Q 48: Ultra-cold Atoms, Ions and BEC III (joint session A/Q)

Time: Thursday 14:30–16:30 Location: HS 1010

Q 48.1 Thu 14:30 HS 1010

ATOMIQ: An easy-to-use abstarction layer for ARTIQ — •Suthep Pomjaksilp[1], Christian Hölzel[2], Florian Meinert[2], Herwig Ott[1], and Thomas Niederprüm[1] — [1]Department of Physics and research center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Kaiserslautern, Germany — [2]5th Institute of Physics, Universität Stuttgart, Stuttgart, Germany

In recent years, the emergence of a vast landscape of quantum technology experiments created a still growing demand for high perfomance experiment control systems. In contrast to proprietary systems, the Sinara hardware and ARTIQ software ecosystem are fully open-source while reaching nanosecond timing performance. Yet, the subset of Python commands used by ARTIQ predominantly describes hardware like digital frequency synthesizers, DACs and ADCs, making it time-consuming to implement experimental sequences.

The ATOMIQ framework aims to bridge the gap between this hardware and entities familiar to experimental physicists like AOM controlled lasers, coils and cameras. In addition, ATOMIQ consolidates common routines (loading a magneto-optical trap, load and evaporate a dipole trap) into building blocks which can be transported in between experiments while preserving the possibility to leverage the high-perfomance primitives of ARTIQ. Finally, we demonstrate how ATOMIQ can be seamlessly integrated into a non-realtime data acquisition and control system.

Q 48.2 Thu 14:45 HS 1010

Circular Rydberg qubits of alkaline earth atoms in optical tweezers — •Einius Pultinevicius, Christian Hölzl, Aaron Götzelmann, Moritz Wirth, and Florian Meinert — 5th Institute of Physics, Universität Stuttgart, Stuttgart, Germany

We report the first demonstration of trapped circular Rydberg states of an alkaline-earth metal atom (Strontium) in an optical tweezer array. Circular Rydberg states promise orders of magnitude longer lifetimes compared to their low-L counterparts, which allows for overcoming fundamental limitations in the coherence properties of Rydberg atom based quantum simulators and quantum computers. In our experiments, we utilize tweezer trapped Strontium atoms and demonstrate efficient transfer into high-n circular Rydberg atoms with n=79 via rapid adiabatic passage. We implement a qubit between circular states of closeby hydrogenic manifolds coupled via a two-photon microwave transition and study its coherence via Rabi and Ramsey measurements. We also demonstrate trapping of the circular state enabled via the second available valence electron of the Sr atom. Our results open exciting prospects for exploiting unique properties of long-lived circular states of two-valence electron atoms, comprising coherent core excitation, for quantum technologies.

Q 48.3 Thu 15:00 HS 1010

Universal Self-Organization Dynamics in a Strongly Interacting Fermi Gas — •Timo Zwettler[1,2], Tabea Bühler[1,2], Aurélien Fabre[1,2], Gaia Bolognini[1,2], Victor Helson[1,2], Giulia del Pace[1,2], and Jean-Philippe Brantut[1,2] — [1]Institute of Physics, EPFL, Switzerland — [2]Center of Quantum Science and Engineering, EPFL, Lausanne, Switzerland

Cavity-coupled many-body systems constitute a new emergent field in condensed matter systems, where complex quantum materials are combined with cavity quantum electrodynamics (cQED) to substantially modify material properties by strong light-matter coupling.

We realize a prototypical cavity quantum material by combining cQED with a strongly interacting Fermi gas, providing an ideal, microscopically controllable platform for the study of collective light-matter coupling in strongly correlated matter. We explore the interplay of strong, short-range collisional interactions in the Bose-Einstein condensate to Bardeen-Cooper-Schrieffer (BEC-BCS) crossover and engineered, long-range cavity-mediated interactions, which arise from a two-photon scattering process in the transversally pumped atom-cavity system.

In recent experiments, we advance our understanding of density-wave ordering by investigating the out-of-equilibrium dynamics following a quench across the quantum phase transition. By observing the photons leaking from the optical cavity, we reveal the universal behaviour of the order parameter dynamics in this driven-dissipative system.

Q 48.4 Thu 15:15 HS 1010

Repulsively-bound pair states in the 1D extended Hubbard model — •Pascal Weckesser[1,2], Kritsana Srakaew[1,2], David Wei[1,2], Daniel Adler[1,2], Suchita Agrawal[1,2], Immanuel Bloch[1,2,3], and Johannes Zeiher[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany

The binding between two particles is usually mediated by attractive forces. Operating in an external confinement however, one can observe pair-binding despite having repulsive interactions. The existence of such bound states has been conjectured for the one-dimensional extended Hubbard model, yet so far their observation remained elusive.

In this talk, we present our recent findings on realizing one-dimensional extended Hubbard systems for ^{87}Rb atoms trapped in optical lattices and explore the emerging exotic bound states. Here, the long-range repulsion between two adjacent lattices sites is engineered using stroboscopic Rydberg dressing. We probe the presence of the bound state by monitoring the out-of-equilibrium dynamics of two particles using our quantum gas microscope, giving us direct access to the evolution of the density and the underlying correlations. As a final measurement, we explore multiparticle binding between three atoms. Our results path the way to study complex extended Hubbard models and string breaking in spin chains.

Q 48.5 Thu 15:30 HS 1010

Josephson effect in a double-well potential and its generalization for finite temperatures — •Kateryna Korshynska[1,2] and Sebastian Ulbricht[2,3] — [1]Department of Physics, Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska Street, Kyiv 01601, Ukraine — [2]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, D-38116 Braunschweig, Germany — [3]Technische Universität Braunschweig, D-38106 Braunschweig, Germany

In modern cold atom physics the study of many-particle bosonic systems gives insight into fundamental quantum processes and lays the foundation for powerful tools in precision metrology. The quantum nature of a bosonic system manifests itself in the Josephson effect, when the particles are placed in a double-well potential. In this potential one can define time-dependent probabilities of a single particle to be in the left or the right well. From that we develop the description of a many-particle system in the regime of global coherence (BEC) and in the case when the system is partially non-coherent. Focusing on the latter case we address the changes in many-particle dynamics, giving rise to a generalization of Josephson equations, which describe the system in non-equilibrium at finite temperatures. In this regime they predict deviations from the standard Josephson effect, which become more pronounced for high temperatures and a small number of bosons. For low temperatures, moreover, we find that the amplitude of Josephson oscillations is restricted. This prediction can be used to test the principles of statistics of a many-particle quantum system.

Q 48.6 Thu 15:45 HS 1010

Investigating interference with phononic bright and dark states in a trapped ion — •Robin Thomm[1], Harry Parke[1], Alan C. Santos[2], André Cidrim[2], Gerard Higgins[1], Marion Mallweger[1], Natalia Kuk[1], Shalina Salim[1], Romain Bachelard[2,3], Celso J. Villas-Boas[2], and Markus Hennrich[1] — [1]Department of Physics, Stockholm University, Stockholm, Sweden — [2]Departamento de Física, Universidade Federal de São Carlos, São Carlos, Brazil — [3]Institut de Physique de Nice, Université Côte d'Azur, Valbonne, France

Interference underpins some of the most unusual and impactful properties of both the classical and quantum worlds, from macroscopic systems down to the level of single photons. In this work a new description of interference, based on the formation of collective bright and dark states, is investigated experimentally. We employ a single trapped ion, whose electronic states are coupled to two of its motional modes in order to simulate a multi-mode light-matter interaction. We observe the emergence of phononic bright and dark states for both a single phonon and a superposition of coherent states. The collective dynamics of these systems demonstrate that a description of interference based solely on bright and dark states is sufficient to explain the light-matter coupling of any initial state in both the quantum and classical regimes.

Q 48.7 Thu 16:00 HS 1010

Fermi-liquid-like thermal and spin diffusion between unitary superfluids by dissipation — •Meng-Zi Huang, Philipp Fabritius, Jeffrey Mohan, Mohsen Talebi, Simon Wili, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland

Dissipation engineering in strongly correlated systems is an emerging territory of nontrivial interplay between coherent and incoherent dynamics. With direct particle and entropy measurements in a two-terminal setting, we show that the Seebeck response of a strongly-interacting Fermi gas can be enhanced by particle dissipation. This enhancement is robust when changing the dimensionality of the connection between the reservoirs and even the nature of the dissipation mechanisms, namely from spin-selective to pairwise losses. The dissipation also enhances thermal diffusion and spin diffusion, restoring the Fermi-liquid thermal and spin conductance which is initially strongly suppressed in this non-Fermi liquid. Although a microscopic theory is still missing, we provide a phenomenological model that can describe the observations.

Q 48.8 Thu 16:15 HS 1010

A Fermionic Quantum Gas Microscope for the Continuum — •Joris Verstraten, Maxime Dixmerias, Kunlun Dai, Shuwei Jin, Bruno Peaudecerf, Tim de Jongh, and Tarik Yefsah — Ultracold Fermi Gases, Laboratoire Kastler Brossel, Paris, France

Quantum gas microscopes have emerged as powerful tools to investigate the microscopic details of ultracold many-body systems. It enables the imaging of dilute quantum gases with single atom resolution and has shed light on the properties of various systems such as the Bose- and Fermi-Hubbard models. As it relies on optical lattice potentials, this method was restricted to periodic systems, in which atoms are already constrained to move between lattice sites. On the other hand, using a deep optical lattice to pin atoms initially prepared in a continuous trap leads to a non-trivial projection on discrete positions.

Here we report on the realization of a Lithium 6 based quantum gas microscope intended to study the microscopic characteristics of ultracold Fermi gases inside the continuum regime. We investigate the fidelity of the pinning process through a dynamical study of individually prepared non-interacting atoms in free space, and are able to experimentally reconstruct the wavefunction of single atoms expanding from a locally harmonic trap. Imaging fidelity as high as 99% can also be achieved under the right experimental conditions, proving that single-atom imaging of bulk systems is not only technically possible but also a reliable method of measuring the microscopic properties of continuous sytems. This opens up the path for the study of correlations in continuous, strongly interacting systems of fermions.