## Q 36: Ultra-cold Atoms, Ions and BEC III (joint session A/Q)

Time: Wednesday 11:00–13:00 Location: KlHS Mathe

**Invited Talk** Q 36.1 Wed 11:00 KlHS Mathe

**Microscopy of matter wave emission into a two-dimensional structured reservoir** — •Felix Spriestersbach[1,2], Jan Geiger[1,2], Valentin Klüsener[1,2], Immanuel Bloch[1,2,3], and Sebastian Blatt[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, 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

We realize a quantum simulator of an open quantum system using ultracold bosonic strontium atoms trapped in a state-dependent, cavity-enhanced, two-dimensional optical lattice. Atoms in a metastable excited state are tightly trapped by the optical lattice, while ground-state atoms experience a weak periodic potential, enabling tunneling between neighboring lattice sites. Coupling the two states initiates the emission of matter waves, which are represented by the itinerant ground-state atoms. In the optical lattice, the matter waves show a dispersion relation akin to photons in nanophotonic structures. We can precisely control the energy of the matter waves by adjusting the detuning of the optical coupling. We measure the energy-dependent momenta by mapping momentum space to real space followed by read out using microscopy. Using this high level of control, we can alter the emission dynamics depending on the detuning of the coupling. These results demonstrate the possibility of experimentally investigating open quantum systems in two dimensions.

Q 36.2 Wed 11:30 KlHS Mathe

**Quadrupole Coupling of Circular Rydberg Qubits to Inner Shell Excitations** — •Aaron Götzelmann, Einius Pultinevicius, Moritz Berngruber, Christian Hölzl, and Florian Meinert — 5. Physikalisches Institut, Universität Stuttgart, Germany

Divalent atoms provide excellent means for advancing control in Rydberg atom-based quantum simulation and computing due to the second optically active valence electron available. Particularly promising in this context are circular Rydberg atoms, for which long-lived ionic core excitations can be exploited without suffering from detrimental autoionization. Here, we report the implementation of electric quadrupole coupling between the metastable $4D_{3/2}$ level and a very high-$n$ ($n = 79$) circular qubit, realized in doubly excited $^{88}$Sr atoms prepared from an optical tweezer array. We measure the kHz-scale differential level shift on the circular Rydberg qubit via beat-node Ramsey interferometry comprising spin echo. Observing this coupling requires coherent interrogation of the Rydberg states for more than $100\mu s$, which is assisted by tweezer trapping and circular state lifetime enhancement in a black-body radiation suppressing capacitor. Further, we find no noticeable loss of qubit coherence under continuous photon scattering on the ion core, paving the way for laser cooling and imaging of Rydberg atoms.

In my contribution I will show the measurements of the weak electron-electron interaction and our endeavors on employing this for direct fluorescence imaging of circular Rydberg atoms.

Q 36.3 Wed 11:45 KlHS Mathe

**Shapiro steps in driven atomic Josephson junctions** — •Vijay Singh[1], E. Bernhart[2], M. Röhrle[2], H. Ott[2], G. Del Pace[3], D. Hernandez-Rajkov[3], N. Grani[3], M. Frometa Fernandez[3], G. Nesti[3], J. A. Seman[4], M. Inguscio[3], G. Roati[3], L. Mathey[5], and Luigi Amico[1] — [1]QRC, TII, Abu Dhabi, UAE — [2]RPTU Kaiserslautern, Germany — [3]LENS, University of Florence, Italy — [4]UNAM Mexico — [5]ZOQ and IQP, Universität Hamburg, Germany

We report the observation of Shapiro steps in atomic Josephson junctions formed by coupling two ultracold atom clouds. As predicted in the theoretical proposal, periodic modulation of the position of the tunneling barrier induces Shapiro steps in the dc current-chemical potential characteristic. Experiments on a Josephson junction of $^{87}$Rb atoms display Shapiro steps in the current-potential characteristic, exhibiting universal features and providing key insight into the microscopic dissipative dynamics associated with phonon emission and soliton nucleation. Experiments with strongly-interacting Fermi superfluids of ultracold atoms also show the creation of Shapiro steps in the current-potential characteristics, with their height and width reflecting the external drive frequency and the junction nonlinear response. Direct measurements of the current-phase relationship reveal the underlying dissipation mechanism via the emission of vortex-antivortex pairs. These results establish a significant connection between superconducting and atomic Josephson dynamics, with unprecedented control and flexibility over physical parameters. Finally, our results lay the foundation for the development of new atomtronic devices and sensors.

Q 36.4 Wed 12:00 KlHS Mathe

**Modeling thermodynamic and dynamic properties of Bose-Einstein condensate bubbles in microgravity** — •Brendan Rhyno[1,2], Timothé Estrampes[1,3], Gabriel Müller[1], Charles Garcion[1], Eric Charron[3], Jean-Baptiste Gerent[4], Nathan Lundblad[4], Smitha Vishveshwara[2], and Naceur Gaaloul[1] — [1]Leibniz Universität Hannover — [2]University of Illinois at Urbana-Champaign — [3]Université Paris-Saclay — [4]Bates College

The study of Bose-Einstein condensate (BEC) bubbles has received increasing attention in recent years. We discuss our efforts to model the properties of such systems in view of the current Cold Atom Lab experiments and the prospects of realizing BEC bubbles in the microgravity environment of the Einstein-Elevator at the Leibniz University of Hanover. Using an isotropic 'bubble trap' potential, we explore both the thermodynamic and dynamic inflation of dilute Bose-condensed bubbles. In the thermodynamic treatment, adiabatic inflation from an initial filled spherical BEC into a large thin spherical shell leads to condensate depletion. In the dynamic treatment, we study the non-equilibrium expansion and contraction of the system in the vicinity of the BEC phase transition. We conclude by discussing how our work can inform the ongoing experimental efforts.

Q 36.5 Wed 12:15 KlHS Mathe

**Controlled Dynamical Tunneling in Bichromatic Optical Lattices with a Parabolic Trap** — •usman ali[1], martin holthaus[2], and torsten meier[1] — [1]Department of Physics, Paderborn University, Warburger Strasse 100, D-33098 Paderborn, Germany — [2]Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany

We investigate dynamical tunneling of non-interacting ultracold atomic wave packets in the combined potential generated by the superposition of a one-dimensional periodic optical lattice and a parabolic trap. The parabolic lattice potential exhibits strongly localized eigenstates in the regime where the curvature of the periodic lattice exceeds the bandwidth of the uniform periodic lattice. The localization of these states is similar to Wannier-Stark localization in the presence of a locally static force, which gives rise to dynamics resembling Bloch oscillations. Furthermore, due to the symmetry of the parabolic lattice, these eigenstates are nearly two-fold degenerate. The tiny energy splitting between symmetry-related pairs located at opposite ends of the parabolic lattice results in tunneling times that exceed experimentally realizable time scales. We demonstrate that the inclusion of an additional weak optical lattice allows one to control the tunneling times while preserving the states. Thereby controllable dynamical tunneling is achieved, where the Bloch-oscillating wave packet dynamically tunnels between opposite ends of the weakly bichromatic parabolic optical lattice.

Q 36.6 Wed 12:30 KlHS Mathe

**Effects of (non)-magnetic disorder in quasi-1D singlet superconductors** — •Giacomo Morpurgo and Thierry Giamarchi — Department of Quantum Matter Physics, University of Geneva, Geneva, Switzerland

We study the competition between disorder and singlet superconductivity in a quasi-one-dimensional (1D) system. We investigate the applicability of the Anderson theorem, namely that time-reversal conserving (non- magnetic) disorder does not impact the critical temperature, by opposition to time-reversal breaking disorder (magnetic). To do so, we examine a quasi-1D system of spin 1/2 fermions with attractive interactions and forward scattering disorder using field theory (bosonization). By computing the superconducting critical temperature (Tc), we find that, for nonmagnetic disorder, the Anderson theorem also holds in the quasi-1D geometry. In contrast, magnetic disorder has an impact on the critical temperature, which we investigate by deriving renormalization group equations describing the competition between disorder and interactions. Computing the critical temperature as a function of disorder strength, we observe different regimes depending on the strength of interactions. We discuss possible platforms where this can be observed in cold atoms and condensed matter.

Q 36.7 Wed 12:45 KlHS Mathe

**Chiral Magnetic Effect in Optical Lattices** — •Sabhyata Gupta and Luis Santos — Institut für Theoretische Physik - Leibniz Universität Hannover

The Chiral Magnetic Effect (CME) is a quantum phenomenon in which an electric current is generated along the direction of an applied magnetic field in the presence of a chiral imbalance between right- and left-handed fermions. This effect arises due to the chiral anomaly, where the conservation of chiral charge is violated in quantum field theories involving gauge fields. CME plays a pivotal role in revealing topological fluctuations in QCD matter during heavy-ion collisions and has applications in studying the baryon asymmetry in the early universe. However, its experimental exploration in a controlled setting remains challenging due to the complexity of the underlying quantum dynamics. Here, we propose an experimental realization of the CME using ultracold atoms trapped in optical lattices. By implementing a Rice-Mele-like model through spin-orbital coupling and laser-assisted tunneling, our scheme creates a tunable platform to simulate quench dynamics and emulate chiral asymmetry in the presence of magnetic field interactions. This approach bridges the gap between high-energy physics and quantum simulation, enabling precise control over parameters such as fermion masses and magnetic fields, and providing insights into non-equilibrium effects like chirality flipping and mass-induced axial current relaxation