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Single Phonon Quantum Optics

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Abstract:

Acoustic phonons, the energy eigenstates of mechanical vibrations, possess a plethora of interesting features for quantum information processing. In particular, they can serve as long lived quantum memories, directly coupled to photons in the telecom wavelength range. However, controlling individual excitations of motion in micromechanical resonators has thus far been restricted to the domain of microwave radiation, while optical control remained an outstanding goal. In this thesis, I describe how this can be achieved experimentally, employing quantum optics protocols. First, the operation of silicon optomechanical crystals in the quantum regime is demonstrated by creating non-classical photon-phonon pairs through optomechanical down conversion. This quantum interface is subsequently used to characterize heralded single phonons, and to generate quantum entanglement between two remote mechanical oscillators. The realization of these classic quantum optics experiments with single phonons establishes mechanical quantum memories in silicon photonics as a useful resource for future quantum networks.