Ultracold atoms in cavities: Mott states and long range interactions

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We investigate a paradigm example of cavity quantum electrodynamics with many body systems: an ultracold atomic gas inside a pumped optical resonator. In particular, we study the stability of atomic insulator-like states, confined by the mechanical potential emerging from the cavity field spatial mode structure. As in open space, when the optical potential is sufficiently deep, the atomic gas is in the Mott-like state. Inside the cavity, however, the potential depends on the atomic distribution, which determines the refractive index of the medium, thus altering the intracavity field amplitude. We derive the effective Bose-Hubbard model for the system, which exhibits long range order through a hopping parameter depending on number of atoms. We determine the regions of parameters where the atomic insulator states are stable, and predict the existence of overlapping stability regions corresponding to competing insulator-like states. Bistable behaviour, arising from quantum wave packet fluctuations and controlled by the pump intensity, is encountered in the vicinity of the shifted cavity resonance.