PHD Thesis proposal

Title : Superradiant Quantum Phase Transition

Laboratory : Laboratoire de Physique et Modélisation des Milieux Condensés (CNRS-UGA GRENOBLE)

Supervisor : Pierre Nataf (coordinator of the funded IRS project).

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Key words : theoretical physics, cavity quantum electrodynamics, light-matter coupling, quantum Hall effect, phase transition.

Formation : Master in theoretical physics or condensed matter or quantum physics.

Required skills: quantum physics; analytical calculation. Optional: a bit of numerics.

Summary : Cavity quantum electrodynamics has considerably developed recently thanks to the technological progress. Among the paradigmatic models of cavity quantum electrodynamics, the Dicke model, which describes the coupling of N atoms to the same cavity mode, can give rise, *under some conditions*, to the « superradiant » quantum phase transition [1]. Such a transition is predicted for a relatively high value of the light-matter coupling, which has actually been reached in the last five years in some systems, such as superconducting circuits and Landau polaritons [2,3]. But while the technology is ready, the superradiant phase transition has never been observed at equilibrium. Indeed the observation of the « superradiant » phase requires also a diamagnetic energy smaller than a given threshold [4].

Very recently, in our laboratory LPMMC (CNRS-UGA) Grenoble, we have discovered that the Rashba spin-orbit coupling could allow the Landau polaritons, which are a mixed system made of a two-dimensional electron gas under a perpendicular magnetic field and the photons of a resonating cavity, to undergo the superradiant transition [5].

We propose in this PHD projet to develop this new topic by studying the conditions of occurence of the superradiant phase in Landau polaritons. Through a deep **theoretical** study, the PHD student will consider some possible additional physical ingredients (Zeeman coupling, Coulomb interaction, disorder, multi band coupling) in order to guide the experimentalists.

The PHD student will then have the highest chance to be the source and to inspire the first experiment realizing the superradiant quantum phase transition at equilibrium.

Bibliography :

[1] C. Emary and T. Brandes, *PRE*, **67**, 066203 (2003).
[2] D. Hagenmüller, S. De Liberato, and C. Ciuti, *PRB*, **81**, 235303 (2010).
[3] G. Scalari *et al.*, Science, **335**, 1323 (2012).
[4] P. Nataf and C. Ciuti, *Nat. Comm.*, **1**, 72 (2010).
[5] P. Nataf, T. Champel, G. Blatter and D. Basko, *PRL*, **123**, 207402 (2019).