Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: **Laboratoire Kastler Brossel**
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Thesis possibility after internship: YES
Funding: *to be discussed*

Harnessing waveguide-QED
- cold atoms and nanophotonics -

Controlling light-matter interaction at the single-quantum level, is a long-standing goal in optical physics, with applications to quantum optics and quantum information science. However, single photons usually do not interact with each other and the interaction needs to be mediated by an atomic system. Enhancing this coupling has been the driving force for a large community over the past two decades. One pioneering approach is known as cavity quantum electrodynamics (CQED) , where a single atom and a single photon can be strongly coupled via a high-finesse cavity. Cavity-QED led to a better understanding of fundamental aspects of light-matter interaction and to various seminal demonstrations. Combining atoms and nanoscale cavities appeared also as a promising pathway thanks to the tighter confinement of light that enables a drastic enhancement of the atom-field coupling. Modern nanofabrication techniques and the realization of nanoresonators with embedded artificial atoms led also to a solid-state alternative to atom-based CQED and to a very fruitful quantum nanophotonics area of research.

In contrast to nanocavities, **strong transverse confinement in nanoscale waveguides** also recently triggered investigations for coupling **guided light and atomic ensembles**. Specifically, a subwavelength waveguide can provide a large evanescent field that can interact with atoms located in the vicinity. Due to geometrical considerations, a single atom close to the surface can absorb a non-negligible fraction of the guided light, as the effective area of this mode is comparable with the atomic cross-section. This is the direction of the present project that enters into the **emerging field of waveguide-QED**. **The project aims at developing and exploring such single-pass devices for quantum optics, quantum non-linear optics and quantum information applications. Two platforms will be considered: optical nanofiber and slow-mode photonic-crystal waveguide**, which are at different levels of development.

Using a **nanofiber with a 400-nm diameter and a few thousands atoms trapped around**, the team recently realized a first all-fibered quantum memory for light. The team also demonstrated the very efficient reflection of single photons by an ordered one-dimensional array of trapped atoms and the heralding of single-collective atomic excitation in this platform. A novel platform involving a slow-mode photonic-crystal waveguide is being developed.

References:
Demonstration of an optical memory for tightly guided light in an optical nanofiber, PRL 114, 180503 (2015).
Large Bragg reflection from 1D arrays of trapped atoms near a nanoscale waveguide, PRL 117, 133603 (2016).
Waveguide-coupled single-collective excitation of atomic arrays, Nature 566, 359 (2019)

Condensed Matter Physics:	YES	Macroscopic Physics and complexity:	NO
Quantum Physics:	YES	Theoretical Physics:	YES