Q 42: Poster – Ultracold Matter (joint session Q/A)

Bosons; Fermions; Rydberg Systems; Experimental Methods

Time: Wednesday 17:00–19:00 Location: Philo 2. OG

Q 42.1 Wed 17:00 Philo 2. OG

Pattern coarsening in dipolar quantum gases — •Andreea-Maria Oros[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 the LHY correction 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 three-dimensional dipolar condensate, trapped only along the polarisation direction. Therein, we aim to bridge the theory of supersolid dipolar condensates to that of phase transitions present in melting dynamics. Furthermore, we investigate the crystalline properties across the superfluid-supersolid transition by extending procedures employed in Kosterlitz-Thouless-Halperin-Nelson-Young theories, and as a result observe coarsening behaviour in the local orientation.

Q 42.2 Wed 17:00 Philo 2. OG

Stability analysis of a holographic superfluid — •Martin Zboron[1], Gregor Bals[2,3], Carlo Ewerz[2,3], and Thomas Gasenzer[1,2,3] — [1]Kirchhoff-Institut für Physik, Univ. Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institut für Theoretische Physik, Univ. 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. Due to Bekenstein-Hawking entropy, a black brane provides a finite temperature to this system. Allowing particles and energy to fall behind the horizon relates to a strong dissipation in the superfluid. A Bogoliubov-type analysis of small excitations in the bulk reveals their dispersion relation as well as their damping rates, granting insights into the relevant dissipation mechanisms. Numerical results of this analysis enable comparisons of the holographic superfluid to phenomenological models of finite-temperature superfluids, such as the dissipative Gross-Pitaevskii equation, as well as experimentally realised superfluids.

Q 42.3 Wed 17:00 Philo 2. OG

Universal scaling and emergent symmetries in a spin-1 Bose gas far from equilibrium — •Ido Siovitz, Anna-Maria E. Glück, Yannick Deller, Helmut Strobel, Markus K. Oberthaler, and Thomas Gasenzer — Kirchhoff Institute for Physics, Universität Heidelberg

Quantum many-body systems driven far from equilibrium can show universal self-similar scaling dynamics associated with an approach to a non-thermal fixed point. The characterisation of non-equilibrium universality classes remains an open problem. Here we show the thorough investigation of non-equilibrium universality using the spin-1 Bose gas as a platform. We identify rogue waves in the velocity fields of the single components, leading to real-time instantons in the transverse spin degree of freedom. We derive a low-energy effective field theory of the spin-1 gas, taking the form of a double sine-Gordon model for the spinor phase. This model accounts for the subdiffusive and diffusion-type scaling observed in the full microscopic theory. We show Numerical as well as experimental results that support the validity of the effective model. Lastly, we demonstrate that different quenches can lead to two distinct non-thermal fixed points, each associated with a different emergent symmetry signaled by symmetry witnesses derived from Ward identities.

Q 42.4 Wed 17:00 Philo 2. OG

Universal dynamics of 3D Bose gases near the superfluid transition in the collective-scattering regime — •Anne-Solène Bornens, Elisabeth Gliott, and Nicolas Cherroret — Laboratoire Kastler-Brossel, Sorbonne Université, CNRS, ENS-PSL, Collège de France, Paris, France

Understanding the many-body dynamics of a quantum system after a quench is a central challenge in modern physics. In particular, quantum gases quenched across a phase transition display especially intriguing dynamics, as they generically evolve toward a nonthermal fixed point, i.e. a self-similar evolution of correlations with universal dynamical exponents and a critical slowing down. Recently observed experimentally, this phenomenon compellingly extends the notion of universality classes to nonequilibrium statistical physics.

In this work, we theoretically investigate the universal many-body dynamics of three-dimensional Bose gases suddenly cooled across their superfluid phase transition. Using a quantum kinetic framework that captures the collective-scattering regime emerging in the highly occupied part of the spectrum, we uncover a crossover between two dynamical universality classes controlled by the quench depth. For weak quenches, we find early-time inverse and direct energy cascades characteristic of weak turbulence, where collective scattering plays little role. For deep quenches, collective scattering dominates and a turbulent fixed point emerges, marked by modified dynamical exponents, a more pronounced bidirectional cascade, and an overall slowing down of the dynamics.

Q 42.5 Wed 17:00 Philo 2. OG

The Slox Trap: Absorptive Boundaries for Infinitely Extended Physics — •Nikolas Liebster[1,2], Jelte Duchene[1], Elinor Kath[1], Hanyi Jang[1], Helmut Strobel[1], and Markus Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120, Germany — [2]Department of Physics, Ludwig-Maximilians-Universität München, Schellingstr. 4, 80799 Munich, Germany

A common impediment to the comparison between theoretical models and experimental results is finite size effects, which are an experimental reality but a theoretical challenge. One solution is periodic boundaries, which can be implemented experimentally by embedding a D-dimensional system in a D+1-dimensional space (e.g. a torus), but this can be challenging and introduces curvature. An alternative approach is to implement absorptive boundaries, such that reflections and pinning of excitations is avoided, and dynamics in the bulk mimic an infinitely extended system. Here, we experimentally investigate boundary effects in a slanted box, i.e. slox potential, which is homogeneous in the center and rises linearly at the boundary. We compare dynamics in slox and standard box traps, by studying wavepacket dynamics and reflections of high-momentum modes at the boundary. We show that the slox effectively absorbs excitations above a certain momentum-scale, which can be described in terms of finite-temperature dynamics, where damping locally increases at the boundary due to the inhomogeneous (thermal) density distribution.

Q 42.6 Wed 17:00 Philo 2. OG

Dynamics of trapped dipolar Bose gases at BEC-quantum droplet crossover — •Denis Mujo[1], Ivana Vasić[1], Milan Radonić[2,1], and Axel Pelster[3] — [1]Institute of Physics Belgrade, University of Belgrade, Serbia — [2]I. Institute of Theoretical Physics, University of Hamburg, Germany — [3]Physics Department, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

Since the first realization of quantum droplets [1], various experiments have indicated that quantum droplets in a dipolar Bose system are stabilized due to quantum fluctuations [2,3], correcting the ground-state energy. Here we study the dynamics of trapped dipolar Bose gases using both time-dependent variational methods and full three-dimensional simulations of the extended Gross-Pitaevskii equation. Our focus is on the crossover region between a BEC and a quantum droplet, where the system becomes highly sensitive to parameter variations such as changes of the s-wave scattering length or the strength of the trapping confinement. We identify the critical conditions re-

quired to maintain droplet stability when these parameters are varied, including the effects of different variation rates and a complete removal of the trapping potential. And we examine the behavior of collective excitation modes in the vicinity of the BEC-quantum droplet crossover.

[1] H. Kadau et al., Nature **530**, 194 (2016).
[2] A.R.P. Lima and A. Pelster, Phys. Rev. A **84**, 041604(R) (2011).
[3] F. Wächtler and L. Santos, Phys. Rev. A **93**, 061603 (2016).

Q 42.7 Wed 17:00 Philo 2. OG

Supersolid from first principles with Complex Langevin. — •Luca Falzoni[1], Philipp Heinen[1], and Thomas Gasenzer[1,2,3] — [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

The experimental observation of supersolidity in dipolar gases preceded its theoretical understanding, as the supersolid phase is predicted to be unstable within the extended Gross–Pitaevskii equation (eGPE). Current theoretical stabilization relies on heuristic corrections, typically implemented via an *ad-hoc* $\propto |\psi|^5$ term motivated by the Lee–Huang–Yang (LHY) contribution. To consistently go beyond the LHY correction, a quantum-exact approach is required. In this work, we demonstrate that the Complex Langevin method provides a fully non-perturbative, first–principles description of the supersolid regime and successfully captures the emergence of stable supersolid states.

Q 42.8 Wed 17:00 Philo 2. OG

Phase diagrams for dipolar interacting quantum gases — •Robin Ruediger Krill[1], Jan Alexander Koziol[2], Anja Langheld[2], Calvin Krämer[2], Giovanna Morigi[1], and Kai Phillip Schmidt[2] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Department für Physik, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany

We present phase diagrams for ultracold quantum gases of dipolar bosons in an optical lattice. In the low-density regime, we map the quantum gas to a hardcore-bosonic model, where we then can use an extended Stochastic Series Expansion quantum Monte Carlo algorithm to obtain the ground state phase diagrams. Recent investigations of such systems with mean-field approaches indicate rich quantum phase diagrams including a devil's staircase of solid phases and a plethora of exotic lattice supersolids [1]. The quantum Monte-Carlo approach allows us to extend this mean-field study by fully incorporating quantum fluctuations, and thus to analyse the interplay among frustration, long-range interactions, and quantum fluctuations. We determine the phase diagram and verify the existence of supersolid phases in the low-density limit.

[1] J.A Koziol, G.Morigi, K.P. Schmidt, SciPost Phys. 17, 111 (2024)

Q 42.9 Wed 17:00 Philo 2. OG

Sine-Gordon solitons in a spinor Bose-Einstein condensate — •Florian Schmitt, Ido Siovitz, Yannick Deller, Alexander Schmutz, Raphael Schäfer, Alexander Flamm, Helmut Strobel, Markus K. Oberthaler, and Thomas Gasenzer — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

This contribution is concerned with the theoretical analysis of topological defects in a Bose gas governed by the spin-1 Gross-Pitaveskii equation (GPE). We find that for a spinor gas consisting of Rubidium-87 atoms a local imprint in the spinor phase leads to a stable topological defect both in experiment and numerical time evolution. It exhibits key features of a kink solution of the sine-Gordon model, and we can calculate its velocity depending on the quadratic Zeeman shift from the spin-1 GPE Lagrangian as well as from its corresponding effective sine-Gordon theory. We investigate dynamics of kink collisions with respect to the observables of the spin-1 gas and are able to relate this defect living at low spin interaction strength to the exactly solvable regime of the spin-1 GPE Lagrangian.

Q 42.10 Wed 17:00 Philo 2. OG

Topological properties of lattice solitons in the two-dimensional Harper-Hofstadter model — •Hugo Gerlitz, Julius Bohm, and Michael Fleischhauer — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Since the discovery of the integer quantum Hall effect, topological 2D lattice models have attracted significant interest in many-body physics. Recent experiments investigating solitons in waveguides with nonlinear Kerr media [1] have observed interaction-induced transitions between phases of integer and fractional quantized topological transport in 1D lattice models. In one-dimensional systems a quantum mechanical description of lattice solitons is typically done by exact diagonalization or tensor network approaches. These approaches are however strongly limited by system size or not suitable in higher dimensions. Mapping the interacting many-body model of quantum solitons to an effective description of compact objects in a reduced Hilbert-space was successful in reproducing topological properties in 1D models [2]. Motivated by this we here present an effective description of quantum solitons in an interacting two-dimensional Harper-Hofstadter model. With this we show the emergence of effective Peierls phases for the composite object which vary with the particle number and in particular cases can destroy the system*s topological properties altogether.

[1]: Jürgensen et. al., Nature 596, 63-67 (2021) [2]: Bohm et. al., arXiv:2506.00090 (2025)

Q 42.11 Wed 17:00 Philo 2. OG

Observation and detection of crystal phases with variable structures in dipolar quantum gases — •Jianshun Gao, Karthik Chandrashekara, Christian Gölzhäuser, Lily Platt, Julian Kusch, Rémy Dolbeault, and Lauriane Chomaz — Physikalisches Institut, Im Neuenheimer Feld 226, Heidelberg, Germany

Dipolar quantum gases have been found to display exotic phases from anisotropic superfluids, to sefl-bound fluids, and to crystalline states, also including supersolids. These phases spontaneously arise depending on the interactions parameters, trap geoemtries, and atom number in the system. In planar trap geometries, while only triangular crystalline states have yet been observed, various structures of the crystalline states have been predicted. In our experiment, we explore the phase diagram of a quantum gas of Dysprosium atoms in a surfboard-shaped trap by independently controlling the contact interaction and the dipole orientation angle. We observe that the gas transitions from a uniform superfluid to density-modulated states, with either triangular or stripe arrangement. In this poster, we will present an analyse protocol for detecting the density-modulated patterns from the high-intensity in-situ absorption imaging, and extracting the important information: number, dimensions, and anisotropy of the crystal structures, number of neighboring structures and typical distance between them.

Q 42.12 Wed 17:00 Philo 2. OG

Theoretical analysis of the mitigation of Floquet heating with multi-tone drives in a Hubbard lattice — •Carlotta Koroll and •Francesco Petiziol — Technische Universität Berlin, Germany

Floquet engineering allows for the realization of effective Hamiltonians that are difficult to access in static systems. This is achieved by driving a highly controllable quantum system with a periodic signal. However, one limitation is the gradual absorption of drive energy over time, which drags the system towards a featureless state in the long run, a process known as Floquet heating. One technique for minimizing this effect is the design of driving schemes that effectively close energy absorption channels through destructive interference. This has recently been demonstrated in experiments with ultracold atoms in optical lattices using a two-tone drive. We present a theoretical and numerical study of this mechanism in a driven Hubbard lattice. Our goal is to develop a clearer understanding of the underlying heating processes and to determine under which conditions multi-tone driving can effectively mitigate Floquet heating in interacting lattice systems.

Q 42.13 Wed 17:00 Philo 2. OG

Quantum gas microscopy of exotic Hubbard systems — •Philip Kämmle[1], Jan Deppe[1], Liyu Liu[2], Jirayu Mongkolkiatichai[2], Davis Garwood[2], Jin Yang[2], and Peter Schauss[1] — [1]Institute for Quantum Physics, University of Hamburg — [2]University of Virginia

This poster presents our recent developments in quantum simulation of electronic systems using ultra-cold atoms in geometrically frustrated lattices, as well as three-component fermionic systems that reflect the three flavors in quantum chromodynamics. We illustrate the achievement of a Mott insulator with lithium-6 on a symmetric triangular lattice, featuring a lattice spacing of 1003 nm. Through spin removal techniques, we can isolate individual spins and measure nearest neighbor spin-spin correlations across varying interaction strengths. Additionally, we expand quantum gas microscopy to three-flavor Fermi lattice gases in the Hubbard regime. Using site- and flavor-resolved detection, we investigate the phase diagram of the three-flavor Hubbard model, revealing signs of flavor-selective localization and selective pairing at temperatures as low as the tunneling energy scale. Future work aims to explore dynamical systems through transport measurements in a triangular lattice combined with digital micromirror device (DMD) and spatial light modulator (SLM) potentials, facilitating the study of transport dynamics in customized potential landscapes.

Q 42.14 Wed 17:00 Philo 2. OG

Developing a quantum gas microscope with programmable lattices — •Saumya Shah[1,2], Constanze Vogel[1,2], Sarah Waddington[1,2], Isabelle Safa[1,2], Rodrigo Rosa-Medina[1,2], and Julian Léonard[1,2] — [1]Institute of Science and Technology Austria (ISTA), Am Campus 1, 3400 Klosterneuburg, Austria — [2]Atominstitut TU Wien, Stadionallee 2, 1020 Wien, Austria

Experiments involving ultra-cold atoms in optical lattices provide powerful ways for engineering and probing strongly correlated quantum matter. The field has advanced significantly in the past few decades, offering exceptional single-site resolution and single-atom addressing. However, current setups are often restricted by rigid lattice configurations and slow cycle times. In this poster, we showcase our endeavors in building a next-generation quantum gas microscope for fermionic and bosonic lithium atoms. Utilizing auxiliary optical tweezers and direct optical cooling techniques, we aim to assemble small lattice systems with sub-second experimental cycles. We build tailored optical lattices with dynamically reconfigurable geometries by leveraging holographic projection techniques. Our approach paves the way for multiple research areas, which range from quantum simulations of fractional quantum Hall states to frustrated phases with unconventional geometries.

Q 42.15 Wed 17:00 Philo 2. OG

Programmable State Preparation of Ultracold Fermions Using Optical Tweezer Arrays — •Francesco Testi[1,2], Marcus Culemann[1], Jin Zhang[1], Naman Jain[1], and Philipp Preiss[1,3] — [1]Max Planck Institute of Quantum Optics, Garching — [2]Ludwig-Maximilians-Universität München — [3]Munich Center for Quantum Science and Technology, Munich, Germany

Ultracold atoms in optical lattices offer a powerful platform for studying interacting quantum many-body systems and non-equilibrium dynamics. However, the preparation of arbitrary initial states remains a major challenge, as conventional cooling and loading protocols naturally yield only a limited set of configurations such as Mott insulators or charge-density waves. The UniRand experiment aims to overcome this limitation by integrating an optical lattice with an array of dynamically reconfigurable optical tweezers for the preparation of programmable site- and spin-resolved arrangements of fermionic lithium-6 atoms. The poster showcases high-fidelity spin-resolved imaging, efficient loading and evaporation within the tweezer array, and deterministic control over the atomic density in each individual trap. These capabilities allow us to assemble arbitrary spin and density configurations across an 8x8 array with a rapid experimental cycle time of 2-3 s. By combining precise state preparation with fast repetition rates, this programmable-state architecture opens new opportunities for realizing fermionic quantum information protocols and engineering tailored non-equilibrium states to explore previously inaccessible regimes of the Fermi-Hubbard model.

Q 42.16 Wed 17:00 Philo 2. OG

Experimental realization of quantum Hall states with few rotating fermions — •Paul Hill, Johannes Reiter, Maciej Galka, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg (Germany)

Integer and fractional quantum Hall states constitute topological phases of matter featuring exotic macroscopic properties such as the quantization of the transverse resistivity and emergence of 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. Furthermore, we discuss how to explore topological transitions between integer and fractional quantum hall states with our platform, and how off diagonal elements of the density matrix, in the form of probability currents, can be measured.

Q 42.17 Wed 17:00 Philo 2. OG

Phases of Matter in Few Fermions with Dipolar Interactions — •Tim Pohlmann, Ximeng Song, Paula Seyfert, Lennart Naeve, Lennart Hoenen, Philipp Lunt, and Lauriane Chomaz — Physikalisches Institut Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

In this poster, we theoretically investigate few spin-polarized fermions with strong dipolar interactions in a two-dimensional harmonic trap. This project comes alongside of the construction of a new 161Dy experiment. We numerically find the ground states of the Hamiltonian by exact diagonalization for different particle numbers and various tilting angles of the dipoles. The competition of the dipolar interaction strength and directivity, Fermi energy and harmonic oscillator frequency results in a rich phase diagram[1]. This includes anisotropic pairing suggesting the emergence of p-wave superfluidity, and Wigner crystallization at large dipolar interactions[2, 3].
References: [1] Anne-Louise Gadsbølle and G. M. Bruun. Harmonically trapped dipolar fermions in a two-dimensional square lattice. Phys. Rev. A, 85:021604, Feb 2012. [2] G. M. Bruun and E. Taylor. Quantum phases of a two-dimensional dipolar fermi gas. Phys. Rev. Lett., 101:245301, Dec 2008. [3] J. C. Cremon et al. Tunable wigner states with dipolar atoms and molecules. Phys. Rev. Lett., 105:255301, Dec 2010.

Q 42.18 Wed 17:00 Philo 2. OG

Shielding of ultracold Lithium-6 — •Finn Lubenau, Daniel Dux, Tim Schiffer, Tobias Hammel, Maximilian Kaiser, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Heidelberg, Germany

We are presenting the Heidelberg Quantum Architecture [1], a modular quantum gas platform creating a degenerate fermi gas of ^{6}Li, that combines individual modules to implement a large variety of functionalities, that can be quickly updated and exchanged.

Here, we will report on the implementation of an optical dipole trap module at 812 nm near the $2P \longleftrightarrow 3S$ resonance. While the imaging transition used in our system is the D2-line of ^{6}Li at 671 nm between the $2S$ and $2P$ fine structure levels, the 812 nm trap introduces a large light shift of the $2P$ level, as this level has a diverging polarisability at this wavelength, effectively detuning the imaging transition from the imaging laser. This allows for site selective shielding of the atoms and thus enables partial probing of the system.

Additionally, we present a spatial light modulator (SLM) module to create precise and reproducible tuneable light fields, including the ability to correct for optical aberrations and in-shot dynamic repositioning of the atoms.

[1]: T. Hammel, M. Kaiser et al., Modular quantum gas platform, Phys. Rev. A **111**, 033314

Q 42.19 Wed 17:00 Philo 2. OG

Upgrades for the modular quantum gas platform — •Tim Schiffer, Tobias Hammel, Daniel Dux, Finn Lubenau, Maximilian Kaiser, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Heidelberg, Germany

The Heidelberg Quantum Architecture [1] is a modular quantum gas platform, consisting of disentangled modules forming a versatile cold atom experiment.

Here, optical units allow flexible trap geometries, fast reconfiguration and precise mechanical alignment, enabling straightforward adaptation to evolving experimental requirements in our Lithium-6 experiment.

On this poster, we report on the progress made implementing self-aligning modules and modules with increased stability. We discuss the already implemented experimental toolbox, containing optical tweezers, repulsive potentials shaped by a DMD and single-atom and spin-resolved imaging.

[1]: T. Hammel, M. Kaiser, et al., Modular quantum gas platform, Phys. Rev. A **111**, 033314

Q 42.20 Wed 17:00 Philo 2. OG

Design and Optimization of a Zeeman Slower for Ultracold Fermionic Dysprosium Experiments — •Ximeng Song, Paula Seyfert, Tim Pohlmann, Lennart Naeve, Lennart Hoenen, Philipp Lunt, and Lauriane Chomaz — Physikalisches Institut (Universität Heidelberg), Im Neuenheimer Feld 226, 69120 Heidelberg

Producing a high-flux, cool beam of atoms from a high-temperature, effusive oven is a fundamental prerequisite for any ultracold quantum gas experiment. The complex hyperfine structure of lanthanide atoms,

such as Dysprosium, can render standard two-dimensional magneto-optical traps (2DMOT) inefficient due to optical pumping into dark states.

In this work, we present detailed analysis and optimization of a combined Zeeman slower (ZS) and 2DMOT as a primary cooling stage for ^{161}Dy, based on analytical modelling and numerical simulations using the full 216-level hyperfine structure of the 421-nm cycling transition. We determine optimal magnetic-field profiles, laser detunings, and capture velocities. Crucially, the output of the ZS is matched to a low-gradient 2DMOT, whose parameters were likewise optimized for efficient capture of ^{161}Dy at the reduced velocities. The combined ZS-2DMOT system yields a substantial increase in expected atomic flux into the science chamber, providing an experimentally feasible design for the precooling stage of our new fermionic dysprosium experiment.

References: S. Eckel, D. S. Barker, E. B. Norrgard, and J. Scherschligt. PyLCP: A Python package for computing laser cooling physics. Computer Physics Communications 270 (2022).

Q 42.21 Wed 17:00 Philo 2. OG

Hybrid analog-digital quantum simulation with a quantum gas microscope — •Dorothee Tell[1], Si Wang[1], Petar Bojović[1], Johannes Obermeyer[1], Marnix Barendregt[1], Immanuel Bloch[1,2], and Titus Franz[1] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany

Simulating strongly correlated electronic systems is a significant challenge for classic numerical methods which can be overcome by native quantum systems. Both analog simulators that reconstruct the Hamiltonian and allow reading out snapshots of the wave function, or digital systems where the problem is encoded in a qubit platform have shown impressive results exploring special phases of matter.

In our quantum gas microscope we observe fermionic lithium atoms with single-site and spin resolution. We demonstrate state-of-the-art analog and digital tools, which have recently allowed us to study the universal scaling of correlations in doped Fermi-Hubbard systems at the onset of the pseudogap phase [1], high-fidelity collisional quantum gates [2], and spontaneous strong-to-weak symmetry breaking. With these methods at hand, we are aiming towards measuring signatures of high-temperature superconductivity by using a hybrid analog-digital scheme that allows us to perform basis transformations and thereby enables us to measure more relevant quantities [3].

[1] T. Chalopin et al., arXiv:2412.17801 (2024)
[2] P. Bojović et al., arXiv:2506.14711 (2025)
[3] H. Schlömer et al., PRX Quantum 5 (2024)

Q 42.22 Wed 17:00 Philo 2. OG

Towards Fermionic Systems with Dipolar Interactions — •Paula Seyfert, Tim Pohlmann, Ximeng Song, Lennart Naeve, Lennart Hoenen, Philipp Lunt, and Lauriane Chomaz — Physikalisches Institut (Universität Heidelberg), Im Neuenheimer Feld 226, 69120 Heidelberg

We are constructing a new experimental platform to study spin-polarized fermionic systems with strong dipolar interactions under the microscope. The competition of the Fermi energy with the long-range dipolar interactions, alongside the high degree of control on atom number, dipolar strength and orientation offer a rich platform to study exotic quantum many-body phenomena [1].

We adapt the species-agnostic modular quantum gas platform [2] originally developed for ^{6}Li in the group of Selim Jochim to fermionic ^{161}Dy, which possesses one of the largest magnetic moments ($\mu = 10\mu_B$). To tackle the more complicated cooling of this lanthanide atom encompassing a complex hyperfine structure, we implement a compact design of a permanent-magnet Zeeman-Slower and 2D MOT. In the science chamber, consisting of a nano-textured glass cell, the final trapping stage will be a core-shell 3D MOT. In this poster, I will showcase the current status of the design and construction.

References: [1] A.-L. Gadsbølle and G. M. Bruun, 'Harmonically trapped dipolar fermions in a two-dimensional square lattice', Phys. Rev. A 85.2 (Feb. 2012). [2] Tobias Hammel et al., 'Modular quantum gas platform', Phys. Rev. A 111, 033314 (Mar. 2025).

Q 42.23 Wed 17:00 Philo 2. OG

Individual cooler and repumper power stabilisation for counting 6Li-atoms — •Armin Mirzaei Kian, Johannes Reiter, Paul Hill, Maciej Galka, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Deutschland

Precise counting of the number of atoms in a magneto-optical trap down to the single atom level relies on the high-fidelity discrimination between atoms based on their total fluorescence intensity. Experimentally, the latter is altered by laser power fluctuations. In this work we present a technique to improve the signal to noise ratio of counting 6Li-atoms by frequency modulation of the cooler and repumper beams. This method is chosen since the combined beam is indinstinguishable in its properties like polarisation and mode except the small frequency difference resulting in a beat note. Modulating the Acousto-Optic-Modulators of both cooler and repumper by two frequencies respectively, additional sidebands are generated whose amplitudes are proportional to the optical powers of the beams. With subsequent demodulation these signals can be used to feedback and stabilise cooler and repumper power individually, leading to a stronger discrimination of atom number.

Q 42.24 Wed 17:00 Philo 2. OG

Experimental setup for trapping ultracold atoms near 4K solid state samples — •Valerie Leu, Julia Gamper, Cedric Wind, Wolfgang Alt, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

In our experiment we are developing an experimental platform that couples Rydberg atoms to an electromechanical resonator on an atom chip operated in a cryogenic environment. To support the use of interchangeable atom chips, both the experimental apparatus and the cryostat must be engineered so that the chip assembly can be mechanically decoupled from the surrounding system, ensuring reliable removal and replacement of the chips.

This poster presents our progress on constructing this platform. The setup consists of a region for trapping and cooling rubidium atoms in a magneto-optical trap, as well as a cryogenic stage in which the atoms will be coupled to an electromechanical resonator integrated on the atom chip. We describe the design of the cryogenic system and the implementation of a rail-based mechanism that allows the system to be opened, the atom chip to be inserted or exchanged, and the entire assembly to be closed again in a controlled and reproducible manner. This will allow future studies of Rydberg atoms near 4 K surfaces and pave the way for initial experiments on coupling of the atoms to an on-chip microwave source.

Q 42.25 Wed 17:00 Philo 2. OG

Stabilizing a continuous family of quantum many-body scarred states in the PXP model using periodic driving — •Stefan Malijević and Ana Hudomal — Institute of Physics Belgrade, University of Belgrade, Serbia

Experiments on Rydberg atom arrays have revealed a novel class of quantum systems in which a small subset of atypical eigenstates, known as quantum many-body scars, gives rise to persistent revivals and suppresses thermalization for specific initial states [1]. In the strongly interacting regime, this behavior is effectively captured by the PXP model. Recent experiments have shown that periodic driving, when tuned to optimal parameters, can further enhance scar-induced revivals [2]. However, previous studies of the driven PXP model have primarily focused on a few simple initial product states [3]. In this work, we consider a recently discovered continuous family of scarred states in the PXP model with chemical potential, which includes highly entangled states near the quantum phase transition [4]. Using numerical simulations of the periodically driven model, we analyze the response of these states to different driving protocols and identify regimes in which periodic modulation most effectively stabilizes the scarred dynamics.

[1] M. Serbyn et al., Nat. Phys. 17, 675 (2021).
[2] D. Bluvstein et al., Science 371, 1355 (2021).
[3] A. Hudomal et al., PRB 106, 104302 (2022).
[4] A. Daniel et al., PRB 107, 235108 (2023).

Q 42.26 Wed 17:00 Philo 2. OG

Imaging transverse interactions between Rydberg polaritons — •Daniil Svirskiy[1], Bankim Chandra Das[2], Matthias Metternich[1], Enrico Huland[1], Benedikt Beck[1], Nina Stiesdal[1], Wolfgang Alt[1], Ofer Firstenberg[2], and Sebastian Hofferberth[1] — [1]Institute of Applied Physics, University of Bonn, Germany — [2]Weizmann Institute of Science, Rehovot, Israel

Realization of photon-photon interaction is possible via a medium with strong optical nonlinearities, for instance, with a cloud of ultracold Rydberg atoms, where single photons propagate through the atomic medium as interacting Rydberg polaritons under the condition of electromagnetically induced transparency. Most experiments to date were aiming towards 1D systems, where the Rydberg polaritons only interact along their propagation direction and also, only time domain correlations were mainly studied.

On our poster, we will discuss the current approach to probing transverse interactions by detecting transmitted photons with a single-photon-sensitive EMCCD camera. We will also show first experimentally measured images and compare them with numerical simulations based on our 2D model that captures how transverse interactions become imprinted on the outgoing light field. These measurements will provide us with an access to the direct observation of the transversal Rydberg blockade effect. Furthermore, we show the integration of the EMCCD camera in our experimental setup. The EMCCD timing, the pulse sequence in the experiment and the synchronization will be discussed in detail.

Q 42.27 Wed 17:00 Philo 2. OG

Nonlinear Quantum Optics and Rydberg Molecules in Ultracold Ytterbium — •Anthea Nitsch[1], Chris George[1], Tangi Legrand[1], Milena Simić[2], Eduardo Uruñela[1], Xin Wang[1], Wolfgang Alt[1], Matthew Eiles[2], and Sebastian Hofferberth[1] — [1]Institute of Applied Physics, University of Bonn, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Germany

Mapping the strong interactions between Rydberg excitations in ultracold atomic ensembles onto photons enables the achievement of high optical nonlinearities at the single-photon level. Previous demonstrations of this concept have relied exclusively on alkali atoms. In contrast, two-valence-electron species like ytterbium offer unique advantages, including narrow-linewidth laser cooling and, as we show for 174Yb, longer coherence times of polaritons compared to earlier Rubidium-based experiments.

In this poster, we present the latest upgrades and results from our ytterbium apparatus, featuring a flat-top beam to suppress repulsion of ground state atoms and realize photon-photon interactions via Rydberg polaritons. By minimizing frequency noise, we may extend Rydberg polariton coherence times. This is demonstrated by characterizing near-UV laser noise using a portable Mach-Zehnder interferometer. We show electromagnetically induced transparency and Rydberg blockade induced anti-bunching of photons and slow light. We also report the spectroscopic characterization of ultra-long-range ytterbium Rydberg molecules that arise as bound states in the low energy scattering of a highly excited Rydberg electron and a ground state atom.

Q 42.28 Wed 17:00 Philo 2. OG

Long-Range Enhanced Robust Quantum State Transfer in Topological Rydberg Models — •Siri Raupach, Mathias B. M. Svendsen, and Beatriz Olmos — Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

Fast and robust quantum state transfer (QST) between distant nodes in a quantum network is essential in quantum information processing. We present a framework for robust topological QST in a quantum optical realization of the extended SSH and Rice-Mele model with bipartite long-range hoppings. In quasi one dimensional chains of long-range dipole-dipole coupled Rydberg atoms on two spatially offset sublattices, the topological phase depends on this spatial offset and manifests as topologically protected edge states in the non-trivial regime. Thus, robust edge-to-edge QST of a Rydberg excitation can be achieved by varying the sublattice offset adiabatically. In chains consisting of both odd and even numbers of atoms, the transfer efficiency depends on the specifics of the transfer path. Notably, we find that the transfer efficiency is significantly improved when considering realistic long-range hoppings compared to the standard case of nearest neighbor hoppings. The resulting transfer can be implemented well within the lifetime of the Rydberg atoms, and due to its topological nature is robust against positional disorder of the atoms within experimentally realistic tolerances.

Q 42.29 Wed 17:00 Philo 2. OG

Effects of spin-phonon coupling on Rydberg facilitation in a lattice — •Benno Bock, Daniel Brady, and Michael Fleischhauer — University of Kaiserslautern-Landau, Kaiserslautern, Germany

In recent years, Rydberg atoms have proven themselves as a powerful tool for quantum simulators, one of the reasons being their strong and long-ranged interactions. One interesting phenomenon resulting from these interactions is Rydberg facilitation, or anti-blockade, where an atom excited to the Rydberg state moves a neighboring atom into resonance with a laser field, thus facilitating a fast excitation cascade in a regular lattice of trapped atoms. However, along with strong dipolar interactions between Rydberg atoms (spins), come mechanical forces coupling Rydberg atoms to high motional states (phonons) in their respective tweezer traps. For a chain of atoms trapped in tweezer arrays under the facilitation constraint, we numerically simulate the dynamics of the spin-phonon coupling. To this end, we approximate the van-der-Waals interaction potential up to second order. In particular we investigate how the motional degrees of freedom affect the spreading dynamics of Rydberg excitations and indentify parameter regimes of distinct behaviors not seen in previous work [PRL 132, 133401 (2024)], such as Bloch oscillations of excitation chains and a localization regime.

Q 42.30 Wed 17:00 Philo 2. OG

Active magnetic field stabilization for a dipolar quantum gas experiment — •Tim Jeglortz, Paul Uerlings, Fiona Hellstern, Kevin Ng, Michael Wischert, Stephan Welte, Ralf Klemt, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We aim to experimentally investigate the fundamental low-lying excitations of a dipolar quantum gas of dysprosium atoms in a toroidal trap. In particular, we focus on the emergence of the Higgs amplitude mode across the transition from a superfluid to a supersolid as an indicator of spontaneous symmetry breaking. Precise control of the magnetic field is crucial, as the excitation energy close to the critical point in the phase diagram has a steep dependence on the relative dipolar interaction strength, serving as the control parameter, which is in turn set by a magnetic offset field in the vicinity of a Feshbach resonance. This necessitates sub-mG magnetic field stability.

This poster presents a solution for an active magnetic field stabilization setup that allows to attenuate fluctuations relative to an arbitrary offset magnetic field using an array of fluxgate sensors placed outside the science chamber. A digital stabilization loop that runs on a fast microcontroller including high-resolution analog-to-digital and digital-to-analog converters in combination with a dedicated set of field coils allows to infer and control the magnetic field at the site of the atoms and reduce the background noise, particularly power line noise at 50 Hz, up to a bandwidth of 1 kHz.

Q 42.31 Wed 17:00 Philo 2. OG

Velocity field extraction from ultracold gases using bragg scattering — •hanyi jang, elinor kath, jelte duchene, helmut strobel, and markus k. oberthaler — Kirchhoff-Institut für Physik, Heidelberg, Germany

An ultracold quantum gases velocity field offers information about phase, topological defects and transport mechanisms. We have developed a method of estimating the velocity field by Bragg scattering from a moving optical lattice, which enables velocity selective two-photon transition between momentum states. To reconstruct the spatial velocity field of a 2-dimensional Bose-Einstein condensate (BEC), we explored two techniques. A short Bragg pulse generates a broad band response that simultaneously probes a spectrum of velocities, which is advantages for non-reproducible systems. In contrast, a long Bragg pulse produces narrow spectral response that probes single velocity with a higher precision. To assess the performance of the two methods, we benchmark them experimentally on a well-controlled scenario of stationary single vortex in the BEC. We extract the radial velocity profile centered on the vortex core and compare it to the analytic theory prediction and Gross-Pitaevskii simulation.

Q 42.32 Wed 17:00 Philo 2. OG

Towards an optical lattice for lithium-6 at 841 nm — Christian Partes and •Magnus Rusch — Universität Tübingen, Physikalisches Institut, Auf der Morgenstelle 14, 72076 Tübingen

We present the status of our technical preparation for imaging lithium-6 (Li) atoms in a two-dimensional optical lattice using optical tweezers. The lattice operates at 841 nm to match the tune-out wavelength of erbium which is used for sympathetic cooling.

Due to the low mass of the Li atoms, high-frequency intensity noise of the lattice beam may cause significant heating of the gas, so the laser power has to be actively stabilized up to the MHz-range. We provide insight into the current status of our intensity control setup making use of an acousto-optic modulator and an FPGA-based PI-controller.

Additionally, we present the preparation of a two-dimensional optical tweezer array using a spatial light modulator (SLM) and near-resonant light. The SLM phase pattern is controlled by a two-stage Gerchberg-Saxton algorithm, employing both numerical and camera feedback. We aim for a tweezer distance equal to twice the lattice spacing.