Q 9: Bosonic Quantum Gases II (joint session Q/A)

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

Q 9.1 Mon 17:00 Aula

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

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

Q 9.2 Mon 17:15 Aula

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

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

Q 9.3 Mon 17:30 Aula

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

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

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

Q 9.4 Mon 17:45 Aula

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

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

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

Q 9.5 Mon 18:00 Aula

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

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

Q 9.6 Mon 18:15 Aula

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

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

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

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

Q 9.7 Mon 18:30 Aula

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

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

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[2] S. Furukawa and M. Ueda, New J. Phys. 17, 115014 (2015).
[3] T. Ozawa and N. Goldman, Phys. Rev. B 97, 201117 (2018).

Q 9.8 Mon 18:45 Aula

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

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

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