Q 69: Ultra-cold Atoms, Ions and BEC V (joint session A/Q)

Time: Friday 14:30–16:30 Location: F303

Invited Talk Q 69.1 Fri 14:30 F303

Observation of vibrational dynamics in an ion-Rydberg molecule by a high-resolution ion microscope — •Moritz Berngruber[1], Viraatt Anasuri[1], Yiquan Zou[1], Nicolas Zuber[1], Óscar Andrey Herrera Sancho[1,2], Ruven Conrad[1], Florian Meinert[1], Robert Löw[1], and Tilman Pfau[1] — [1]Universität Stuttgart — [2]Escuela de Física, Universidad de Costa Rica, San José

Vibrational dynamics in conventional molecules takes usually place on a timescale of picoseconds or shorter, therefore it is hard to observe. In this talk, we report on a direct spatial observation of vibrational dynamics in an ion-Rydberg atom molecule where the vibrational dynamics happens on much slower timescales and can therefore be directly studied.

Highly excited Rydberg atoms can form quite unusual bonds, which lead to long-range Rydberg molecules with exotic properties, here we study a molecular ion that is formed due to the interaction between an ionic charge and a flipping-induced dipole of a Rydberg atom. Due to the large bond length of the molecule, dynamical processes are slowed down drastically leading to vibrational dynamics in the microsecond regime that can be observed in real space by using a high-resolution ion microscope. By applying a weak external electric field of a few mV/cm, it is possible to control the orientation of the ionic ultralong-range Rydberg molecules directly during the creation process. When the field is quenched off in a subsequent step, the vibrational dynamics can be initialized and observed under the ion microscope in real space.

Q 69.2 Fri 15:00 F303

Dynamics of a driven atomic Josephson junction — •Vijay Singh[1], Ludwig Mathey[2], and Luigi Amico[1] — [1]Quantum Research Centre, Technology Innovation Institute, Abu Dhabi, UAE — [2]Zentrum für Optische Quantentechnologien and Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany

Using classical-field simulations we study the dynamics of a Josephson junction created by separating two two-dimensional atomic clouds with a tunneling barrier. We explore various condensate geometries, as well as different barrier protocols. This allows us to characterize the DC to AC Josephson effect, which we compare with the prediction of the two-coupled equations. Furthermore, we consider a periodic driving of the barrier protocol to study the driving effect on the voltage-current characteristic, resulting in reminiscent Shapiro steps. We discuss these dynamical behaviors in both underdamped and overdamped regimes and describe them using the two-coupled equations.

Q 69.3 Fri 15:15 F303

Quantum simulations with circular Rydberg atoms — •Christian Hölzl, Aaron Götzelmann, Moritz Wirth, and Florian Meinert — 5th Institute of Physics, Universität Stuttgart, Stuttgart, Germany

Highly excited low-L Rydberg atoms in configurable mircotrap arrayshave recently proven highly versatile for exploring quantum many-body systems with single particle control. We aim to increase the coherence time of the Rydberg platform by using high-L circular Rydberg states, which promise orders of magnitude longer lifetimes compared to their low-l counterparts. I will report on the status of a new experimental apparatus for realizing arrays of trapped and long-lived circular Rydberg atoms at room temperature. To this end, we have prepared single Strontium atoms inside a suppression capacitor made from indium tin oxide (ITO). The capacitor is designed to stabilize the circular Rydberg atoms against detrimental black-body radiation, while keeping excellent high-NA optical access for visible light. I will report on our progress to laser-excite Rydberg singlet F-states via a three-photon scheme. The latter serve as a suitable starting point for accessing circular Rydberg states via adiabatic state transfer.

Q 69.4 Fri 15:30 F303

Time-resolved meausrements of the anomalous Hall velocity — •Alexander Ilin, Klaus Sengstock, and Juliette Simonet — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

The anomalous velocity is a purely intrinsic interference effect that gives rise to many fascinating transport phenomena in solids, including the anomalous Hall effect (AHE), the spin Hall effect (SHE), and their quantized versions. However, measuring the anomalous velocity in real solid-state materials is challenging as a direct observation of electron wave-packet dynamics is usually impeded by inherent short times for scattering.

Here, we report on direct measurements of the anomalous velocity for condensates in an accelerated optical boron-nitride lattice. By tracing the coherent evolution of Bloch states in momentum space, we can precisely extract the time-dependent anomalous velocity along different paths in reciprocal space and infer the associated local Berry curvature. Using this method, we demonstrate geometric pumping and a bosonic counterpart of the valley Hall effect for condensates in the second Bloch band, where atoms in different valleys experience a net anomalous transport into opposite direction.

Q 69.5 Fri 15:45 F303

Tuneable Long-range Interaction by Coupling Opposite Parity Rydberg States — •Philip Osterholz, Lea Steinert, Arno Trautmann, Ludwig Müller, Roxana Wedowski, and Christian Gross — Physikalisches Institut, Eberhard Karls Universität Tübingen, 72076 Tübingen, Germany

Rydberg atoms in optical tweezers have proven to be a major working horse in studying long-range interacting systems. The tunability of the interaction allows for exploring large regions of phase diagrams and novel physics in various experimental settings. Here, we present how the dipolar coupling between opposite parity rydberg states can extend the interaction range in current rydberg tweezer experiments. This paves the way for studying quantum spin systems with an enriched variety of interactions in state-of-the-art quantum simulators.

Q 69.6 Fri 16:00 F303

Tailoring the Phonon Environment of Embedded Rydberg Aggregates — •Sidharth Rammohan[1], Alexander Eisfeld[2], and Sebastian Wüster[1] — [1]IISER Bhopal, Madhya Pradesh, India. — [2]MPIPKS, Dresden, Germany.

State-of-the-art experiments can controllably create Rydberg atoms inside a Bose-Einstein condensate (BEC) [1], where the electron-atom interactions can be tuned making the hybrid system suitable for quantum simulation. In our work we study the dynamics of a single or multiple Rydberg atoms embedded inside a BEC, to assess their utility for controlled studies of excitation transport. For this, we first develop a theoretical framework to calculate the input parameters like the bath correlation function, initially for a single Rydberg atom, possibly in two internal states in a BEC [2]. The electron-atom contact interactions lead to Rydberg-BEC coupling, which creates phonons in the BEC. Using the spin-boson model with the calculated parameters, we examine the decoherence dynamics of a Rydberg atom in a superposition of the states, resulting from the interaction with its condensate environment and also study the emergence of Non-Markovian features in the system [3]. The scenario with a single Rydberg atom is then extended to the aggregate case, where one of the atoms in the aggregate is in the p state, while the rest are in the s state, allowing us to set up dynamics similar to those found in light-harvesting complexes. References: [1] J. B. Balewski, et.al,. Nature 502 664 (2013). [2] S. Rammohan, et.al,. Phys. Rev. A 103, 063307 (2021). [3] S. Rammohan, et.al,. Phys. Rev. A 104, L060202 (2021).

Q 69.7 Fri 16:15 F303

Sympathetic cooling of charged particles in separate Penning traps via image currents — •Hüseyin Yildiz[1], Peter Micke[2,3], Markus Wiesinger[2], Christian Will[2], Fatma Abbass[1], Stefan Erlewein[2,4], Julia Jäger[2,4,5], Barbara Latacz[4], Andreas Mooser[2], Daniel Popper[1], Gilbertas Umbrazunas[4,6], Elise Wursten[4], Klaus Blaum[2], Christian Ospelkaus[5,7], Wolfgang Quint[8], Jochen Walz[1,9], Christian Smorra[1,4], and Stefan Ulmer[4,10] — [1]Johannes Gutenberg-Universität Mainz — [2]Max-Planck-Institut für Kernphysik — [3]CERN — [4]RIKEN — [5]Physikalisch-Technische Bundesanstalt — [6]Eidgenössisch Technische Hochschule Zürich — [7]Leibniz Universität Hannover — [8]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [9]Helmholtz-Institut Mainz — [10]Heinrich-Heine-Universität Düsseldorf

Cooling of trapped charged particles to the mK range or even below is crucial in many precision experiments, but can be a challenge when suitable laser transitions are missing. We recently demonstrated a new sympathetic cooling method to cool a single proton via image currents of a laser-cooled Be^+ cloud located in a separate trap. This concept is promising, because it is not limited to small distances and is generally scalable. In particular, any kind of charged particles can be cooled, including antimatter and highly charged ions.

This talk summarizes our previous work and reports about our recent progress towards an advanced coupling scheme based on a detuned LC-circuit.