Q 41: Ultra-cold Atoms, Ions and BEC II (joint session A/Q)

Time: Thursday 11:00–13:00 Location: HS 1098

Q 41.1 Thu 11:00 HS 1098

Realization of the ^{88}Sr fine-structure qubit: The building block for a 500-qubit quantum computer demonstrator (QRydDemo) — •Govind Unnikrishnan[1], Jennifer Krauter[1], Philipp Ilzhöfer[1], Ratnesh Kumar Gupta[1], Jiachen Zhao[1], Achim Scholz[1], Christian Hölzl[1], Aaron Götzelmann[1], Sebastian Weber[2], Nastasia Makki[2], Hans Peter Büchler[2], Jürgen Stuhler[3], Florian Meinert[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]Toptica Photonics AG, 82166 Gräfelfing, Germany

The QRydDemo project aims to realize a quantum computer demonstrator with 500 qubits based on the novel fine-structure qubit encoded in the metastable triplet manifold of ^{88}Sr, which enables fast gates (100 ns) and a long coherence time (10 ms). Here, we demonstrate the first step towards this goal by realizing preparation, readout and coherent operations on the fine-structure qubit. In addition to driving Rabi oscillations bridging an energy gap of 17 THz, we also carry out Ramsey spectroscopy with which we extract the coherence time T_2 in our system. A full quantum mechanical model is used to simulate our experiments by including noise sources to identify the main constraints limiting our coherence time and project improvements to our system in the immediate future.

Q 41.2 Thu 11:15 HS 1098

Dysprosium Quantum Gas Microscope — •Kevin Ng, Fiona Hellstern, Jens Hertkorn, Paul Uerlings, Lucas Lavoine, Ralf Klemt, Tim Langen, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

With quantum gas microscopy providing access to study particle interactions and correlations on the microscopic scale, engineering analogues to simulate and understand solid state systems with a high degree of control has become possible. Although single atoms can be trapped and imaged in optical lattices, most existing quantum gas microscopes trap and image atoms using light with relatively long wavelengths, and where only short-range contact interactions exist between atoms. Here, we present our progress toward building a quantum gas microscope with dysprosium atoms that will be trapped in lattices using ultraviolet ($\sim$ 360nm) light, where enhanced anisotropic dipolar interactions compete with tunable inter-site particle tunnelling and on-site interactions. Owing to the enhanced dipolar interaction strength between dysprosium atoms in optical lattices of such a short wavelength, our quantum gas microscope opens up the possibility to observe novel phases of matter in a variety of lattice geometries. Our planned experimental setup and initial steps toward characterising the trapping properties of dysprosium at 360nm will be presented.

Q 41.3 Thu 11:30 HS 1098

Stabilization of a paramatrically driven BEC: an open quantum system approach — •Larissa Schwarz, Simon B. Jäger, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany

We theoretically analyze the effects of periodically modulated repulsive interactions in a Bose-Einstein condensate (BEC) that features intrinsic damping mechanisms. We derive a master equation describing the dynamics of the momentum modes of the BEC in the parameter regime of weak driving strengths. Above a threshold for the modulation strength we find that the BEC becomes unstable. Below this threshold the combination of damping and periodic driving guides the system into a stationary state that shows an enhancement of fluctuations for specific momentum modes that can be controlled by the driving frequency. We analyze the stationary state of these fluctuations, quantify the condensate depletion and analyze the squeezed and anti-squeezed quadratures generated by the parametric driving, emphasizing the possibility to generate non-classical states of matter.

Q 41.4 Thu 11:45 HS 1098

Collisional energy effects on atom-ion Feshbach resonances — •Fabian Thielemann[1], Joachim Siemund[1], Daniel Hönig[1], Wei Wu[1], Krzystof Jachymski[2], Thomas Walker[1,3], and Tobias Schaetz[1] — [1]Physikalisches Institut, Albert-Ludwigs Universität Freiburg — [2]Faculty of Physics, University of Warsaw — [3]Blackett Laboratory, Imperial College, London

Collisions between particles are at the heart of many physical and chemical processes. The ability to control them down to the single quantum level is crucial to understanding the constituents and their interaction. We use our hybrid setup to combine a single Ba^{+}_{138} ion with a cloud of ultra-cold, spin-polarized Li_6 near degeneracy. We investigate the transition from the classical to the quantum regime of collisions and show to what extent individual atom-ion Feshbach resonances of this combination depend on the collisional energy. With the help of a quantum recombination model, we make first steps towards distinguishing between resonances that occur due to different open-channel partial-wave contributions.

Q 41.5 Thu 12:00 HS 1098

A quantum-gas microscope for ultracold strontium atoms — Sandra Buob[1], Jonatan Höschele[1], Vasiliy Makhalov[1], •Antonio Rubio-Abadal[1], and Leticia Tarruell[1,2] — [1]ICFO - Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain — [2]ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain

Quantum-gas microscopes offer novel observables to study quantum many-body systems, but have so far been mostly restricted to alkali atoms. Alkaline-earth species, like strontium, offer a range of desirable features, due to their electronic structure, which can significantly expand the toolbox of Hubbard-type quantum simulation.

In this talk, I will present the realization of site-resolved imaging of a quantum gas of bosonic strontium in a clock-magic optical lattice. We realize fluorescence imaging via the blue 461-nm transition and simultaneous attractive Sisyphus cooling via the narrow 689-nm intercombination line. From the raw fluorescence images, we are able to reconstruct the atomic occupation with fidelities above 95%. Our experiment opens the door to future microscopic studies of the dissipative Bose-Hubbard model, as well as SU(N) fermions.

Q 41.6 Thu 12:15 HS 1098

Phase-Stable Traveling Waves Stroboscopically Matched for Super-Resolved Observation of Trapped-Ion Dynamics — •Florian Hasse, Deviprasath Palani, Apurba Das, Frederike Doerr, Leon Goepfert, Ole Pikkemaat, Ulrich Warring, and Tobias Schaetz — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

We introduce an approach, creating and maintaining the coherence of four oscillators: a global microwave reference field, a polarization-gradient traveling-wave pattern of light, and the spin and motional states of a single trapped ion. The features of our method are showcased by probing the 140-nm periodic light pattern and stroboscopically tracing dynamical variations in position and momentum observables with noise floors of 1.8(2) nm and 8(2) zμNs, respectively.

We are currently expanding our methods towards non-classical squeezed states to realize the transfer of spatial entanglements, present in multimode squeezed states, into the robust electronic degrees of freedom (DOF) of multiple ions. For this we switch the trapping potential of two $^{25}Mg^{+}$ ions fast enough to induce a non-adiabatic change of the ions' motional mode frequencies, preparing the ions in a squeezed state of motion, accompanied by the formation of entanglement in the ions' motional DOF. This is a promising ansatz to study analogs of physics of the early universe, as particle pair creation during cosmic inflation, and relativistic quantum effects, e.g., Hawking radiation.

A summary of our previous work is published on Arxiv: https://arxiv.org/abs/2309.15580

Q 41.7 Thu 12:30 HS 1098

Fractional angular momentum quantization in Atomtronic circuits — •Wayne Jordan Chetcuti[1], Juan Polo[1], Andreas Osterloh[1], and Luigi Amico[1,2,3] — [1]Quantum Research Center, Technology Innovation Institute, P.O. Box 9639 Abu Dhabi, UAE — [2]Dipartimento di Fisica e Astronomia and INFN-Sezione di Catania, Via S. Sofia 64, 95127 Catania, Italy — [3]Centre for Quantum Technologies, National University of Singapore 117543, Singapore

In this talk, I showcase the latest results for bosonic and fermionic matter-wave circuits in the context of Atomtronics. For attractively interacting bosons, the system sees the formation of bound states, which are the quantum analogs of bright solitons found in the mean-field regime. Considering the full many-body regime allows us access to a new phenomenology arising from the strong correlations in the system. Specifically, for a ring geometry pierced by a synthetic gauge field, we find that the angular momentum quantization per particle acquires fractional values depending on the number of particles constituting the bound state. The phenomenon of fractionalization manifests as new plateaus in the angular momentum and presents potentially important applications in the field of metrology and sensing. Analogous phenomenology is found in SU(N) fermionic systems in similar configurations. However, the physical origin of the angular momentum quantization present in these systems depends on the nature of the interactions, be they repulsive or attractive. The feature of fractionalization has promising applications to interferometry using these massive bound states in fermionic and bosonic systems.

Q 41.8 Thu 12:45 HS 1098

Magnetic field shielding and rotation stabilisation in the Einstein-Elevator — •Alexander Heidt — Institut für Transport- und Automatisierungstechnik, Hannover, Deutschland

There is an increasing focus on the exploration of space, its potential colonisation and the use of its advantages for fundamental physical research. To make this possible, technologies are required that work in microgravity. The Einstein-Elevator was developed and built out of the motivation to research technologies suitable for space. It is also able to simulate various gravity conditions. Numerous projects from various disciplines are currently being worked on, such as from mechanical engineering to develop new production processes and from physics to carry out basic research into atomic interferometry. One of these is the INTENTAS project, which aims to measure the entanglement of atoms in microgravity. The "spin-exchange collisions" method is used here, whereby weak magnetic field fluctuations can prevent such entanglement of atoms. In order to ensure this entanglement reliably, a magnetic field fluctuation of a few nanotesla is required. For this reason, a magnetic shield was designed as part of the project that suppresses magnetic field fluctuations in the Einstein-Elevator (10 *T) to a few nanotesla. On the other hand, the DESIRE project aims to find evidence of dark energy. However, the setup is sensitive to rotations, so the Einstein-Elevator has been extended with reaction wheels to compensate for any rotations that occur.