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Quantum Acoustics with Multi-mode Surface Acoustic Wave Cavities

Recent demonstrations of quantum control over collective mechanical excitations using superconducting qubits promises to bring the unique capabilities of phononic systems to developing quantum technologies. Of specific interest here, the slow speed of elastic waves in a solid means significant delays can be engineered in chip-scale geometries, a trait underlying the widespread success of commercial surface acoustic wave filters. I will describe how quantum acoustics with surface acoustic waves coupled to superconducting qubits can leverage these delays to not only build cavities with high densities of resonant modes but also precisely control the qubit-phonon interaction to suit experimental demands, a combination with potential applications in constructing a quantum random access memory. Towards this goal, I will show that the hybrid system can achieve interaction strengths large enough for the single-phonon Stark shifts to exceed the relevant dissipation rates, leading to the resolution of phonon number states in the qubit spectrum.