Acoustic Phonons in the Quantum Limit

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Superconducting qubits are providing very interesting approaches to building hybrid quantum systems, connecting these high-performance microwave frequency electrical devices to other quantum systems. One compelling opportunity is provided by the ability to use superconducting qubits to control and measure acoustically-active structures, structures that can potentially serve to link these qubits to other two-level systems or to e.g. optical signals. I will describe our recent progress in coupling superconducting qubits to surface acoustic wave structures, where we have recently demonstrated the quantum control of a single microwave-frequency mechanical mode in a surface acoustic wave (SAW) resonator. We can controllably store and recover single phonons and measure the Wigner function of stored quantum states in the resonator [1]. I will also show more recent results where a long SAW resonator with a 500 ns phonon bounce time was used to release and recapture individual itinerant phonons, and transfer quantum states between two superconducting qubits. By sharing half a phonon between the two qubits, we are able to acoustically generate a high-fidelity Bell state between the two qubits.

[1] K. J. Satzinger et al., “Quantum control of surface acoustic wave phonons”, *Nature* **563**, 661–665 (2018).
[2] A. Bienfait et al., “Phonon-mediated quantum state transfer and remote qubit entanglement”, *Science* **364**, 368-371 (2019).