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Quantum many body systems with qubits and phonons in the solid state Ö.O. SOYKAL, University of Maryland, CHARLES TAHAN, Laboratory for Physical Sciences — We previously proposed a nano-mechanical system where phonons trapped in an acoustic cavity can strongly hybridize with impurity qubit states in silicon (forming a so-called cavity-phoniton). Here, we extend the idea to the quantum many-body limit by investigating the physics of phonon-tunnel-coupled arrays of such components. The silicon qubit cavity phoniton system potentially offers advantages in this regime over purely optomechanical systems where the optomechanical coupling is still quite small. First, single phonons in a crystal can have large effective de Broglie wavelengths (microns). Second, as we have previously shown, qubit-phonon coupling can be quite large, easily allowing the system to enter the strong coupling regime and enabling phonon-blockade. Such arrays can be fabricated in semiconductor heterostructures or in on-chip, optomechanical crystals. We calculate the parameter regime where the Mott-Superfluid quantum phase transition occurs in realizable devices. We also demonstrate the emergence of super-splitting, phonon anti-bunching, and phonon blockade through the non-equilibrium density matrix master equation approach in few cavity systems.

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