Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique des Solides
CNRS identification code: UMR 8502
Internship director'surname: SIMON Pascal/ MORA Christophe
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Web page: https://sites.google.com/site/pascalsimonphysics/

Internship location: Orsay
Thesis possibility after internship: YES
Funding: NO If YES, which type of funding:

Title: **Harnessing topological properties with a strong light-matter coupling**

The study of the quantum-mechanical interaction between light and matter has been a driving field in physics in the past century with various applications in different research fields, such as quantum information and quantum computing. Experimental advances in cavity quantum electrodynamics (CQED) have proven their ability to couple quantum coherent systems such as real or artificial atoms with light [1]. More recently it has been made possible to even integrate solid state materials with optical cavities [2] opening the door to harness their electronic properties and eventually to emulate new exotic collective phases of matter. Moreover, such system combines in an elegant manner quantum electronic transport and quantum optics, where both optical and electronic observables can be measured in parallel. Therefore, it offers a new paradigm to test and foster our understanding of the light-matter interaction at the nanoscale.

Recently, we have explored the strong coupling regime between light and two-dimension (2D) electronic matter and established a general criterion for determining the onset of an equilibrium superradiant phase, an exotic phase which breaks time reversal symmetry in which photons macroscopically populate the cavity [3]. Investigating simple non-interacting toy models in the strong light-matter regime, we have found that properties of the resulting superradiant phases can be drastically different from the original electronic model. More specifically, we have found that light-matter interaction can induce non-trivial topology in the system, which manifest as protected zero edge modes or topological bands [3].

During this internship, the student will further explore the topological properties induce by the strong light-matter interaction in a more realistic graphene-like model. He will analyze the phase diagram of such system as function of the parameters of the model and calculate various transport and optical observables.

[1 J. M. Raimond, M. Brune, and S. Haroche, Rev. Mod. Phys. 73, 565 (2001).
[2] G. Scalari et al., Science 335, 1323 (2012).
[3] D. Guerci, P. Simon, and C. Mora, arXiv:2005.08994

Profile: Condensed matter theory, quantum optics, quantum transport and many-body physics.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

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