A 17: Ultra-cold Atoms, Ions and BEC II (joint session A/Q)

Time: Wednesday 14:30–16:30 Location: N 1

Invited Talk A 17.1 Wed 14:30 N 1

Three-body dynamics between an ion and two Rydberg states — •Jennifer Krauter[1], Maximilian Futterknecht[1], Óscar Andrey Herrera Sancho[1], Florian Anschütz[1], Utzuri Högl Vidal[1], Moritz Berngruber[2], Florian Meinert[1], Robert Löw[1], and Tilman Pfau[1] — [1]5th Institute of Physics, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [2]Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

As a versatile tool, our high-resolution ion microscope has sucessfully been used to study the dynamics between bound and unbound Rydberg atom-ion pair states in the ultracold regime. With our experimental apparatus we achieve high temporal and spatial resolution of at least 200 nm, which is well-suited for the real space study of these pair dynamics. Here, we want to show that the binding mechanism between ions and Rydberg atoms is not limited to diatomic molecules but can be extended to polyatomic systems, for which we expect interactions that are even more intricate. We are particularly interested in bound states that comprise two Rydberg atoms and one ion. For this scenario, we predict a rich interaction potential that combines the interaction between induced dipoles, ion-Rydberg atom interactions, and the Rydberg blockade effect, leading to potential wells that support bound molecular states between the three particles. Experimentally, we are working toward realizing and studying these systems both spectroscopically as well as in real space, hoping to gain insight into the underlying fewbody physics.

A 17.2 Wed 15:00 N 1

Measuring inter-atomic friction with ultracold gases — •Silvia Hiebel, Sabrina Burgardt, Julian Fess, and Artur Widera — RPTU University Kaiserslautern-Landau

Usually, friction is characterized at the macroscopic scale. Over the past 25 years, microscopic measurements have become possible – for example, by dragging single atoms across surfaces with lateral force microscopes or by studying lubricity with dipole potentials acting on trapped ions. Yet, to understand transport in complex media, we also need direct access to friction at the level of individual atoms embedded in a gaseous environment.

We present our measurements of the friction of single atoms in a tilted optical lattice interacting with an ultracold atomic bath. A one-dimensional lattice allows controlled transport of individual atoms with tunable transport parameters, generating well-defined forces that can exceed gravity by several orders of magnitude and enabling access to distinct diffusion regimes. By pulling the single probe atoms through a dense ultracold bath, we observe the interplay between the driven impurity and its environment and extract the resulting effective friction.

A 17.3 Wed 15:15 N 1

Fast Parallel Atom Sorting for a Rydberg Atom Quantum Computer Demonstrator — •Achim Scholz[1,2], Christopher Bounds[1,2], Manuel Morgado[1,2], Govind Unnikrishnan[1,2], Ralf Berner[1,2], Jiachen Zhao[1,2], Julia Hickl[1,2], Maximilian Kob[1,2], Sebastian Weber[3,2], Hans-Peter Büchler[3,2], Simone Montangero[4], Christoph Tresp[5], Jürgen Stuhler[5], Tilman Pfau[1,2], and Florian Meinert[1,2] — [1]5th Inst. of Physics, University of Stuttgart — [2]IQST — [3]Inst. for Theoretical Physics III, University of Stuttgart — [4]Inst. for Complex Quantum Systems, University of Ulm — [5]TOPTICA Photonics AG

The QRydDemo project aims to realize a Rydberg atom quantum computer demonstrator based on the fine-structure qubit in ^{88}Sr. This qubit not only allows for fast single-qubit gates via strong two-photon Raman transitions but also enables triple-magic trapping at an expected wavelength of 592 nm, for both qubit states and the Rydberg state are magically trapped. These conditions are promising for the realization of high-fidelity multi-qubit operations wherefore we employ a novel all electro-optical tweezer setup comprised of 20 AODs at the triple-magic wavelength. Each AOD can realize a 1D-array with up to 64 tones to finally create a 500 qubit array by folding the independent rows with a three-staged step mirror. Utilizing this architecture, we present our progress on single atom loading and cooling, as well as rearrangement towards sorting and dynamical pattern generation. The availability of fast parallel reshuffling within the qubit coherence time paves the way towards flexible qubit connectivity and operations.

A 17.4 Wed 15:30 N 1

Towards Commissioning a Linear Surface Trap for Ions with Real-Time Control and Open-Science Workflows — •Tobias Spanke, Frederike Dörr, Florian Hasse, Lucas Eisenhart, Deviprasath Palani, Jörn Denter, Mario Niebuhr, Ulrich Warring, and Tobias Schätz — Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg

We present a modern trapped-ion platform that combines a microfabricated surface-electrode trap, real-time control, and open-science workflows for scalable quantum control and precision collision studies. We report on the commissioning of a linear surface-electrode ion trap from Sandia National Laboratories [1] operated with ARTIQ real-time control and versioned experiment pipelines for experiments with ^{25}Mg^{+} ions. A stabilized multi-wavelength laser system enables robust loading, Doppler cooling, and coherent control [2]. As a first application, we implement "Phoenix Flyby Calibration", a laser-triggered neutral-gas source for time-resolved benchmarking of ion-neutral collision dynamics in our trapped-ion apparatus. This commissioning lays the groundwork for systematic studies of background-gas-induced heating and loss in surface traps and for transferable protocols for real-time control and open-science workflows in trapped-ion experiments.

[1] Revelle, M. C. (2020), Phoenix and Peregrine Ion Traps, arXiv:2009.02398 [physics.app-ph] (2020)

[2] Palani, D. et al. (2023), High-Fidelity Transport of Trapped-Ion Qubits in a Multi-Layer Array, arXiv:2305.05741 [quant-ph] (2023)

A 17.5 Wed 15:45 N 1

Ultracold mixture of erbium and lithium atoms — •Kirill Karpov, Alexandre De Martino, Florian Kiesel, Jonas Auch, Eduard Heidt, and Christian Gross — Eberhard Karls Universitaet Tuebingen, Tuebingen, Germany

The extreme mass imbalance between Er and Li offers a unique platform for exploring impurity physics and emergent many-body phenomena. In this experiment, we produce a mixture of ^{166}Er and ^{6}Li. We achieve Bose-Einstein condensation for erbium via evaporative cooling, while lithium is sympathetically cooled by the erbium. Furthermore, the tune-out wavelength of Er enables species-selective confinement. This allows for the far-detuned conservative trapping of Li without perturbing the Er background. Such species-selective trapping schemes open a new level of control in mixture experiments, paving the way for studying the properties of moving Bose polarons.

A 17.6 Wed 16:00 N 1

Generation of Laughlin states of ultracold atoms exploiting coherent driving — •Alberto Tabarelli de Fatis[1], Iacopo Carusotto[1], Christof Weitenberg[2], Alexander Schnell[3], and André Eckardt[3] — [1]Pitaevskii BEC Center, CNR-INO and Dipartimento di Fisica, Universitá di Trento, Trento, Italy — [2]Department of Physics, TU Dortmund University, 44227 Dortmund, Germany — [3]Institut für Physik und Astronomie, Technische Universität Berlin, Berlin, Germany.

Realizing fractional quantum Hall (FQH) states in a well-controlled environment such as neutral ultracold atoms, has proven extremely challenging, restricting experiments to a very small number of particles N=2,3.

I present a proposal to generate Laughlin states in an FQH system coupled to a BEC reservoir via an angular-momentum-selective coherent pump. By adiabatically varying the strength and detuning of the pump, vacuum is converted into a Laughlin state, without changing the system Hamiltonian, and avoiding gap closing associated with the topological phase transition. This scheme allows the generation of quite large (of order N=10) Laughlin states with excellent fidelity, as well as quasihole excitations on top of it, without fine-tuning of the driving parameters, and with reasonable preparation times.

An experimental realization of our proposal will open new perspectives in the use of ultracold atoms as quantum simulators of condensed matter systems and its extension to non-Abelian states will provide a powerful platform for topological quantum computing.

A 17.7 Wed 16:15 N 1

Fractal ground state of mesoscopic ion chains in periodic potentials — Raphaël Menu[1], Jorge Yago Malo[2], •Joshua Weissenfels[1], Vladan Vuletić[3], Maria Luisa Chiofalo[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Dipartimento di Fisica Enrico Fermi, Universita di Pisa and INFN, Largo B. Pontecorvo 3, I-56127 Pisa, Italy — [3]Department of Physics, MIT-Harvard Center for Ultracold Atoms, and Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Trapped ions in a periodic potential are a paradigm of a frustrated Wigner crystal. The dynamics are captured by a long-range Frenkel-Kontorova model. We show that the classical ground state can be mapped to the one of a long-range Ising spin chain in a magnetic field, whose strength is determined by the mismatch between the chain's and substrate lattice's periodicity. The mapping is exact when the substrate potential is a piecewise harmonic potential and holds for any two-body interaction decaying as $1/r^\alpha$ with the distance r. We show that the ground state is a devil's staircase of regular, periodic structures as a function of the mismatch and of the interaction exponent α. The predictions of the piecewise parabolic potentials are compared with the case when the substrate is a sinusoidal potential.