# Q 83: Ultra-cold Atoms, Ions and BEC VI (joint session A/Q)

Time: Friday 14:30–16:00 Location: N 1

Q 83.1 Fri 14:30 N 1

**High fidelity quantum logic on two trapped-ion qubits without ground-state cooling** — Amy Hughes, Raghavendra Srinivas, Clemens Löschnauer, •Hannah Knaack, Roland Matt, Chris Ballance, Maciej Malinowski, Thomas Harty, Tyler Sutherland, and Oxford Ionics team — Oxford Ionics, Oxford, United Kingdom

We introduce the *smooth gate* - a novel entangling gate method for trapped-ion qubits where residual motional errors are adiabatically eliminated by ramping the gate detuning. We combine the power of this technique with the robustness of electronic qubit control [1] to perform two-qubit gates with an estimated error of $< 1 \times 10^{-4}$ without the use of ground-state cooling. We characterise the gate error using a new protocol (inspired by subspace randomised benchmarking [2]) which does not require the use of any single-qubit rotations. We further show that the error remains $< 5 \times 10^{-4}$ for Doppler-cooled ions with gate mode temperatures of up to $\bar{n} = 9.4(3)$. These results show that trapped-ion quantum computers can be operated above the Doppler limit, allowing for significantly faster device operation.

[1] C. M. Löschnauer et al., PRX Quantum 6, 040313 (2025)
[2] C. H. Baldwin et al., Phys. Rev. Research 2, 013317 (2020)

Q 83.2 Fri 14:45 N 1

**Hybridization of topological defects and repulsive polarons in a Bose gas** — •Taha Alper Yogurt[1], Matthew Eiles[1], Nikolay Yegovtsev[2], and Victor Gurarie[2] — [1]Max Planck Institute for the Physics of Complex Systems Nöthnitzer St. 38 01187 Dresden, Germany — [2]Department of Physics and Center for Theory of Quantum Matter, University of Colorado, Boulder Colorado 80309, USA

The immersion of an impurity in a bosonic medium has enabled systematic exploration of the Bose polaron problem across the entire range of impurity-medium coupling strengths. Both attractive and repulsive polarons arising from inherently attractive impurity-medium interactions, such as those involving Rydberg or ionic impurities in neutral ultracold gases, have been extensively investigated. While the attractive polaron represents the ground state of the many-body impurity-bath system, the nature of the metastable repulsive polaron remains less understood. Here, we present a unified framework for describing both attractive and repulsive polarons in one- and two-dimensional (1D and 2D) Bose gases. By obtaining ground- and excited-state solutions of the Gross-Pitaevskii equation for a finite-range impurity potential in a weakly interacting Bose medium, we demonstrate that repulsive polarons are adiabatically connected to topological defects supported by the condensate. In 2D, these defects correspond to vortices and dark ring solitons, while they manifest as distinct solitonic configurations in 1D. Furthermore, we uncover a crossover between the repulsive and attractive polaron branches as the impurity-bath coupling strength increases.

Q 83.3 Fri 15:00 N 1

**Spin-coherent eigenstates in quantum magnets** — •Felix Gerken and Thore Posske — University of Hamburg, Hamburg, Germany

At special points in the parameter space of quantum magnets, product states can emerge as eigenstates. For a wide range of one-, two-, and higher-dimensional models, their appearance is connected to phenomena such as spin liquids, anyonic phases, and quantum scars. We provide a unified framework through a complete classification of spin-coherent eigenstates of Heisenberg XXZ Hamiltonians with Dzyaloshinskii-Moriya interaction on general graphs and for arbitrary spin quantum numbers, formulated in terms of Kirchhoff rules for spin supercurrents. We find that these spin-coherent eigenstates not only span a large degenerate subspace, but are also accompanied by additional extensive degeneracy that is linked to exotic condensates, which could be studied in atomic gases and quantum spin lattices.

Q 83.4 Fri 15:15 N 1

**High-repetition-rate fermionic quantum gas microscope for quantum simulation** — •Robin Groth[1,2], Andreas von Haaren[1,2], Liyang Qiu[1,2], Janet Qesja[1,2], Luca Muscarella[1,2], Titus Franz[1,2], Timon Hilker[3], Immanuel Bloch[1,2,4], and Philipp Preiss[1,2,4] — [1]Max Planck Institute of Quantum Optics, Garching — [2]Munich Center for Quantum Science and Technology — [3]University of Strathclyde, Glasgow — [4]Ludwig Maximilian University of Munich

Fermionic quantum simulators provide a powerful platform for exploring the physics of high-temperature superconductivity, topological phases, and many-body dynamics - challenges that persist even with the advent of qubit-based quantum computing. Here, we present a high-repetition-rate fermionic quantum gas microscope optimized for rapid data acquisition. Fast cycle times below 4 seconds are achieved through high-power optical traps, rapid evaporative cooling, and efficient spin-resolved fluorescence imaging. These fast experimental cycles enable the collection of sufficient statistics to measure higher-order spin correlations, opening the door to systematic exploration of the phase diagram of the doped Fermi-Hubbard model. Looking ahead, planned upgrades to the apparatus will incorporate site-resolved addressing for precise single-particle control, enabling the investigation of quantum-information-processing schemes within this fermionic platform.

Q 83.5 Fri 15:30 N 1

**Simulating the Fermi Hubbard model with a quantum gas microscope** — •Luca Muscarella[1,2], Andreas von Haaren[1,2], Robin Groth[1,2], Janet Qesja[1,2], Liyang Qiu[1,2], Ino Ahrens[1,2], Titus Franz[1,2], Timon Hilker[3], Philipp Preiss[1,2], and Immanuel Bloch[1,2,4] — [1]Max-Planck Institute of Quantum Optics — [2]Munich Center for Quantum Science and Technology — [3]University of Strathclyde, Glasgow — [4]Ludwig Maximilian University Munich

Ultracold fermionic systems have emerged as a leading platform for studying strongly correlated quantum matter, offering direct access to regimes that challenge both classical numerics and even qubit-based architectures. Using our newly developed quantum gas microscope, we can create and probe large, low-entropy ensembles of fermions with a short experimental cycle time. Building on this technical capability, we now demonstrate the preparation of a Mott insulator containing over 500 atoms in a square optical lattice. Leveraging a newly implemented programmable lattice with tunable geometry, we aim to probe exotic phases of the doped Fermi-Hubbard model. These measurements will allow systematic exploration of strongly correlated regimes that remain beyond the reach of classical computation.

Q 83.6 Fri 15:45 N 1

**Edge localized states in the bosonic SSH model with interaction.** — •Anna Posazhennikova and Tara Steinhöfel — Institut für Physik, Universität Greifswald, Greifswald, Germany

We study the bosonic SSH chain with Hubbard on-site interaction, at zero temperature. Since the model can be viewed as a merger of the Bose-Hubbard and Su-Schrieffer-Heeger model, it is expected to undergo both a quantum phase transition from a superfluid Bose-Einstein condensate to a so-called Mott insulator, as well as a topological phase transition when changing dimerization patterns. We find for the topologically nontrivial limit and sufficiently weak interactions, there are edge localized hole states and discuss their origin.