Q 50: Ultracold Matter (Fermions) I (joint session Q/A)

Time: Thursday 11:00–12:45 Location: HS V

Q 50.1 Thu 11:00 HS V

Erbium-Lithium: towards a new quantum mixture experiment — Alexandre De Martino, Kiesel Florian, Karpov Kirill, •Jonas Auch, and Christian Gross — University of Tübingen, Tübingen, Germany

The goal of this Erbium-Lithium mixture experiment, is to lower the current temperature limit for fermions. One key for this shall be the strong mass imbalance, as we use heavy bosonic erbium atoms as a heat reservoir for the light fermionic lithium atoms. While trapping erbium in a shallow trap at 1064 nm, we want to utilize the tuneout wavelength of erbium at 841 nm. This enables an additional, narrow trap for lithium. In addition to this cooling aspect, the combination of erbium and lithium enables polaron physics, with heavy dopants of erbium in an lithium environment.

Q 50.2 Thu 11:15 HS V

Spectral structure and dynamics of partially distinguishable fermions on a lattice — •Caroline Stier, Edoardo Carnio, Gabriel Dufour, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg

We study the fermionic many-body quantum dynamics generated by a Hubbard-like Hamiltonian with nearest neighbour interaction and a continuously tunable level of distinguishability of the particles. For not strictly indistinguishable fermions, distinct invariant symmetry sectors of the many-body Hilbert space are populated, with tangible impact on the many-body dynamics. We identify the regime of tunneling and interaction strengths where the many-body eigenstates acquire ergodic structure, and investigate how the interplay between dynamical instability and partial distinguishability affects the evolution of the many-body counting statistics.

Q 50.3 Thu 11:30 HS V

Building a programmable quantum gas microscope — •Isabelle Safa[1], Sarah Waddington[1], Tom Schubert[1], Rodrigo Rosa-Medina[1], and Julian Leonard[1,2] — [1]Atominstitut TU Wien, Stadionallee 2, 1020 Wien, Austria — [2]Institute of Science and Technology Austria (ISTA), Am Campus 1, 3400 Klosterneuburg, Austria

Ultracold atoms in optical lattices offer a versatile platform for simulating and probing strongly correlated quantum matter. While quantum gas microscopy techniques have enabled unprecedented single-site resolution, key remaining challenges of the field are still posed by rigid lattice configurations and slow cycle times.

Here, we present our ongoing efforts to tackle these issues by designing and building a next-generation quantum gas microscope for fermionic and bosonic lithium atoms. Our approach relies on atom-by-atom assembly in small lattice systems by means of auxiliary optical tweezers, combined with all-optical cooling techniques to facilitate sub-second experimental cycles. The holographic projection of a blue-detuned, short-spacing lattice will provide reconfigurability and fast tunneling dynamics, leading to diverse research avenues for our new project, from the simulation of Bose- and Fermi-Hubbard models with unconventional geometries to strongly correlated topological phases.

Q 50.4 Thu 11:45 HS V

A versatile Quantum Gas Platform - Heidelberg Quantum Architecture — •Tobias Hammel, Maximilian Kaiser, Daniel Dux, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Heidelberg, Germany

Programmable quantum simulation and computation with ultracold quantum systems requires the combination of sophisticated functionalities that have to work all at the same time, in particular including high precision optical potentials.

With our new experimental platform, we present a solution which helps to manage this increasing complexity. This platform is characterized by optical modules which can be implemented into the experiment plug-and-play in a fast, repeatable and predictable way.

In this talk our implementation of the platform is presented including optical modules generating dipole traps, tweezers, an optical accordion and box potentials. Furthermore, we present first experimental results realized within this platform.

Q 50.5 Thu 12:00 HS V

Fate of the Higgs mode in confined fermionic superfluids — •René Henke[1], Cesar R. Cabrera[1], Hauke Biss[1], Lukas Broers[2], Jim Skulte[2], Hector Pablo Ojeda Collado[2], Ludwig Mathey[1,2], and Henning Moritz[1] — [1]Institut für Quantenphysik, Universität Hamburg — [2]Zentrum für optische Quantentechnologien, Universität Hamburg

In superconductors and superfluids, the order parameter characterizes the phase coherence and collective behavior of the system. Fluctuations in the phase and amplitude of the order parameter give rise to the Goldstone and Higgs modes, respectively. In confined systems, these dynamics as well as the static properties of superfluids are expected to change dramatically. As an example of the latter, shape resonances in nano wires and films are predicted to enhance the superfluid gap and raise T_c.

Here, I will report on the observation of a hybridization between Higgs and breathing oscillations in a quasi-2D fermionic superfluid. When modulating the confinement, we observe a well-defined collective mode throughout the BEC-BCS crossover. In the BCS regime, the excitation energy follows twice the pairing gap, as expected for an amplitude oscillation, drops below it in the strongly correlated regime, and approaches the breathing mode frequency, in excellent agreement with an effective field theory for order parameter dynamics. The mode vanishes when approaching the superfluid critical temperature. Our results provide insights into the complex interplay between confinement-induced effects and fundamental excitations in reduced dimensions.

Q 50.6 Thu 12:15 HS V

Quantum Computation with fermionic Li-6 atoms in optical lattices — •Johannes Obermeyer[1], Petar Bojović[1], Si Wang[1], Marnix Barendregt[1], Dorothee Tell[1], Immanuel Bloch[1,2], Titus Franz[1], and Timon Hilker[3] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ludwig-Maximilians-Universität, München, Germany — [3]University of Strathclyde, Glasgow, UK

In our quantum gas microscope, we load fermionic Li-6 atoms into isolated double wells in optical superlattices. By precisely controlling the relative phase and intensity of the superlattices, we encode single- and two-qubit gates within these isolated double-wells, which constitute the building blocks for digital, fermionic quantum computation. Site-resolved measurement of spin and density allows us to fully characterize the initial state preparation and the quantum gate fidelity. In this talk, I will present how we realized high-fidelity SWAP$^{\alpha}$ two-qubit gates with over one hundred atoms. We demonstrate long coherence and stability of the qubit and we characterize main error mechanisms. These results hold substantial promise for quantum computation tasks, including the simulation of electronic systems like molecular structures.

Q 50.7 Thu 12:30 HS V

Exploring Integer and Fractional Quantum Hall states with six rapidly rotating Fermions — •Paul Hill, Johannes Reiter, Jonas Drotleff, Philipp Lunt, Maciej Galka, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg (Germany)

The quantum Hall effect features remarkable states that due to their exotic topological properties and strongly correlated nature have stimulated a rich body of research going far beyond the condensed matter community, where the effect was originally discovered. The effect manifests in two forms: the integer (IQH) and fractional (FQH) quantum Hall effect, distinguished by the significance of repulsive particle interactions. In earlier experiments, we have realized a two-particle Laughlin (FQH) state by rapidly rotating two interacting spinful fermions confined in a tight optical tweezer. Building on this technique, we now present first results for a larger system consisting of six particles: the realization of a two-component IQH state comprising 3+3 spinful fermions. Through imaging of the individual atoms, we capture snapshots of the many-body density and observe a hallmark feature of IQH states–a uniform flattening of the particle density distribution. Our result not only highlights the scalability of the approach but also paves the way for studying FQH states due to the tunability of the interactions between the particles. This brings within reach the realization of a three-particle Laughlin state and the observation of a quantum phase transition between IQH states of weakly interacting fermions and FQH states of interacting bosonic molecules.