Q 31: Ultracold Matter IV – Bosons, Rydberg Systems, and Others (joint session Q/A)

Time: Wednesday 14:30–16:30 Location: P 2

Q 31.1 Wed 14:30 P 2

Interfacing Rydberg atoms with a high overtone bulk acoustic wave resonator in the GHz regime — •Julia Gamper, Valerie Leu, Cedric Wind, Wolfgang Alt, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Rydberg atoms have electric dipole-allowed transitions from microwave to optical frequencies, making them ideal for hybrid quantum platforms interfacing optical photons and on-chip devices. We specifically are developing a novel hybrid system, coupling Rydberg microwave transitions to the motion of an electromechanical resonator.

In this talk, we present our first approach towards this goal, combining ultracold atoms trapped with an atom chip and a high-overtone bulk acoustic wave resonator (HBAR). Specifically, we aim to use a superconducting Z-wire trap to position atoms near a 4K sample and with optimal overlap with the HBAR electric field. We present our calculations on Rydberg-oscillator coupling, showing that strong coupling between single Rydberg excitation and single phonon is reachable with current HBARs. Our chip design includes a coplanar waveguide resonator, whose second harmonic is resonant with both the Rydberg atoms and the HBAR, enabling classical driving of both components of the hybrid system. Our first application of this hybrid system is cooling of the oscillator mode well below the 4K environment temperature via engineered dissipation of the coupled Rydberg atoms.

Q 31.2 Wed 14:45 P 2

Spectroscopic signatures of emergent elementary excitations in a kinetically constrained long-range interacting two-dimensional spin system — •Tobias Kaltenmark[1], Chris Nill[1,2], Christian Gross[1], and Igor Lesanovsky[1,3] — [1]Universität Tübingen, Tübingen, Germany — [2]University of Bonn, Bonn, Germany — [3]The University of Nottingham, Nottingham, United Kingdom

Lattice spin models featuring kinetic constraints constitute a paradigmatic setting for the investigation of glassiness and localization phenomena. The intricate dynamical behavior of these systems is a result of the dramatically reduced connectivity between many-body configurations. This truncation of transition pathways often leads to a fragmentation of the Hilbert space, yielding highly collective and therefore often slow dynamics. Moreover, this mechanism supports the formation of characteristic elementary excitations, which we investigate here theoretically in a two-dimensional Rydberg lattice gas. We explore their properties as a function of interaction strength and range, and illustrate how they can be experimentally probed via sideband spectroscopy. Here, we show that the transition rate to certain delocalized superposition states of elementary excitations displays collective many-body enhancement. This work can be found in (Kaltenmark et al., 2025, arXiv:2511.13279).

Q 31.3 Wed 15:00 P 2

Dissipative Optical Nonlinearities in Ultracold Ytterbium — •Tangi Legrand, Xin Wang, Anthea Nitsch, Chris George, Wolfgang Alt, Eduardo Uruñuela, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Photon-photon interactions at the single-quantum level can be achieved and controlled by strong optical nonlinearities arising from interactions between Rydberg excitations in dense and ultracold atomic ensembles. Two-valence-electron species such as ytterbium offer novel advantages, including narrow-linewidth laser-cooling, optical detection and ionization, and access to long-lived nuclear-spin memory states.

In this talk, we present an experiment that investigates the interactions between a large number of Rydberg polaritons propagating simultaneously through a high-density ^{174}Yb medium. Using a narrow-line magneto-optical trap, we prepare dense clouds at microkelvin temperatures and drive Rydberg transitions via a counter-propagating two-photon scheme. A flat-top excitation beam, together with the long Rayleigh range of the near-UV probe, result in a high optical depth per blockade volume. We then generate and characterize Rydberg polaritons under electromagnetically induced transparency conditions and investigate how ytterbium's atomic structure–such as the absence of hyperfine splitting in bosonic isotopes–modifies dephasing mechanisms, blockade behavior, and collective dynamics. In particular, we detect dissipative nonlinearities through photon-antibunching and assess the coherence of the stored excitation.

Q 31.4 Wed 15:15 P 2

Functional approach to quantum depletion in the thermodynamic limit — •Jin Han[1], Thomas Gasenzer[1,2], and Jan M. Pawlowski[2] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227 — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16

We present a study of repulsive U(1)-bosonic gas with large scattering length. The effective action under consideration respects Galilean invariance and provides proper description for superfluidity and neutral superconductivity at an energy regime far below the mass gap of a solitonic excitation. The resolution of this system requires non-perturbative methods, and we apply the functional renormalisation group, formulated for quantum systems at vanishing temperature and finite chemical potential. In particular, we compute the three-momentum scaling of the atomic density over Bose-Einstein condensate and explain its connection with the Lee-Huang-Yang correction characterizing the two-body Tan's contact. To conclude, we promote the idea of anomalous quantum depletion.

Q 31.5 Wed 15:30 P 2

Tuning the Effective Range via Periodic Driving — •Sejung Yong and Axel Pelster — Department of Physics, RPTU Kaiserslautern-Landau, Germany

Combining Floquet physics with Feshbach resonances leads to dynamically created scattering resonances, which can physically be identified as Floquet bound states [1]. Experimentally these emerging Floquet-Feshbach resonances turned out to be observable via particle loss spectroscopy [2]. Thus, periodic driving allows now an unprecedented level of control for both resonance position and width for the s-wave scattering length. Here we extend the Floquet-Feshbach analysis by systematically taking the lowest energy-dependence of the scattering amplitude into account. With this we find how periodic driving changes the underlying effective range, which may have consequences for nonuniversal effects in ultracold quantum gases [3]. Exemplarily we show that a monochromatic drive of a broad magnetic Feshbach resonance yields a narrow Floquet-Feshbach resonace. [1] C. Dauer, A. Pelster and S. Eggert, Phys. Rev. Lett. 135, 033402 (2025). [2] A. Guthmann, F. Lang, L. M. Klein, S. Barbosa, and A. Widera, Sci. Adv. 11, 10 (2025). [3] N. Kaschewski, A. Pelster, and C.A.R. Sá de Melo, Phys. Rev. Res. 7, 033186 (2025).

Q 31.6 Wed 15:45 P 2

Interplay between topology and disorder in driven honeycomb lattices — •Johannes Arceri[1,2], Alexander Hesse[1,2], Moritz Hornung[1,2], Dizhou Xie[1,2], Christoph Braun[1,2], and Monika Aidelsburger[1,2] — [1]Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Floquet engineering -periodic modulation of a system's Hamiltonian-has emerged as a powerful tool for the realization of exotic, genuinely out-of-equilibrium quantum systems with no static counterpart. In particular, so-called anomalous Floquet phases display topological edge modes even though bulk bands carry zero Chern number, evading the standard bulk-boundary correspondence.

A defining feature of topological phases of matter is their robustness to spatial disorder. Technique to probe the topological nature of engineered Bloch bands often rely on translational invariance of the underlying lattice, thus failing in the presence of disorder. In the present work, we employ an experimental scheme for real-space detection of edge modes to identify disorder-driven phase transitions between two distinct topological regimes in a periodically driven honeycomb lattice.

Moreover, disordered anomalous Floquet systems are predicted to host a unique topological phase -the anomalous Floquet-Anderson insulator- in which chiral edge modes coexist with Anderson-localized bulk bands. We probe localization in the anomalous Floquet regime by performing quantum walks in modulated lattices, with and without a topological interface.

Q 31.7 Wed 16:00 P 2

An autonomous Thouless Pump — •Julius Bohm[1], James

Anglin[1], and Michael Fleischhauer[1,2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Research Center QC-AI, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

The Thouless pump is a paradigmatic example for a dynamical topological process in non-interacting 1+1-dimensional lattice systems [1]. Cyclic variation of lattice parameters can lead to quantized transport of particles in that lattice protected by a topological invariant. By now theoretical as well as experimental approaches for these pumps rely on direct modulation of the lattice parameters in time. Recent experiments [2] have shown, that replacing the lattice parameter by dynamical quantum degrees of freedom can lead to self-sustained topological pumps. We here present a theoretical model, where a single spin controlling the lattice particles and being subject to a constant magnetic field "drives" the system into a pumping phase without explicit time-dependencies. This pumping phase represents a non-equilibrium topological phase in excited eigenstates of the interacting system. We numerically determine the phase diagram of the system with parameter regions of quantized topological transport in the excited eigenstate and trivial phases without quantized transport. We derive analytic approximations for the corresponding critical parameters and introduce a topological invariant governing the topological transport.

[1] D. J. Thouless, Phys. Rev. B 27, 6083 (1983) [2] D. Dreon, et al., Nature 608, 494-498 (2022)

Q 31.8 Wed 16:15 P 2

Dipole induced phonon topology in one-dimensional Rydberg atom arrays — •Christian Gommeringer — Universität Tübingen

We study the topological properties of phonons in trapped Rydberg atom arrays, which arise from dipole-dipole interactions between the atoms. For various one-dimensional geometries, from zigzag to armchair configurations, we analyze the symmetries of the phononic Hamiltonian which give rise to topologically localized phonon excitations on the system boundaries. Because the phonon-phonon interactions here do not naturally respect chiral symmetry, which is crucial for realizing 1D topological phases, we show how an appropriate, geometry-dependent choice of the dipole moment orientation can restore this symmetry and enable topological characterization. The interplay between two phononic degrees of freedom in the harmonic trap potential, mediated by the dipole-dipole interactions, leads to interesting topological phases with winding numbers between zero and two. The corresponding edge states exhibit strong localization and robustness, making them potentially useful for applications in Rydberg-array-based quantum transport.

As an outlook we aim to explore how the phonon topology influences transport phenomena. Topological states in the electronic degrees of freedom in Rydberg arrays have already been shown to support topologically protected photon pumping. Studying the effect of spin-phonon coupling can provide new control mechanisms in the realm of topological transport.