Towards Cavity-Based Entanglement of an Atomic Register Under a Microscope

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We present a new experimental platform combining optical cavity quantum electrodynamics (CQED) with a single-atom resolution microscope. Our experiment is aimed at extending the generation of multiparticle entanglement to a 1D register of up to a 100 neutral atoms, while detecting and controlling the state of each individual atom.

To achieve this goal, we have developped a new generation of dual-wavelength high-finesse fiber Fabry-Perot cavity [1]. Rubidium atoms are trapped in a one-dimensional optical lattice (at 1560 nm) along the axis of the cavity. An effective long range interaction between the atoms is provided by their coupling with a cavity mode resonant at the Rb atomic transition (780 nm). By optimizing the overlap between the two intracavity standing waves, every trapped atoms is strongly and identically coupled with the entangling mode at 780 nm. As shown on Figure 1, the microcavity has been placed under a high-resolution microscope, which we plan to use for single-site detection and addressing.

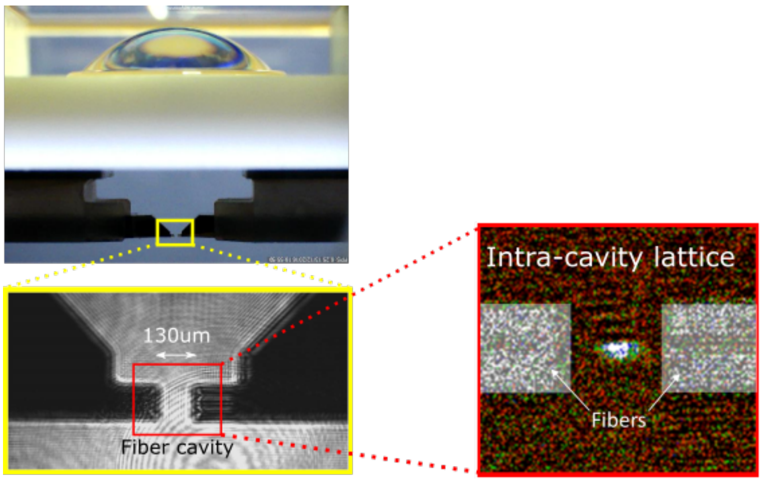

Fig. 1: Optical image of the heart of the all-in-vacuum experiment. The fiber Fabry-Perot cavity (first inset) is placed at the focus of a high-numerical aperture lens. The second inset shows an absorption image of 2000 trapped atoms in the cavity lattice.

Starting from a magneto-optical trap about 1 cm below the resonator, we load up to 2000 atoms in the cavity mode by transporting them in an "atom elevator". It is based on a moving crossed dipole trap, where one of the laser beam is displaced by an acousto-optical deflector. We will present the first signature of strong coupling between the atoms and the resonant cavity mode, which is the observation of large collective Rabi coupling of 3 GHz for 2000 atoms. We will also show the latest results of our effort to detect trapped atoms with single-site resolution in the intracavity lattice. The implementation of a moving laser beam through the microscope for single-site addressing will also be discussed.

This new experimental platform will provide an ideal test-bed to investigate multi-particle entanglement generation in many different contexts, such as in Quantum Zeno Dynamics schemes [2], at the critical point of an effective Dicke model [3], as well as reservoir-engineering techniques [4] .

References

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