QI 5: Superconducting Qubits and Hybrid Systems

Time: Monday 11:00–12:30 Location: F428

Invited Talk QI 5.1 Mon 11:00 F428

Building Superconducting Quantum Hardware towards Error-Corrected Quantum Computing — •Christopher Eichler — Department of Physics, FAU Erlangen, Germany

Quantum Computers will ultimately rely on near-perfect logical gates, implemented while correcting errors at the physical level. The need for developing quantum hardware optimized for performing fast, repeatable, and high-fidelity syndrome measurements in quantum error-correcting codes such as the surface code therefore becomes increasingly important. In my talk, I will present advances in performing qubit readout and two-qubit gates in multi-qubit superconducting quantum processors, which enabled the recent experimental demonstration of repeated quantum error correction in surfaces codes. I will show how quantum processors optimized for quantum error correction can also serve as a testbed to explore noisy intermediate-scale quantum algorithms. The talk will conclude with a discussion about open challenges and opportunities to advance the speed and fidelity of syndrome detection in scalable device architectures by exploiting tunable coupling elements.

QI 5.2 Mon 11:30 F428

Towards High-Fidelity Fluxonium Quantum Processors — •Florian Wallner[1,2], Johannes Schirk[1,2], Ivan Tsitsilin[1,2], Christian Schneider[1,2], Niklas Bruckmoser[1,2], Leon Koch[1,2], and Stefan Filipp[1,2] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany

To solve real-world problems on error-corrected quantum computers it is estimated that multiple hundreds to thousands of physical qubits have to be combined to build one logical qubit. This results in an impractical large overhead in the number of qubits and demands new types of qubits with orders of magnitude improvements in performance.

Here, we report on our recent advances to build superconducting fluxonium qubits that offer distinct advantages compared to the widespread transmons-type qubits. We show high coherence times and fast high-fidelity single qubit gates, realized through the flux bias line, which significantly reduces the control line overhead associated with flux qubits. Furthermore, we demonstrate a dispersive readout with assignment fidelity greater than 96%. Since these qubits have low transition frequencies a significant thermal population needs to be removed at the start of each experiment. We achieve this by employing an unconditional active reset and a conditional real-time feedback-assisted reset that can later enable dynamical circuits. In addition, we provide an outlook on our efforts to build multi-qubit devices and multi-qubit gates.

QI 5.3 Mon 11:45 F428

High-impedance resonators based on granular aluminum — •Mahya Khorramshahi[1], Martin Spiecker[1], Patrick Paluch[2], Thomas Reisinger[1], and Ioan Pop[1] — [1]Institute for Quantum Materials and Technology, Karlsruher Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany — [2]Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

Superconductors with characteristic impedance larger than the resistance quantum are a valuable resource in superconducting circuits. They enable the design of protected qubits such as Fluxoniums or 0-pi qubits and can improve the coupling to small-dipole-moment objects, which may be useful for interfacing with spin-qubits, donor spins, etc. Here we present compact resonators in the lower GHz regime with a high characteristic impedance given by a high-kinetic-inductance material, namely granular aluminum, with spurious modes above 10GHz. We fabricated the resonators with an electron-beam lithography lift-off process, and we coupled them using a 50 Ohm coplanar waveguide architecture. Measurements performed in a dilution cryostat reveal that the resonators maintain high-quality factors in the single photon regime, a valuable resource for future quantum hardware implementations

QI 5.4 Mon 12:00 F428

Rare earth ions in molecular crystals for quantum information application — •Jannis Hessenauer[1], Evgenij Vasilenko[1], Weizhe Li[1], Christina Ioannou[1], Kumar Senthil Kuppusamy[2], Mario Ruben[2], and David Hunger[1,2] — [1]Karlsruher Institut für Technologie (KIT), Physikalisches Institut — [2]Karlsruher Institut für Technologie (KIT), Institut für Quantenmaterialen

Rare-earth ions in solid state hosts are promising candidates for optically addressable spin qubits, owing to their long optical and spin coherence times in the solid state [1]. Recently, rare earth ions in organic molecules have demonstrated outstanding coherence properties, while also promising a large parameter space for optimization by chemically engineering of the host molecule [2]. We characterize the optical properties of novel rare earth ion based molecular materials at low temperature using techniques such as photoluminescence excitation spectroscopy, absorption spectroscopy and spectral hole burning. We observe narrow homogenous and inhomogeneous linewidths and long-lived spin polarization, confirming the great potential of molecular rare earth materials for quantum information applications.

[1] Kinos, Adam, et al. "Roadmap for rare-earth quantum computing." arXiv preprint arXiv:2103.15743 (2021).

[2] Serrano, Diana, et al. "Ultra-narrow optical linewidths in rare-earth molecular crystals." Nature 603.7900 (2022): 241-246.

QI 5.5 Mon 12:15 F428

Schrödinger cat states of a 16-microgram mechanical oscillator — •Marius Bild[1,2], Matteo Fadel[1,2], Yu Yang[1,2], Uwe von Lüpke[1,2], Phillip Martin[1,2], Alessandro Bruno[1,2], and Yiwen Chu[1,2] — [1]Department of Physics, ETH Zürich, 8093 Zürich, Switzerland — [2]Quantum Center, ETH Zürich, 8093 Zürich, Switzerland

While the principle of superposition in quantum physics is routinely validated for microscopic systems, it is still unclear why we do not observe macroscopic objects to be in superpositions of states that can be distinguished by some classical property. I will present our experiments, that harness the resonant Jaynes-Cummings interaction between a high overtone resonator mode of a bulk acoustic wave resonator and a superconducting qubit, to demonstrate the preparation of Schrödinger cat states of motion. In such a state, the constituent atoms oscillate in a superposition of two opposite phases with an effective oscillating mass of $16\mu g$. Making use of the circuit quantum acoustodynamics toolbox we have developed, we furthermore show control over amplitudes and phases of the created Schrödinger cat states, and investigate their decoherence dynamics by observing the disappearance of Wigner negativities. Our results can find applications in continuous variable quantum information processing and in fundamental investigations of quantum mechanics in massive systems.