Q 12: Quantum Computing and Simulation II

Time: Monday 17:00–18:45 Location: P 10

Invited Talk Q 12.1 Mon 17:00 P 10

Topological pumping and quantum information — •Konrad Viebahn, Yann Kiefer, Zijie Zhu, Lars Fischer, Marius Gächter, Giacomo Bisson, Samuel Jele, Lisa Peters, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, Switzerland

Topological pumps provide a powerful method for transporting particles with remarkable precision by slowly and cyclically modulating a lattice potential. This transport is topologically protected - a feature it shares with the quantum Hall effect - making it inherently robust against noise and experimental imperfections.

In this talk, I will introduce a novel paradigm of this concept: moving beyond the transport of individual particles to the pumping of qubits carrying quantum information. Our experiments, which employ ultracold fermions in dynamical optical lattices [1,2], demonstrate the coherent transport of not only single atoms but also entangled Bell pairs over hundreds of lattice sites. This capability allows us to perform fundamental quantum computations during transport, including high-fidelity two-qubit gates. I will show how we can chain these operations together to build non-local quantum circuits and generate complex entanglement patterns across the lattice.

[1] Zhu et al. PRX (2025), Splitting and connecting singlets in atomic quantum circuits

[2] Kiefer et al. arXiv:2507.22112, Protected quantum gates using qubit doublons in dynamical optical lattices

Q 12.2 Mon 17:30 P 10

Benchmark of transport-induced motional excitations in an 8-qubit quantum processor — •Phil Nuschke[1], Rodrigo Munoz[1], Teresa Meiners[1], Brigitte Kaune[1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We present a framework to analyse the effect of transport on the motional states of ions in a trapped-ion quantum processor. By decomposing the shuttling protocol into primitive operations, we can evaluate their heating effects individually and combine results algebraically, avoiding full simulations for entire trajectories. We benchmark this method on an 8-qubit quantum processor, integrating the cost of motional operations at the compiler level.

Q 12.3 Mon 17:45 P 10

A dual-species Rydberg array for distributed quantum information processing — •Adrien Bouscal[1,2,3], Mullai Sampangi[1,2,3,4], Max Gewald[1,2,3], Pit Steinmetz[1,2,3,4], Balázs Dura-Kovács[1,2,3], Mehmet Öncü[1,2,3], Jacopo de Santis[1,2,3], Dimitrios Vasileiadis[1,2,3,4], and Johannes Zeiher[1,2,3] — [1]LMU München, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology, 80799 München, Germany — [4]Technische Universität München, 85748 Garching, Germany

Quantum error correction requires ancilla qubits that can be replenished, reset, and read out mid-circuit without disturbing the data qubits. A dual-species architecture enables these capabilities through element-selective optical addressing with inherently low crosstalk. We report on the design of a compact dual-element source for a hybrid tweezer array combining rubidium (Rb) and ytterbium (Yb) coupled to an optical cavity. An atomic beam of Yb from an effusion cell is trapped in a 2D MOT after being slowed in a short Zeeman slower, whose magnetic field gradient is produced by the 2D MOT permanent magnets. From this transversely-cooled beam, a 3D MOT and tweezers will be loaded in a separate science cell. We also plan to implement continuous reloading of Rb qubits via transport with an optical conveyor belt from a distant 3D MOT. This platform enables interfacing logical quantum processors with optical modes and opens perspectives for fast feedback, long-lived nuclear-qubit memories, quantum networking, and distributed quantum information processing.

Q 12.4 Mon 18:00 P 10

Mediated Gates and Quantum Cellular Automata in a Dual-Species Rydberg Array — •Alexander Impertro[1,2], Ryan White[1,2,3], Ka Hui Goh[1,2], Vikram Ramesh[3], Shraddha Anand[3], and Hannes Bernien[1,2,3] — [1]Institute for Quantum Optics and Quantum Information, 6020 Innsbruck, Austria — [2]University of Innsbruck, 6020 Innsbruck, Austria — [3]University of Chicago and Pritzker School of Molecular Engineering, Chicago, IL 60637, USA

A key challenge in scaling up quantum processors and simulators is the need to implement individual qubit control in a resource-efficient yet performant manner. Rydberg arrays consisting of two distinct atomic species are a particularly promising platform to achieve this goal, with independent addressing and readout transitions enabling selective qubit control as well as mid-circuit operations. In this talk, we present how such a dual-species architecture allows the execution of a broad class of quantum circuits using only simple global control. Formulated in the framework of quantum cellular automata, we leverage discrete pulse sequences based on high-fidelity interspecies-mediated gates to prepare Bell, GHZ and cluster states, which we can additionally grow into graph-like states with longer-range connectivity. Moreover, the versatile Rydberg interaction landscape provided by two atomic species opens up the possibility to perform long-range multi-qubit gates. Together, these results showcase how dual-species processors enable a highly efficient use of control resources, enhance scalability and thus pave the way for the next generation of quantum information and simulation experiments.

Q 12.5 Mon 18:15 P 10

Measurement Based Quantum Computing with Trapped-Ion Qudits — •Tim Gollerthan[1], Alena Romanova[2], Peter Tirler[1], Manuel John[1], Keshav Pareek[1], Lisa Parigger[1], Raphael Poloczek[1], Timo Spalek[1], Lukas Gerster[1], Michael Meth[1], Wolfgang Dür[2], and Martin Ringbauer[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Theoretische Physik, Universität Innsbruck, Austria

Measurement-based quantum computing (MBQC) is a leading model for quantum computation. In contrast to the circuit model, it exploits highly entangled universal resource state, on which computations are driven by local measurements. This allows for blind quantum computing as a secure technique for cloud-based quantum computing and facilitates stabilizer error correction codes. MBQC has been implemented in a variety of platforms, including photonic and trapped-ion quantum hardware in recent years. However, the vast majority of work is restricted to qubit-based cluster states. Employing multi-level information carriers instead has the potential to elevate MBQC to a new level of potential, since qudit systems feature a more extensive gate set, enhanced efficiency in encoding and computation as well as more complex entanglement structures. In consequence, resource states that extend beyond the well-known qubit cluster state, can be harnessed for MBQC. The presentation will report on the exploration of Qudit-MBQC with a state-of-the-art trapped-ion quantum processor.

Q 12.6 Mon 18:30 P 10

Integrated generation of photonic graph states for measurement-based quantum computing — •Jeldrik Huster[1,2], Louis Hohmann[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST)

Photonic quantum devices have been used to demonstrate a broad range of quantum applications, namely quantum computation, communication and network applications. Essential for the scaling to higher qubit numbers, are integrated solutions in the telecom band, due to their small footprint, high phase stability and low loss connectivity. Most photonic implementations rely on multipartite entangled states, especially graph states. Here, we present our recent progress on a silicon on insulator photonic chip for the generation of graph states with up to four qubits. We generate four-qubit Greenberger-Horne-Zeilinger (GHZ) and linear graph states with fidelities of over 83% and 75%, respectively. These states are used to show photonic measurement-based quantum computing (MBQC). We demonstrate single-qubit and two-qubit gates as well as the implementation of Grover's search and Deutsch's algorithm. This is made possible by the chip's high coupling efficiency to single modes fibres and reconfigurability via tuneable beam splitter and phase shifters.