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A Rydberg Atom Ensemble-Surface Phonon Polariton Quantum Hybrid System[1] YUANXI CHAO, JITENG SHENG, Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, 440 W. Brooks St. Norman, OK 73019, USA, NICHOLAS P. BIGELOW, Department of Physics and Astronomy, The University of Rochester, 206 Bausch and Lomb Hall, Rochester, NY 14627, USA, JAMES P. SHAFFER, Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, 440 W. Brooks St. Norman, OK 73019, USA
— We investigate a quantum hybrid system in the strong coupling regime, formed by a Rydberg atom ensemble and a surface phonon polariton (SPhP) propagating on a periodically poled piezoelectric metamaterial surface. We present our theoretical results and initial experiments on the possibilities for achieving strong coupling. Due to the large Rydberg transition dipole moments and the local field enhancement of confined SPhP excitations, the strong coupling regime can be achieved with a dilute atomic ensemble and a proper superlattice design according to our calculations. With submicron periodically poled crystals, even when the atomic ensemble is mms away from the crystal surface, the collective atom-surface coupling can exceed the loss rates, leading to the observation of strong coupling phenomena. For our work, the Rydberg transition from $87S_{1/2}$ to $87P_{1/2}$ in rubidium is chosen to couple to a SPhP mode at $\sim$5 GHz, corresponding to a periodically poled Lithium Niobate (PPLN) surface with a period of $\sim$1 μm. To fabricate the PPLN we use the direct e-beam write poling method.

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