NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2019-2020

Statistical physics in fluids of interacting photons

General Scope:

Exciton-polaritons (polaritons) are the elementary excitations of semiconductor microcavities, in which the excitonic transition[1] of an embedded semiconductor quantum well is in the strong-coupling regime with photons from the cavity mode. Polaritons thus have a half-light, half-exciton hybrid nature, which is an extraordinary resource. For instance, their photonic fraction provides them with a low effective mass that makes them “behave” like photons, while their excitonic fraction provides them with the ability to interact with each other, a property which is absent in regular photons. The resulting physics is so rich that, a new class of quantum fluids has been defined after them, and known as “quantum fluids of light” [1].

Like any classical fluid, a polariton fluid is subject to fluctuations, like waves on top of the sea. However, there are two key differences with this example: these fluctuations are neither thermal (i.e. at equilibrium), nor classical. As a result, key characteristics of the fluid such as temperature, and entropy are notions that need to be entirely revisited. In this internship/PhD project, the aim is to investigate experimentally the characteristics of these fluctuations (e.g. their amplitude and spectrum).

Research topic and facilities available:

During the internship, we will generate fluctuations in a controlled way, using quench-like perturbation of the polariton fluid, and measure the resulting fluctuations by an optical spectroscopy technique derived from Brillouin scattering [2]. The project can be followed by a PhD project, in which fluctuations will be created by a controlled defect moving within the fluid, and the resulting force (known as the “drag force” in the context of quantum fluids) exerted by the fluid on the defect will be measured. Different regime will be investigated such as the superfluid regime [3] in which the force experienced by the defect, and the resulting perturbations are suppressed, and new regimes that are specific to nonequilibrium systems and so far have never been achieved experimentally [4,5].

This research will be carried out at Institut Néel, in a fully equipped and ready laboratory of optical spectroscopy. It will start in 2020 as a M2 internship, and could be followed by a PhD thesis. The work will start under the direct supervision of the supervisor, and later on, with the support of a post doc fellow.

Bibliography: [1] I. Carusotto et al. *Rev. Mod. Phys*. 85, 299 (2013); [2] P. Stepanov, et al. *Nature Comm*. 10, 3869 (2019) ; [3] A. Amo et al. *Nature Physics* 5, 805 (2009) ; [4] M. Van Regemortel et al. *Phys. Rev. B* 89, 085303 (2014); [5] M.-G. Hu et al. *Phys. Rev. Lett.* 117, 055301 (2016)

Possible collaboration and networking:

A key collaborator in this work is the theory group of Anna Minguzzi (LPMMC, CNRS), which is situated next door, and provides deep understanding of the phenomena, develops new theoretical descriptions, and provides numerical modelization of these experiments. This work takes place in the context of other well-established collaborations in France, Italy, Australia and Germany.

Required skills:

The candidate must have a good track-record during his/her master classes. Strong motivation, and a genuine taste for experimental physics addressing fundamental questions is a key asset.

Starting date: internship 2020 ; possibly followed by 3 years PhD

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[1] A semiconductor *exciton* is an electron-hole pair bound by Coulomb interaction.