbruck, Austria

Recently, using Rydberg-states for gate operation in trapped ions has been shown to greatly reduce two qubit gate times down to 700ns [1]. Those experiments were performed in a macroscopic Paul trap at room temperature. We propose to perform similar experiments but in a cryogenic environment as well as on a of surface ion trap chip that is industrially microfabricated at Infineon Technologies [2,3]. This will prove further scalability of this gate scheme.

As UV-Lasers are needed for the Rydberg gate operation, we discuss material and design choices for making our ion trap resilient against radiation down to a wavelength of around 240nm and show successful microfabrication of an ion trap on a sapphire substrate.

[1] Chi Zhang et al., Nature 580, 345-349 (2020)
[2] Ph. Holz et al., Adv. Quantum Technol. 3, 2000031 (2020)
[3] S. Auchter et al., Quantum Sci. Technol. 7, 035015 (2022)

A 38.5 Fri 12:15 HS 1199

Industrial microfabrication of 2D and 3D ion traps for quantum information processing — •Yves Colombe[1], Silke Auchter[1], Klemens Schüppert[1], Matthias Dietl[1,2], Alexander Zesar[1,3], Jakob Wahl[1,2], Max Glantschnig[1,4], Christian Flasch[1,4], Simon Schey[1,5], Fabian Laurent[1,6], Michael Pfeifer[1,2], Fabian Anmasser[1,2], Michael Hartmann[7], Leon Dixius[7], Mohammad Abu Zahra[7], Jens Repp[7], Nina Megier[1], Matthias Brandl[7], and Clemens Rössler[1] — [1]Infineon Technologies, Villach, Austria — [2]University of Innsbruck, Innsbruck, Austria — [3]University of Graz, Graz, Austria — [4]PTB, Braunschweig, Germany — [5]University of Stockholm, Stockholm, Sweden — [6]Montan University of Leoben, Leoben, Austria — [7]Infineon Technologies, Oberhaching, Germany

Scaling TIQC to thousands of ions requires microfabricated traps produced in highly reliable facilities. Industrial fabrication provides precise process control as well as in-line measurements tools that ensure high reliability and reproducibility.

Various ion trap designs have been produced at Infineon Technologies cleanroom facilities, including 2D ion trap arrays and 3D traps assembled at wafer level. In this talk I will report on our current work towards large-scale ion traps, including fabrication on dielectric substrates (fused silica, sapphire), through-glass-vias, use of Kelvin probe force microscopy for DC surface potential measurements, integration of fs-laser-written optical waveguides, and development of electronic devices that can operate at 4 K.

A 38.6 Fri 12:30 HS 1199

Optical integration in ion-trap chips at Infineon — •Alexander Zesar[1,2], Jakob Wahl[2,3], Bernhard Lamprecht[5], Philipp Hurdax[5], Klemens Schüppert[2], Clemens Rössler[2], Yves Colombe[2], Silke Auchter[2], Sofia Cano Castro[2,6], Max Glantschnig[2,7], Marco Schmauser[3], Marco Valentini[3], Philipp Schindler[3], Thomas Monz[3,4], and Joachim Krenn[1] — [1]University of Graz, Graz, Austria — [2]Infineon Technologies Austria AG, Villach, Austria — [3]University of Innsbruck, Innsbruck, Austria — [4]Alpine Quantum Technologies GmbH, Innsbruck, Austria — [5]Joanneum Research Materials, Weiz, Austria — [6]Polytecnico di Milano, Milan, Italy — [7]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Trapped ions are among the most researched and advanced quantum computing (QC) hardware platforms. Currently used free-space optics for ion addressing will block upscaling due to beam pointing errors and spatial restrictions. Therefore, future QC architectures with trapped ions require integrated waveguiding and focusing for scalable and stable placement of laser beams in microfabricated ion-trap chips.

This talk gives a concise overview of photonics and optics integration schemes developed at Infineon. We will discuss some of the challenges that come with femtosecond-laser-written waveguides as well as slab waveguides in conjunction with focusing grating couplers, including fiber-to-chip coupling and integration density. The talk concludes with an outlook on scalable ion-trap chips with integrated photonics as a necessary condition for useful trapped-ion quantum computing.

A 38.7 Fri 12:45 HS 1199

How to Wire a 1000-Qubit Trapped-Ion Quantum Computer — Maciej Malinowski[1], David Allcock[1,2], •Clemens Matthiesen[1], and Chris Ballance[1,3] — [1]Oxford Ionics, Oxford, UK — [2]University of Oregon, Eugene, USA — [3]University of Oxford, Oxford, UK

Scaling up quantum computers requires efficient signal delivery to the quantum processor (the "wiring" challenge). It is likely that integration of control electronics into the processor package will be necessary, but this process is heavily constrained by chip microfabrication and chip operation specifications. Here, we present our WISE (Wiring using Integrated Switching Electronics) architecture as an answer to the wiring question, where judicious integration of simple switching electronics into the ion trap chip is combined with parallel trap electrode control [1]. This significantly reduces the number of signal sources needed, such that a fully connected 1000-qubit trapped ion quantum computer might be operated using only ~ 200 signal sources.

[1] M. Malinowski *et al.*, PRX Quantum **4**, 040313 (2023)

A 39: Precision Measurements II (joint session Q/A)

Time: Friday 11:00–13:00 Location: HS 1221

A 39.1 Fri 11:00 HS 1221

Noise Description in Bragg Atom Interferometer Using Squeezed States — •Julian Günther[1,2], Jan-Niclas Kirsten-Siemss[2], Naceur Gaaloul[2], and Klemens Hammerer[1] — [1]Institut für Theoretische Physik, Hannover, Germany — [2]Institut für Quantenoptik, Hannover, Germany

Using entanglement for N-particle states in matter wave interferometers allows one to outperform the standard quantum limit of $\frac{1}{\sqrt{N}}$ for the uncertainty in the phase measurement. We consider the use of one-axis twisted, spin squeezed atomic states in a Bragg Mach-Zehnder interferometer. We evaluate the phase uncertainty in the phase measurement taking into account the fundamental multi-port and multipath nature of the Bragg processes, and determine optimally squeezed states for a given geometry.

This project was funded within the QuantERA II Programme that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101017733 with funding organisation DFG (project number 499225223).

A 39.2 Fri 11:15 HS 1221

Squeezing-enhanced Bragg guided BEC interferometry — •Matthew Glaysher[1], Robin Corgier[2], and Naceur Gaaloul[1] — [1]Institut für Quantenoptik, Leibniz Universität, Hannover — [2]LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, France

Atom interferometers test fundamental theories and have practical applications such as gravimeters, gradiometers and gyroscopes. Using uncorrelated or classically correlated atomic probes, state-of-the-art devices already operate at the standard quantum limit (SQL) set by their finite baseline and/or atom number resources.

To push the boundaries of compact devices, we study the realisation of a Bose-Einstein condensate (BEC) guided interferometer based on Bragg diffraction [R. Corgier et al., PRA, 103 (2021)]. Taking advantage of the BEC oscillations in the waveguide and the possibility to tune atom-atom interactions we investigate the generation of spin-squeezing dynamics between the two modes in well-defined and well-controlled momentum states. The entangled input state feeds a second interferometer sequence with quantum-enhanced sensitivity capabilities. Realistic aspects of the state-preparation parameters, including diffraction efficiencies and BEC collisions and deformations, are addressed in our scheme.

This project was funded within the QuantERA II Programme that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101017733 with funding organisation DFG (project number 499225223).

A 39.3 Fri 11:30 HS 1221

Analytical theory of double Bragg diffraction in light-pulse atom interferometers — •Rui Li[1], Klemens Hammerer[2], and Naceur Gaaloul[1] — [1]Leibniz University Hanover, Institute for quantum optics, Hannover, Germany — [2]Leibniz University Hanover, Institute for theoretical physics, Hannover, Germany

In this talk, we provide some new physical insights into a recently used tool in atom interferometry, namely the double Bragg diffraction (DBD). We derive an effective two-level-system (TLS) Hamiltonian via Magnus expansion for describing the so-called *quasi-Bragg regime* where most light-pulse atom interferometers are operating. With this effective TLS Hamiltonian, we systematically study the effects of polarization error and AC-Stark shift due to second-order process on the efficiency of double-Bragg beam-splitters. Furthermore, we show that effects of Doppler broadening can be easily included by extending our TLS description to a three-level-system description. With the help of our effective theory, we design an optimal beam-splitter via a time-dependent detuning and show its robustness against polarization error and asymmetric beam-splitting due to Doppler effect.

This work is supported through the Deutsche Forschungsgemeinschaft (DFG) under EXC 2123 QuantumFrontiers, Project-ID 390837967 and under the CRC1227 within Project No. A05 as well as by DLR funds from the BMWi (50WM2250A-QUANTUS+)

A 39.4 Fri 11:45 HS 1221

Wave-packet evolution during laser pulses for single- and two-photon atomic diffraction — •Nadja Augst and Albert Roura — Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm

Light-pulse atom interferometry is a valuable tool for high-precision inertial sensing and also offers promising prospects for dark-matter and gravitational-wave detection [1]. This work investigates the wave-packet evolution for an atom's center of mass during a laser pulse of arbitrary duration driving either a single-photon transition or Raman diffraction, and the results are also valid for Bragg diffraction in the deep Bragg regime. In particular, we consider the effects of finite pulse duration on the central trajectory of the atomic wave packets for beam-splitter and mirror pulses as well as pulses with arbitrary pulse areas. Our analysis encompasses a wide range of the cases including square and Gaussian pulse shapes as well as an arbitrary detuning of the central momentum.

While the resulting deviations of the central trajectories are typically quite small, they can have a significant impact on the interferometric phase shift in high-precision measurements and a detailed analysis is therefore important. Our approach relies on a description of the matter-wave propagation in terms of central trajectories and centered wave packets [2].

[1] K. Bongs et al., Nature Rev. Phys. 1, 731 (2019).
[2] A. Roura, Phys. Rev. X 10, 021014 (2020).

A 39.5 Fri 12:00 HS 1221

Squeezing Enhanced Matterwave Interferometry with BECs — •Christophe Cassens, Bernd Meyer-Hoppe, and Carsten Klempt — Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, D-30167 Hannover, Germany

The gravitational acceleration can be measured with atom interferometers with unprecedented resolution. The ultimate resolution is fundamentally restricted by the standard quantum limit. This restriction can be lifted by operating the interferometer with entangled atoms, which carry quantum correlations among them. Here we present how a squeezed state in the magnetic field insensitive clock states of a Rb-87 BEC of 6000 atoms can be used to improve the sensitivity of an atom gravimeter sequence to -1.5dB below the SQL and -3.3dB below the sensitivity achieved in the same sequence with a coherent state. The here presented technique promises to be applicable in state-of-the-art BEC-based matterwave-interferometers and to increase their sensitivity especially in size, weight and power limited environments.

A 39.6 Fri 12:15 HS 1221

Simulating matter-wave lensing of BECs in 2D and 3D — •Nico Schwersenz and Albert Roura — Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm

The extended microgravity conditions granted by cold-atom experiments in space enable free-evolution times of many seconds, which can be exploited in high-precision measurements based on atom interferometry. However, in order to reach such long evolution times, it is necessary to employ ultracold atoms combined with matter-wave lensing techniques, and a detailed modeling is required.

We present full 3D numerical simulations performed on a GPU cluster of BECs freely expanding for tens of seconds and compare them to effectively 1D and 2D simulations for spherically- and axially-symmetric configurations. A particularly interesting case arises when the lensing potential is applied after the BEC has expanded sufficiently so that the diffraction effects associated with the finite size of the BEC dominate over the mean-field interaction. This enables the validation of our simulations in a regime where the time-dependent Thomas-Fermi approximation fails to provide an accurate description of the dynamics. Finally, as an application of our methods for axially-symmetric configurations, additional features that arise in the anisotropic case will be discussed as well.

A 39.7 Fri 12:30 HS 1221

Simulation of atomic diffraction through a nanograting — •Matthieu Bruneau[1,2], Charles Garcion[1,2], Julien Lecoffre[2], Quentin Bouton[2], Eric Charron[3], Gabriel Dutier[2], and Naceur Gaaloul[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Laboratoire de physique des lasers, Université Sorbonne Paris Nord, Villetaneuse, France — [3]Université Paris-Saclay, CNRS, Institut des Sciences Moléculaires d'Orsay, France

Recent advances in the field of cold atoms have made atomic interferometry a versatile and precise tool with various applications, particularly in fundamental physics experiments.

This contribution focuses on the modeling of an experiment involving the diffraction of cold metastable Argon atoms through a transmission nanograting at the Laboratoire de Physique des Lasers. The observed diffraction pattern in this experiment is intrinsically related to the dispersion forces between the atoms and the material. A numerical model of the experiment has been developed, and the influence of these forces has been thoroughly investigated.

The simulation is based on an efficient numerical solution of the time-dependant Schrödinger equation that overcomes the limitations of the more standard semi-classical approach. This methodology provides an accurate description of the diffraction pattern, allowing a Casmir-Polder force measurement beyond the state of the art.

This work is supported by DLR funds from the BMWi (50WM2250A-QUANTUS+).

A 39.8 Fri 12:45 HS 1221

Double Bragg atom interferometry with Bose-Einstein condensates in microgravity — •Julia Pahl[1], Anurag Bhadane[2], Dorthe Leopoldt[3], Sven Herrmann[4], André Wenzlawski[2], Sven Abend[3], Patrick Windpassinger[2], Ernst M. Rasel[3], Markus Krutzik[1,5], and The QUANTUS Team[1,2,3,4,6,7] — [1]HU Berlin — [2]JGU Mainz — [3]LU Hannover — [4]U Bremen — [5]FBH Berlin — [6]U Ulm — [7]TU Darmstadt

QUANTUS-2 is the 2nd generation mobile atom interferometer operating at the ZARM drop tower in Bremen. With its high-flux, atom chip-based atomic rubidium source, it serves as a pathfinder for future space missions. We are examining key technologies like the generation of Bose-Einstein condensates (BECs), implementation of magnetic lensing or application of various atom interferometry geometries with interferometry times over one second. In this talk, we present our latest results on double Bragg atom interferometry of magnetically lensed rubidium ensembles, using asymmetric Mach-Zehnder interferometers. By exploiting the emerging interferometer fringes we can visualize the anharmonicities of the magnetic lens and determine the interferometer contrast as well as the effective kinetic energy of the ensemble in a single shot. Interferometer times of $2T \approx 1.7\,s$ have been reached.

This project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action under grant number DLR 1952-1957.

A 40: Ultra-cold Atoms, Ions and BEC V (joint session A/Q)

Time: Friday 14:30–16:30 Location: HS 1010

A 40.1 Fri 14:30 HS 1010

Pairing dome from an emergent Feshbach resonance in a strongly repulsive bilayer model — •Hannah Lange[1,2,3], Lukas Homeier[1,3], Eugene Demler[4], Ulrich Schollwöck[1,3], Annabelle Bohrdt[3,5], and Fabian Grusdt[1,3] — [1]LMU Munich, Germany — [2]MPI for Quantum Optics, Garching, Germany — [3]Munich Center for Quantum Science and Technology, Germany — [4]ETH Zurich, Switzerland — [5]University of Regensburg, Germany

A key to understanding unconventional superconductivity lies in unraveling the pairing mechanism of mobile charge carriers in doped antiferromagnets, giving rise to an effective attraction between charges even in the presence of strong repulsive Coulomb interactions. In this talk, I will consider a mixed-dimensional t-J ladder, a system that has recently been realized with ultracold atoms [1], and show how it can be extended with a nearest neighbor Coulomb repulsion. With repulsion turned off, the system features tightly bound hole pairs and large binding energies (closed channel). When the repulsion strength is increased, a crossover to more spatially extended, correlated pairs of individual holes (open channel) can be observed. In the latter regime, we still find robust binding energies that are strongly enhanced in the finite doping regime. The effective model in the strongly repulsive regime reveals that the attraction is mediated by the closed channel, in analogy to atomic Feshbach resonances between open and closed channels [2].

[1] Hirthe et al., Nature 2023
[2] Lange et al., arXiv:2309.15843, 2309.13040

A 40.2 Fri 14:45 HS 1010

ARPES spectroscopy of an extended Majumdar-Ghosh model — •Simon M. Linsel[1,2], Nader Mostaan[1,2,3], Annabelle Bohrdt[2,4], and Fabian Grusdt[1,2] — [1]LMU Munich, Germany — [2]Munich Center for Quantum Science and Technology, Germany — [3]Université Libre de Bruxelles, Brussels, Belgium — [4]University of Regensburg, Germany

Experimental and numerical spectroscopy have revealed novel physics in anti-ferromagnets, in particular in frustrated and doped systems. The Majumdar-Ghosh (MG) model has an analytically known spin-disordered ground state of dimerized singlets as a result of magnetic frustration. Here we study the single-hole angle-resolved photoemission spectroscopy (ARPES) spectrum of an extended MG model, where we introduce a spin-density interaction that is experimentally accessible with ultracold molecules. We report a bound spinon-holon ground state and clear signatures of a spinon-holon molecule state and polarons in the ARPES spectrum at different magnetizations. We also apply a Chevy ansatz to gain analytical insights into the molecule spectrum. Our results provide new insights into the physics of dopants in frustrated t-J models.

A 40.3 Fri 15:00 HS 1010

In-Situ Observation of Antibunching at the Single-Atom Level in a Continuous Fermi Gas — •Tim de Jongh, Maxime Dixmerias, Joris Verstraten, Cyprien Daix, Bruno Peaudecerf, and Tarik Yefsah — Laboratoire Kastler Brossel, Paris, France

Fermionic systems adhere to Pauli Exclusion, one of the most fundamental principles of quantum mechanics that prevents identical fermions from occupying the same quantum state. This leads to an antibunching of particles which manifests itself in density-density correlations and sub-Poissonian number fluctuations. Here we present the direct, in situ observation of antibunching at the single-atom level. Using a newly developed Lithium 6 quantum gas microscope devoted to the study of continuous many-body systems, we probe both the density correlations and number fluctuations in an ultracold two-dimensional, non-interacting Fermi Gas in continuous space. For these highly degenerate gases, we observe distinct antibunching behavior in the density correlations as well as a clear suppression of the number fluctuations in the gas. The ability to distinguish the quantum fluctuation (zero temperature) contribution and the thermal contribution, allows us to use the fluctuation-dissipation theorem to extract the temperature of these samples from the number fluctuations, offering a direct thermometry method for single-atom imaging techniques. These results represent the first application of a quantum gas microscope to a many-body system in continuous space and offer the perspective to probe strongly interacting Fermi gases in free space at an unprecedented length scale.

A 40.4 Fri 15:15 HS 1010

Towards Probing Heat Transport in an Anharmonic Ion Chain — •Moritz Göb[1], Bo Deng[1], Lea Lautenbacher[2], Giovanni Spaventa[2], Daqing Wang[1,3], Martin B. Plenio[2], and Kilian Singer[1] — [1]Institut für Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Institut für Theoretische Physik und IQST, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany — [3]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany

Trapped ions are a versatile platform, which is well suited for probing thermodynamics down to a single atom [1]. We have indentified nonlinear dynamics that results in a Duffing-type resonance that can be used to improve sensing of very small forces [2]. Motivated by these results we present how the experimental setup has relevance in the context of resource theory and how the special features of the tapered ion trap can be exploited to implement a model system for heat transport [3].

[1] J. Roßnagel, S. T. Dawkins, K. N. Tolazzi, O. Abah, E. Lutz, F. Schmidt-Kaler, and K. Singer, A single-atom heat engine, Science 352, 325 (2016).

[2] B. Deng, M. Göb, B. A. Stickler, M. Masuhr, K. Singer, and D. Wang, Amplifying a zeptonewton force with a single-ion nonlinear oscillator, PRL 131, 153601 (2023).
[3] M. Lostaglio, An introductory review of the resource theory approach to thermodynamics, Rep. Prog. Phys. 82 114001 (2019).

A 40.5 Fri 15:30 HS 1010

Optimal time-dependent manipulation of Bose-Einstein condensates — •Timothé Estrampes[1,2], Alexander Herbst[1], Annie Pichery[1,2], Gabriel Müller[1], Dennis Schlippert[1], Ernst M. Rasel[1], Éric Charron[2], and Naceur Gaaloul[1] — [1]Leibniz University Hannover, Institut für Quantenoptik, Germany — [2]Université Paris-Saclay, CNRS, Institut des Sciences Moléculaires d'Orsay, France

Quantum sensing experiments benefit from fast Bose-Einstein Condensate (BEC) generation with small expansion energies. Here, we theoretically find the optimal BEC collimation parameters with painted optical potentials to experimentally achieve 2D expansion energies of 438(77) pK taking advantage of the tunable interactions by driving Feshbach resonances and engineering the collective oscillations. Based on these findings and corresponding simulations, we propose a scenario to realize 3D expansion energies on ground below 16 pK, going beyond the experimental state of the art in microgravity [A. Herbst et al., arXiv:2310.04383 (2023)].

Furthermore, we report on current theoretical studies of the dynamics of space single- and dual-BEC experiments including applications in NASA's Cold Atom Lab aboard the International Space Station or the sounding rocket mission MAIUS-2, paving the way for next-generation quantum sensing experiments, including tests of fundamental physics such as Einstein's equivalence principle.

This work is supported by the "ADI 2022" project funded by the IDEX Paris-Saclay, ANR-1-IDEX-0003-02 and the DLR with funds provided by the BMWi under Grant No. CAL-II 50WM2245A/B.

A 40.6 Fri 15:45 HS 1010

Magnetic polarons beyond linear spin-wave theory: Mesons dressed by magnons — •Pit Bermes and Fabian Grusdt — LMU Munich & MCQST, Munich, Germany

When a mobile impurity is doped into an antiferromagnet, its movement will distort the surrounding magnetic order and yield a magnetic polaron. The resulting complex interplay of spin and charge degrees of freedom gives rise to very rich physics and is widely believed to be at the heart of high-temperature superconductivity in cuprates. Recent experimental realizations of the doped Fermi-Hubbard model in ultra-cold quantum gases allowed to probe the local structure of the polarons. Drawing from experimental insights, we present a new quantitative theoretical formalism to describe these quasiparticles in the strong coupling regime. Based on the phenomenological parton description and geometric string picture, we construct an effective Hamiltonian with weak coupling to the spin-wave excitations in the background, making the use of standard polaronic methods possible.

We apply our formalism to calculate beyond linear spin-wave spectra, analyze the pseudogap expected at low doping and resolve the difference between hole an electron doping on local correlations.

A 40.7 Fri 16:00 HS 1010

A fluid of 10 ultracold fermions — •Lars Helge Heyen[1], Giuliano Giacalone[1], and Stefan Floerchinger[2] — [1]Universität Heidelberg, Deutschland — [2]Friedrich-Schiller-Universität Jena, Deutschland

Recent experiments in heavy-ion collisions have challenged our understanding of the applicability of fluid dynamics by showing typical signatures of collective flow with only a small number of final state particles. Motivated by this, we investigate fluidlike behavior in a system of few ultracold fermions. Our key observable is the inversion of the shape of the cloud after release from an anisotropic harmonic trap. This elliptic flow is shown to persist down to as low as 10 particles. I discuss ongoing efforts to understand these experimental observations.

A 40.8 Fri 16:15 HS 1010

Anisotropic and Non-Additive Interactions of Rydberg Impurities in Bose-Einstein Condensates — •Aileen A.T. Durst[1,2], Seth T. Rittenhouse[3,2], Hossein R. Sadeghpour[2], and Matthew T. Eiles[1] — [1]Max-Planck-Institute for the Physics of Complex Systems, Germany — [2]ITAMP, Harvard & Smithsonian, USA — [3]United States Naval Academy, USA

The interaction between a highly electronically excited atomic impurity and surrounding BEC atoms is typically characterised by a scattering length which can rival or even surpass the average interparticle spacing. The significance of this interaction depends on the density: when the average distance between Bosons is smaller than the scattering length, the system exhibits a rich absorption spectrum which extends typical polaron physics. However, within a dense bath, the absorption spectrum consists only of a single broad Gaussian, indicating an almost classical response. The scattering length and interaction strength of a Rydberg impurity can be altered by changing the principal quantum number. Additionally, the electronic angular momentum of the impurity can be changed in order to control the nature of the interaction potential, which becomes anisotropic when the spherical symmetry is broken. In free space, this manipulation leads to the emergence of (2l+1) degenerate electronic potential energy surfaces, introducing additionally non-additive interactions. Our investigation delves into the impact of these non-additive and anisotropic interactions on the absorption spectrum of a Rydberg impurity within an ideal BEC.

A 41: Precision Spectroscopy of Atoms and Ions V / Ultra-cold Plasmas and Rydberg Systems II (joint session A/Q)

Time: Friday 14:30–16:30 Location: HS 1098

A 41.1 Fri 14:30 HS 1098

Laser Spectroscopy of Californium-253,254 — •Sebastian Berndt for the Fermium-Collaboration — Johannes Gutenberg Universität Mainz, 55099 Mainz, Germany

Laser resonance ionization spectroscopy (RIS) is an efficient and element-sensitive technique to study the atomic and nuclear structure of transuranium elements. We present recent activities at the RISIKO mass separator at Johannes Gutenberg University Mainz (JGU) regarding laser spectroscopy of the exotic isotopes ^{253,254}Cf. Here, theoretical predictions point to a relevant role of ^{254}Cf in kilonova events associated with r-process nucleosynthesis in the cosmos. For this study, targets of $^{244-248}$Cm were neutron-irradiated at the High Flux Isotope Reactor, Oak Ridge National Laboratory (ORNL) to breed ^{253,254}Es, which was chemically separated at ORNL's Radiochemical Engineering Development Center. This sample was shipped to JGU via Florida State University and then sent to Institut Laue-Langevin for a second irradiation with thermal neutrons to produce ^{255}Es (39.8 d). As the sample also contained about 10^9 atoms of ^{252}Cf, this was in addition transmuted to ^{253,254}Cf. The hyperfine structure of the 420 nm ground state transition in ^{253}Cf as well as the isotope shift of ^{254}Cf in the 417 nm and 420 nm ground-state transitions were investigated with high resolution RIS, giving access to the nuclear ground-state properties.

A 41.2 Fri 14:45 HS 1098

Laser-induced population transfer in $^{25}Mg^+$ at the CRYRING@ESR storage ring — •Konstantin Mohr for the STOA-Collaboration — Institut für Kernphysik, TU Darmstadt, Germany

At the magnetic storage ring CRYRING@ESR located at the GSI facility for heavy ion research the laser spectroscopy experiment is performed on $^{25}Mg^+$ to investigate the interplay between internal and external degrees of freedom, i.e. quantum states and particle momenta.

Particular interest is devoted to the question whether it is possible to achieve and maintain a nuclear polarization of $^{25}Mg^+$ by optical pumping within the magnetic manifold of the hyperfine structure. This was studied with an electron-cooled coasting ion beam as well as in bunched beam operation at energies of about 155keV/u. In bunched-beam operation, it turned out that both the laser-induced spontaneous force and the varying velocity of the ions due to synchrotron oscillations need to be considered in order to explain the subtleties of the resonance shape.

We present our recent results and discuss the dynamic behavior of both modes of operation.

We acknowledge support from the BMBF under contract numbers 05P21RDFA1 and 05P19PMFA1, and from the DFG–Project-Id 279384907–SFB 1245.

A 41.3 Fri 15:00 HS 1098

Stopping mass-selected alkaline-earth metal monofluoride beams via formation of unusually stable anions — •Konstantin Gaul[1], Ronald F. Garcia Ruiz[2], and Robert Berger[1] — [1]Fachbereich Chemie, Philipps-Universität Marburg,Hans-Meerweinstraße 4, 35032 Marburg, Germany — [2]Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Direct laser-coolability and a comparatively simple electronic structure render alkaline-earth metal monofluoride molecules (MF), versatile laboratories for precision tests of fundamental physics. In this theoretical work, prospects for efficient stopping and cooling of hot beams of mass-selected MF molecules via their anions are explored. With sophisticated quantum chemical methods it is shown that these molecular anions posses an unusually strong chemical bond and have favourable photo-electron detachment energies. For RaF^- a vibronic structure with favorable properties for efficient pre-cooling is identified. This study indicates even chances for direct laser-cooling of the anion.

A 41.4 Fri 15:15 HS 1098

Precise Temperature Characterization of Project 8's Atomic Hydrogen Source — •Brunilda Muçogllava and Martin Fertl for the Project 8-Collaboration — Johannes Gutenberg Universität Mainz

In order to achieve a neutrino mass sensitivity of 40 meV, the Project 8 experiment aims to use the Cyclotron Radiation Emission Spectroscopy technique to analyze the atomic tritium beta decay spectrum. Due to the radioactive nature of tritium, initial measurements have been carried out using a Hydrogen Atom Beam Source (HABS) at the Mainz atomic test stand. Molecular hydrogen is introduced into the HABS setup, flowing through a 1 mm diameter tungsten capillary which is radiatively heated to ~2300 K by a tungsten filament. This causes the molecules to thermally dissociate in a temperature-dependent way. Accurate capillary temperature measurements with low uncertainty at these high temperatures are required to characterize the source accurately and understand the dissociation efficiency from molecular to atomic hydrogen. This talk will present infrared spectroscopy measurement results of the capillary, addressing challenges arising from uncertain emissivity values, ultra-high vacuum conditions, and device-dependent absolute calibration.

A 41.5 Fri 15:30 HS 1098

Quantum Gate Optimization for Rydberg Architectures in the Weak-Coupling Limit — •Nicolas Heimann[1,2,3], Lukas Broers[1,2], Nejira Pintul[1,2], Tobias Petersen[1,2], Koen Sponselee[1,2], Alexander Ilin[1,2,3], Christoph Becker[1,2], and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

We demonstrate machine learning assisted design of a two-qubit gate in a Rydberg tweezer system. Two low-energy hyperfine states in each of the atoms represent the logical qubit and a Rydberg state acts as an auxiliary state to induce qubit interaction. Utilizing a hybrid quantum-classical optimizer, we generate optimal pulse sequences that implement a CNOT gate with high fidelity, for experimentally realistic parameters and protocols, as well as realistic limitations. We show that local control of single qubit operations is sufficient for performing quantum computation on a large array of atoms. We generate optimized strategies that are robust for both the strong-coupling, blockade regime of the Rydberg states, but also for the weak-coupling limit. Thus, we show that Rydberg-based quantum information processing in the weak-coupling limit is a desirable approach, being robust and optimal, with current technology.

A 41.6 Fri 15:45 HS 1098

FRESNEL: Engineering a Neutral Atom Quantum Computer — •Guillaume Villaret for the FRESNEL-Collaboration — Pasqal SAS, 7 Rue Léonard de Vinci, 91300 Massy, France

Based on the work from the group of A. Browaeys and T. Lahaye at Institut d'Optique, quantum startup PASQAL developed and produced a first generation of commercial QPUs called FRESNEL. These devices allow analogical computations on arrays of up to 100 Rydberg atoms. Interfaced through a cloud access, these QPUs already proved their reliability. They allowed quantum software engineers to propose and demonstrate applications for solving hard combinatorial optimisation problems, non-linear differential equations and classifying sets of graphs using machine learning. Some of these QPUs are currently under construction in two HPC centers in Jülich, Germany and in Bruyères-le-Châtel, France. This represents a big step forward in term of reliability for neutral atoms QPUs, and more generally for cold atoms technologies which require a high level of engineering. We will give an overview of the technical building blocks of the FRESNEL products, discuss its capabilities for analog-based quantum computing in the NISQ era, and present the latest results.

A 41.7 Fri 16:00 HS 1098

NON-ADIABATIC COUPLINGS AS A STABILIZATION MECHANISM IN LONG-RANGE RYDBERG MOLECULES — AILEEN DURST, •MILENA SIMIĆ, NEETHU ABRAHAM, and MATTHEW EILES — Max-Planck-Institut for The Physics of Complex Systems, Dresden, Germany

The electronic potential curves of long-range Rydberg molecules composed of a Rydberg atom and a ground-state atom possess several distinctive features, including oscillations as a function of internuclear distance and, for an alkaline ground state atom, a steep drop when the electron-atom scattering interaction becomes resonant. This latter feature is accompanied by a narrow avoided crossing between potential energy curves, which implies that non-adiabatic couplings could become significant very close to the position of this rapid change in the potential curve. When these couplings are sufficiently strong, they can stabilize the molecule by shielding the vibrational states from the steep drop and possible decay. To demonstrate the importance of the non-adiabatic couplings in a rubidium Rydberg molecule, we compare the binding energies and lifetimes of the vibrational states obtained in the Born Oppenheimer approximation with those including beyond-Born Oppenheimer effects.

A 41.8 Fri 16:15 HS 1098

Quantum Optimization of Two-Qubit Gate of Neutral Rydberg Atoms — •Aslam Parvej[1,2], Nicolas Heimann[1,2], Lukas Broers[1,2], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg, Germany

The fundamental cause of error for the high-fidelity gates in the quantum computing architectures of neutral atoms in optical tweezer arrays is the unwanted entanglement of motional excitations in the tweezer traps. We study the machine learning aided neutral Rydberg atoms in the weakly-interacting regime of two Rydberg atoms, with van der Walls interaction to implement a high-fidelity two-qubit controlled-Z gate while returning to the system to its motional ground states and generates an optimized pulse using hybrid quantum-classical optimizer. In the set up, the Rydberg state is coupled with logical qubit via global Rabi pulse and the motional degrees of freedom inside optical tweezers is coupled with each Rydberg atom.

A 42: Precision Measurements III (joint session Q/A)

Time: Friday 14:30–16:30 Location: HS 1221

A 42.1 Fri 14:30 HS 1221

Coriolis bias estimation in the transportable Quantum Gravimeter QG-1 — •Pablo Nuñez von Voigt[1], Nina Heine[1], Najwa Al-Zaki[1], Waldemar Herr[2], Christian Schubert[2], Ludger Timmen[3], Jürgen Müller[3], and Ernst M. Rasel[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Hannover, Germany — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodäsie und Inertialsensorik, Hannover, Germany — [3]Leibniz Universität Hannover, Institut für Erdmessung, Hannover, Germany

The Quantum Gravimeter QG-1 relies on the interferometric interrogation of magnetically collimated Bose-Einstein condensates (BEC) in a transportable setup. The falling BEC is detected via absorption imaging, allowing a better characterization of uncertainties of the motional degrees of freedom than fluorescence detection. The horizontal velocity component is utilized to estimate the uncertainty in the bias acceleration due to the Coriolis effect. Estimations from a gradiometer measurement are presented together with proposed measures to compensate for the Coriolis effect.

We acknowledge financial funding by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 434617780 - SFB 1464 and under Germany's Excellence Strategy - EXC 2123 QuantumFrontiers, Project-ID 390837967.

A 42.2 Fri 14:45 HS 1221

Inertial sensing deploying painted optical potentials — •Knut Stolzenberg, Sebastian Bode, Christian Struckmann, Alexander Herbst, Daida Thomas, Naceur Gaaloul, Ernst Rasel, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

Inertial sensors based on atom interferometers can become a viable addition to classical IMUs, e.g., for autonomous driving or aviation in GNSS-denied environments. While they are superior with respect to their accuracy and long-term stability, it remains challenging to simultaneously measure accelerations and rotations in one or more axes in present experiments. In our experiment a 1064 nm crossed optical dipole trap (ODT) is used for creation of quantum-degenerate ensembles. By using acousto-optical deflectors in both ODT beam paths, we add versatile control over the trapping potentials with respect to position and trap depth. This allows for the creation of BECs amounting to a total number of up to 300×10^3 ultracold ^{87}Rb atoms prepared in the magnetically insensitive state $F = 1, m_F = 0$. We report on prospects of implementing guided quantum inertial sensors by light-pulsed atom interferometry in waveguides and by atomtronics in painted potentials.

A 42.3 Fri 15:00 HS 1221

Enhancing the sensitivity and dynamic range of atom interferometer measurements using an integrated opto-mechanical vibration sensor — •Ashwin Rajagopalan, Ernst M. Rasel, Sven Abend, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik,
Welfengarten 1, 30167 Hannover, Germany

The measurement sensitivity of an atom interferometer (AI) is predominantly impaired by vibrational noise, this is due to its slow measurement rate and relatively small dynamic range. As a first proof of principle, we demonstrated implementing a miniaturized AI compatible opto-mechanical accelerometer to a T = 10 ms AI which resolves measurement ambiguity and measures the local gravitational acceleration with an uncertainty of 4×10^{-6} ms^{-2} after an integration time of 18000 seconds without any vibration isolation. We are now in preparation to implement the next enhanced version of the opto-mechanical accelerometer which is fully integrated with the retro-reflection mirror of the AI, such that the AI and accelerometer share a common inertial reference. This new accelerometer incorporates a Fabry Pérot interferometer with a mirror reflectivity of 99.9 percent for highly sensitive read-out. An efficient vibrational signal read-out scheme has been implemented and first correlation with a state of the art commercial accelerometer has been observed even at sub-Hertz frequencies.

Funded by the DFG EXC2123 QuantumFrontiers - 390837967 supported by the DLR with funds provided by BMWK under Grant No. DLR 50NA2106 (QGyro+) and DFG SFB 1464 TerraQ.

A 42.4 Fri 15:15 HS 1221

Towards compact and field deployable quantum sensors for inertial navigation — •Ann Sabu[1], Polina Shelingovskaia[1], Yueyang Zou[1], Mouine Abidi[1], Philipp Barbey[1], Ashwin Rajagopalan[1], Christian Schubert[2], Matthias Gersemann[1], Dennis Schlippert[1], Ernst M. Rasel[1], and Sven Abend[1] — [1]Institut für Quantenoptik - Leibniz Universität, Welfgarten 1, 30167 Hannover — [2]Deutsches Zentrum für Luft- und Raumfahrt

Quantum sensors using atom interferometry enable precise measurements of inertial forces with long-term stability. Highly sensitive and compact quantum sensors for field applications still pose a challenge.

In this talk, the progess of three experimental devices will be presented: a robust single-axis accelerometer for dynamic applications; a transportable multi-axis gyroscope; and a six-axis quantum sensor capable of measuring accelerations and rotations compatible for quantum navigation.

Telecom fiber laser systems are used for all the three devices. For the multi-axis gyroscope and the six-axis sensor, we exploit atom chip technology to create Bose-Einstein condensates for its low expansion rates. We also use a combination of twin-lattice and relaunch mechanisms to form multiple loops, providing a framework for both compact and large-area sensors along with large momentum transfer.

We acknowledge financial support by the DFG EXC2123 QuantumFrontiers - 390837967 and by the DLR with funds provided by BMWK under Grant No. DLR 50NA2106 (QGyro+).

A 42.5 Fri 15:30 HS 1221

Optically guided BEC interferometry with a single wavelength — •Simon Kanthak[1], Rui Li[2], Ekim Hanimeli[3], Mikhail Cheredinov[2], Matthias Gersemann[2], Sven Herrmann[3], Naceur Gaaloul[2], Sven Abend[2], Ernst M. Rasel[2], Markus Krutzik[1], and the QUANTUS team[1,2,3,4,5] — [1]Institut für Physik, HU Berlin — [2]Institut für Quantenoptik, LU Hannover — [3]ZARM, Universität Bremen — [4]Institut für Quantenphysik, Uni Ulm — [5]Institut für Angewandte Physik, TU Darmstadt

Precision sensing with Bose-Einstein condensates (BECs) has been achieved in macroscopic interferometers with underlying large scale enclosed space-time areas. As an alternative approach, trapped atom systems offer the opportunity for BEC sensors in more compact packages. This requires an optical guide, crossed beams and beam splitters usually operated at different wavelengths.

We report on an optically guided BEC interferometer operated with a single wavelength. To this end, atoms are first Bose condensed and delta-kick collimated using the magnetic potentials supplied by an atom chip. A single far-detuned focused beam in a linear retroreflector configuration then provides both the tools to levitate as well as symmetrically split and recombine the matter-wave packets to form a guided Mach-Zehnder type atom interferometer.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) under grant number DLR 50WM2250B (QUANTUS+).

A 42.6 Fri 15:45 HS 1221

First experiments in the Hannover Very Long Baseline Atom Interferometer facility — •Vishu Gupta[1], Kai Grensemann[1], Dorothee Tell[1], Ali Lezeik[1], Mario Montero[1], Jonas Klussmeyer[1], Klaus Zipfel[1], Christian Schubert[1,2], Ernst Rasel[1], and Dennis Schlippert[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodasie und Inertialsensorik

The gravitational acceleration of freely falling atoms can be measured accurately by tracking their movement with vertical lattices of light in a matter-wave interferometer scheme. The Very Long Baseline Atom Interferometry (VLBAI) facility at the Hannover institute of technology allows for highly accurate inertial measurements with applications ranging from fundamental physics to geodesy. The 10 m baseline facility with Bose-Einstein Condensates (BECs) and high performance seismic attenuation system (SAS) raises great potential for absolute gravimeter. In the Hannover VLBAI facility, rubidium BECs will be launched into the 10 m baseline to perform interferometery based on Bragg momentum transfer. Here we present the recent development of

the VLBAI facility. To this point the installation of the Hannover VLBAI facility is complete with the Bragg interferomtery laser system, an all-optical source of rubidium BEC and high-performance in-vacuum SAS. We demonstrate the current status of the all optical Rb-BEC source, first steps for passive vibration isolation using an SAS and the necessary methods such as matter-wave lenses and Bragg beam splitters for first inertial measurements.

A 42.7 Fri 16:00 HS 1221

Probe thermometry with continuous measurements — •Julia Boeyens[1], Björn Annby-Andersson[2], Pharnam Bakhshinezhad[2,3], Géraldine Haack[4], Martí Perarnau-Llobet[4], Stefan Nimmrichter[1], Patrick P. Potts[5], and Mohammad Mehboudi[3,4] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Siegen 57068, Germany — [2]Physics Department and NanoLund, Lund University, Box 118, 22100 Lund, Sweden — [3]Technische Universität Wien, Stadionallee 2, 1020 Vienna, Austria — [4]Département de Physique Appliquée, Université de Genève, 1211 Genève, Switzerland — [5]Department of Physics, University of Basel and Swiss Nanoscience Institute, Klingelbergstrasse 82, 4056 Basel, Switzerland

Accurate thermometry plays a vital role in natural sciences. A well studied approach is to prepare a probe and allow it to interact with a thermal environment of unknown temperature for a fixed time before being measured. However, in some experimentally relevant settings, it is more practical to allow the probe to interact continuously with the environment. We consider a minimal model consisting of a two-level probe coupled to the thermal environment. Monitoring thermal transitions enables real-time estimation of temperature. We discuss adaptive and non-adaptive strategies. In particular, we evaluate the Fisher information for the trajectories of the probe and optimise according to this. Finally, we investigate the performance of the thermometer when the measurements made are subject to noise. This lays the foundation for experimentally realised real-time adaptive thermometry.

A 42.8 Fri 16:15 HS 1221

Sideband Thermometry on Ion Crystals — •Ivan Vybornyi[1], Laura Dreissen[2,3], Dominik Kiesenhofer[4,5], Helene Hainzer[4,5], Matthias Bock[4,5], Tuomas Ollikainen[4,5], Daniel Vadlejch[2], Christian Roos[4,5], Tanja Mehlstäubler[2,6], and Klemens Hammerer[1] — [1]Institut für theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany — [3]Department of Physics and Astronomy, LaserLab, Vrije Universiteit, De Boeleaan, 1081 HV Amsterdam, The Netherlands — [4]Universität Innsbruck, Institut für Experimentalphysik, Technikerstraße 25, 6020 Innsbruck, Austria — [5]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstraße 21a, 6020 Innsbruck, Austria — [6]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Coulomb crystals of cold trapped ions are a leading platform for quantum computing, simulations and metrology. For these applications, it is essential to be able to determine the crystal's temperature with high accuracy, which is a challenging task for large crystals due to complex many-body correlations. Recently [arXiv:2306.07880v3] we presented an ion crystal thermometry method that deals with this problem. With two experiments (4 ions 1D linear chain and 19 ions 2D crystal) we test the new method and cross-check it via other techniques. The results confirm the new method being accurate and efficient. Current work aims to generalize ion thermometry for non-thermal states of motion.

A 43: Ultrafast Dynamics III and High-harmonic Generation (joint session MO/A)

Time: Friday 14:30–16:30 Location: HS 3044

A 43.1 Fri 14:30 HS 3044

Absolute photoemission timing in neon — •Maximilian Forster, Maximilian Pollanka, Christian Schröder, and Reinhard Kienberger — Chair for laser and x-ray physics, E11, Technische Universität München, Germany

We measure the relative photoemission time delay between the Ne2p, Ne2s and the Iodine 4d states in iodomethane utilizing attosecond streaking. This allows us to experimentally determine the absolute time delay of neon 2s and 2p photoelectrons for the first time. The delay of neon, being the first ever evidence of atomic delay, has received repeated attention by both experimental and theoretical investigations due to the large cross section and convenient properties of neon. While helium has been the gold standard for absolute time delay measurements, enabled by remarkable theoretical agreement, due to spectral overlap helium cannot be used to reference neon. Recent developments, namely the availability of different chronoscopes, enable measuring the absolute time delay of neon. We take the path via iodomethane and the I4d core state, which has been timed on an absolute scale, and use it to reference neon. The delay between Ne2s and Ne2p can be extracted simultaneously, allowing for a positive consistency check with previous experiments conducted only with neon. Timing neon on an absolute scale allows an assignment of absolute values to these experiments in retrospect and establishes neon as a chronoscope species.

A 43.2 Fri 14:45 HS 3044

Isosteric molecules in the time-domain — •Maximilian Pollanka, Christian Schröder, Maximilian Forster, and Reinhard Kienberger — Physik Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany

We report on absolute photoemission timing measurements on isosteric molecules in the gas phase. Photoemission time delays are accessed via streaking spectroscopy on attosecond timescales. To be able to (directly) access absolute photoemission times of the respective outer and inner valence states of N2O and CO2 we are using iodomethane (I4d) as a timing reference. In a complementary study He was used as reference to cross-check the results as well as to verify the usability of the respective chronoscope species. Due to the similarities in molecular structure (isostericity) and electronic configurations (isoelectronicity) between these investigated molecules, the pure effect of the specific molecular/orbital characteristics is expected to be probed. Additionally, N2 and CO is studied in the same way on the basis of their isosteric behavior. The experimental data show great similar tendencies but also differences between the compared molecular orbitals, which are determined but not completely understood up to now. Nonetheless, recent theoretical calculations hint towards an additional channel coupling photoemission time delay contribution that can be assigned to electron correlations responsible for re-disturbing the excitation among different final photoionization channels.

A 43.3 Fri 15:00 HS 3044

Attosecond time-resolved coincidence spectroscopy of ethylene — •Barbara Merzuk[1], David Busto[1,2], Ioannis Makos[1], Dominik Ertel[1], Marvin Schmoll[1], Benjamin Steiner[1], Fabio Frassetto[3], Luca Poletto[3], Robert Moshammer[4], Claus Dieter Schröter[4], Thomas Pfeifer[4], Serguei Patchkovskii[5], Jakub Benda[6], Zdeněk Mašín[6], and Giuseppe Sansone[1] — [1]Albert-Ludwigs-Universität Freiburg,Germany — [2]Lund University,Sweden — [3]CNR,Padova,Italy — [4]MPIK,Heidelberg,Germany — [5]MBI Berlin,Germany — [6]Charles University,Prague,Czech Republic

Studying photoionization dynamics and characterising the time delays associated with the photoemission of an electron wave packet can unveil important characteristics of coupled electronic-nuclear dynamics in molecular systems. Attosecond photoelectron spectroscopy in combination with electron-ion coincidence detection is beneficial since this allows disentangling the different photoionization and dissociation channels. Additionally, it may give access to the orientation of the molecule at the instant of photoionization. Using our experimental setup that consists of an attosecond beamline, based on high-order harmonic generation operating at 50 kHz repetition rate, we investigate the photoionization dynamics in ethylene molecules by performing RABBIT (Reconstruction of Attosecond Beating By Interference of Two-photon transitions) measurements while detecting photoelectrons and photoions in coincidence. The experimental results are interpreted with the help of multi-electron R-matrix calculations of two-photon ionization.

A 43.4 Fri 15:15 HS 3044

Probing well aligned molecular environments on surfaces via attosecond streaking — •Pascal Scigalla[1], Sven Paul[1], Christian Schröder[1], Peter Feulner[2], and Reinhard Kienberger[1] — [1]Chair for laser and x-ray physics, E11, Technische Universität München, Germany — [2]Surface and Interface Physics, E20, Technische Universität München, Germany

We report on the photoemission timing measurements of well-aligned iodomethane and -ethane molecules on a Pt111 surface. In this set of experiments, we clock the I4d photoemission of iodine against the Platinum valence photoemission using the attosecond streak camera technique, allowing the extraction of a relative photemission delay. As the $I4d$ photoemission in the selected energy range is dominated by a giant resonance in the $I4d \rightarrow ef$ channel, its photoemission time is mostly unaffected by its chemical environment; thus, any observed change in the photoemission delay can be attributed to the traversed potential landscape of the molecule. By carefully selecting the detection angle and crystal surface coverage we can reliably choose whether only parts of the molecule or its entirety was traversed by the detected photoelectron wavepackets. It is furthermore possible to investigate the influence of slight coverage variations onto the observed photoemission delay. Planned, complementary scattering simulations will be used to gain deeper insight into the observations with the goal to establish photoemission timing experiments as an efficient and accurate means to study molecular environments on surfaces.

A 43.5 Fri 15:30 HS 3044

Automatic optimization of intense high-harmonic pulses — •José Gómez Torres, Frederic Ussling, Simon Wächter, Alessandro Colombo, Linos Hecht, Katharina Kolatzki, Alexandre Rosillo Vorsin, Mario Sauppe, and Daniela Rupp — ETH Zurich, Laboratory for Solid State Physics, John-von-Neumann-Weg 9, 8093 Zurich, Switzerland

High harmonic generation (HHG) allows the production of extreme ultraviolet pulses ranging from picosecond up to attosecond timescales from intense infrared (IR) pulses, making it an invaluable tool for the study of ultrafast phenomena. It has been recently demonstrated that HHG is capable of producing pulses intense enough for diffraction experiments like coherent diffraction imaging of isolated nanoparticles [1]. Very intense pulses of short time duration in a stable delivery over hours are necessary for this, requiring a time-consuming optimization of the experimental parameters. We developed a tool for the automatic optimization of HHG parameters, sweeping different geometric parameters of the setup and measuring for each step the pulse energy achieved. Due to the complexity of simulating the specific conditions of the experiment, this trial and error approach is a necessary final step to achieve the highest pulse energy. In order to optimize the XUV peak focal intensity, we perform electron spectroscopy on a diffuse gas in the focus region. Via IR-XUV pump probe, RABBITT measurements can be carried out for the temporal characterization of pulses.

[1] D. Rupp et al., Nature Communication 8, 493 (2017)

A 43.6 Fri 15:45 HS 3044

Orbital interference effects in low-order harmonic generation in benzene — •Samuel Schöpa, Falk-Erik Wiechmann, Franziska Fennel, and Dieter Bauer — Universität Rostock, Rostock, Germany

We explore the impact of the driving laser's ellipticity and polarization on the low-order harmonic spectrum of benzene and find a strong interference in the 5th harmonic between emission originating from transitions between π orbitals and emission from σ orbitals. The contribution of the π orbitals entirely vanishes due to interference for driving with a laser polarized along a σ_v mirror axis. However, the π orbital's contribution takes over for elliptic polarization while being fundamentally different from the σ orbital emission, i.e., having the opposite helicity and a perpendicular major polarization axis. The resulting interference yields a complex dependence of the low-order harmonic spectrum of benzene on the ellipticity and the polarization of the driving field.

A 43.7 Fri 16:00 HS 3044

Observation of HHG from organic molecular crystals — •Falk-Erik Wiechmann[1], Samuel Schöpa[1], Alexander Villinger[2], Dieter Bauer[1], and Franziska Fennel[1] — [1]Institute of Physics, Rostock, Germany — [2]Institute of Chemistry, Rostock, Germany

This project aims at a detailed understanding of the harmonic generation process in large organic molecules in the crystalline phase. Unlike previous studies, which were limited to small molecules in the gas phase, we introduce organic molecular crystals as a novel target for HH spectroscopy, taking advantage of the inherent molecular alignment. Unlike in gas phase experiments, neighboring molecules in organic crystals experience a weak but finite coupling, leading to 'solid like' features, e.g. a delocalization of the electronic states over several unit cells. With a fundamental 4000 nm mid-IR beam reaching 6 TW/cm2 we demonstrate that HHG up to the order of 17 is possible without imposing physical damage. When the fundamental driving polarization is rotated, maxima of harmonic emission occur at polarization directions parallel to connecting axes between neighboring molecules, reflecting the crystal structure. Despite the linearly polarized driving field, the emitted harmonics exhibit elliptical polarization with a main axis different from the fundamental polarization direction.

A 43.8 Fri 16:15 HS 3044

High-order Harmonic Generation (HHG) in the nonadiabatic regime over a sub-mm glass chip — •Sabine Rockenstein[1,2], Agata Azzolin[1,2], Gaia Giovanetti[2], Guangyu Fan[2,3], Md Sabbir Ahsan[2,4], Oliviero Cannelli[2], Lorenzo Colaizzi[1,2,5], Erik P Månsson[2], Davide Faccialà[4], Fabio Frassetto[4], Dario W Lodi[5], Cristian Manzoni[4], Rebeca M Vàzquez[4], Michele Devatta[4], Roberto Osellame[4], Luca Poletto[4], Salvatore Stagira[4,5], Caterina Vozzi[4], Vincent Wanie[2], Andrea Trabattoni[2,6], and Francesca Calegari[1] — [1]UHH (DE) — [2]DESY (DE) — [3]CUI (DE) — [4]CNR (IT) — [5]Politecnico di Milano (IT) — [6]Uni. Hannover (DE)

HHG-based sources are nowadays operating up to the soft-x spectral region. One of the main challenges remains to extend the cut-off frequency while retaining high-photon flux. Approaches based on the so-called nonadiabatic regime have allowed to overcome phase matching limitations and achieve substantial cut-off extension [1]. We present a new HHG source, operating with high driver laser intensities (up to 1E16 W/cm^2) and a laser-micromachined glass cell allowing for highly efficient gas confinement over 900 μm, to achieve nonadiabatic phase matching. The setup was operated with both 800-nm and 1500-nm sub-35-fs driving pulses. With the 800-nm driver, the HHG energy cutoff was extended to 100 eV in Argon and 180 eV in Neon, 160 eV were reached using the 1500-nm driver in Argon. Our results highlight the potential of optimizing the nonadiabatic regime for covering the water-window spectral region. [1] Johnson et al., Sci. Adv. 4(5), 2018