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On-chip cavity quantum phonodynamics: spin qubits and nano/optomechanics

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Sound can be just as quantum as light. But our toolbox for single quanta of sound, i.e. phonons, is currently insufficient. Here we propose a new component that enables a chip-based, solid-state analogue of cavity-QED utilizing acoustic phonons instead of photons. We show how long-lived and tunable acceptor impurity states in silicon nanomechanical cavities can play the role of a matter non-linearity for coherent phonons just as, for example, the Josephson qubit plays in circuit-QED. Both strong coupling (number of coherent Rabi oscillations of approximately 100) and strong dispersive coupling (0.1-2 MHz) can be reached in the 1-20 GHz frequency range, making the system compatible with existing high-Q, nanomechanical resonators. We give explicit experimental signatures and measurement protocols of the acceptor-cavity system via a phonon probe. This system enables the control of single phonons and phonon-phonon interactions, dispersive phonon readout of the acceptor qubit, and compatibility with other nano/optomechanical components such as phonon-photon translators. (This work in collaboration with Rusko Ruskov, LPS; work with Oney Soykal, LPS, will also be discussed.)