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Quantum acoustics with superconducting qubits

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The ability to engineer and manipulate different types of quantum mechanical objects allows us to take advantage of their unique properties and create useful hybrid technologies. Thus far, complex quantum states and exquisite quantum control have been demonstrated in systems ranging from trapped ions to superconducting resonators. Recently, there have been many efforts to extend these demonstrations to the motion of complex, macroscopic objects. These mechanical objects have important applications as quantum memories or transducers for measuring and connecting different types of quantum systems. In particular, there have been a few experiments that couple motion to nonlinear quantum objects such as superconducting qubits. This opens up the possibility of creating, storing, and manipulating non-Gaussian quantum states in mechanical degrees of freedom. However, before sophisticated quantum control of mechanical motion can be achieved, we must realize systems with long coherence times while maintaining a sufficient interaction strength. These systems should be implemented in a simple and robust manner that allows for increasing complexity and scalability in the future. In this talk, I will describe our recent experiments demonstrating a high frequency bulk acoustic wave resonator that is strongly coupled to a superconducting qubit using piezoelectric transduction. In contrast to previous experiments with qubit-mechanical systems, our device requires only simple fabrication methods, extends coherence times to many microseconds, and provides controllable access to a multitude of phonon modes. We use this system to demonstrate basic quantum operations on the coupled qubit-phonon system. Straightforward improvements to the current device will allow for advanced protocols analogous to what has been shown in optical and microwave resonators, resulting in a novel resource for implementing hybrid quantum technologies.