Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: Center for Nanoscience and Nanotechnology (C2N)
CNRS identification code: UMR 9001
Internship director'surname: Jacqueline Bloch and Sylvain Ravets
e-mail: Jacqueline.bloch@c2n.upsaclay.fr, Phone number: 01 70 27 04 71
Sylvain.Ravets@c2n.upsaclay.fr, Phone number: 01 70 27 04 72
Internship location: C2N, 10 bd Thomas Gobert, Palaiseau
Thesis possibility after internship: YES
Funding: YEs type of funding: ERC project : ANAPOLIS

Experimental exploration of out of equilibrium Bose Einstein condensates

A fascinating property of bosons, quantum particles with integer spin, is their ability to massively occupy a single quantum state. In this regime, the cloud of bosons behave as a macroscopic coherent ensemble with non-linear properties emerging from interactions. So far most experiments have focused on the physics of closed systems such as isolated clouds of cold atoms. The phase diagram of closed BEC has been explored and shown very rich physics with universal statistical properties and scaling laws.

Recently a novel class of BEC has been considered, where the system is open and constantly loses particles via dissipative process. To reach a steady state, dissipation needs to be compensated via pumping so that the condensate shows out of equilibrium dynamics. Interestingly the openness of the system fundamentally changes the physics of the BEC and many open questions need to be addressed both theoretically and experimentally: what are the statistical properties of open BECs? What universal scaling laws can be identified? How is the coherence affected by the presence of drive and dissipation?

In this project, we propose to explore this physics both experimentally and theoretically using BECs made of photons in optical cavities. By strongly coupling the photons to electronic excitations in semiconductor materials, we realize hybrid light-matter quasi-particles (polaritons) that can undergo Bose Einstein Condensation above some threshold excitation power. An asset of this experimental system is that all physical observables can be optically measured by advanced spectroscopy techniques, allowing to obtain density, phase, correlations both in real and momentum space.

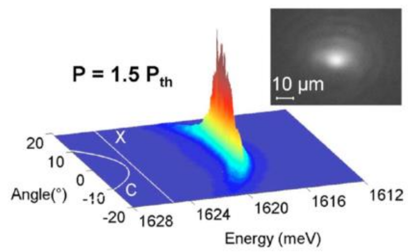

Image of the collected emission from a 2D polariton BEC: (inset: spatial density profile of the condensate) angle resolved spectrum of the condensate.

Using nanotechnology tools available at C2N, our group has developed a unique expertise in generating out of equilibrium polariton Bose Einstein Condensate, both in 1D and 2D. Recently we have probed coherence in space and time of a 1D Bose Einstein Condensate and demonstrated the emergence of scaling laws, which are specific to open systems [1], thus opening the way to experimentally explore the statistical physics of open systems. The subject of the internship and following PhD is to explore the uncharted territory of 2D open BECs.

This research is mostly experimental but also present a strong theoretical side developed in collaboration with a group of theoreticians based in Grenoble. The applicant will contribute to the optical spectroscopy experiments under cryogenic conditions, to the analysis of the experimental data and to scientific discussions with theoreticians. A solid background in quantum and solid-state physics is highly recommended together with a strong appetite for experimental work.

[1] Q. Fontaine et al., Nature 608, 687 (2022)

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES