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Waveguide-QED with cold atoms and nanophotonic waveguides

In recent years, coupling atoms to nanophotonic structures has become a promising approach to realize nonlinear quantum optical protocols, offering better scalability and figures of merit than free-space approaches, as well as new paradigms for atom-photon interactions. In particular, the use of nanophotonic waveguides has emerged as powerful tool for such implementations, due to the strong atom-photon coupling in single pass configuration arising from the tight transverse confinement of the propagating light. In this talk I will present our recent progress in this emerging neutral-atom waveguide-QED field of research.

Using an atomic array trapped around a nanofiber in a Bragg configuration, we implemented a mirror consisting of a few thousand atoms that can be switched from a transparent to a reflective state using an additional laser field in Electromagnetically Induced Transparency configuration. This realization of a reflective photon router works at record-low fW power levels. We further pushed the performance by adding a third laser field coupled to the metastable state, which can control the reflectance of our atomic Bragg mirror with as low as a few tens of photons, nearing the few-photon nonlinearity regime.

A powerful additional degree of freedom of nanophotonic waveguides is the possibility to engineer the dispersion relation by periodically structuring the waveguide. Close to the photonic band gap, slow modes arise whose coupling to nearby atoms is enhanced, realistically to reach strong coupling. I will describe our efforts towards strong coupling of cold atoms to photonic-crystal waveguides. We have designed waveguides that can support a slow-mode resonant with an atomic transition, as well as dipole trapping in the vicinity of the waveguide. Loading atoms near the waveguide is a strong challenge and I will describe how novel structures and optical techniques can be used.

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