Quantum memory for light using an ion Coulomb crystal in an optical cavity

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We report on our experimental progress towards the realization of a quantum memory for light with ion Coulomb crystals [1] in an optical cavity. By placing a Coulomb crystal consisting of thousands of $^{40}Ca^{+}$ ions in an optical resonator, it is possible to achieve a strong light-matter interaction at the single photon level, while maintaining the excellent coherence properties of trapped ions [2]. The recent observations of cavity electromagnetically induced transparency (EIT) in such a system [3] open for the dynamical storage of quantum states of light using cavity–EIT based protocols [4]. As equally strong coupling for the different transverse cavity modes has been demonstrated [5], interesting perspectives also exist for the simultaneous storage of different spatial modes of light inside the crystal. Another interesting feature is the possibility of working with ion Coulomb crystals containing two different species, e.g. two isotopes [6]. Due to the mass separation of the ions in the crystal, the lighter ions form a central cylindrical core surrounded by the heavier ions [7]. In addition to the sympathetic cooling of the interacting ions by the outer ions, and hence potentially extending the lifetime of the quantum memory to seconds, such two-component crystals also provide a way to control the shape of the inner crystal, which should allow for an enhanced efficiency of the memory [8]. Potential further enhancement of the coupling strengths between the ions and the cavity field could be obtained by applying optical dipole potentials [9]. Finally, the possibility to turn such an ion Coulomb crystal-based quantum memory into a photon number counting device will also be investigated [10].

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