# Q 25: Poster – Cold Atoms and Molecules, Matter Waves (joint session Q/A/MO)

Time: Tuesday 14:00–16:00 Location: Tent

Q 25.1 Tue 14:00 Tent

**Dephasing of Rydberg excitations in optical traps** — •Simon Schroers[1], Lukas Ahhlheit[1], Daniil Svirskiy[1], Nina Stiesdal[1], Jan de Haan[1], Chris Nill[2], Igor Lesanovsky[2], Wolfgang Alt[1], and Sebastian Hofferberth[1] — [1]Institut für Angewandte Physik, Universität Bonn — [2]Institut für Theoretische Physik, Universität Tübingen

Collective Rydberg-excitations of $N$ atoms by a single photon offer a distinct platform for strong light-matter interaction, due to the enhanced coupling by $\sqrt{N}$. This allows for instance the creation of Rydberg superatoms, namely an atom cloud smaller than the Rydberg-blockade-volume acting as an effective two level-system strongly coupled to a few-photon driving field.

On this poster we show recent experimental results of how we implement a so-called magic wavelength trap for ground state and Rydberg atoms. The magic trap equalizes the AC Stark shifts for both states, thereby enhancing the ground-to-Rydberg state coherence time. Using photon-storage measurements we demonstrate that the optimal wavelength for such a trap depends on the trap's geometry, as the almost-free Rydberg electron samples different regions of the trap.

We also show an investigation of Rabi oscillation dephasing between the ground and a collectively excited state of a superatom. Comparing simulations and experimental data we demonstrate that the frequency noise of the excitation lasers plays a significant role in the dephasing and identify the noise regimes that are most crucial for such dephasing.

Q 25.2 Tue 14:00 Tent

**Chiral Van der Waals interactions between Rydberg atoms** — •Fabian Spallek[1], Stefan Aull[1], Steffen M. Giessen[2], Kilian Singer[1], Robert Berger[2], Akbar Salam[3], and Stefan Yoshi Buhmann[1] — [1]University Kassel, Germany — [2]Phillips-University Marburg, Germany — [3]Wake Forest University, USA

We study the Van der Waals potential between two atoms prepared in chiral superpositions of electronic Rydberg states. By harnessing external electric and magnetic fields, one can induce chiral asymmetry in the Rydberg states, which in turn gives rise to a chiral component in the near-field Van der Waals potential. This chiral component emerges from the interplay of electric and magnetic dipole-dipole interactions and contributes to the overall Van der Waals potential in addition to the conventional electric dispersion interaction. We derive effective potentials by performing various orientational averages and identify specific chiral Rydberg states that significantly enhance chiral the discriminatory component. These states offer a promising platform for realizing strong chiral interactions between Rydberg atoms, potentially enabling novel applications in quantum control and sensing.

Q 25.3 Tue 14:00 Tent

**Machine learning optimized time-averaged potentials** — •Max Schlösinger[1], Oliver Anton[1], Victoria Henderson[1,3], Elisa Da Ros[1], Mustafa Gündoğan[1], Simon Kanthak[1], and Markus Krutzik[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489 Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Straße 4, 12489 Berlin — [3]now: RAL Space, Fermi Ave, Harwell, Didcot OX11 0QX, United Kingdom

Time-averaged potentials (TAPs) are a versatile tool for the generation and manipulation of ultracold atom clouds. Using a CCD-based setup to characterize a 2D acousto-optic deflector (2D-AOD) system, we implement and test machine learning routines to optimize 2D geometries, such as harmonic potentials. This approach allows us to compare different methods, evaluate metrics like homogeneity, and improve the predictability of the resulting potentials.

By employing optimization algorithms such as CMA-ES and various Bayesian optimizers, we compare their performance in terms of speed and efficiency. Additionally, we plan to implement an active learning optimizer to minimize the number of required iterations, which is crucial for future integration into a $^{87}$Rb Bose-Einstein condensate (BEC) experiment. Ultimately, these advancements will enhance the evaporative cooling routine and improve the performance of a $^{87}$Rb BEC-based quantum memory [1].

[1] Phys. Rev. Research **5**, 033003 (2023)

Q 25.4 Tue 14:00 Tent

**Rydberg superatoms coupled with super-extended evanescent field nanofiber at the single-photon level** — •Ludwig Müller[1], Knut Domke[1], Tangi Legrand[1], Thomas Hoinkes[2], Xin Wang[1], Eduardo Uruñuela[1], Wolfgang Alt[1], and Sebastian Hofferberth[1] — [1]Institute of Applied Physics, University of Bonn, Germany — [2]Department of Physics, Humboldt University of Berlin, Germany

Both Rydberg superatoms driven by free-space photonic modes and single emitters coupled to photonic waveguides have paved the way for strong coherent light-matter coupling at the few-photon level. By combining advantages of both ideas, we aim to achieve homogeneous coupling of multiple Rydberg superatoms coupled to a field confined by a nanofiber. Fibers with diameters of a few hundred nanometers are successfully used to trap and couple arrays of single atoms by their evanescent field. Recent advances allow the fibers to be tapered to even smaller diameters, allowing more than 99 % of the energy to be guided outside the fiber with effective field diameters of $\gtrsim 13\,\lambda$ [1], bringing them up to typical Rydberg blockade radius sizes.

On this poster, we will we will present the current status of planning and building our new Nanofiber experiment such as the vacuum chamber and first tests of the nanofibers. We select Ytterbium due to its advantage of having the two-photon Rydberg excitation transitions close together with 399 nm and 395 nm, which simplifies the fiber design and is expected to have low thermal dephasing effects.

[1] R. Finkelstein *et. al.* Optica **8**, 208-215 (2021)

Q 25.5 Tue 14:00 Tent

**Interfacing high overtone bulk acoustic wave resonators and Rydberg atoms in a 4K environment** — •Samuel Germer, Valerie Mauth, Cedric Wind, Julia Gamper, Wolfgang Alt, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Rydberg atoms possess electric dipole transitions over a large range of the electromagnetic spectrum and are therefore promising candidates for realizing hybrid quantum systems that bridge the microwave and optical regimes. We aim to realize such a hybrid system in which an electromechanical resonator mode can be cooled down to its quantum mechanical ground state via interactions with Rydberg atoms.

On this poster, we discuss the setup build of three parts, the magneto optical trap for Rubidium atoms, an ultra high vacuum chamber hosting the atom chip in a closed-cycle cryostat and a magnetic transport connecting both. The cryostat provides a 4K environment which is a prerequisite for cooling the high overtone bulk acoustic wave resonator (HBAR) close to its ground state and allows the use of superconducting components.

We present machine learning based optimization of the magneto optical trap and magnetic transport. Moreover, a first generation chip, consisting of a superconducting Z-wire trap and a microwave resonator, has been fabricated and characterization measurements are shown. For a second generation atom chip, featuring the HBAR, first simulations are presented which allow, among other things, to estimate the coupling strength between Rydberg atoms and the resonator.

Q 25.6 Tue 14:00 Tent

**Cascaded Nonlinearities for Effectively Interacting Bose-Einstein Condensates of Photons** — •Niels Wolf, Andreas Redmann, Christian Kurtscheid, Frank Vewinger, Julian Schmitt, and Martin Weitz — Institut für Angewandte Physik, Bonn, Deutschland

Bose-Einstein condensation has been observed in ultracold atomic gases, polaritons, and, more recently, in low-dimensional photon gases. Since the photon-photon interaction is vanishingly small, thermalization of photons, e.g. as dye microcavity photon condensates in the latter systems, is achieved not through particle-particle collisions, but rather via contact with a reservoir, here the dye molecules [1]. Nevertheless, strong photon-photon interactions, such as effective Kerr interactions induced by cascaded second-order nonlinearities, could enable the realization of an interacting photon Bose-Einstein condensate. This could, e.g. open pathways to generating highly entangled photon states by purely thermodynamical methods [2]. We employ a triply resonant optical parametric oscillator setup with independent control over pump and subharmonic wavelength cavities. This configuration enables the generation of cascaded second-order nonlinearities, producing a phase shift potentially stronger than that of direct Kerr interaction. Suitable frequency filtering is crucial to tune the optical parametric oscillator to degeneracy, which is essential for fully characterizing the phase shift and determining the effective Kerr coefficient.

[1] J. Klaers et al., Nature 468, 545 (2010) [2] C. Kurtscheid et al., Science 366, 894 (2019)

Q 25.7 Tue 14:00 Tent

**Evalutation of machine learning algorithms for applications in quantum gas experiments** — •Oliver Anton[1], Elisa Da Ros[1], Philipp-Immanuel Schneider[3,4], Ivan Sekulic[3,4], Sven Burger[3,4], and Markus Krutzik[1,2] — [1]Institut für Physik and IRIS, Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut, Berlin — [3]JCMwave GmbH, Berlin — [4]Zuse Institute Berlin (ZIB), Berlin

The generation of clouds containing cold and ultra-cold atoms is a complex process that requires the optimization of noisy data in multi dimensional parameter spaces. Optimization of such problems can present challenges both in and outside of the lab due to constrains in time, expertise, or access for lengthy manual optimization.
Machine learning offers a solution thanks to its ability to efficiently optimize high dimensional problems without the need for knowledge of the experiment itself. In this poster, we present the results of benchmarking various optimization algorithms and implementations. Their performance is tested in a cold atom experiment, subjected to inherent noise [1]. Current research aims towards the preparation of the cloud for quantum memory applications [2], by engineering the optical density using the tested algorithms.

[1] O. Anton et al., Machine Learning: Science and Technology 5 025022, 2024
[2] E. Da Ros et al., Physical Review Research 5 033003, 2023

Q 25.8 Tue 14:00 Tent

**A Dipolar Quantum Gas Microscope in UV Optical Lattices** — •Fiona Hellstern, Kevin Ng, Paul Uerlings, Michael Wischert, Alexandra Köpf, Tanishi Verma, Stephan Welte, Ralf Klemt, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We present progress on our dipolar quantum gas microscope, enabling in situ, single-atom, and single-site resolved detection of Dysprosium atoms in 180 nm spaced UV optical lattices. Using 360 nm light, we can create various lattice geometries to explore strongly correlated quantum phases. Due to the small lattice spacing, nearest-neighbor dipolar interactions can reach 200 Hz at 10 nK, granting us access to phases where long-range dipolar interactions play a dominant role.

UV spectroscopy has been performed to characterize key transitions, including isotope-specific features and a King plot analysis, essential for precise lattice control and future measurements. We present our results on the characterization of our high-NA (0.9) in-vacuum objective, highlighting its ability to achieve 180 nm spatial super-resolution through the implementation of shelving techniques. Finally, we outline our plans to leverage these tools for exploring novel quantum phases, dipolar many-body physics, and emergent phenomena in strongly interacting systems.

Q 25.9 Tue 14:00 Tent

**Developing a quantum gas microscope with programmable lattices** — Sarah Waddington[1], Isabelle Safa[1], Tom Schubert[1], •Rodrigo Rosa-Medina[1], and Julian Léonard[1,2] — [1]Atominstitut, TU Wien, Vienna, Austria — [2]Institute of Science and Technology Austria (ISTA), Klosterneuburg, Austria

Experiments with ultracold atoms in optical lattices offer a versatile platform for engineering and probing strongly correlated quantum matter. While quantum gas microscopy has significantly advanced the field, enabling unprecedented single-site resolution, current experimental setups are often constrained by rigid lattice configurations and slow cycle times.

Here, we present our ongoing efforts to design and build a next-generation quantum gas microscope for fermionic and bosonic lithium atoms. Our approach relies on atom-by-atom assembly of small lattice systems employing auxiliary optical tweezers combined with all-optical cooling techniques to facilitate sub-second experimental cycles. By leveraging holographic projection techniques, we create tailored optical lattices with dynamically reconfigurable geometries. Our approach opens diverse research avenues, ranging from quantum simulation of fractional quantum Hall states to frustrated phases with unconventional geometries.

Q 25.10 Tue 14:00 Tent

**Cooling and trapping of Hg atoms with enhanced UV laser systems** — •Rudolf Homm and Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schlossgartenstraße 7, 64289 Darmstadt

The use of cold Hg atoms in a MOT offers a variety of experimental opportunities. The two stable fermionic isotopes are promising for a new time standard based on an optical lattice clock, using the $^1S_0$ - $^3P_0$ transition at 265.6 nm. All stable isotopes can also form ultracold Hg dimers via photoassociation, combined with vibrational cooling.

Our setup includes two UV laser systems combined with a MOT for Hg atoms and a 2D-MOT for isotope preselection. Each laser system consists of a MOFA configuration, followed by two frequency-doubling stages.

The cooling laser provides a stable frequency and high power, generating over 1 W at 253.7 nm using Doppler-free saturation spectroscopy and an elliptical focus within the BBO crystal. The spectroscopy laser produces over 300 mW at 254.1 nm, mode hop free tunable over 16 GHz with a maximum scan rate of 3 Hz, using a feed-forward setup to stabilize the cavities.

We aim to achieve a high density of Hg atoms in the MOT to improve the signal for dimer spectroscopy. The latest results on trapping of Hg atoms with the improved UV laser systems will be presented.

Q 25.11 Tue 14:00 Tent

**Correlation Functions for Interacting Fermi Gases in the BCS Regime** — •Nikolai Kaschewski, Sejung Yong, and Axel Pelster — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany

Recent progress in developing quantum gas microscopes in the continuum [1-3] has opened new possibilities for detecting experimentally correlation functions in the realm of ultracold gases. Motivated by this, we present mean-field calculations of density-density correlation functions for interacting Fermi gases in the BCS regime.

Our results turn out to be strongly influenced not only by the temperature and the interaction strength for a harmonic confinenmnt [4], but also by the effective range of the interaction in the homogeneous case [5]. As the latter has so far remained to be an elusive scattering parameter, its experimental detection via correlation function measurements is promising. This can shed new light on the prediction of two different superfluid phases for interacting Fermi gas [5].

[1] T. Jongh et al., arXiv:2411.08776 (2024).
[2] J. Xiang et al., arXiv:2411.08779 (2024).
[3] R. Yao, et al., arXiv:2411.08780 (2024).
[4] S. Yong et al., arXiv:2311.08853 (2023).
[5] N. Kaschweski, C. A. R. Sá de Melo, and A. Pelster, submitted for publication.

Q 25.12 Tue 14:00 Tent

**Studying Dipolar Supersolids in Toroidal Geometries using DMDs** — •Tanishi Verma[1], Paul Uerlings[1], Fiona Hellstern[1], Kevin Ng[1], Alexandra Köpf[1], Michael Wischert[1], Stephan Welte[1,2], Ralf Klemt[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology and CZS Center QPhoton, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Supersolids are characterised by a combination of the crystal structure of solids and the frictionless flow of superfluids, and can be realised experimentally through the self-organisation of long-range interacting trapped BECs into states of matter that resemble crystal like structures. In a recent work, dipolar supersolids in toroidal traps have been studied theoretically. Toroidal traps provide continuous rotational symmetry and periodic boundary conditions, which can be used to study the different amplitude and sound modes which emerge during the superfluid to supersolid phase transition, especially the Higgs amplitude mode, which has yet to be experimentally observed.

We plan to load the BEC produced in our new-generation Dysprosium machine in a toroidal trap made with a Digital Micromirror Device (DMD), and also implement a lightsheet using a 532nm laser for z-direction confinement. This poster presents our progress on the optical setup in order to create toroidal traps to study toroidal dipolar supersolids and their excitation modes.

Q 25.13 Tue 14:00 Tent

**High-pressure xenon-noble gas mixtures as a thermalization mediator for VUV photons** — •Thilo Falk vom Hövel, Eric Boltersdorf, Frank Vewinger, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn

In recent years, microcavity-based Bose-Einstein condensates of photons have become an established experimental platform. In these experiments, photons in the green-to-orange spectral range are confined to high-finesse microcavities filled with a liquid dye solution. Via repeated absorption and emission cycles, the photons adopt a thermal energy distribution, mediated by the thermalization of the dye molecules' rovibronic levels. Conveying these principles into the VUV spectral regime (100 - 200 nm) would allow for the construction of a coherent light source in a regime where the realization of a laser is difficult. For this endeavor, we intend to replace the dye molecules by a dense xenon-noble gas mixture, with xenon as the optically active constituent. For thermalization, we aim to exploit the transitions around a wavelength of 147 nm between the quasimolecular states associated with the (atomic) $5p^6$ and $5p^5 6s$ levels. We report on recent results on the spectroscopic investigation of such mixtures, with sample pressures of up to 100 bar. Centerpiece is a detailed study of absorption and emission spectra, with particular emphasis on the influence of the constituent partial pressures. The fulfillment of the thermodynamic Kennard-Stepanov relation is investigated, which constitutes an essential prerequisite for the suitability of a medium as a thermalization mediator for photons.

Q 25.14 Tue 14:00 Tent

**Topological signatures in the dynamical response of periodically driven Su-Schrieffer-Heeger model** — Soumya Sasidharan[1], •Souradeep Roy Choudhury[2], Ahmet Levent Subaşı[3], and Naveen Surendran[1] — [1]Indian Institute of Space Science and Technology, Valiamala, Thiruvananthapuram-695547, India — [2]Goethe-Universität, Institut für Theoretische Physik, 60438 Frankfurt am Main, Germany — [3]Department of Physics, Faculty of Science and Letters, Istanbul Technical University, 34469 Maslak, Istanbul, Turkey

We study the dynamics of periodically driven Su-Schrieffer-Heeger model subjected to a range of driving conditions. In the large-amplitude, high-frequency regime, we establish a remarkable correspondence between the bulk dynamical response and the topology of the Floquet phase. At half-filling, we compute the dynamical order parameter Q, which is the time-averaged occupancy of an initially filled band. We show that Q is quantitatively related to a topological invariant. Furthermore, we obtain topologically protected edge states in the nontrivial phases.

Q 25.15 Tue 14:00 Tent

**STIRAP for High Fidelity Spin-Flip in Ultracold $^6Li$** — •Ellen Bräutigam, Carl Heintze, Sandra Brandstetter, Maciej Gałka, and Selim Jochim — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

We report on the implementation of Stimulated Raman Adiabatic Passage (STIRAP) in an ultra-cold few fermion $^6Li$ system.The atoms are transferred with high fidelity between the hyperfine states $|3\rangle$ and $|4\rangle$ in the ground state manifold. The transition is mediated via resonant coupling to an excited state in the D2 manifold while avoiding its population, ensuring negligible scattering and no atom loss. This method achieves robust and fast state transfer on the order of $1\mu$s, providing a reliable tool for precise quantum state control. Among other things, this allows us in combination with Feshbach resonance to perform a sudden interaction quench.

Q 25.16 Tue 14:00 Tent

**Effects of dipolar cutoff shapes on numerical calculation of properties of dipolar condensates** — •Denis Mujo[1] and Antun Balaž[1,2] — [1]Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Serbian Academy of Sciences and Arts

Here we study the impact of various shapes of dipolar cutoffs on the numerical calculation of ground state properties of dipolar Bose-Einstein condensates (BECs) and quantum droplets. In particular, we examine three distinct setups: the pure dipolar potential, where no cutoff is introduced; the analytically known spherical cutoff; and the cylindrical cutoff, that partially needs to be calculated numerically [1]. To understand how these different cutoff shapes affect the calculated values of physical properties of the ground state, we systematically vary key discretization parameters associated with each configuration. We demonstrate how the calculation precision of the cutoff translates into the precision of numerically obtained values of condensate and droplet properties.

[1] H.-Y. Lu et al., Phys. Rev. A **82**, 023622 (2010).

Q 25.17 Tue 14:00 Tent

**Auto-ponderomotive beam manipulation for interaction-free measurements with electrons** — •Franz Schmidt-Kaler[1], Nils Bode[1], Fabian Bammes[1], Michael Seidling[1], Robert Zimmermann[1], Justus Walther[1], Lars Radtke[1], and Peter Hommelhoff[1,2] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]Department Physik, Ludwig-Maximilians-Universität München (LMU), 80799 München

Cryo-electron microscopy achieves angstrom resolution for biological samples but requires reconstructing images from hundreds of thousands of identical molecules due to electron beam damage. *Interaction-free* measurements with electrons offer the potential for true single-particle analysis of radiation-sensitive samples. This method, already explored in the optical domain, requires developing electron-optical elements such as beam splitters, resonators, and guides. We present a resonator for 50 eV electrons, a guide for up to 9.5 keV electrons, and determine the first Matthieu stability regime for auto-ponderomotive devices. Our goal is to integrate these components into standard SEMs for broader applicability.

Q 25.18 Tue 14:00 Tent

**Quantum gas microscopy of triangular-lattice Mott insulators** — •Jan Deppe[2], Liyu Liu[1], Jirayu Mongkolkiattichai[1], Davis Garwood[1], Jin Yang[1], and Peter Schauss[2] — [1]University of Virgina — [2]Institute for Quantum Physics, University of Hamburg

This poster highlights our recent advances in the quantum simulation of electronic systems employing ultracold atoms in geometrically frustrated lattices. Frustrated quantum systems, known for hosting exotic phases like spin liquids, present a formidable challenge to condensed matter theory due to their extensive ground state degeneracy. Our focus centers on a triangular lattice, a paradigmatic example of geometric frustration where the degree of frustration is tunable. The triangular Hubbard model is a paradigm system for the study of kinetic frustration, which shows up in destructive interference between paths of holes, leading to antiferromagnetic polarons in hole-doped regime even at elevated high-temperatures. In our work, we showcase the realization of a Mott insulator of lithium-6 on a symmetric triangular lattice with a lattice spacing of 1003 nm. Spin removal techniques allow us to resolve individual spins and measure nearest neighbor spin-spin correlations across different interaction strengths. We find good agreement with numerical linked cluster expansion calculations and Quantum Monte Carlo simulations. Future endeavors involve the use of spin-resolved imaging through Stern-Gerlach splitting for full density and spin resolution. Additionally, exploration of bound states in strongly repulsive interacting systems is on the horizon.

Q 25.19 Tue 14:00 Tent

**Polarization properties of Photon Bose Einstein Condensates** — •Sven Enns[1], Julian Schulz[1], Kirankumar Karkihalli Umesh[2], Frank Vewinger[2], and Georg von Freymann[1,3] — [1]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern Landau, Germany — [2]Institut für Angewandte Physik, Universität Bonn, Germany — [3]Fraunhofer Institute for Industrial Mathematics ITWM, Kaiserslautern, Germany

We experimentally investigate properties of harmonically trapped photon gases in a dye-filled microcavity. Specifically, we analyze the polarization of thermal and condensed light and their dependence on the polarization of the pump beam. Our experimental setup enables the creation of arbitrary polarization states on the Poincaré sphere for the pump beam. Additionally, the measurement basis can be switched from linear to circular polarization allowing for a proper evaluation of the photon gas's polarization by measuring fractions of two orthogonal polarization states simultaneously. In contrast to previous setups, the dye solution is pumped through the cavity mirrors and the pump beam coincides with the optical axis of the resonator so that no spontaneous symmetry breaking is expected. In agreement with previous theoretical work [1], there is a remarkable increase of the polarization strength above the condensation threshold for a linear polarized pump. While the polarization of the condensate aligns with that of the pump beam, a circularly polarized condensate cannot be obtained. Below the condensation threshold, the photon gas stays unpolarized.

[1] R. I. Moodie, P. Kirton, and J. Keeling, Phys. Rev. A 96 (2017).

Q 25.20 Tue 14:00 Tent

**Programmable Optical Lattices for Quantum Gas Microscopy** — •Tom Schubert[1], Isabelle Safa[1], Sarah Waddington[1], Rodrigo Rosa-Medina[1], and Julian Léonard[1,2] — [1]Atominstitut, Technische Universität Wien, Austria — [2]Institute of Science and Technology Austria (ISTA), Klosterneuburg, Austria

Creating tailored optical potentials on demand is crucial for quantum simulation experiments with ultracold atoms, supporting the exploration of diverse strongly correlated phenomena, such as magnetic frustration or topological order. In this poster, we present the design and projection of tuneable lattice potentials using holographic beam shaping methods, combined with precise corrections of optical aberrations. The corrections and projection of the potentials are achieved employing a Digital Micromirror Device (DMD) and a Spatial Light Modulator (SLM), which facilitate phase and amplitude modulation through the use of programmable diffraction gratings. Through the correction process, we enable phase correction of wavefront aberrations with resolutions on the order of $\lambda/100$. For shaping the corrected beam into the desired optical lattices, we implement different holographic projection methods, including basic Fourier Transform and the Gerchberg-Saxton algorithm, and analyze their performance. Further we implemented a versatile experiment control system (ARTIQ), employing FPGA hardware, facilitating real-time manual control of the SLM-DMD structure. As a result, we are able to implement a variety of optical potentials, ranging from lattices in box-shape potentials to linearly tilted superlattices.

Q 25.21 Tue 14:00 Tent

**Stochastic phase noise in momentum-dependent Rabi oscillations** — •Samuel Böhringer, Fabian Kienle, and Richard Lopp — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany

The laser-driven two-level system is the most fundamental model in quantum optics. It plays a central role in the description of beam splitters and mirrors in matter-wave interferometry and various other experiments with the ultimate goal to achieve high-precision measurements. A limiting factor to the precision of these measurements is laser phase noise. While there are numerous models for the description of laser phase noise in driven systems, they are lacking the inclusion of the center-of-mass (COM) degrees of freedom. However, the COM-motion is crucial for many application. We provide a theoretical model for phase noise in Rabi oscillations including the COM degrees of freedom. In particular, we derive and solve a set of stochastic differential equations that describe the evolution of momentum-dependent observables during a laser pulse with phase noise.

Q 25.22 Tue 14:00 Tent

**Extending the holographic superfluid model** — •Martin Zboron[1], Gregor Bals[2,3], Thomas Gasenzer[1,2,3], and Carlo Ewerz[2,3] — [1]Kirchhoff-Institut für Physik, Uni Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institut für Theoretische Physik, Uni Heidelberg, Philosophenweg 16, 69120 Heidelberg — [3]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

Gauge-gravity duality establishes a connection between strongly correlated quantum systems and higher-dimensional gravitational theories at weak coupling. Utilising an Abelian Higgs model in an asymptotically anti-de Sitter spacetime, one obtains the so-called holographic s-wave superfluid. A rich phenomenology is embodied in this model making dynamics of defects, such as quantised vortices, amenable to precise quantitative analysis. Aside from vortex dynamics in the dissipative superfluid, excitations like Kelvin waves on top of vortex lines can be studied as well as the instability of vortices with high winding numbers. Recent proposals presented possible extensions of the model in order to capture the transition to a holographic model of supersolidity, allowing access to dynamics of vortices as well as their pinning and unpinning within the supersolid state. This also opens a path to understanding the spin-down of pulsars in a supersolid framework.

Q 25.23 Tue 14:00 Tent

**Optical dipole trapping of Rubidium in microgravity** — •Marian Woltmann, Yann Sperling, Jan Stiehler, Marius Prinz, and Sven Herrmann — Center of Applied Space Technology and Microgravity (ZARM), University of Bremen, Germany

The sensitivity of atom interferometric sensors typically scales with the squared interrogation time. Therefore space-borne atom interferometry offers the potential of highly increased senitivities that can be utilized for e.g. gravimetric measurements as well as for tests of fundamental physical principles.

Within the PRIMUS project we develop a compact all-optical matterwave source in a drop tower experiment. The all-optical approach utilizing a $\lambda = 1064\,\mathrm{nm}$ crossed beam optical dipole trap enables the use of Feshbach resonances and offers the advantages of symmetric trapping potentials and magnetic substate insensitive trapping. With our drop tower setup we demonstrated rapid Bose-Einstein condensation of $^{87}$Rb with a minimum evaporation time of $t_{\mathrm{evap}} = 1.3\,\mathrm{s}$ to reach a critical phase space density on ground, while now focusing on the efficient preparation in microgravity. The PRIMUS-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 2042.

Q 25.24 Tue 14:00 Tent

**Long-term stable laser injection locking for quasi-CW applications** — Alexandre de Martino, Florian Kiesel, •Kirill Karpov, Jonas Auch, and Christian Gross — Eberhard Karls Universitaet Tuebingen, Tuebingen, Germany

In our work we present a passive stabilization scheme for injection locking of high-power semiconductor laser diodes, that is generally applicable, technically easy to implement, and extremely cost-effective. It is based on the externally synchronized automatic acquisition of the optimal injection state. Central to our simple but powerful scheme is the management of thermalization effects during lock acquisition. By periodical relocking, spectrally pure amplified light is maintained in a quasi-CW manner over long timescales. We characterize the performance of our method for laser diodes amplifying 671nm light and demonstrate the general applicability by confirming the technique to work also for laser diodes at 401nm, 461nm, and 689nm. Our scheme enables the scaled operation of injection locks, even in cascaded setups, for the distributed amplification of single frequency laser light.

Q 25.25 Tue 14:00 Tent

**Enhancing Rydberg Atom Cooling and Trapping with a Tunable Light Sheet** — Shuanghong Tang, Philip Osterholz, Silpa Baburaj-Sheela, Jule Brosig, •Lukas Fischer, Fabio Bensch, and Christian Gross — Eberhard Karls Universität Tübingen

The utilisation of Rydberg atoms trapped in optical tweezers provides a robust platform for the investigation of strongly interacting and correlated many-body systems. In order to facilitate the tunability of the trapping potential in the vertical direction, we implemented a thin light sheet. The tunability of the vertical confinement increases the trapping frequency, thereby facilitating Raman sideband cooling through the elevation of trap frequencies and the mitigation of gravitational forces, which allows for the implementation of shallower tweezers during the cooling process. A further challenge is the phenomenon of Talbot plane loading, which results in an undesired population of atoms in the planes adjacent to the tweezer array. To address this issue, the light sheet can be employed for loading, thereby ensuring that the atomic reservoir is confined to the primary tweezer plane.

Q 25.26 Tue 14:00 Tent

**Pattern formation in dipolar quantum gases** — •Andreea-Maria Oros[1], Niklas Rasch[1], Wyatt Kirkby[1,2], Lauriane Chomaz[2], and Thomas Gasenzer[1,3] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227 — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 276 — [3]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16

Ultracold dipolar gases have garnered increasing interest over the past years. The anisotropic and long-range character of the dipolar interaction and the stabilizing nature of the quantum fluctuations give rise to supersolidity, superglasses, and exotic states of matter. Depending on the atom number, scattering length, and trapping geometry, different supersolid morphologies, such as triangular, honeycomb, and labyrinthine, have already been theoretically predicted to be the possible ground states of such a system. Our work expands on these phases by considering the out-of-equilibrium dynamics of a harmonically trapped, three-dimensional dipolar condensate. Following a quench in the scattering length across a phase transition boundary, we investigate the dynamical formation of supersolids, and demonstrate quenches into the triangular, honeycomb, and labyrinth phases. We furthermore investigate systems which have artificially been brought out of equilibrium, such as systems with imprinted vortex ensembles, or where the initial state differs from one that could naturally occur, in order to better aid the search for non-thermal fixed points, as well as far-from-equilibrium and novel phenomena.

Q 25.27 Tue 14:00 Tent

**Quantum gas microscopy of Rydberg-dressed extended Bose Hubbard models** — •David Gröters[1,2,3], 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[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MC-QST), 80799 Munich, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany

The competition of different length scales in quantum many-body systems leads to various novel phenomena, including the emergence of correlated dynamics or non-local order. Off-resonant optical coupling to Rydberg states, known as Rydberg dressing, has been proposed as a versatile tool to engineer long-range interactions in lattice-based quantum simulators. So far however, this approach has been limited by collective losses, limiting Rydberg dressing to immobile spin systems.

On this poster, I present our recent findings on realizing an itinerant one-dimensional extended Bose Hubbard model using Rydberg-dressed $^{87}$Rb atoms in optical lattices [1]. Here, we reduce the collective losses by two orders of magnitude using stroboscopic dressing. Harnessing our quantum gas microscope, we probe the correlated out-of-equilibrium dynamics of extended-range repulsively-bound pairs at low filling, and kinetically-constrained "hard rods" at half filling. Near equilibrium, we observe density ordering when adiabatically turning on the extended-range interactions.

[1] https://arxiv.org/abs/2405.20128

Q 25.28 Tue 14:00 Tent

**Trapping and interfacing laser-cooled strontium atoms using an optical nanofibre** — •Luca Göcke, Hector Letellier, Philipp Schneeweiss, Jürgen Volz, and Arno Rauschenbeutel — Department of Physics, Humboldt-Universität zu Berlin, Germany

We are in the process of building an experimental setup for trapping and optically interfacing laser-cooled strontium atoms using the evanescent field surrounding an optical nanofibre. The nanofibre is produced from a standard step-index optical fibre in a heat-pull process. It features a waist diameter of 200 nm where light is still efficiently guided while a significant part of the light propagates in the form of an evanescent field surrounding the nanofiber. Atoms are trapped in a one-dimensional (1D) optical lattice formed by two fiber-guided light-fields, red- and blue-detuned with respect to the strong transition at a wavelength of 461 nm. The aim is to realize a compensated trap, where the wavelengths of the trapping fields are magic for the 7.4 kHz wide intercombination line at 689 nm. This will allow us to implement advanced schemes for loading single atoms into the 1D optical lattice and to investigate the phenomenon of selective radiance [1], where the atoms themselves act as the waveguide. Here we will present our compact design for trapping strontium atoms from a laser ablated source with a “hot MOT” (operated at 461 nm wavelength), then transfer them to a “cold MOT” (operated at the intercombination line) and to the nanofibre trap.

[1]: A. Asenjo-Garcia et al. PRX 7, 031024 (2017)

Q 25.29 Tue 14:00 Tent

**Fractal ground state of mesoscopic ion chains in periodic potentials** — Raphael Menu[1], Jorge Yago Malo[2], •Joshua Weissenfels[1], Vladan Vuletic[3], Maria Luisa Chiofalo[2], and Giovanna Morigi[1] — [1]Universität des Saarlandes, Saarbrücken, Germany — [2]Università di Pisa, Pisa, Italy — [3]Massachusetts Institute of Technology, Cambridge, USA

Trapped ions in a periodic potential are a paradigm of a frustrated Wigner crystal. The dynamics is captured by a long-range Frenkel-Kontorova model. We show that the classical ground state can be mapped to the one of a long-range Ising spin chain in a magnetic field, whose strength is determined by the mismatch between chain’s and substrate lattice’s periodicity. The mapping is exact when the substrate potential is a piecewise harmonic potential and holds for any two-body interaction decaying as $1/r^\alpha$ with the distance $r$. The ground state is a devil’s staircase of regular, periodic structures as a function of the mismatch and of the interaction exponent $\alpha$. While the staircase is well defined in the thermodynamic limit for $\alpha > 1$, for Coulomb interactions, $\alpha = 1$, we argue that it disappears and the sliding-to-pinned transition becomes a crossover, with a convergence to the thermodynamic limit scaling logarithmically with the chain’s size. Due to this slow convergence, fractal properties can be observed even in chains of hundreds of ions at laser cooling temperatures.

Q 25.30 Tue 14:00 Tent

**Lattice phase stabilization for a dipolar quantum gas microscope** — •Alexandra Köpf[1], Fiona Hellstern[1], Kevin Ng[1], Paul Uerlings[1], Michael Wischert[1], Tanishi Verma[1], Stephan Welte[2], Ralf Klemt[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]5. Physikalisches Institut, Center for Integrated Quantum Science and Technology and CZS Center QPhoton, Universität Stuttgart

This poster presents the development of a dipolar quantum gas microscope using Dysprosium atoms, focusing on the critical role of optical lattice phase stabilization. Dysprosium atoms will be trapped and imaged in a 360 nm UV lattice, achieving nearest-neighbor dipolar interactions of approximately 200 Hz at 10 nK. Maintaining precise lattice stabilization is also essential to confine the atoms within the narrow depth of focus (approximately 260 nm) of the high-resolution in-vacuum objective (NA = 0.9). To achieve this, we use a 1064 nm infrared lattice for vertical confinement, complemented by an active phase stabilization scheme, stabilizing the lattice relative to the objective position. This setup employs FPGA-based boards to monitor and stabilize the lattice phase through a Michelson interferometer, ensuring robust atom confinement and alignment. This approach enables controlled, long-timescale investigations of dipolar quantum phenomena, offering new insights into strongly interacting quantum systems.

Q 25.31 Tue 14:00 Tent

**A comparison of sub-Doppler cooling techniques using a nano-structured atom chip** — •Kai-Christian Bruns, Julian Lemburg, Joseph Muchovo, Vivek Chandra, Sam Ondracek, Hendrik Heine, and Ernst M. Rasel — Leibniz Universität Hannover, Institut für Quantenoptik

In the field of cold atomic physics, various sub-Doppler cooling techniques are being used. We investigate two different molasses cooling schemes using an atom chip with a nano-fabricated grating. These chips simplify and miniaturize quantum systems by enabling the trapping of atoms in a MOT with a single incident beam. Additionally, the use of grating atom chips also enhances the scalability and portability of such devices. These techniques holds promise for a wide array of applications, from fundamental research to practical implementations in earth observation.

In this poster, we compare sub-Doppler cooling of $^{87}$Rb utilizing bright and gray molasses techniques. We manage to cool the atoms to 13 $\mu$K and 5 $\mu$K respectively. Additionally, we see an increase in phase-space density by a factor of three, when comparing gray molasses to bright molasses. To understand the benefits that this improvement could bring to experiments employing Bose-Einstein-condensates, we study the transfer into a magnetic trap.

Q 25.32 Tue 14:00 Tent

**Double Bragg atom interferometry with Bose-Einstein condensates in microgravity** — •Anurag Bhadane[1], Dorthe Leopoldt[2], Priyanka Barik[2], Govindarajan Prakash[3], Julia Pahl[4], Sven Herrmann[3], Andre Wenzlawski[1], Sven Abend[2], Markus Krutzik[4,5], Patrick Windpassinger[1], Ernst Rasel[2], and The Quantus Team[1,2,3,4,6,7] — [1]JGU Mainz — [2]LU Hannover — [3]ZARM, U Bremen — [4]HU Berlin — [5]FBH Berlin — [6]U Ulm — [7]TU Darmstadt

The QUANTUS-2 device is a mobile, robust, high-flux atom interferometer utilizing $^{87}$Rb, designed for microgravity environments such as those provided by the Bremen drop tower and Gravitower. The Gravitower enables higher repetition rates for experiments, establishing QUANTUS-2 as a testbed for future space-based missions.

Our experiment employs a magnetic lens via the quadrupole field of an atom chip, achieving extended coherence times and enabling interferometry durations exceeding one second with double Bragg diffraction under microgravity conditions. On this poster, we report recent advancements in atom interferometry at extended timescales, along with the characterization of the system in the Gravitower.

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 numbers DLR 50WM1952-1957 and DLR 50 WM 2450A-F

Q 25.33 Tue 14:00 Tent

**Mean-field parton construction of Rydberg Quantum Spin Liquid from microscopic properties** — •Benno Bock, Simon Ohler, and Michael Fleischhauer — RPTU, Kaiserslautern, Germany

Quantum Spin Liquids (QSL) represent an exotic phase of matter elusive to experiments. One hallmark property is the absence of magnetic spin order even at zero temperature. Despite numerous attempts, the unambiguous experimental confirmation of QSL states remains difficult. In this context, the possibility of realizing QSL physics on Rydberg atom-based quantum simulators has been a promising avenue for investigation [Semeghini et al., Science 374 (2021)].

Recently, the existence of a QSL state has been investigated numerically with Exact Diagonalization (ED) in a system of Rydberg atoms on a honeycomb lattice featuring density-dependent Peierls phases [Ohler et al., PRR 5 (2023)]. Later investigations using projective symmetry group arguments [Tarabunga et al., PRB 108 (2023)] confirmed the state to be a chiral spin liquid by comparing ground-states of ansatz Hamiltonians with ED results. In this work, we take a different approach, deriving explicitly the mean-field parton Hamiltonian starting from the microscopic Rydberg properties. We then determine the mean-field ground-state self-consistently, which yields a more accurate representation of the Rydberg ground-state. It shows large overlap with the ED simulation but is in principle not restricted to small system sizes.

Q 25.34 Tue 14:00 Tent

**Aberration correction and trap creation in a dipolar quantum gas microscope** — •Michael Wischert[1], Kevin Ng[1], Fiona Hellstern[1], Paul Uerlings[1], Alexandra Köpf[1], Tanishi Verma[1], Stephan Welte[2], Ralf Klemt[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology — [2]5. Physikalisches Institut, Center for Integrated Quantum Science and Technology and CZS Center QPhoton, Universität Stuttgart

This poster focuses on calibrating and correcting optical aberrations as well as holographically projecting optical traps for a dipolar quantum gas microscope. To achieve large nearest-neighbor interactions (200 Hz at 10 nK), a 180 nm spaced near-UV lattice with dysprosium atoms will be used. This setup requires a high NA objective (NA 0.9) where minimizing imaging aberrations is critical for maintaining image fidelity. To mitigate these aberrations, we introduce a spatial light modulator (SLM) after the objective, enabling phase manipulation of the collected light and correction of the distorted wavefront. We test and compare different methods for calibrating and correcting aberrations using the SLM. Additionally, we explore the use of the SLM in creating tailored optical trap potentials by projecting and analyzing various trap geometries in a separate setup. Our work aims at exploring how SLMs can be utilized to improve imaging performance in quantum gas microscopes.

Q 25.35 Tue 14:00 Tent

**Quantum turbulence in a dipolar Bose gas at the anomalous non-thermal fixed point** — •Niklas Rasch[1] and Thomas Gasenzer[1,2] — [1]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

This work focuses on quantum turbulence in the vicinity of an anomalous non-thermal fixed point (NTFP) characterized by slow, subdiffusive coarsening of a length scale. The NTFP is approached in the temporal evolution of a quasi-2d dipolar Bose gas starting from variously sampled initial vortex configurations. Already in the early dynamics, we observe the build-up of an inverse energy cascade and recover Kolmogorov's $-5/3$ power law in the incompressible energy spectrum. Due to the irreversible conversion of incompressible (vortices) into compressible energy (sound) this is understood in the context of decaying turbulence. By studying higher moments of the velocity circulation, we aim to understand the role that intermittency plays in the approach to a non-thermal fixed point. Further, using the high tunability of the anisotropic and long-range dipolar interaction we can probe its effects on the quantum turbulent behavior.

Q 25.36 Tue 14:00 Tent

**Exploring extended Hubbard models in an optical superlattice** — •Valentin Jonas, Nick Klemmer, Janek Fleper, Ameneh Sheikhan, Corinna Kollath, Michael Köhl, and Andrea Bergschneider — Physikalisches Institut, Bonn, Germany

Ultracold atoms in optical lattices allow for simulating strongly correlated many-body systems in the Hubbard model. Its quantum phases arising from the interplay of tunneling and on-site interaction have been extensively studied over the last few years experimentally, while systems beyond the simple Hubbard model are much less explored.

Our experimental apparatus uses fermionic potassium atoms in a 3D optical lattice with an in-plane superlattice to realize chains of double wells. By asymmetrically shaking the double wells, we recently realized an effective Floquet system with additional pair tunneling while fully suppressing the dynamics of single particles. By controlling the drive frequency, we could tune the system and enhance pair tunneling up to the size of the superexchange [1].

Currently, we are investigating excited two-particle states in the superlattice such as repulsively bound atom pairs and can demonstrate their deterministic preparation in the double wells. These states are predicted to be connected to pair states featuring unconventional superconductivity.

[1] N. Klemmer et al., PRL (Accepted), 2024

Q 25.37 Tue 14:00 Tent

**Reaction-Diffusion Dynamics of Quantum Gases** — •Hannah Lehr, Igor Lesanovsky, and Gabriele Perfetto — Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

We consider the dynamics of quantum gases underlying coherent motion as well as dissipative reactions. For Fermions we discuss e.g., k-body losses $kA \to \emptyset$. In this case the universality lies within the long time decay of the particle density. For Bosons we consider also particle creating processes as branching $A \to A + A$. The competition between the latter and single body decay and coagulation $A + A \to A$ leads to an absorbing state phase transition in the stationary state. Our goal is to understand how quantum effects impact on the universality class of the transition.

We tackle these problems combining a variety of methods ranging from kinetic large-scale equations via the time-dependent generalized Gibbs ensemble method (TGGE), and Keldysh field-theory diagrammatic expansion. Specifically, for the Fermi gas under weak k-body losses we find long-time decay for the density of particles different from mean field. For the Bose gas, we observe a rich stationary phase diagram different from the classical counterpart of the model.

Our findings show that quantum effects impact on large-scale universal behaviour leading to novel universality classes compared to classical physics. These results are experimentally relevant since they directly connect to cold-atomic processes involving dissipative processes such as particle losses and creation.

Q 25.38 Tue 14:00 Tent

**Single-Atom Addressing in Optical Lattices Using UV Raman Transitions** — •Francesco Testi[1,4], Andreas von Haaren[1,2], Robin Groth[1,2], Luca Muscarella[1,2], Janet Quesja[1,2], Liyang Qiu[1,2], Immanuel Bloch[1,2], Timon Hilker[1,3], Titus Franz[1,2,4], and Philipp Preiss[1,2] — [1]Max Planck Institute of Quantum Optics, Garching — [2]Munich Center for Quantum Science and Technology — [3]University of Strathclyde, Glasgow — [4]Ludwig Maximilian University of Munich

FermiQP is a demonstrator for a lattice-based fermionic quantum processor utilizing ultracold fermions in optical lattices. Operating in analog mode, the system facilitates precision studies of the two-dimensional Fermi-Hubbard model. In its digital mode, it implements a universal gate set on the spin degree of freedom, enabling advanced state engineering and local basis transformations. Combined with a rapid preparation cycle for degenerate Fermi gases, FermiQP opens new pathways for fermionic quantum information processing, with applications in quantum chemistry and strongly correlated materials.

We present a single-atom addressing scheme for coherently manipulating the internal states of individual Lithium-6 atoms within an optical lattice. The scheme employs two-photon Raman transitions at a UV wavelength of 323 nm, optimizing atomic coherence while minimizing cross-talk to neighboring atoms. We provide a comprehensive characterization of the 323 nm laser system and introduce an addressing system based on Acousto-Optic Deflectors capable of delivering up to six independently steerable beams in two dimensions.

Q 25.39 Tue 14:00 Tent

**Challenges behind performing atom interferometry in extended free fall** — •Priyanka Barik[1], Dorthe Leopoldt[1], Anurag Bhadane[2], Julia Pahl[3], Sven Abend[1], Sven Herrmann[4], André Wenzlawski[2], Patrick Windpassinger[2], Markus Krutzik[3,7], Ernst M. Rasel[1], and QUANTUS Team[1,2,3,4,5,6,7] — [1]LU Hannover — [2]JGU Mainz — [3]HU Berlin — [4]ZARM, U Bremen — [5]U Ulm — [6]TU Darmstadt — [7]FBH Berlin

The QUANTUS-2 apparatus is a high-flux $^{87}$Rb BEC machine, based on a magnetic chip-trap, which generates $1\times10^5$ atoms at a 1Hz rate. High-precision quantum sensing with atom interferometers requires long interrogation time of several seconds with ultra-low expansion rates of the BECs. Thus, we perform our experiment in the Drop Tower in Bremen with a novel matter-wave lens system for the collimation of the condensate. The QUANTUS-2 setup experiences noticeable tilts and rotations which alter the spatial rotation of the $^{87}$Rb atomic cloud and its projection along the imaging axes and the interferometry pulses. These rotations lead to position offsets, which become more pronounced as the TOF is increased, and, hence, are expected to contribute to a loss of contrast of the interferometer. We report on the proposal to mitigate these problems using a retro-reflective mirror mounted on a tip/tilt platform which will pave the way for long interrogation times. 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 numbers DLR 50WM1952-1957 and DLR 50 WM 2450A-F.

Q 25.40 Tue 14:00 Tent

**Design and characterization of a compact and transportable strontium MOT** — •Darius Hoyer and Simon Stellmer — Physikalisches Institut, Bonn, Deutschland

The broad linewidth of the 461 nm (5s5s) $^1S_0 \rightarrow$ (5s5p) $^1P_1$ transition of strontium allows for efficient laser cooling and trapping in a magneto-optical trap (MOT). This results in a bright MOT that is visible to the naked eye. Thus the Sr MOT is an ideal toy model for making quantum optics more accessible to a wide audience.
We present the design of a transportable Sr MOT based on permanent magnets for the Zeeman slower and the MOT.

Q 25.41 Tue 14:00 Tent

**Rydberg interactions in ultracold Ytterbium** — •Florian Pausewang, Tangi Legrand, Xin Wang, Ludwig Müller, Eduardo Uruñuela, Wolfgang Alt, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Mapping the strong interactions between Rydberg excitations in ultracold atomic ensembles onto photons opens the door to achieving high optical nonlinearities at the single-photon level. While previous demonstrations of this concept have relied exclusively on alkali atoms, two-valence-electron species like ytterbium offer unique advantages, such as narrow-linewidth laser cooling and, for Yb-174, potentially longer coherence times of polaritons compared to earlier Rubidium-based experiments. In this poster, we present our new ytterbium apparatus including Yb-specific challenges as light-induced atomic repulsion and two-photon ionization processes, and discuss our progress towards photon-photon interactions by Rydberg polaritons. We also report the spectroscopic characterization of ultra long-range Yb Rydberg molecules that arise as bound states in the low energy scattering of a highly excited Rydberg electron and a ground state atom. Our experimental setup featuring a dual-chamber compact design and a two-color MOT allows the creation of dipole trapped atomic ensembles at high density and low temperature, with $5\cdot10^6$ atoms and $T < 10\,\mu$K within 2 s. Further evaporative cooling down to condensation is possible. Additionally, a field ionization system with ion detection via a Micro-Channel Plate enables high-precision spectroscopy.

Q 25.42 Tue 14:00 Tent

**Toward Magnetically Insensitive $^{39}$K BECs** — •Wei Liu, Constantin Avvacumov, Alexander Herbst, Ashwin Rajagopalan, Knut Stolzenberg, Daida Thomas, Ernst Rasel und Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

The sensitivity of an atom interferometer(AI) is generally limited by the standard quantum limit (SQL). Entangled interferometer schemes generated through atom-atom interactions in a trapped configuration can surpass the SQL, thereby enhancing the sensitivity of the AIs. However, trapped AIs are constrained by phase diffusion stemming from collisions at high atomic density. Feshbach resonances can suppress phase diffusion in trapped AI by tuning scattering length, enabling measurements with high-densities and large atomnumbers. $^{39}$K BEC are ideal canidiates for such interfermetry schemes, as they feature broad resonans at low magnetic fields.

To create $^{39}$K BEC in $m_F = 0$ suitable for AI at low field, the narrowness of resonance at 59.3G and spin-changing collision pose significant challenges for evaporative cooling. We present several schemes for generating a $^{39}$K BEC in $m_F = 0$ through using microwave pulses and co-propagating Raman beam before and after evaporative cooling and discuss their limitations.

Q 25.43 Tue 14:00 Tent

**Matter-wave interferometry with large metal clusters in a free-fall setup** — •Eric van den Bosch and Klaus Hornberger — University of Duisburg-Essen, Germany

Matter-wave interferometry can be used to probe fundamental quantum properties on increasingly large scales. Using ionising gratings produced by UV lasers mitigates some of the limitations of material gratings, while also allowing for more versatile setups. We study an optical time-domain ionising matter-wave interferometer (OTIMA) setup [1] in a free-fall tower aimed at masses of up to $10^7$ amu. We treat the influence of gravity and the Coriolis force in three dimensions and discuss possible experimental schemes to counteract the Coriolis effect.

[1] Nimmrichter, Haslinger, Hornberger, Arndt (2011). Concept of an ionizing time-domain matter-wave interferometer. New Journal of Physics, 13(7)

Q 25.44 Tue 14:00 Tent

**Langevin dynamics of a Bose gas coupled to a small heat bath** — •Carsten Henkel and Sasha Roewer — Universität Potsdam, Institut für Physik und Astronomie

In an elongated, quasi-one-dimensional trap, a degenerate Bose gas is formed by atoms in the lowest quantum state of the "radial" confinement. Atoms in higher states can provide a heat bath which is, however, not much larger compared to the degenerate gas. We study with the help of Langevin dynamics (stochastic Gross-Pitaevskii equation) the evolution of the complex order parameter, taking into account the exchange of energy and particles with the heat bath. Curiously, as the heat bath gets smaller, its temperature drops, and the Bose gas is more degenerate. At the same time, temperature fluctuations are larger. Thermodynamically relevant quantities like the internal energy are extracted from the simulations. We also explore non-equilibrium situations with an externally imposed temperature difference.

Q 25.45 Tue 14:00 Tent

**Symmetry-Preserving Condensation of Photons** — Andreas Redmann, •Riccardo Panico, Frank Vewinger, Julian Schmitt, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstrasse 8, 53115 Bonn, Germany

We investigate the statistical behavior of a Bose-Einstein condensate of photons in a dye-filled optical microcavity. This system enables the observation of grand-canonical statistical conditions through the coupling of photons to a reservoir of dye molecules, supporting the coexistence of macroscopic occupation and unusually large fluctuations of the particles number. Building on prior demonstrations of grand-canonical statistics [1,2], we push the boundaries of our system to explore conditions for which the first- and second-order coherence times become comparable. In this regime, the condensate exhibits a discontinuous phase, driven by the relatively high probability of having zero particles in the condensate, with spontaneous emission of photons from the reservoir setting the phase of the condensate each time. Despite this, photons are expected to exhibit macroscopic occupation on average, while at the same time having characteristics of incoherent light sources. From a thermodynamic perspective, this would translate to the formation of a condensate without spontaneous symmetry breaking.

[1] Julian Schmitt, et al., Laser Spectroscopy, pp. 85-96 (2016)
[2] Julian Schmitt, et al., Phys. Rev. Lett. **116**

Q 25.46 Tue 14:00 Tent

**Assessing interactions of Rb vapor with mirror coatings for compact cold-atom sources** — •Constantin Avvacumov, Alexander Herbst, Wei Liu, Ashwin Rajagopalan, Knut Stolzenberg, Daida Thomas, Ernst Rasel, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

Atom interferometers are effective tools for fundamental research and geodesy applications, e.g. for gravimetry. Fundamentally, quantum projection noise motivates the development of high-flux cold atom sources. A typical first cooling stage of atom interferometers is a two-dimensional magneto-optical trap (2D-MOT). In recent years, attempts to improve on 2D-MOTs' SWaP (size, weight, and power) budget raised questions regarding the compatibility of high-quality optical coatings exposed to alkali vapor, e.g., rubidium or potassium.

In this poster, we present systematic analysis of the interaction of Rb vapor with highly reflective coating materials (gold, silver, aluminium, dielectric coatings) and compare samples with and without protective coating. In our mirror testing setup, we observe mirror reflectivity degradation as a function of time and Rb partial pressure in a long-term perspective. Six mirror samples are exposed to alcali vapor at partial pressures up to and about saturation level (about $5 * 10^{-7}$ mbar at room temperature). The results show significant reduction in mirror lifespan at Rb pressures above saturation level, which varies, however, for different samples. Analysis of the reactivity of alkali vapor with various materials at different pressures has an application in design of future compact quantum optical experiments.

Q 25.47 Tue 14:00 Tent

**Local Chern number for noninteracting fermions in the Haldane model with external confinement** — •Daniel Samoylov and Walter Hofstetter — Goethe Universität, Institut für Theoretische Physik, 60438 Frankfurt, Germany

We numerically study the formation of topological domains in the Haldane model on a honeycomb lattice in the presence of an external trapping potential. To map out topological domains in real space we calculate the local Chern number of the system as a function of position. The local Chern number was introduced by Bianco and Resta [1] as a topological marker of the Chern number. In order to test our implementation, we calculate the local Chern number of the Haldane model without external potential and confirm the results in [1]. By adding an external potential to the system, we find different topological domains which are indicated by a spatial variation of the local Chern number across the honeycomb lattice. We investigate the formation of topologically non-trivial domains, both as a function of the Fermi energy and for different shapes of the trapping potential. Related results were obtained for the Hofstadter model in [2].

[1] R. Bianco and R. Resta, Phys. Rev. B 84, 24 (2011)
[2] U. Gebert, B. Irsigler, and W. Hofstetter, Phys. Rev. A 101, 6 (2020)

Q 25.48 Tue 14:00 Tent

**Laser-induced lattice potentials for optical quantum gases inside microcavities** — •Purbita Kole[1], Nikolas Longen[1], Daniel Ehrmanntraut[1], Peter Schnorrenberg[1], Kevin Peters[1], and Julian Schmitt[1,2] — [1]Universität Bonn, IAP, Wegelerstr. 8, 53115 Bonn — [2]Universität Heidelberg, KIP, Im Neuenheimer Feld 227, 69120 Heidelberg

Lattice potentials provide a fundamental ingredient for the description and study of the behaviour of particles in crystal-like structures, most notably in condensed matter systems. The realisation of photon Bose-Einstein condensates in arrays of coupled dye-filled microcavities opens a new platform for such physics owing to the high degree of tunability of the potentials in 1D and 2D. Here, we present laser-induced reversible and irreversible mirror structuring techniques for the generation of periodic lattice potentials for photon Bose-Einstein condensates with variable site-resolved control of the potential energy. As the dispersion relation for the two-dimensional photon gas inside an optical dye-filled microcavity depends on the cavity length, static potentials are introduced by modulating the mirror surface with a laser writing method. Harnessing the thermo-optic effect in the dye solution, we then modify the optical path length in a reversible way by projecting structured light onto an absorbing Si-layer in the backside of one of the cavity mirrors. The two-fold tuning of lattice potentials opens the possibility to study a variety of novel Hermitian and non-Hermitian effects with quantum gases of light.

Q 25.49 Tue 14:00 Tent

**Fast 24-bit analog-to-digital converter for high-precision experiment control** — •Jonas Drotleff, Philipp Lunt, Johannes Reiter, Paul Hill, Maciej Gałka, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Cold atom experiments rely on precision measurements and stable experimental parameters to prepare and control quantum states with high fidelity. High-dynamic range analog-to-digital converters (ADCs) minimize the information loss caused by the digitalization and play a major role in modern experiment control systems. We present a novel measurement device that provides a large dynamic range (19 noise-free bits) at sampling rates of up to 2 million samples per second. At lower sampling rates, the converter yields up to 24 noise-free bits, allowing for enhanced flexibility in the type and bandwidth of input signals. With its small and portable design, the device allows for digitalization close to the signal's origin, thereby eliminating long signal paths and subsequent noise pickup. This ADC is the first step towards more precise control of experimental parameters, with potential applications in the range from ultra-precise stabilization of optical trap depths to magnetic offset field control at unprecedented levels.

Q 25.50 Tue 14:00 Tent

**Towards trapping of single atoms in a micro-fabricated optical tweezer** — •Marian Rockenhäuser[1], Lukas Blessing[2], and Tim Langen[1] — [1]TU Wien, Atominstitut, Cold Molecules and Quantum Technologies — [2]Universität Stuttgart, 5. Physikalisches Institut

The trapping of single ultracold atoms is a crucial technique for applications in quantum computation, communication, and sensing. However, one of the main disadvantages of most experiments is their considerable large size and complexity. Here we present our progress towards the miniaturization of a classic single atom experiment. This is achieved by the use of a sophisticated compact laser system and the integration of a 3D-printed optical tweezer with a rubidium magneto-optical trap. The tweezer is created using micrometer-scale lenses fabricated directly onto the tip of a standard optical fiber. These unique properties enable the efficient trapping of single atoms and the collection of their fluorescence using the same fiber. Its unique properties will make it possible to both trap single atoms and the subsequent collection of their fluorescence with high efficacy. Based on this, a single-photon source can be realized which will have extensive applications in the field of quantum information processing.

Q 25.51 Tue 14:00 Tent

**Quantum simulation and computation using fermions in an optical superlattice** — •Marnix Barendregt[1], Thomas Chalopin[1,2], Petar Bojović[1], Si Wang[1], Johannes Obermeyer[1], Dominik Bourgund[1], Titus Franz[1], Immanuel Bloch[1], and Timon Hilker[1,3] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Université Paris-Saclay, Institut d*Optique Graduate School, CNRS, Laboratoire Charles Fabry, Palaiseau 91127, France — [3]Department of Physics, University of Strathclyde, Glasgow, G4 0NG, UK

Strongly-correlated materials show rich phase diagrams at low temperatures and finite dopings. The Fermi-Hubbard model and its variations are believed to describe many of these phases, including cuprate high-Tc superconductivity and the pseudogap phase. We have implemented a single-site and spin resolved quantum gas microscope with an optical superlattice. Control over the doping and temperature has allowed us to explore large regions of the Fermi-Hubbard phase diagram and find indications of the pseudogap phase by measuring spin and dopant-spin correlations up to fifth order. Additionally, atoms in the superlattice can be isolated into an array of double wells, which we dynamically control to implement two-qubit collisional gates with excellent fidelity. This paves the way for fermionic quantum computation.

Q 25.52 Tue 14:00 Tent

**Experimental Study of the Solidity and Smecticity of a Driven Superfluid** — •Nikolas Liebster, Marius Sparn, Elinor Kath, Jelte Duchene, Helmut Strobel, and Markus Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Bosonic quantum gases have been shown to result in spontaneously arising, self-stabilized periodic density modulations when the two-particle interaction strength is driven in time. Here we experimentally demonstrate that such states share key properties to a seemingly different physical system, namely supersolids, not only in their superfluidity and periodic density structure but also in their excitations. This correspondence is made possible through the effective theory of hydrodynamics of supersolids, which is constructed using assumptions of spontaneously broken symmetries and conserved quantities. We experimentally investigate both stripe patterns as well as two-dimensional crystals, using novel techniques to instigate sound modes in each configuration.

Q 25.53 Tue 14:00 Tent

**Realization and characterization of a tunable 2D optical accordion for ultracold atoms** — •Krishnan Sundararajan, Alexander Guthmann, Felix Lang, Louisa Marie Kienesberger, and Artur Widera — Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany

Optical lattices, formed by the interference of coherent laser beams, are powerful tools for manipulating quantum gases. A versatile implementation, the optical "accordion," enables tuneable lattice spacing by adjusting the angle between beams. We aim to develop such a setup using a beam splitter made of custom Dove prisms bonded with UV-curing epoxy, combined with a large aspherical lens. The prism pair splits a single beam into two parallel rays, whose separation depends on the incoming beam properties. Focusing these rays creates an interference pattern forming the lattice potential. We will present the design, assembly, and ex-situ characterization of this optical accordion and its extension to a 2D configuration for accessing lower-dimensional systems with ultracold lithium-6 atoms.

Q 25.54 Tue 14:00 Tent

**Two-dimensional grating magneto-optical trap** — •Joseph Muchovo, Julian Lemburg, Sam Ondracek, Kai-Christian Bruns, Vivek Chandra, Hendrik Heine, and Ernst M. Rasel — Leibniz Universität Hannover, Institut für Quantenoptik

Ultracold atoms provide exciting opportunities for advancing matter-wave interferometry and enabling more precise tests of fundamental physics in a variety of experimental and applied settings. To achieve larger atom numbers and higher repetition rates, two-dimensional (2D) magneto-optical traps (MOTs) can be employed as separate source chambers. These offer distinct advantages in the pre-cooling and faster, more efficient loading of atoms into three-dimensional grating MOTs, a key step for many precision measurements. To realise field applications of quantum sensors utilising cold atoms, there is need for simpler, more efficient and more compact sources.

In this poster, we will present the design and implementation of a 2D grating MOT requiring only a single input cooling beam in combination with pusher-retarder beams, thereby simplifying the setup. This innovative approach will result in a robust, highly compact, and efficient source of ultracold atoms that can be used in field and space applications.

Q 25.55 Tue 14:00 Tent

**Developing a hybrid tweezer array of Rydberg atoms and polar molecules** — •Kai Voges, Daniel Hoare, Joe Vagge, Qinshu Lyu, Jonas Rodewald, Ben Sauer, and Michael Tarbutt — Centre for Cold Matter, Imperial College London, UK

Hybrid tweezer arrays of atoms and molecules are an innovative tool for new applications in quantum science and technology. The combination of Rydberg atoms with their large electric dipole moment and polar molecules with their rich level structure and long state coherence times makes this approach a promising platform for quantum simulation [1] and computing [2,3].

In this poster, we present our recent results on the realization of such a hybrid tweezer array based on ultracold Rb atoms and directly laser-coolable CaF molecules. We discuss the advantages and challenges of using two different ultracold particle types and present our preparation strategies for the atoms and molecules. In addition, we show our results in single atom trapping, imaging and tweezer trap characterisation and present our progress for highly efficient tweezer loading.

Our approach will make it possible to construct arbitrary patterns of atoms and molecules. Through the dynamic rearrangement of tweezers and the long-range interactions mediated by Rydberg atoms, this hybrid platform will be a compelling candidate for scalable quantum computing.

[1] J. Dobrzyniecki et al., PRA 108, 052618 (2023)
[2] C. Zhang et al., PRX Quantum 3, 030340 (2022)
[3] K. Wang et al., PRX Quantum 3, 030339 (2022)

Q 25.56 Tue 14:00 Tent

**Observation of an integer quantum Hall state of six fermions** — •Johannes Reiter, Paul Hill, Philipp Lunt, Jonas Drotleff, Maciej Galka, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Deutschland

Integer and fractional quantum Hall states underpin the understanding of topological phases of matter featuring exotic macroscopic properties such as the quantization of the transverse resistivity and emergence of robust edge currents.

Expanding upon our deterministic preparation of a spinful two-particle Laughlin state [arXiv:2402.14814], we present the recent observation of an integer quantum Hall state of six rapidly rotating fermions confined in a tight optical tweezer. Momentum-space imaging of the many body density reveals the hallmark uniform flattening of the particle density distribution and provides access to the microscopic correlations. This measurement demonstrates the scalability of our atom-by-atom assembly technique of quantum hall states and opens new avenues for probing the microscopic dynamics of topological phase transitions.

Q 25.57 Tue 14:00 Tent

**Exploring the superfluid phase diagram for imbalanced Fermi gases in 2D** — •René Henke, Cesar R. Cabrera, Moritz von Usslar, Artak Mkrtchyan, and Henning Moritz — Institut für Quantenphysik, Universität Hamburg

In Fermionic superfluids, condensation occurs through the pairing of fermions with opposite momenta and spin. This process is disturbed by introducing a spin imbalance, which leads to a mismatch between the respective Fermi surfaces. The result is a complex phase diagram including different phases, such as phase separation between a balanced superfluid and free fermions, as well as more exotic phases like the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state, where the pairs carry non-zero momentum. As of now, the phase diagram of imbalanced Fermi gases in two dimensions remains largely unexplored.

In this poster, we present our results on spin-imbalanced homogeneous Fermi gases in two dimensions. Using lattice modulation spectroscopy, we excite a collective mode associated to the superfluid order parameter of the system. Our results show how this collective mode vanishes at a critical polarization and interaction strength, providing a step towards understanding exotic pairing in low dimensions.

Q 25.58 Tue 14:00 Tent

**Towards a Potassium-39 quantum gas microscope** — Scott Hubele, •Yixiao Wang, Martin Schlederer, Alexandra Mozdzen, Guillaume Salomon, and Henning Moritz — Institute for Quantum Physics, University of Hamburg, Germany

The rapid development of quantum simulation has enabled us to study many-body physics with cold atom experiments in a controlled way, avoiding the computational complexity of solving the problems with classical computers. The introduction of quantum gas microscopes further allows to study the system with single-site resolution in real space.

In our experiment, we prepare ultracold Potassium-39 in a 1064nm optical lattice in a bowtie configuration, which can be well described by the Bose-Hubbard model, and confine the atoms in quasi-2D geometry with a pancake-shaped trap and a vertical repulsive lattice. To achieve single-site resolution, we employ Raman sideband imaging at near-zero magnetic field to cool the atoms while simultaneously collecting fluorescence photons with a high-NA objective.

Here, we present the progress towards building a Potassium-39 quantum gas microscope and introduce the experimental techniques for preparing ultracold atoms in the optical lattices and imaging them with high resolution using Raman sideband imaging.

Q 25.59 Tue 14:00 Tent

**An experimental study of the heating of laser-cooled atoms in a nanofiber-based two-color trap** — •Antoine Glicenstein, Riccardo Pennetta, Daniel Lechner, Jürgen Volz, Philipp Schneeweiss, and Arno Rauschenbeutel — Department of Physics, Humboldt-Universität zu Berlin, 10099 Berlin, Germany

The lifetime of atoms in nanofiber-based optical traps is significantly smaller than in comparable free-space traps. This experimental observation has been made for different types of trapped atoms such as Cesium or Rubidium, and the mechanical motion of the nanofiber has been proposed to be the major factor behind the excess heating [1]. By analyzing the polarization fluctuations of light transmitted through the nanofiber, we observe the nanofiber's fundamental torsional mode [2], which exhibits a Q-factor of up to $10^7$ and a resonance frequency close to the trapping frequencies. In order to study its potential influence on the atoms' lifetime, a piezo actuator is integrated into the nanofiber holder. While we successfully implemented feedback cooling to suppress the torsional motion and actively drove the torsional mode, neither approach resulted in a significant modification of the lifetime, indicating that the torsional mode is irrelevant for the heating rate of trapped atoms. Our research now shifts to investigating flexural modes, which are theoretically predicted to contribute most strongly to the heating [1] but are experimentally more challenging to address.

[1] Hümmer et al., PRX 9, 041034 (2019) [2] Tebbenjohanns et al., PRA 108, L031101 (2023)

Q 25.60 Tue 14:00 Tent

**Possible configurations of the Heidelberg Quantum Architecture** — •Daniel Dux, Tobias Hammel, Maximilian Kaiser, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Heidelberg, Germany

We present the current status of our new modular Lithium-6 platform. Besides a high degree of adaptability, this platform aims for a very fast cycle rate. We show first results from some of the already implemented modules, such as dipole traps, optical tweezers, an optical accordion to provide a 2D confinement, RF coils that enable fast spin flips, a free space imaging setup that allows simultaneous spin selective readout and a self optimization routine to set experiment parameters. Given these modules, we will discuss possible configurations that will be achievable within the Heidelberg Quantum Architecture and find applications in quantum technologies.

Q 25.61 Tue 14:00 Tent

**Deterministic Generation of Localized Spin Excitations in a Spin-1 BEC** — Yannick Deller, •Alexander Schmutz, Raphael Schäfer, Alexander Flamm, Helmut Strobel, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Deutschland

We present the experimental techniques to reliably generate localized spin excitations in a quasi one-dimensional ferromagnetic spin-1 BEC. We utilize a steerable laser at the tuneout-wavelength for $^{87}$Rb in order to locally induce an effective magnetic offset field which can be controlled on the $\mu$m scale. Localized transitions between hyperfine states are implemented by amplitude modulation of the laser beam at the transition frequency [1].
To characterize the resulting spin excitations, we track their time evolution in all relevant observables by employing a generalized POVM readout scheme [2].
We investigate their properties such as lifetime and propagation speed in different parameter regimes and compare with numerical simulations and analytical models to investigate for a topological classification of the excitations.

1 Lannig et. al., PRL 125, 170401 (2020)
2 Kunkel et. al., PRL 123, 063603 (2019)

Q 25.62 Tue 14:00 Tent

**Heidelberg Quantum Architecture - Fast and modular quantum simulation** — •Finn Lubenau, Maximilian Kaiser, Daniel Dux, Tobias Hammel, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Heidelberg, Germany

We are presenting our Heidelberg Quantum Architecture, a quantum gas platform that combines individual modules to implement a large variety of functionalities, that can be quickly updated and exchanged.

Currently, the core modules consist of a cold atom source that allows for very fast cycle time, dipole traps and optical tweezers, high fidelity single atom and spin resolved imaging, confinement to a 2D plane using an optical accordion. Here we will present progress on implementing a spatial light modulator (SLM) module to create tunable light fields in a precise and reproducible way, including the ability to correct for optical aberrations.

Q 25.63 Tue 14:00 Tent

**ORKA - Towards a Cavity Enhanced All Optical Rb87 BEC Source for Atom Interferometry 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 atoms and generate Bose-Einstein-condensates (BEC). This usually comes at the price of an increased power budget for the trapping lasers. For setups that require energy efficiency, e.g. in space, magnetic chip traps are thus often preferred. However, these also come with their own 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 1064nm optical dipole trap for Rb87 to mitigate the power needs for all optical evaporative cooling. We are working on employing a bow-tie cavity for evaporative cooling down to a BEC to then be used as a matterwave source for interferometry in free-fall experiments at the Gravitower Bremen facility. Here we present our design and current progress of the experiment as well as first tests of the resonator. 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.

Q 25.64 Tue 14:00 Tent

**Ground Support for the BECCAL Laser System for Cold Atom Experiments onboard the ISS** — •Hamish Beck[1], Hrudya Thaivalappil Sunilkumar[1], Marc Kitzmann[1], Matthias Schoch[1], Christoph Weise[1], Bastian Leykauf[1], Evgeny Kovalchuk[1], Jakob Pohl[1], Achim Peters[1], and the BECCAL Collaboration[1,2,3,4,5,6,7,8,9,10] — [1]HUB, Berlin — [2]FBH, Berlin — [3]JGU, Mainz — [4]LUH, Hanover — [5]DLR-SI, Hanover — [6]DLR-QT, Ulm — [7]UULM, Ulm — [8]ZARM, Bremen — [9]DLR, Bremen — [10]DLR-SC, Braunschweig

The Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) is designed for operation onboard the International Space Station (ISS). This multi-user facility will enable experiments with K and Rb ultra-cold atoms and BECs in mircogravity. Fundamental physics will be explored at longer time- and lower energy-scales compared to those achieved on earth.

The BECCAL laser system is comprised of micro-integrated diode lasers, miniaturized free-space optics on Zerodur boards, and a system of fibres to bring light to the physics package. The design is subject to strict size, weight, and power (SWaP) constraints, and the operation of the system is supported by extensive ground-based systems.

The ground-based systems built for validation and testing will be presented alongside the design of the flight model.

This work is supported by the DLR with funds provided by the BMWK under grant number 50WP2102.

Q 25.65 Tue 14:00 Tent

**Kármán vortex streets in a dissipative superfluid** — •Georg Trautmann[1], Gregor Bals[2,3], Thomas Gasenzer[1,2,3], Carlo Ewerz[2,3], and Davide Proment[3,4,5] — [1]Kirchhoff-Institut für Physik, Uni Heidelberg — [2]Institut für Theoretische Physik, Uni Heidelberg — [3]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung — [4]School of Engineering, Mathematics and Physics, University of East Anglia, Norwich Research Park — [5]Centre for Photonics and Quantum Science, University of East Anglia

Moving an obstacle potential in a two-dimensional Bose-Einstein condensate can lead, depending on the potential's size and velocity, to different phases of vortex shedding. Of particular interest is the formation of a long-lived alternating series of vortex pairs with the same winding number, similar to the Bérnard-von Kármán vortex street known from classical fluid dynamics. Furthermore, simulating the vortex dynamics in a dissipative framework allows one to compare observations to a holographic superfluid where the strongly correlated quantum system is modeled through a higher-dimensional, weakly coupled gravitational theory. Recent literature has already shown successfully that the trajectories of simple vortex configurations simulated by dissipative Gross-Pitaevskii equations can be matched to the holographic analog. On the experimental side, the strongly dissipative quantum fluid can also describe liquid helium close to the lambda-transition qualitatively. Additionally, strong dissipation gives rise to further phases of vortex shedding that are not present in the non-dissipative condensate.