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/

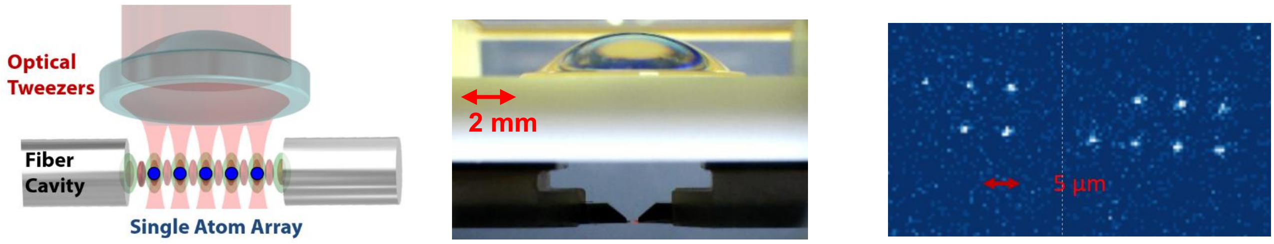
Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: PEPR

Atom-Tweezer Array 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. These dynamics depend critically on the interaction range between qubits.

In this context, coupling cold atoms to the optical mode of a cavity offers a unique platform for engineering effectively infinite-range interactions between atoms, mediated by the cavity field. Cavity quantum electrodynamics (CQED) systems have proven to be powerful tools for generating many-particle entangled states thanks to their long-range interactions and all-to-all connectivity. However, conventional CQED systems have long been limited in terms of single particle control and spatially resolved detection.

At LKB, we have recently overcome this limitation by developing a new experimental platform that combines a high-finesse optical microcavity, allowing operation in the strong regime of cavity QED, with a high-numerical aperture lens. This lens enables single particle control and detection by generating an array of individually controllable tweezers (see figure).



Left: Principle of the experimental setup: An array of optical trap and control a register of single atoms inside an optical micro-cavity. Center: I mage of the actual experiment. Right: Single-shot fluorescence imaging of a single atom array.

The combination of cavity-mediated long-range interactions and local control via tweezers opens up new avenues for engineering spatial correlations of entangled states and monitoring their propagation with single-particle resolution. For quantum simulations, this allows us to explore transport phenomena in spin systems, with tunable disorder, dissipation and external driving. Beyond simulation, the creation of spatially delocalized entangled states provides a resource for quantum-enhanced multiparameter estimation, a rapidly developing area in quantum metrology.

Depending on experimental progress at the time, the internship project will focus on either the real-time control of the optical tweezers within our setup or the implementation of Raman lasers to realize cavity-assisted Raman transitions. The internship can naturally lead to a PhD thesis. The student will join a highly motivated team, work in a stimulating research environment, and gain hands-on experience in optics, lasers, cold atoms and cavity QED physics.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:
Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES