An array of single atoms strongly coupled to a cavity for quantum metrology and simulation.

Pierre-Antoine Bourdel
Constance Poulain, Jakob Reichel, Romain Long.

Laboratoire Kastler Brossel, École Normale Supérieure, 24, rue Lhomond, Paris, France

pierre-antoine.bourdel@lkb.ens.fr

Strongly coupling an array of single qubits to a cavity offers the prospect of any-to-any interactions between the qubits, single qubit state read-out (fast or quantum non-demolition) and multiparticle entanglement generation.
Towards this objective, we have built a platform where cold rubidium atoms are strongly coupled to a fiber-based Fabry-Perot cavity. A high-numerical aperture lens combined with acousto-optic deflectors [1] [2] will allow to 1) generate a 1D chain of tens of single atoms, trapped in tweezers, strongly, equally and maximally coupled to the cavity mode 2) store single atoms in a 1D atomic register outside of the cavity 3) move atoms between the register and the cavity, for fast readout and entanglement generation.
With this setup, we have mapped the cavity mode with atoms trapped in the tweezers, achieved the single-atom collisional blockade regime and measured the single-atom Rabi splitting. We are now setting up the multiple-tweezer configuration to enter the regime of strong coupling CQED with a controllable number of single atoms. Our platform will then allow multi-parameter quantum metrology (e.g. measuring magnetic gradients with entanglement-enhanced precision) [3]. With our future 1D chain of spins, we will also simulate the quantum transport of an excitation in the chain in presence of disorder [4], and explore quantum information dynamic in the chain, such as scrambling [5].

References

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[2] D. Barredo et al., Science 354, 1021 (2016)
[3] M. Gessner et al., Nature Comm. 11, 3817 (2020)
[4] J. Dubail et al., Phys. Rev. A 105, 023714 (2022)
[5] G. Bentsen et al., Phys. Rev. Lett. 123, 130601 (2019)

Figures

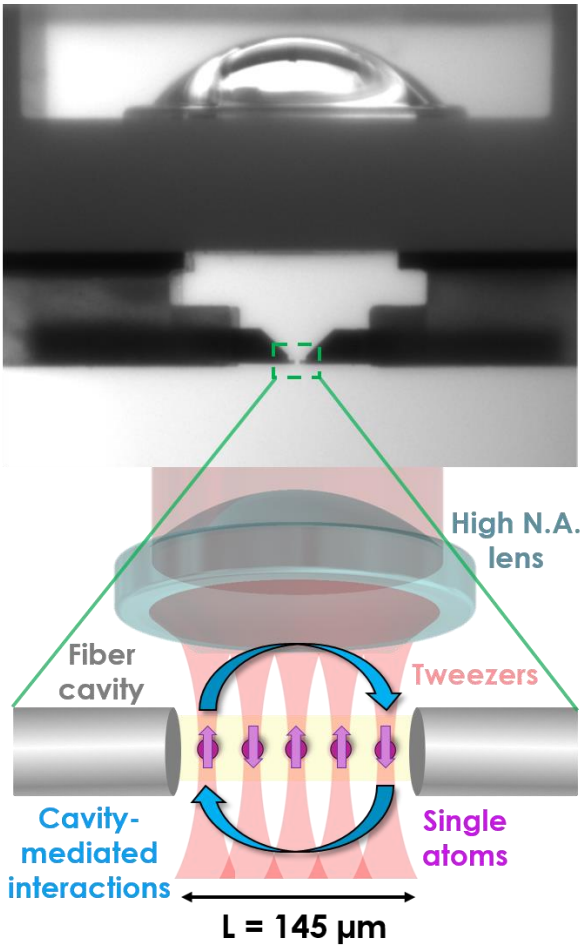

Figure 1.