**Master 2*: International Centre for Fundamental Physics***

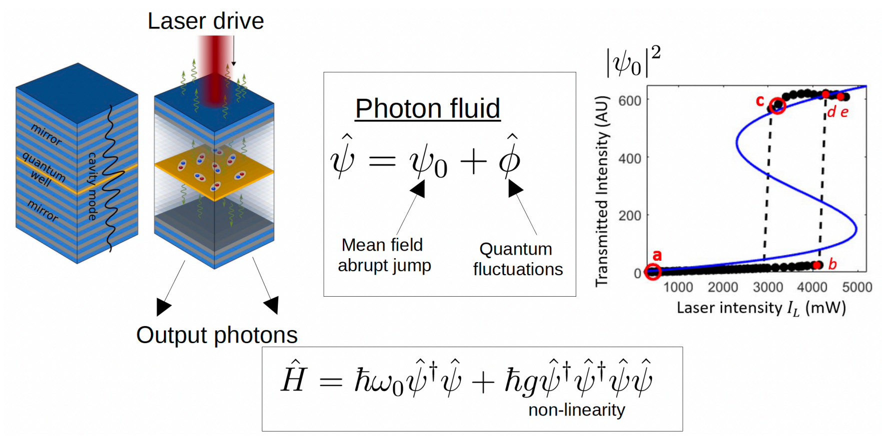
## INTERNSHIP PROPOSAL

**Laboratory name:** Laboratoire Kastler Brossel (LKB)
**CNRS identification code:** UMR 8552
**Internship director'surname**: Irénée Frérot and Nicolas Cherroret
**e-mail**: nicolas.cherroret@lkb.upmc.fr ; irenee.frerot@lkb.upmc.fr **Phone number:** 01 44 27 44 00
**Web page**: https://www.lkb.fr/quantumtheory/
**Internship location**: Sorbonne Université, Paris
**Thesis possibility after internship**: YES
**Funding**: YES **If YES, which type of funding**: Candidature bourse EDPIF

# *Theoretical study of entangled photons across an abrupt jump in an exciton-polariton cavity*

Exciton-polaritons (EP) are hybrid light-matter quasi-particles, hosted in the crystalline lattice of semiconducting microcavities under an appropriate laser drive. In the micro-cavity, the photons of the laser drive hybridize with electron-hole pairs in the semiconductor. This creates EP, which build what is called a « quantum fluid of light » [1]. EP have many analogies with cold atoms systems (for instance, they may exhibit Bose-Einstein Condensation, and the analogue of a superfluid behavior), but also fundamental differences stemming from the fact that they only exist under a laser drive ; and also from the fact that dissipation plays a major role in creating the steady-state for the EP fluid. Being at the interface of non-linear optics, condensed matter physics and quantum information science, EP are a fascinating playground for studying quantum many-body phenomena, from very fundamental questions to potential quantum technologies applications [2]. Such systems are also experimentally studies at LKB, which further motivates their theoretical description.

During the internship, we will theoretically study the behavior of an EP quantum fluid of light across a spontaneous abrupt jump in the micro-cavity light intensity (Figure below, right panel). This abrupt jump occurs at the onset of a bistable regime due to the interplay of non-linear effects, drive and dissipation, and is well understood from mean-field (classical) arguments. We will investigate the fate of quantum fluctuations on top of the mean-field behavior, to potentially unveil the generation of quantum-entangled photons. This strong enhancement of quantum fluctuations across an abrupt jump of the mean-field intensity has analogies with quantum quenches in cold atom systems, but also with more exotic quantum phenomena such as the dynamical Casimir effect.




The theoretical tools used in this project involve mean-field theory (a driven-dissipative version of Gross-Pitaevskii equation, describing Bose-Einstein Condensates), Bogoliubov theory capturing quantum fluctuations at a Gaussian level of approximation, numerical simulations by truncating the Hilbert space describing the quantum fluid dynamics, and input-output theory to relate the behavior of the intra-cavity EP system to the observable light field outside of the cavity, which bears key signatures of the complex state of light formed inside of the cavity.

[1] I. Carusotto & C. Ciuti, « Quantum fluids of light », Rev. Mod. Phys. **85**, 1 (2013)
[2] I. Carusotto, « How to exploit driving and dissipation to stabilize and manipulate quantum many-body states », C.R. Phys. **26**, p.533-569 (2025)