Q 13: Ultra-cold Atoms, Ions and BEC I (joint session A/Q)

Time: Monday 17:00–19:00 Location: F303

Invited Talk Q 13.1 Mon 17:00 F303

Multi-frequency optical lattice for dynamic lattice-geometry control — Marcel Kosch[1], •Luca Asteria[1,2], Henrik Zahn[1], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]Institut für Laserphysik, Hamburg University — [2]The Hamburg Centre for Ultrafast Imaging — [3]Zentrum für Optische Quantentechnologien, Hamburg

Ultracold atoms in optical lattices are pristine model systems with a tunability and flexibility that goes beyond solid-state analogies. However, a fast change of the lattice geometry remains intrinsically difficult. Here we introduce a multi-frequency lattice for fast and flexible lattice-geometry control and demonstrate it for a three-beam lattice, realizing the full dynamical tunability between honeycomb lattice, boron-nitride lattice and triangular lattice on the microsecond scale, i.e., fast compared to the relevant energy scales. At the same time, the scheme ensures intrinsically high stability of the lattice geometry. We introduce the concept of a geometry phase as the parameter that fully controls the geometry and observe its signature as a staggered flux in a momentum space lattice. Tuning the geometry phase allows to dynamically control the sublattice offset in the boron-nitride lattice. We use a fast sweep of the offset to transfer atoms into higher Bloch bands, and perform a new type of Bloch band spectroscopy by modulating the sublattice offset. Finally, we generalize the geometry phase concept and the multi-frequency lattice to 3D optical lattices and quasi-periodic potentials. This scheme will allow novel Floquet and quench protocols to create and probe, e.g., topological properties.

Q 13.2 Mon 17:30 F303

Sturdy and Compact Laser System for Cold Atom Experiments in BECCAL on the ISS — •Tim Kroh[1,2], Victoria Henderson[1,2], Jakob Pohl[1,2], Matthias Schoch[1], Christoph Weise[1], Hrudya Thaivalappil Sunilkumar[1], Hamish Beck[1], Bastian Leykauf[1], Evgeny Kovalchuk[1], Jean Pierre Marburger[3], Faruk Alexander Sellami[3], Esther del Pino Rosendo[3], André Wenzlawski[3], Matthias Dammasch[2], Ahmad Bawamia[2], Andreas Wicht[2], Patrick Windpassinger[3], Achim Peters[1,2], and the BECCAL Team[1,2,3,4,5,6,7,8,9,10] — [1]HUB, Berlin — [2]FBH, Berlin — [3]JGU, Mainz — [4]DLR-SC — [5]DLR-SI — [6]DLR-QT — [7]IQ & IMS, LUH — [8]ILP, UHH — [9]ZARM, Bremen — [10]IQO, UULM

BECCAL (Bose-Einstein Condensate–Cold Atom Laboratory), a multi-user facility designed for operation on the ISS, is a DLR and NASA collaboration built on the heritage of NASA's CAL, sounding rocket and drop tower experiments. Fundamental physics will be explored with Rb and K BECs and ultra-cold atoms in microgravity, at longer time- and ultra-low energy scales compared to those achieved on earth. The laser system design provides a reliable and robust combination of micro-integrated diode lasers (from FBH) and miniaturized free-space optics on Zerodur boards (from JGU), interconnected with fiber optics, to meet the unique challenge of matching the complexity of the required light fields to the stringent size, weight, and power limitations on the ISS. An update one the BECCAL laser system design will be given based on the requirements, concepts, and heritage which formed it. Funding by DLR / BMWK grant numbers 50 WP 2102, 2103, 2104.

Q 13.3 Mon 17:45 F303

Observation of vortices and vortex stripes in a dipolar BEC of Dysprosium — •Lauritz Klaus[1,2], Thomas Bland[1,2], Elena Poli[2], Claudia Politi[1,2], Giacomo Lamporesi[3], Eva Casotti[1,2], Russell Bisset[2], Manfred Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Institut für Experimentalphysik, Universität Innsbruck, Austria — [3]INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento, Italy

Quantized vortices are a defining feature of superfluid systems under rotation and have been extensively investigated in ultracold atom experiments with isotropic contact interactions. However, they have never been observed in dipolar quantum gases. We here report on the creation of vortices in a strongly magnetic Bose-Einstein-Condensate (BEC) of ^{162}Dy atoms. We are imparting angular momentum to the BEC by the means of magnetostirring, a novel technique making use of the alignment of the dipolar atoms along the rotating magnetic field. We show that for a critical rotation frequency, the dipolar BEC starts to nucleate vortices and that the vortices arrange in stripes along the direction of the magnetic field during the rotations. The next key step will be extending the concept of magnetostirring to the recently observed supersolid states and study the vortex formation in this very exotic state of quantum matter.

Q 13.4 Mon 18:00 F303

Optimizing optical potentials with physics-inspired learning algorithms — •Martino Calzavara[1,4], Yevhenii Kuriatnikov[2], Andreas Deutschmann-Olek[3], Felix Motzoi[1], Sebastian Erne[2], Andreas Kugi[3], Tommaso Calarco[1,4], Jörg Schmiedmayer[2], and Maximilian Prüfer[2] — [1]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Control (PGI-8), 52425 Jülich, Germany — [2]Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria — [3]Automation and Control Institute, TU Wien, Gußhausstraße 27-29, 1040 Vienna, Austria — [4]Institute for Theoretical Physics, Universität zu Köln, 50937 Cologne, Germany

We present our new experimental and theoretical framework which combines a broadband superluminescent diode (SLED/SLD) with fast learning algorithms to provide speed and accuracy improvements for the optimization of 1D optical dipole potentials, here generated with a Digital Micromirror Device (DMD). We employ Machine Learning (ML) tools to train a physics-inspired model acting as a digital twin of the optical system predicting the behavior of the optical apparatus including all its imperfections. Implementing an algorithm based on Iterative Learning Control (ILC), we optimize optical potentials an order of magnitude faster than heuristic optimization methods. We compare iterative model-based "offline" optimization and experimental feedback-based "online" optimization. Our methods provide a new route to fast optimization of optical potentials which is relevant for the dynamical manipulation of ultracold gases.

Q 13.5 Mon 18:15 F303

A strontium quantum gas microscope with cavity-enhanced optical lattices — •Valentin Klüsener[1,2], Dimitry Yankelev[1,2], Jan Trautmann[1,2], Sebastian Pucher[1,2], Felix Spriestersbach[1,2], Immanuel Bloch[1,3,2], and Sebastian Blatt[1,3,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology, 80799 München, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München, Germany

Alkaline-earth atoms in optical lattices have emerged as a powerful platform for precision measurements, quantum simulation and quantum computation with neutral atoms. We present a setup combining techniques developed for optical atomic clocks and quantum gas microscopes, thus marrying high frequency resolution with microscopic spatial resolution. We demonstrate single-site and single-atom resolved fluorescence imaging of individual strontium atoms in a large and homogeneous cavity enhanced optical lattice. To prepare a two-dimensional system we optically address a single layer of the optical lattice on the ultra-narrow 1S0-3P2 transition. The required high spatial resolution is achieved by application of a magnetic field gradient and precise engineering of lattice light shifts. We perform high resolution fluorescence imaging of single atoms by employing a two color imaging scheme. Narrow-line sideband cooling suppresses heating and allows to maintain low temperatures during the imaging process.

Q 13.6 Mon 18:30 F303

Quantum Simulation of Spin 1 Heisenberg Models with Dysprosium — •Katharina Brechtelsbauer and Hans-Peter Büchler — Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

In this work, we propose Dysprosium atoms for the simulation of the one-dimensional spin-1 Heisenberg model, which is known to have a rich phase diagram including the famous Haldane phase [1]. For realizing the model, we make use of the strong dipolar exchange interactions that naturally occur in the ground state of Dysprosium due to its large total angular momentum of J=8. To implement spin-1 particles, we encode the spin degree of freedom into three Zeeman sub-levels which are

energetically isolated by applying a magnetic field. Using the density-matrix renormalization group, we analyze the ground-state properties of the resulting effective model. We find that a chain of fermionic Dysprosium atoms in a suitable magnetic field can form a Haldane state with the characteristic spin-1/2 edge modes. Furthermore, we discuss the use of AC Stark shifts and Raman-type schemes to isolate effective spin-1 systems and to increase the tunability of the model parameters.

[1] W. Chen, K. Hida, and B. C. Sanctuary, Phys Rev B 67, 104401 (2003)

Q 13.7 Mon 18:45 F303

Simulation of sympathetic cooling in a linear paul trap driven by alternative waveforms — •Paul Oskar Sund[1], Martin Kernbach[1,2], and Andreas W. Schell[1,2] — [1]Leibniz Universität, Hannover, Deutschland — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

Linear quadrupole ion traps have been established as a versatile platform for quantum computing and atomic clocks, since they allow for an environment-isolated manipulation of multiple ions simultaneously combined with flexible optical access. However, the preparation of ion species by sympathetic cooling at room-temperature demands up to several minutes, while encountering rf-heating and scattering losses. In general, the particles dynamic is determined by the ponderomotive trap force resulting from the periodical oscillating electrical field, which is dependent on the applied waveform.

Therefore the ongoing cooling dynamics were investigated by numerically solving the Mathieu's differential equations of motion in a two-particle sympathetic cooling model under various driving waveforms and initial conditions. The simulation reveals differences in rf-heating, cooling speed and steady state energies at Coulomb-crystallization. Furthermore, shifted stability regions compared to the harmonic trap driving are found. Based on these results a further systematic investigation with alternative driving waveforms appears to be promising for improving the trapping stability and preparation times.