

Master 2: International Centre for Fundamental Physics

INTERNSHIP PROPOSAL

Laboratory: Laboratoire Kastler Brossel

Location: Département de Physique de l'ENS, 24 rue Lhomond, 75005 Paris

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Web page: <https://www.lkb.fr/atomchips/>

Thesis possibility after internship: YES

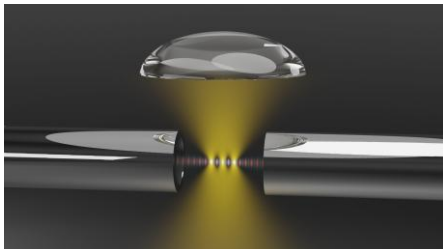
Funding: YES

If YES, which type of funding: PEPR

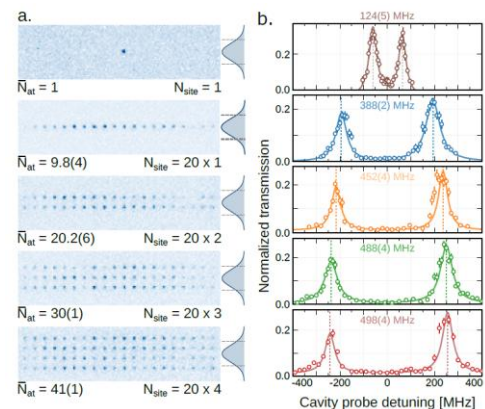
Atom-Tweezer Arrays in an Optical Microcavity for Quantum Technologies

Understanding how correlations, entanglement and information are generated and propagate within many-body systems is one of the central challenges of quantum physics, with deep implications for quantum technologies. In this context, coupling cold atoms to the optical mode of a cavity offers a unique playground for engineering effectively infinite-range, photon-mediated interactions between atoms. Yet, conventional cavity quantum electrodynamics (CQED) systems have offered limited single-particle control and spatially resolved detection.

At LKB, we have recently overcome this limitation by developing an experiment coupling arrays of individually trapped ^{87}Rb atoms to a high-finesse fiber Fabry-Perot microcavity in the strong-coupling regime. We demonstrated extended single-atom arrays, site-resolved fluorescence imaging, cavity-based qubit detection, and collectively enhanced atom-cavity coupling ([arXiv:2607.21515](https://arxiv.org/abs/2607.21515)). Our work is part of the rapidly emerging field of high-cooperativity cavity QED with optical-tweezer arrays. The project is now entering a new phase, moving from the development of the atom-cavity platform toward its first applications to many-body physics.



*Above: Principle of the experimental setup: an array of optical tweezers trap single atoms inside an optical fiber microcavity.
Right: Averaged fluorescence images of single atom arrays and the corresponding vacuum Rabi splittings.*



The combination of cavity-mediated long-range interactions and local control via tweezers opens up new avenues for engineering spatial correlations in entangled states and monitoring their propagation with single-particle resolution. This allows us to explore quantum simulations of transport phenomena in spin systems with tunable disorder, as well as the creation of spatially delocalized entangled states for multiparameter quantum metrology.

The internship will focus on experimental developments supporting these directions. Depending on the progress of the experiment, this may involve, for example, shaping excitation beams for the cavity geometry or automating and stabilizing laser-locking systems for long-duration data acquisition. It can naturally lead to a PhD thesis on many-body cavity QED with individually controlled atoms. The student will gain hands-on experience in optics, lasers, cold atoms and cavity QED physics in a stimulating experimental environment.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES

Quantum Physics: YES

Soft Matter and Biological Physics:

Theoretical Physics: YES

NO