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

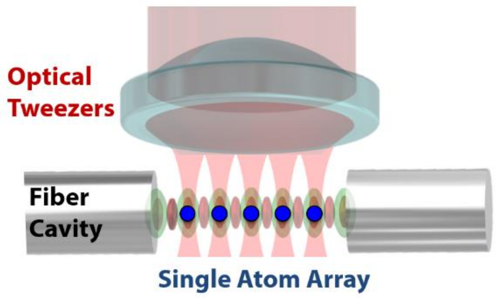
Supervisors: Romain Long (long@lkb.ens.fr), Jakob Reichel (reichel@lkb.ens.fr)
Web page: http://www.lkb.upmc.fr/atomchips/

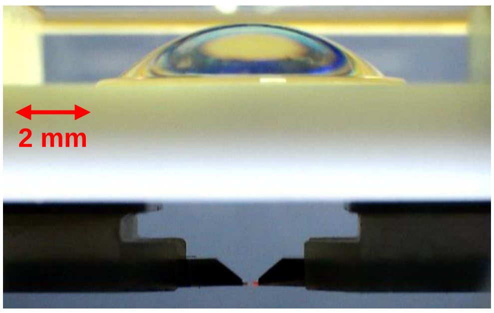
Thesis possibility after internship: YES

Quantum simulation with an atom-tweezer array in an optical microcavity

Understanding the dynamics of entanglement and quantum information within a many-body system represents a central challenge in quantum physics, with far-reaching implications for the advancement of quantum technologies. The dynamic properties of the system depend strongly on the range of the interaction between the qubits. In this context, the coupling of cold atoms with the optical mode of a cavity offers a unique platform for engineering infinite long-range interactions between atoms, mediated by the cavity.

Cavity quantum electrodynamics (CQED) systems have proven to be one of the most powerful tools for generating many-particle entangled states. So far, however, they are constrained in terms of single particle control and spatially resolved detection. At LKB, we have recently accomplished a significant milestone with the development of an experimental setup that combines a high-finesse optical microcavity, allowing us to work 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. Right: an image of the actual experiment.

The combination of cavity-mediated long-range interactions between atoms and the local control offered by the tweezers opens up new avenues for engineering spatial correlations of entangled states and monitoring their propagation with single-particle resolution. In the realm of quantum simulations, this will allow us to investigate transport phenomena in spin systems, with the ability to introduce additional elements such as disorder, dissipation and driving. Furthermore, these spatially delocalized entangled states will serve as a resource to perform quantum-enhanced estimation of multiple parameters, a very promising new topic in the field of quantum metrology.

The focus of the internship project is to implement real-time polarization control of the dipole light used to generate the tweezers within our experimental setup. The internship can naturally be followed by a PhD thesis. The student will become an integral part of our highly motivated team, operating within an inspiring research environment and will have the opportunity to 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