Q 24: Poster II

Time: Tuesday 17:00–19:00 Location: KG I Foyer

Q 24.1 Tue 17:00 KG I Foyer

Spectroscopy of Heteronuclear Xenon-Noble Gas Dimers - Towards Bose-Einstein Condensation of VUV-Photons — •Eric Boltersdorf, Thilo vom Hövel, Jeremy Andrew Morín Nenoff, Frank Vewinger, and Martin Weitz — University of Bonn, Institute for Applied Physics, 53115 Bonn

Photons confined in a dye-filled optical microcavity can exhibit Bose-Einstein condensation upon thermalization through repeated absorption and (re-)emission processes by the dye molecules. This has been experimentally demonstrated for photons in the visible spectral regime in 2010. In this work, an experimental approach is investigated to realize Bose-Einstein condensation of vacuum-ultraviolet (100 nm-200 nm; *VUV*) photons via repeated absorption and (re-)emission cycles between two electronic state manifolds of xenon-noble gas excimer molecules in dense gaseous ensembles (pressure of up to 100 bar).

(Re-)emission and absorption to achieve thermalization are considered to occur between the quasi-molecular states associated with the xenon $5p^6$ and $5p^5 6s(J=1)$ states, respectively. We plan to pump the photon gas inside a high-pressure optical microcavity with light at near 129 nm wavelength, which can be generated by third-harmonic generation of near-ultraviolet light around 387 nm. The pump drives the $5p^6 \rightarrow 5p^5 6s'(J=1)$ transition in xenon. We report on the results of spectroscopic measurements, indicating the formation of heteronuclear noble gas excimers. Also, the fulfillment of the thermodynamic Kennard-Stepanov relation, a fundamental prerequisite for a gas to serve as a thermalization medium, has been successfully investigated.

Q 24.2 Tue 17:00 KG I Foyer

Realization of Effective Interactions in Bose-Einstein Condensates of Photons — •Niels Wolf, Andreas Redmann, Christian Kurtscheid, Frank Vewinger, Julian Schmitt, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn, Germany

Bose-Einstein condensation can be observed with ultracold atomic gases, polaritons, and since about a decade ago also with low-dimensional photon gases. In atomic Bose-Einstein condensates thermal equilibrium is obtained by inter-particle collisions. Since photon-photon interactions remain vanishingly small in the experimental cavity system, thermalization of photons is achieved via thermal contact of the photons with molecules in liquid solution filled into a microcavity [1]. Nevertheless, via strong photon-photon interaction, i.e. a Kerr-interaction, lattices of photon gases could in future enable the creation of highly entangled resource states for multiple partner quantum connectivity [2].

Our experiment uses a triply resonant optical parametric oscillator setup, which independently controls cavities for the pump and subharmonic wavelength respectively. In this way, a Kerr-nonlinearity originating from cascaded second order nonlinearities to subharmonics of the incident optical radiation has been experimentally demonstrated.

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

Q 24.3 Tue 17:00 KG I Foyer

Dimensional Crossover in a Quantum Gas of Light — •Kirankumar Karkihalli Umesh[1], Julian Schulz[2], Julian Schmitt[1], Martin Weitz[1], Georg von Freymann[2,3], and Frank Vewinger[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [2]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern Landau, 67663 Kaiserslautern, Germany — [3]Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany

We experimentally study the properties of a harmonically trapped photon gas undergoing Bose-Einstein condensation along the dimensional crossover from one to two dimensions. The photons are trapped inside a dye microcavity, where polymer nanostructures provide a harmonic trapping potential for the photon gas. By varying the aspect ratio of the trap we tune from an isotropic two-dimensional confinement to an anisotropic, highly elongated one-dimensional trapping potential. Along this transition, we determine caloric properties of the photon gas, and find a softening of the second-order Bose-Einstein condensation phase transition observed in two dimensions to a crossover behaviour in one dimension.

Q 24.4 Tue 17:00 KG I Foyer

Observation of topological edge states of photons by controlled coupling to the environment — •Nikolas Longen[1], Helene Wetter[2], Michael Fleischhauer[3], Stefan Linden[2], and Julian Schmitt[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany — [2]Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany — [3]Fachbereich Physik, RPTU Kaiserslautern-Landau, Erwin-Schrödinger Str. 46, 67663 Kaiserslautern, Germany

Topology is an important paradigm for our understanding of phases of matter in condensed matter, cold atoms and photonic systems. Here we present a new approach to realize topological states, which result from coupling the system to an environment. In a proof-of-principle study, we first eperimentally demonstrate open-system topological states using a plasmon-polariton waveguide plattform. The underlying, *a priori* topologically trivial lattice consists of a unit cell of four lattice sites which is equipped with spatially varied losses leading to a topological band structure. By tuning the hopping and the dissipation in the waveguide system, we observe both the emergence and the breakdown of a localized topological edge state. Moreoever, we present ongoing work, in which we develop an experimental platform to study non-Hermitian topological states in lattices of photon Bose-Einstein condensates within a dye-filled optical microcavity. The coupling to the reservoir of dye molecules here allows for gain, thermalization and tunable coherence properties of the photons, opening new pathways for the exploration of topological states in open systems.

Q 24.5 Tue 17:00 KG I Foyer

Collective oscillation modes of dipolar quantum droplets — •Denis Mujo and Antun Balaž — Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia

Since the first experimental realization of quantum droplets in dipolar Bose systems [1], it was shown [2] that they are stabilized against the collapse due to quantum fluctuations that correspond to the shift of the chemical potential [3]. We examine the behavior of collective oscillation modes of self-bound dipolar quantum droplets using a variational and numerical approach. We focus on cylindrically symmetric states and variationally derive frequencies and eigenvectors of low-lying collective modes, i.e., the breathing and the quadrupole mode. The obtained results are compared to full 3D numerical simulations based on the extended Gross-Pitaevskii equation, which includes both the quantum fluctuation and condensate depletion terms.

[1] H. Kadau et al., Nature **530**, 194 (2016).
[2] I. Ferrier-Barbut et al., Phys. Rev. Lett. **116**, 215301 (2016).
[3] A. R. P. Lima and A. Pelster, Phys. Rev. A **84**, 041604(R) (2011); Phys. Rev. A **86**, 063609 (2012).

Q 24.6 Tue 17:00 KG I Foyer

String Theory Applied: The Holographic Superfluid in One Spatial Dimension — •Florian Schmitt[1], Gregor Bals[2], Andreas Samberg[2,3], Carlo Ewerz[2,3], and Thomas Gasenzer[2,1] — [1]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [3]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt

This contribution is concerned with the investigation of non-equilibrium dynamics of superfluids in one spatial dimension enabled by the holographic description in terms of field theory in higher-dimensional black-hole-anti-de-Sitter spacetimes. We perform numerical solutions, applying the famous AdS/CFT duality of string and large-N field theory in a bottom-up fashion. Following the principles of holography this leads us to a way of calculating dynamics matched to the standard Gross-Pitaevskii-equation (GPE) based methods. The one-dimensional holographic superfluid is of peculiar fashion due to the renormalization needed on the boundary, which is due to the Weyl anomaly on the boundary not only consisting of the expected central charge. Of particular interest to us are topological defects, therefore we imprint solutions to the GPE, such as solitons, onto the superfluid and investigate how they evolve.

Q 24.7 Tue 17:00 KG I Foyer

Ultracold Quantum Gases in Spatially and Temporally Engineered Environments — •Erik Bernhart, Marvin Röhrle, Marco Decker, Jian Jiang, and Herwig Ott — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Ultracold quantum gas experiments combined with high resolution and highly controllable optical techniques offer a unique platform to study quantum phenomena in driven quantum systems. Here, we report on the experimental realization of a Kapitza trap for ultracold 87Rb atoms, where the dynamical stabilization of the atomic motion by a time periodically modulated potential is demonstrated. While the time average of the potential vanishes, the corresponding Floquet-Hamiltonian results in a non-trivial effective time independent potential, which acts as a trap for the atoms.

To continue the investigations on driven systems and extend them to transport processes in time modulated optical potentials, we have upgraded our setup, which now combines a scanning electron microscope and a high resolution optical objective, through which we can imprint arbitrary repulsive potential landscapes, generated by an AOD. We have implemented a weakly coupled bosonic Josephson junction, with tunable and movable tunneling barrier and benchmark our system by observing the DC Josephson effect.

Q 24.8 Tue 17:00 KG I Foyer

Anomalous non-thermal fixed point in a quasi-2d dipolar Bose gas — •Niklas Rasch[1], Santo Maria Roccuzzo[1,2], 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 226 — [3]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16

In this work we focus on anomalous non-thermal fixed-points in the temporal evolution of a 2d dipolar Bose gas, exhibiting slow, subdiffusive coarsening characterized by algebraic growth of a characteristic length scale $L(t) \sim t^{\beta}$ with $\beta \ll 1/2$. Starting from variously sampled vortices on a uniform background, we evolve the Bose gas using the semi-classical truncated-Wigner approach. In the classical regime we reproduce the anomalous scaling exponent $\beta \simeq 1/5$ known from the single-component Bose gas with contact interactions, for various dipolar strengths and tilting angles. In the quantum regime we also recover such anomalously slow, subdiffusive scaling but find a dependence on the tilting angle, which leads to different scaling exponents and less stable scaling regimes. Within a quasi-2d setting, we analyze the dependence of the observed scaling exponents on the effects of anisotropy and on the long-range nature of the dipolar interaction. Anisotropy in the vortex configuration emerges; however, it is not reflected in the self-similar scaling. We focus on the role of vortex (anti-)clustering and observe regimes of strong clustering without correlation with the emergence of anomalously slow scaling.

Q 24.9 Tue 17:00 KG I Foyer

A new dysprosium quantum gas experiment — •Lucas Lavoine[1], Jens Hertkorn[1], Paul Uerlings[1], Kevin Ng[1], Fiona Hellstern[1], Tim Langen[1,2], Ralf Klemt[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart — [2]Atominstitut, TU Wien

Dysprosium offers the possibility to study degenerate quantum gases with anisotropic and long-range dipolar interactions competing with contact interactions. Tuning the relative interaction strength has led to the observation of new many-body states, including droplets and supersolids. While most of the experiment have been done in one-dimensional traps, recent theoretical works predict an exotic phase diagram in two-dimensional traps (2D), including honeycomb, labyrinthine, supersolid phases. The labyrinthine patterns are characterized by amorphous spatial structures consisting of elongated and bent density stripes and support superfluid flows along the stripes. We have recently built up a new dysprosium machine. With our new setup, we produce large Bose-Einstein condensates (BEC) with faster cycle times. By means of a high-NA (0.5) objective and a phase-contrast imaging technique, we are able to resolve spatial structures of about 0.5 micrometers. We plan to load the BEC in tailored potentials made by a digital micro-mirror device (DMD) with the aim to explore both the phase diagram of a 2D dipolar quantum gas and study the superfluid properties of the supersolid states by means of persistent currents in rotating ring-shaped potentials. On this poster we present the new experimental setup and report our recent experimental achievements.

Q 24.10 Tue 17:00 KG I Foyer

Resummations of the two-particle irreducible quantum effective action — •Hannes Köper[1] and Thomas Gasenzer[1,2] — [1]Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg

The two-particle irreducible quantum effective action can be formulated in terms of the Luttinger-Ward functional, which is diagrammatically given by the series of all two-particle irreducible vacuum Feynman diagrams. In this work, we reformulate infinite series of vacuum Feynman diagrams for scalar quantum field theories, whose potentials admit discrete frequency spectra such as the sine-Gordon model, in terms of spin systems on graphs. While the frequencies of the potential directly correspond to the possible spin values, the graph's topology is tightly connected to the class of vacuum diagrams that is being summed over. Different graph topologies thus correspond to different selective resummations of diagrams. In particular, cycle graphs correspond to "ring"-type resummations often encountered in next-to-leading order in $1/N$ expansions. This allows us to compute a closed form expression for the Luttinger-Ward functional within "ring-approximation" in terms of the eigenvalues of an associated transfer operator. We also present how the formalism may be applied to polynomial and $O(N)$-symmetric potentials.

Q 24.11 Tue 17:00 KG I Foyer

Optical quantum gases in box and ring potentials — •Patrick Gertz, Leon Espert Miranda, Andreas Redmann, Kirankumar Karkihalli Umesh, Frank Vewinger, Martin Weitz, and Julian Schmitt — Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany

Quantum gases provide exquisite experimental control over dimensionality, shape of the energy landscape or the coupling to reservoirs, which opens the door to investigate novel states of matter both in and out of equilibrium. Here we report on the experimental realization of a quantum gas of photons inside box and ring-shaped potentials within a dye-filled optical microcavity. The trapping potential for the particles is provided by imprinting static nanostructures on the cavity mirror surface using a laser-induced delamination of the mirror coating. In a corresponding box-shaped cavity geometry, we have realized a 2D optical quantum gas at room temperature with uniform density and measured its compressibility and equation of state. In more recent work, we have achieved the quasi-1D, periodically closed confinement of photon gases in ring potentials. Prospects of this work include studies of the Kibble-Zurek mechanism and of flux qubits.

Q 24.12 Tue 17:00 KG I Foyer

Low-Energy Effective Field Theory for a Spin-1 BEC Far From Equilibrium — •Anna-Maria Elisabeth Glück, Ido Siovitz, Hannes Köper, and Thomas Gasenzer — Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

The spin-1 Bose gas quenched far from equilibrium displays remarkable universal spatio-temporal self-similar scaling, which we hypothesize to be due to the system's vicinity to a non-thermal fixed point during its evolution back to equilibrium. This study introduces a low-energy effective field theory for the description of the phase-excitation dynamics in a one-dimensional spin-1 Bose gas following a quench from the polar to the easy-plane phase. In particular, we explore the incorporation of density fluctuations beyond the 1-loop order. Through numerical simulations, we subsequently compare the far-from-equilibrium scaling behavior of the effective theory to that of the fundamental theory.

Q 24.13 Tue 17:00 KG I Foyer

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 226 — [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 LHY corrections give rise to supersolidity, superglasses, and exotic states of matter. Different supersolid ground states, such as triangular, honeycomb, or even labyrinthine ones, were already theoretically predicted, depending on the atom number, scattering length, and trapping frequency. 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, including those exhibiting novel crystalline structures. We further search for far-from-equilibrium phenomena, e.g., non-thermal fixed points, self-similar scaling, and the spontaneous formation of vortices in the pattern-forming regime. At the moment, quenches into the triangular and stripe phases have proven to be successful and promise insights into new physics, where time oscillations akin to a quadrupole mode of the droplets have been observed.

Q 24.14 Tue 17:00 KG I Foyer

Dynamical phases emerging from light-mediated interaction — •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.

We are experimentally exploring the light-matter interaction of a Bose-Einstein condensate (BEC) with a single light mode of an ultra-high finesse optical cavity. The key feature of our cavity is the very small field decay rate ($\kappa/2\pi = 3.5$ kHz), which is in the order of the recoil frequency ($\omega_{rec}/2\pi = 3.6$ kHz). This leads to a unique situation of a recoil-resolved cavity. Pumping the system with a steady state light field, red detuned with respect to the atomic resonance, the Dicke model is implemented including the self-organisation phase transition. Starting in the self-ordered superradiant phase and modulating the amplitude of the pump field, we observe a dissipative discrete time crystal, whose signature is a robust subharmonic oscillation between two symmetry-broken states. Modulation of the phase of the pump field gives rise to an incommensurate time crystalline behaviour. For a blue-detuned pump light with respect to the atomic resonance, we observe limit cycles (LCs). Since the pump protocol is time-independent, the emergence of LCs demonstrates the breaking of continuous time-translation symmetry.

Q 24.15 Tue 17:00 KG I Foyer

A Digital Micromirror Device setup and feedback algorithm for enhanced control of two-dimensional potentials in cold atoms experiments — •Marcel Kern, Marius Sparn, Nikolas Liebster, Elinor Kath, Jelte Duchêne, Helmut Strobel, and Markus Oberthaler — Kirchhoff-Institut für Physik, Heidelberg, Deutschland

Spatial light modulators are widely used in ultracold atom experiments to produce arbitrary optical traps. A seemingly simple, but important example is the box potential. Also, for dynamic processes, such as the injection of vortices, more complicated, time-dependent potentials are needed. However, imperfections in the incident light and projection system perturbs the expected potential, requiring finer control of the light potential along with active correction.

In our two-dimensional Bose-Einstein condensate (BEC) experiment of 39-K atoms, a Digital Micromirror Device (DMD) illuminated with off-resonant light is used to configure the in-plane potential. A second DMD that uses near-resonant light will allow manipulations on different energy scales to optimize the existing potential and manipulate the BEC locally. Additionally, feedback algorithms optimizing on light and atom distributions will further increase the quality of the created light potentials. We present the planning and characterization of a second DMD setup, as well as the optimization algorithms developed for our experiment.

Q 24.16 Tue 17:00 KG I Foyer

Time evolution in the Bose-Hubbard model using Matrix Product States — •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

The dynamical evolution of out of equilibrium configurations in the Bose-Hubbard model is studied using Matrix Product States and Time-Evolving Block Decimation (TEBD). The goodness of the method is benchmarked against the exact dynamics implemented via an expansion of the time-evolution operator using Chebyshev polynomials for 'small' systems. We determine the optimal truncation value of the on-site modes' occupation number as a function of the interaction strength in order to capture faithfully the short time evolution across the chaotic phase using TEBD. Considering systems at unit density, sizes $L \gtrsim 40$, and times $t \lesssim 3$ (tunneling times) we analyse the fingerprint of the emergence of the chaotic phase from the potentially diffusive spreading of density-density correlations at early times.

Q 24.17 Tue 17:00 KG I Foyer

A new experimental platform to explore dipolar quantum phenomena in ultracold gases of magnetic atoms — Shuwei Jin, Jianshun Gao, Karthik Chandrashekara, Christian Gölzhäuser, Sarah Philips, Joschka Schöner, and •Lauriane Chomaz — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226

Ultracold quantum gases of highly magnetic atoms, such as dysprosium (Dy), have opened new avenues for the study of quantum phenomena. In particular, they bring into play the competition of anisotropic long-range dipole-dipole interactions, tunable short-range contact interactions, geometry, mean-field and beyond-mean-field effects. Mastering these competitions has led to the discovery of novel many-body quantum states in recent years, including liquid-like droplets, droplet crystals, and supersolids.

With my new group at the University of Heidelberg, we have designed and implemented a novel compact setup in which we have successfully produced large quantum degenerate gases of bosonic Dy atoms, achieved fine control of the dipolar and contact interactions, and are currently mastering their imaging with submicron resolution. We plan to load these quantum degenerate gases into tailorable traps that cross from 3D to 2D and have versatile in-plane potentials. Here I will present the design and implementation of our novel experimental setup, report on our recent achievements, and discuss prospective investigations we plan to undertake both in and out of equilibrium.

Q 24.18 Tue 17:00 KG I Foyer

Curved and Expanding Spacetimes studied with a Quantum Field Simulator — Celia Viermann[1], Marius Sparn[1], Nikolas Liebster[1], Maurus Hans[1], •Elinor Kath[1], Álvaro Parra-López[3], Mireia Tolosa-Simeón[4], Natalia Sánchez-Kuntz[5], Tobias Haas[6], Christian Schmidt[2], Helmut Strobel[1], Stefan Floerchinger[2], and Markus K. Oberthaler[1] — [1]KIP, Uni Heidelberg, Germany — [2]ITP, Uni Jena, Germany — [3]DFT, Uni Madrid, Spain — [4]LTPIII, Ruhr-Uni Bochum, Germany — [5]ITP, Uni Heidelberg, Germany — [6]CQIC, Uni libre de Bruxelles, Belgium

In most cosmological models, a rapid expansion of space in the early history of our universe is responsible for the creation of first structures. As the description of the involved processes is a theoretical challenge, quantum field simulators have proven to be valuable tools that offer an experimental approach to complex dynamics. We present such an experimental platform, based on a two-dimensional BEC, in which the phononic field simulates the evolution of a free, massless, scalar field in an FLRW spacetime. Positive and negative spatial curvatures can be implemented through specific atomic density distributions and can be made visible by observing the propagation of wave packets. An expanding spacetime can be simulated by decreasing the interatomic interactions. These expansions give rise to phononic excitations in a process analogue to cosmological particle production. We show that a statistical analysis of the resulting density fluctuation allows to differentiate between different expansion histories, which can be understood by mapping the process onto a stationary Schrödinger equation.

Q 24.19 Tue 17:00 KG I Foyer

Spin- and momentum-correlated atom pairs mediated by photon exchange and seeded by vacuum fluctuations — •Rodrigo Rosa-Medina, Fabian Finger, Nicola Reiter, Jacob Fricke, Panagiotis Christodoulou, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland

Engineering pairs of massive particles that are simultaneously correlated in their external and internal degrees of freedom is a major challenge, yet essential for advancing fundamental tests of physics and quantum technologies. Experiments with ultracold atoms provide a versatile platform for manipulating and detecting such correlations at a microscopic level.

In our experiment, we couple a spinor Bose-Einstein condensate of

Rb-87 atoms to a high-finesse optical cavity. By leveraging the strong light-matter interactions, we engineer correlated pairs of atoms both in their internal (spin) and external (momentum) degrees of freedom through the exchange of virtual cavity photons. The measured pair statistics are compatible with pair production being seeded by vacuum fluctuations in the corresponding atomic modes. We observe a collectively enhanced formation of atom pairs and demonstrate their correlated nature by probing momentum-space noise correlations. Furthermore, we optically control the interplay between unitary and competing dissipative processes, and observe coherent pair oscillations. Our findings provide prospects for quantum-enhanced matterwave interferometry and quantum simulation experiments with correlated atoms.

Q 24.20 Tue 17:00 KG I Foyer

Polarons and bi-polarons in strongly interacting 1D Bose gases — •Dennis Breu, Martin Will, and Michael Fleischhauer — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

We investigate the ground state, the dynamics and effective interactions of quantum impurities immersed in an interacting 1D Bose gas utilising Tensor Network simulations. The algorithm allows us to theoretically probe Bose polarons in the regime of strong interactions in the Bose gas for the full range of Tonks parameters γ. We calculate the polaron binding energy as well as Born-Oppenheimer polaron interaction potentials and bi-polaron bound states and compare them to analytical predictions in the weak and strong coupling regimes. Furthermore we investigate the dynamics of a single finite mass impurity inside a finite size 1D Bose gas. Here we find a crossover to a localised impurity at the edges of the system instead of one that is spread over the whole system. Finally by making use of time-evolving block decimation (TEBD) we study the dynamics of impurities accelerated by a constant force inside a strong interacting 1D Bose gas and find oscillations reminiscent of Bloch oscillations.

Q 24.21 Tue 17:00 KG I Foyer

Spinor Bose-Einstein condensate as Platform for Studying Extreme Wave Events — Yannick Deller, Ido Siovitz, •Alexander Schmutz, Felix Klein, Helmut Strobel, Thomas Gasenzer, and Markus K. Oberthaler — Kirchhoff Institut for Physics, Ruprecht-Karls-University Heidelberg

Many-body systems far from equilibrium can exhibit self-similar dynamics characterized by universal exponents. Studies of the 1D spinor Bose gas have shown [1], that the value of these exponents is connected with the occurrence of extreme wave excitations in the mutually coupled magnetic components. Numerical simulations showed that real-time instanton defects appear as a result of the caustics, manifesting as spin-1 vortices in space-time. To characterize these experimentally, we employ local spin-dependent phase imprints. We investigate the resulting deterministic excitations and their connections to real-time instantons.

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

Q 24.22 Tue 17:00 KG I Foyer

The Quantum Gas Magnifier as a Coherence Microscope — •Mathis Fischer, Justus Brüggenjürgen, 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, the novel technique of quantum gas magnification opens the way to explore 3D systems with large occupation numbers with sub-lattice site resolution.

We report on the realization of an all-optical quantum gas magnifier for ultracold Lithium-7 atoms. The all-optical approach allows us to address the broad Feshbach resonance of Lithium to control the interaction strength. With this technique, we directly image the Talbot carpet that forms when releasing the atoms from an optical lattice. After certain ballistic expansion times, the wave packets originating from each lattice site overlap and constructively interfere with each other, such that an image of the original density distribution is obtained. We map out the spatial coherence by analyzing the contrast of consecutive Talbot copies. The technique should also allow to reconstruct the fluctuating phase profile of individual samples imaged at a single Talbot copy. This will realize a coherence microscope with spatially resolved access to phase information allowing to study domain walls, thermally activated vortex pairs, or to locally evaluate coherence in inhomogeneous quantum many-body systems.

Q 24.23 Tue 17:00 KG I Foyer

The smallest possible heat engine — James Anglin and •Viviane Bauer — Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany

Microscopic engines are a research focus in both biochemistry and nanotechnology. While other forms of engines besides heat engines are also being considered, the fully microscopic limit of a heat engine is a fundamentally important problem in physics. What happens to thermodynamics when not only the working fluid and mechanism of a heat engine are microscopic, but even the hot and cold reservoirs are? We have found a theoretical model for such fully microscopic heat engines in the form of two coupled three-mode Bose-Hubbard systems (two trimers). Such subsystems can equilibrate in chaotic ergodization. If coupled together they exhibit energy and particle transport: the processes, which heat engines exploit to perform work. We can also couple a weight to the Bose-Hubbard system, in a way which uses this transport to lift the weight. Moreover we have identified a dynamic mechanism which can stabilise this lifting process. The result is a system which operates just like a heat engine, except for being fully microscopic. The structure of coupled chaotic subsystems both supports and requires an understanding of the fully microscopic heat engine in terms of open-system control.

Q 24.24 Tue 17:00 KG I Foyer

Heidelberg Quantum Architecture: Highly controlled light potentials in a 2D Fermi gas — •Johanna Schulz, Juan Carlos Provencio Lameiras, Suraj Iyer, Tobias Hammel, Maximilian Kaiser, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut - Heidelberg University, Heidelberg, Germany

Heidelberg Quantum Architecture (HQA) is a new ^{6}Li quantum gas experiment providing a fast, versatile, and expandable experimental platform for programmable quantum simulation. In this poster we present two optical modules that allow for creating various potentials, an accordion lattice and a Digital Micromirror Device.

A lot of interesting physics arises in lower-dimensional systems and in the crossover between dimensions. Going to 2D can be conducted using an optical accordion that creates an interference pattern with tuneable lattice spacing between 1.2μm and 15μm. That way, we can create quickly varying potentials, allowing for optimized loading and wide control of the 2D system. This we realize in a highly compactified optical module increasing stability and enhancing maintainability.

To generate nicely controllable light potentials, one can use, among other devices, a digital micromirror device (DMD). We present an exceptionally compact setup to create arbitrary potentials. One physical system that we want to simulate is a box potential in a scale of up to 200μm and as small as 50μm to confine the atoms.

Q 24.25 Tue 17:00 KG I Foyer

Signatures of Anderson localization in a degenerate Fermi gas beyond exponential density distributions — •Sian Barbosa, Maximilian Kiefer-Emmanouilidis, Felix Lang, Jennifer Koch, and Artur Widera — Department of Physics and Research Center OPTIMAS, RPTU, Kaiserslautern, Germany

Disorder can fundamentally modify the transport properties of a system. A striking example is Anderson localization, suppressing transport due to destructive interference of propagation paths. Especially in inhomogeneous many-body systems, not all particles will localize for finite-strength disorder, and the system can become partially diffusive. Even for extended, i.e. non-localized states, exponential tails can develop after purely diffusive transport and falsely simulate localization, especially when the diffusion coefficient becomes energy dependent. I will present the results of our experimental investigation of a degenerate, spin-polarized Fermi gas released into a disorder potential formed by an optical speckle pattern. Using standard observables, such as diffusion exponent and coefficient, localized fraction, or localization length, we find that some show signatures for a transition to localization above a critical disorder strength, while others show a smooth crossover to a modified diffusion regime. In laterally displaced disorder, we spatially resolve different transport regimes simultaneously which allows us to extract the subdiffusion exponent expected for weak localization. Our work suggests alternative measures to the misleading concept of exponential tails.

Q 24.26 Tue 17:00 KG I Foyer

Fermi accelerating an Anderson-localized Fermi gas to superdiffusion — Sian Barbosa, Maximilian Kiefer-Emmanouilidis, •Felix Lang, Jennifer Koch, and Artur Widera

— Department of Physics and Research Center OPTIMAS, RPTU, 67663 Kaiserslautern, Germany

Disorder can have dramatic impact on the transport properties of quantum systems. Anderson localization, arising from destructive quantum interference of multiple scattering paths suppresses the transport entirely. Processes involving time-dependent random forces such as Fermi acceleration, proposed as a mechanism for high-energy cosmic particles, can expedite particle transport significantly. The competition of these two effects in time-dependent inhomogeneous or disordered potentials can give rise to fascinating dynamics. Experimental observations are paramount, although scarce. Here, I present our experimental study of the dynamics of an ultracold, non-interacting Fermi gas expanding inside a disorder potential with finite spatial and temporal correlations. Depending on the disorder's strength and rate of change, we observe several distinct regimes of tunable anomalous diffusion, ranging from weak localization and subdiffusion to superdiffusion. Especially for strong disorder, where the expansion reveals effects of localization, an intermediate regime is present in which quantum interference appears to counteract acceleration. Our system connects the phenomena of Anderson localization with second-order Fermi acceleration and paves the way toward experimentally investigating Fermi acceleration when entering the regime of quantum transport.

Q 24.27 Tue 17:00 KG I Foyer

Rapid Fermionic Quantum Simulation for Random Unitary Observables — •Marcus Culemann[1,2], Daniel Dux[1], Xinyi Huang[1,2], Jonas Kruip[1,3], Naman Jain[1], Jin Zhang[1], and Philipp Preiss[1,4] — [1]Max Planck Institute of Quantum Optics, Garching — [2]Ludwig-Maximilians-Universität, Munich — [3]ETH Zurich — [4]Munich Center for Quantum Science and Technology

Ultracold atoms in optical lattices provide an experimental platform to perform controlled single-particle operations in many-body systems. The UniRand experiment aims to leverage this control to study physics at the interface between condensed matter physics and quantum information science. One exciting avenue towards this goal are measurements in random bases using so-called random unitary protocols. They are predicted to give access to global density matrix properties and provide a general way of characterizing many-body systems in and out of equilibrium. We report on the progress of building a fermionic quantum simulator capable of realizing random unitaries with high repetition rates and a high-fidelity readout process. At present, the experiment demonstrates the use of 2D-MOT as a cold atom source, capable of loading with high rates into the 3D-MOT, and atom counting capability with single atom resolution. The envisaged system combines evaporative cooling in optical tweezer arrays followed by quantum state assembly in a tunable optical lattice. The readout process aims to reach single site resolution by using matter wave magnification and spin-resolved free-space imaging. The poster will summarize the current status and future prospects of the experiment.

Q 24.28 Tue 17:00 KG I Foyer

Identification of Quantum Phases with Unsupervised Machine Learning — •Niklas Käming[1,3], Paolo Stornati[2], Klaus Sengstock[1,3,4], and Christof Weitenberg[1,3,4] — [1]IQP - Institut für Quantenphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]ICFO - Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona), Spain — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [4]ZOQ - Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Machine learning techniques are a versatile tool to identify many-body quantum states without knowledge of the order parameters. Using such techniques to identify phases of matter has gained high popularity in many-body physics and the cold quantum gas community. In this poster, we present unsupervised machine-learning techniques that have been proven to be universally successful in mapping out the extended Fermi-Hubbard model from simulated entanglement spectra and the Haldane model from experimental cold quantum gas data. In the future, we hope to find new phases of matter by performing experiments in theoretical non-tractable regimes.

Q 24.29 Tue 17:00 KG I Foyer

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

Ultracold Fermions cannot be cooled below about 10% of the Fermi temperature with conventional methods. 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 construction and implementation of first cooling stages of a two species apparatus for the optimized symp. cooling of fermionic Li with bosonic Er. This mixture has several promising features, that have not yet been utilized for symp. cooling in any other mixture. Pushing the temperature limit is essential for the quantum simulation of strongly correlated phenomena, in particular in optical lattice.

Q 24.30 Tue 17:00 KG I Foyer

Heidelberg Quantum Architecture: Fast spin manipulation and magnetic field stabilization in a Fermi gas — Johanna Schulz, •Suraj Iyer, Juan Carlos Provencio Lameiras, Tobias Hammel, Maximilian Kaiser, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut - Heidelberg University, Heidelberg, Germany

Heidelberg Quantum Architecture (HQA) is a new ^{6}Li quantum gas experiment providing a fast, versatile, and expandable experimental platform for programmable quantum simulation. This poster presents techniques for spin manipulation and stabilization of magnetic fields generated by our Feshbach coils.

To prepare a deterministically controlled mixture of spin states, we drive Rabi oscillations between hyperfine states of the $2S_{1/2}$ ground state. We build radiofrequency and microwave coils that are mounted outside the science glass cell, to keep the components exchangeable, hence providing high magnetic fields at the position of the atoms. We are aiming for magnetic fields and Rabi oscillations in the order of 100kHz, which is about ten times faster than other machines in our group.

In the HQA high-fidelity control of interactions is realized by stabilizing the magnetic bias fields generated by the Feshbach coils. Fluctuations are mitigated by using a PID loop which measures the coil current through current transducers (CT). By using multiple CTs, we can achieve precise tunability of individual field parameters which includes the field offset, the field gradient, and the field curvature.

Q 24.31 Tue 17:00 KG I Foyer

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.

Q 24.32 Tue 17:00 KG I Foyer

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

Fermionic quantum systems, adjustable in atom numbers, are our tool to explore emergent many-body phenomena. Our experimental setup allows the deterministic preparation of 6Li atoms in the ground state of a two-dimensional harmonic potential.

We use matter wave magnification techniques to measure individual atoms' positions or momenta. Previous experiments unveiled phase transitions [1] and Cooper pairs [2].

In our experiments we observe elliptic flow in systems as small as 10 particles, challenging the traditional understanding of hydrodynamics [3]. Presently, we're focused on exploring the transition from a two-particle bound state to the many-body Cooper pairs using our ability to access real space correlations.

Future objectives include extracting the contact parameter, studying open shell configurations akin to nuclear physics, and observing interference among identical few-body systems.

[1]Bayha et al. Nature 587 (2020)
[2]Holten et al. Nature 606 (2022)
[3]Brandstetter et al. arXiv: 2308.09699v1 (2023)

Q 24.33 Tue 17:00 KG I Foyer

Heidelberg Quantum Architecture: Fast and modular programmable quantum simulation — •Maximilian Kaiser[1], Tobias Hammel[1], Philipp Preiss[2], Matthias Weidemüller[1], and Selim Jochim[1] — [1]Physikalisches Institut - Heidelberg University, Heidelberg, Germany — [2]Max Planck Institute of Quantum Optics, 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 poster, we give an overview of its design and its inherent modular structure which can be easily adapted to the needs of most of today's quantum gas experiments.

We present the interface concept of our machine alongside the capabilities of our current experimental toolbox, implemented as exchangeable modules. These include among others tunable 2D confinements, arbitrarily shaped potential landscapes, single-atom counting capabilities, and spin-resolved-imaging. Enabled by this toolbox, we report on the latest research results such as the sub-second production of a degenerate fermi gas of ^{6}Li atoms.

Q 24.34 Tue 17:00 KG I Foyer

Quantized pumping in optical lattices: interactions and edge modes — •Giacomo Bisson, Zijie Zhu, Konrad Viebahn, Samuel Jele, Marius Gächter, Anne-Sophie Walter, Joaquin Minguzzi, Stephan Roschinski, Kilian Sandholzer, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich

Understanding the underlying geometric properties of wave functions in topological quantum systems is essential in explaining phenomena such as the quantized Hall effect and Thouless pumps. However, interparticle interactions can affect the topology of a system. In our work, we study topological Thouless pumps via an experimental realization using optical lattices where the Hubbard interaction can be tuned. We observe regimes with robust pumping, as well as an interaction-induced breakdown. The pump shows robustness against weak interactions, both repulsive and attractive. Strongly attractive interactions enable quantized transport through the formation of fermion pairs. Conversely, strong repulsive interaction impairs topological pumping, necessitating pump trajectory modifications to restore it. Furthermore, we explore pump trajectories that are trivial in the non-interacting case and non-trivial in the interacting case resulting in an interaction-induced charge pump. Additionally, we study the transport properties of gapless edge modes in a harmonically confined topological pump. When ultracold fermionic atoms reach a critical slope of the confining potential, quantized Hall drifts reverse, indicating a topological boundary. This reversal corresponds to a band transfer between bands with Chern numbers C = +1 and C = -1 through a gapless edge mode.

Q 24.35 Tue 17:00 KG I Foyer

Towards quantum gas microscopy with dynamically projected optical lattices — •Samuel Jele, Marius Gächter, Giacomo Bisson, Zijie Zhu, Tilman Esslinger, and Konrad Viebahn — Institute for Quantum Electronics, ETH Zurich

In this poster, a novel design for a quantum gas microscope of fermionic potassium (K40) will be presented. In addition to a high-NA objective, the key idea behind achieving single-site resolution makes use of two superimposed accordion lattices with variable and independent lattice constants [1]. By handing over atoms on individual sites from one accordion lattice to the other during lattice expansion, an, in principle, arbitrarily large atom spacing can be achieved, giving access to single-site-resolution with very low imaging duration and lattice depth. Besides single-site resolution, the setup is designed for a repetition rate of 1Hz. For this we implement a parallelisation scheme for laser cooling, evaporative cooling, as well as physics measurements of multiple runs. In addition, a steep magnetic gradient ($>$ 1000G/cm) for rapid evaporative cooling, two separate 3D MOT chambers for potassium and rubidium and fast transport to the glasscell using a moving lattice will help us achieve this goal. The implementation of the accordion lattice using acousto-optic deflectors will allow us to project various lattice structures by simply changing the RF driving signal. This enables us to study more complex systems, such as the Lieb lattices, quasi-periodic structures as well as novel Floquet driving schemes.

[1]: Simon Wili et al., New J. Phys. 25 033037 (2023)

Q 24.36 Tue 17:00 KG I Foyer

Prospects for experiments with ultracold atoms in a five-fold symmetric quasicrystal optical lattice with tunable geometrie — •Jonathan Bracker[1], Luca Asteria[1,2], Marcel Nathanael Kosch[1], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany — [3]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany

Quasicrystal lattices constitute a fascinating middleground between periodic lattices and disordered systems with intricate topological properties and exotic many-body phases. They can be considered as a projection from a higher dimensional space, from which they inherit their topology. First experiments with ultracold atoms in quasiperiodic lattices have been realized in recent years, but so far, the higher dimensional space had a trivial geometry. Here we present a way to realize a quasicrystal lattice with a non-trivial underlying geometry. This setup is characterized by a five-fold rotational symmetry and we discuss how it will be realized via a multi-frequency scheme with full dynamical control over the geometric degree of freedom [1]. We also present numerical results on the expected transport and localization properties as a function of this geometric degree of freedom.

[1] M. Kosch et al., Phys. Rev. Research 4, 043083 (2022)

Q 24.37 Tue 17:00 KG I Foyer

Linear Prediction Algorithms to enhance Impurity Solvers for Dynamical Mean Field Theory — •Bastian Schindler — Goethe-Universität, Institut für Theoretische Physik, 60438 Frankfurt am Main, Germany — Arnold-Sommerfeld-Zentrum für Theoretische Physik, LMU München, Theresienstr. 37, 80333 München

In the poster based on my bachelors thesis an empirical study of different linear prediction algorithms (Yule-Walker, Burg, covariance, modified covariance) using various implementations in python is presented. These algorithms are based on an autoregressive process and are being tested on the Greens functions generated during four different dynamical mean field theory (DMFT) simulations. To evaluate real world performance the root mean squared error is computed on a test sample, which was excluded from the previous fitting process. The dependency of this error with respect to most of the important hyperparameters is analysed systematically. Spectrums implementation of the covariance method is found to perform superiorly on weakly oscillating functions, whereas the Burg method from the same package overall performs better on strongly oscillating functions. The discarded weight is found to be a good parameter to distinguish between the two cases. A Nelder-Mead optimization scheme to find the relevant hyperparameters is successfully implemented. As my current interest in my masters project (Bose-Hubbard model with disorder) revolves heavily around bosonic DMFT, the link to (B)DMFT will be emphasized more than in the original thesis.

Q 24.38 Tue 17:00 KG I Foyer

Cooperative effects in dense cold atomic gases including magnetic dipole interactions — •Nico Bassler[1,2], Ishan Varma[3], Marvin Proske[3], Patrick Windpassinger[3], Kai Phillip Schmidt[1], and Claudiu Genes[2,1] — [1]Department of Physics, Friedrich-Alexander Universität Erlangen-Nürnberg (FAU), D-91058 Erlangen, Germany — [2]Max Planck Institute for the Science of Light, D-91058 Erlangen, Germany — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55122 Mainz, Germany

We theoretically investigate cooperative effects in cold atomic gases exhibiting both electric and magnetic dipole-dipole interactions, such as occurring for example in clouds of dysprosium atoms. We distinguish between the quantum degenerate case, where we take a many-body physics approach, and the quantum non-degenerate case, where we use the formalism of open system dynamics. For quantum non-degenerate gases, we illustrate the emergence of tailorable spin models in the high-excitation limit. In the low-excitation limit, we provide analytical and numerical results detailing the effect of magnetic interactions on the directionality of scattered light and characterize sub- and superradiant effects. For quantum degenerate gases, we study the interplay between sub- and superradiance effects and the fermionic or bosonic quantum statistics nature of the ensemble.

Q 24.39 Tue 17:00 KG I Foyer

Photon Storage using Cold Caesium in an Interrupted Waveguide — •Matt Overton, David Johnson, Danielle Baldolini, Nathan Cooper, and Lucia Hackermuller — School of Physics and Astronomy, University of Nottingham, UK

Cold atoms are useful for many quantum information applications. Their strong interactions with light give them many uses in atom-photon junctions. However, one difficulty with cold atoms is integrating them with waveguides and other photonic devices. Here we demonstrate a method that involves trapping the atoms inside a micromachined hole through an optical fibre. By carefully selecting the geometry of the cavity, one can tune the transmission of light through it, with convex parabolic surfaces having the greatest transmission [1].

Here we use caesium atoms to demonstrate electromagnetically induced transparency (EIT) within the waveguide hole. EIT allows the transparency of a medium to be controlled using a laser field. The effects this has on the complex susceptibility leads to slow light and (if the control laser power is reduced to zero) can also lead to photon storage. Integrating cold atoms into an optical waveguide for storage like this has obvious applications in quantum computing and quantum communication.

[1] Cooper, N., Da Ros, E., Briddon, C. et al. Prospects for strongly coupled atomphoton quantum nodes. Sci Rep 9, 7798 (2019)

Q 24.40 Tue 17:00 KG I Foyer

Quantum gas mixtures in an Earth-orbiting research laboratory — •Annie Pichery[1,2], Timothé Estrampes[1,2], Gabriel Müller[1], Nicholas P. Bigelow[3], Eric Charron[2], Naceur Gaaloul[1], and the CUAS Consortium[3] — [1]Leibniz Universität Hannover,Institut für Quantenoptik, Germany — [2]Université Paris-Saclay, CNRS, Institut des Sciences Moléculaires d'Orsay, France — [3]University of Rochester, Rochester, NY, USA

The Cold Atom Laboratory (CAL) is a multi-user Bose-Einstein Condensate (BEC) machine aboard the International Space Station, operated by NASA's Jet Propultion Lab. Since its upgrade in 2020, it enables the production and manipulation of dual-species BEC mixtures of K and Rb. We report here about the first quantum mixture experiments realized in space [E. Elliott et al., Nature 623, 502 (2023)] and study its dynamics in weightlessness to prepare dual-species atom interferometry and future tests of the Universality of Free Fall.

Space provides, indeed, an environment where atom clouds can float for extended times of several seconds, as well as miscibility conditions different from ground. Simulating these quantum phases and the dynamics of interacting dual species presents however computational challenges due to the long expansion times. We present a novel theoretical framework based on re-scaled computation grids that allowed to follow the extended free dynamics of quantum mixtures in space.

We acknowledge financial support from the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) under Grant No. CAL-II 50WM2245A/B.

Q 24.41 Tue 17:00 KG I Foyer

Rydberg superatoms for waveguide QED — •Daniil Svirskiy, Lukas Ahlheit, Christoph Biesek, Jan de Haan, Nina Stiesdal, Wolfgang Alt, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Waveguide-systems where quantum emitters are strongly coupled to a single propagating light mode offer an interesting platform for quantum nonlinear optics. We work towards realizing a cascaded waveguide system utilizing Rydberg superatoms - single Rydberg excitations in individual atomic ensembles smaller than the Rydberg blockade-volume - as effective, directional two-level emitters. Due to the collective nature of the excitation, the superatom effectively represents a single emitter, that is coupled to the inicdent single photon light. The directional emission of the superatom into the initial probe mode realizes a waveguide-like system in free space without any actual light-guiding elements.

On this poster, we show how a Rydberg superatom allows manipulation of single photons, and demonstrate how we implement a one-dimensional chain of Rydberg superatoms with low internal dephasing. To increase coherence time, we use a magic wavelength optical lattice that traps atoms in both the ground- and the Rydberg state and thus reduce atomic motion and limit dephasing of the collective excitation.

We further show how we use an interferometer setup to perform quantum state tomography on multi-photon pulses passing through the superatoms in order to characterize the effective photon-photon interaction mediated by the superatom chain.

Q 24.42 Tue 17:00 KG I Foyer

Interfacing electromechanical oscillators and Rydberg atoms in a closed-cycle cryostat — •Leon Sadowski, Cedric Wind, Johanna Popp, Julia Gamper, Valerie Mauth, Wolfgang Alt, Hannes Busche, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Rydberg atoms exhibit strong electric dipole transitions between Rydberg states, which allow coupling to other quantum systems at microwave frequencies. Here, we present the prospect to couple Rydberg atoms to electromechanical oscillators, which can possess high Q factors at microwave frequencies, and our implementation of a cryogenic cold atom setup for such experiments.

On this poster, we present our progress on the construction of the experimental setup that is centered around an UHV closed-cycle cryostat that allows to perform experiments in a 4 K environment and includes a vibration-isolation system that reduces vibrations below 25 nm. Moreover, we show our design of a chip on which we integrate the oscillator and a superconducting wire trap that allows for magnetic trapping of Rubidium atoms above the oscillator at distances of several 10 μm. For the oscillator, we perform finite element simulations of the field radiated due to thermal phonons and deduce interaction strengths with Rydberg atoms of order kHz to MHz if the oscillator is near its quantum ground state.

In summary, the 4 K environment combined with dissipative interactions with Rydberg atoms should enable cooling the oscillator to its ground state without the need of a dilution refrigerator.

Q 24.43 Tue 17:00 KG I Foyer

Rydberg superatoms coupled with super-extended evanescent field nanofiber at the single-photon level — •Tangi Legrand[1], Ludwig Müller[1], Thomas Hoinkes[2], Xin Wang[1], Thilina Muthu-Arachchige[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 thighly 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 present our strategy for building an apparatus that allows multiple Rydberg superatoms to be trapped around a nanofiber with a diameter of about 100 nm. 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 24.44 Tue 17:00 KG I Foyer

Rydberg quantum optics in ultracold Ytterbium gases — •Eduardo Uruñuela, Xin Wang, Thilina Muthu-arachchige, Tangi Legrand, Ludwig Müller, Wolfgang Alt, 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 such as narrow-linewidth laser-cooling, optical detection and ionization or long-lived nuclear-spin memory states.

In this poster, we present our experimental progress on the realization of strong interaction between photons, enabled by Yb-174 Rydberg polaritons formed in a 1-D ultracold Ytterbium gas. Owing to the zero nuclei spin of Yb-174 and singlet spin state in bivalent structure, the longer coherent time is expected. The singlet transition at 399 nm also helps us produce a long-focused dipole trap with higher OD in one dimension. Specifically, we discuss our implementation of ultracold Yb atoms in narrow-line MOT and elongated dipole trap with compact and fast-loading two-chamber experiment setup, and generation of the Rydberg polaritons under Rydberg electromagnetically induced transparency.

Q 24.45 Tue 17:00 KG I Foyer

Critical exponents of a non-equilibrium phase transition in a facilitated Rydberg gas — •Daniel Brady, Simon Ohler, and Michael Fleischhauer — RPTU Kaiserslautern

We study a gas of driven Rydberg atoms, where excitations can spread through facilitation, comparable to the spread of an infectious disease. Importantly, the system shows a non-equilibrium dynamical phase transition from an active to an absorbing state, depending on driving and density. This transition is characterized by two critical exponents, which we investigate numerically close to the critical point as a function of the gas temperature. For the case of very low temperatures, we find a directed percolation-type transition due to the effects of Rydberg blockade, whereas for increasing temperatures we find a crossover to a mean-field transition. We also study the fast *avalanches* of excitations at the critical point and find they are power-law distributed with an exponent that is independent of temperature and comparable to many other systems known under the term self-organized criticality.

Q 24.46 Tue 17:00 KG I Foyer

Experimental Setup for the Generation of Chiral Orbital States with Rydberg Atoms — •Peter Zahariev[1,3], Stefan Aull[1], Steffen Giesen[2], Robert Berger[2], and Kilian Singer[1] — [1]Experimentalphysik I - Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [2]Fb.15 - Chemie, HansMeerwein-Straße 4, 35032 Marburg — [3]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72, Tzarigradsko Chaussee, 1784 Sofia, Bulgaria

We present an experimental setup based on a magneto-optical trap of Rubidium atoms and two photon excitation into Rydberg states, that allows for the preparation of chiral orbital Rydberg states. Using hydrogen-like wave functions [1], it is possible to construct an electron density and probability current distribution that has chiral nature. The radio frequency setup and the electric field configuration to generate and detect these states is presented. This experiment will allow us to identify interaction induced energy shifts that are caused by the chiral nature of the wave function only. The results will be also valuable for chiral discrimination of molecules [2].

[1] A. Ordonez, O. Smirnova. Propensity rules in photoelectron circular dichroism in chiral molecules. I. Chiral hydrogen, Phys. Rev. A 99, 043416 (2019)

[2] S Y Buhmann *et al*, Quantum sensing protocol for motionally chiral Rydberg atoms, *New J. Phys.* **23** 083040 (2021)

Q 24.47 Tue 17:00 KG I Foyer

Rydberg spectroscopy in the strong driving regime and self-organized criticality — •Patrick Mischke[1,2], Florian Binoth[1], Jana Bender[1], Thomas Niederprüm[1], and Herwig Ott[1] — [1]Department of Physics and Research center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau — [2]Max Planck Graduate Center with the Johannes Gutenberg-Universitätt Mainz (MPGC)

Autler-Townes splitting in coupled two-level-systems is a well-known effect in atomic physics. However, for strong driving in real atomic systems, additional states like other hyperfine structure states or magnetic sublevels are admixed. As a result, complex spectra, deviating from the symmetrical two-level Autler-Townes splitting, emerge.

We experimentally investigate these spectra in a thermal cloud of ^{87}Rb atoms by resonantly coupling the $6P_{3/2}, F = 3$ state to a Rydberg state with varying Rabi frequency.

Our experiments confirm, that multilevel effects have to be considered in the Autler-Townes regime. As a general rule, the splitting between peaks is not equal to the Rabi frequency if the coupling strength exceeds the energetic distance of adjacent states.

In a manybody system, Rydberg atoms interact strongly over very large distances, leading to effects such as blockade and facilitation. In the absence of disorder, an off-resonantly driven system is expected to exhibit a phase transition between an active and an absorbing phase. We present experimental data and our work towards understanding the role of disorder.