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Excitons and Polaritons for Optical Lattice Ultracold Atoms in Cavity QED[1]

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The quantum phase transition from the superfluid to the Mott insulator phase is predicted by the Bose-Hubbard model and realized for optical lattice ultracold atoms. We extend the model to include excited atoms and their coupling to cavity photons. In applying a mean field theory we calculate the phase diagram, where the Mott insulator reappears for deeper optical lattices [1]. In the Mott insulator we consider the system as an artificial crystal similar to molecular crystals with advantages due to the controllability of the system parameters. In such a system electronic excitations are delocalized due to resonance dipole-dipole interactions and in exploiting the lattice symmetry they form collective electronic excitations termed excitons [2]. We show that excitons in low dimensional systems include dark and bright modes, and in free space they can be metastable or superradiant, which deviates from the case of a single atom, the fact that implies the use of resonators [3]. We suggest optical lattice ultracold atoms as new frontiers of matter for cavity QED. In the strong coupling regime excitons and cavity photons are coherently mixed to form new quasiparticles called polaritons [4]. We suggest polariotons as a nondestructive observation tool for the different phases and properties of the system. We present different set-ups that have the potential to realize optical lattice ultracold atoms within a cavity. We emphasize the recent experiment in using tapered nanofibers, which are simultaneously used to trap and optically interface cold atoms through evanescent fields [5]. This system constitutes a hybrid quantum system combining both atomic and solid state devices.

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[2] H Zoubi, H Ritsch, *PRA* **76**, 013817 (2007). [3] H Zoubi, H Ritsch, *EPL* **90**, 23001 (2010).
[4] H Zoubi, H Ritsch, *EPL* **87**, 23001 (2009).
[5] H Zoubi, H Ritsch, *NJP* **12,** 103014 (2010).

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