LABORATOIRE CHARLES COULOMB MONTPELLIER

Internship proposal - 2nd year master
Waveguide Polariton Lasers: Solitons and Topological lasers

Supervision : Thierry Guillet, L2C (CNRS-Université de Montpellier, Thierry.Guillet@umontpellier.fr)
Web : https://coulomb.umontpellier.fr/-Collective-states-in-semiconductors-

The interaction between electronic excitations (excitons) and photons is strongly enhanced in optical microcavities, compared to a bulk medium. When the interaction is large enough, it can reach the strong coupling regime, where the perturbation theory isn't suitable anymore to understand the light-matter interaction. In this regime, the new eigenstates are the so-called polaritons, half exciton/half photon quasi-particles. They can be generated, transported, accumulated in dense quantum phases and brought into strong interactions. The discovery of the Bose condensation of polaritons in 2006 [1] (at low temperature in a GaAs microcavity) has triggered many interesting research projects and led to the discovery of the superfluidity of polariton condensates, the observation of unique kinds of vortices in these "quantum fluids of light", and the development of polaritonic devices.

GaN and ZnO-based polaritonic devices have raised a large interest in the community thanks to their robust excitons and large oscillator strength. Indeed polariton condensates can be demonstrated at room temperature, which is a striking advantage with respect to GaAs devices operated at cryogenic temperatures. Within a collaboration with the laboratories CRHEA, C2N and IP (with present fundings from ANR NEWAVE and Labex Ganext), our group L2C/OECS has demonstrated in 2013 the condensation of polaritons in a ZnO microcavity at 300K [2] and then developed an alternative platform based on polaritons in GaN ridge waveguides [3-7] i.e. an optical waveguide in which propagating photons and excitons are in the strong coupling regime [3]. With this last platform, we have investigated laser physics at small photon numbers [4,5], nonlinear and topological photonics [6], mode-locking and soliton physics [7]. This research stands at the frontier between non-linear optics, nanophotonics, quantum opto-electronics and Bose condensate physics.

The present internship is focused on the foreseen demonstration of a topological polariton laser operating at room temperature. A topological photonic crystal has been imprinted on the polariton waveguide, following a recent theoretical proposal [6]. The topological lasers will be studied by combining advanced optical spectroscopy and imaging of their emission both in real space and k-space, in order to evidence the photonic/polaritonic states involved in lasing, and their topological nature.

We are looking for a motivated student interested in optical experiments. The applicants are expected to have a background in semiconductor physics, quantum mechanics and optics.

The internship could lead to a continuation on a PhD position, with a secured funding.

References

1. Kasprzak, J. et al., *Bose-Einstein condensation of exciton polaritons,* Nature (2006).
2. Li, F. *et al., From Excitonic to Photonic Polariton Condensate in a ZnO-Based Microcavity*, Phys Rev Lett (2013).
3. C. Brimont *et al., Strong coupling of exciton-polaritons in a bulk GaN planar waveguide*, Phys. Rev. Applied (2020); arXiv
4. P.M. Walker *et al., Ultra-low-power hybrid light–matter solitons*, Nat. Commun. (2015).
5. H. Souissi *et al., Ridge Polariton Laser: Different from a Semiconductor Edge-Emitting Laser,* Phys. Rev. Applied (2022); arxiv
6. I. Septembre *et al., Soliton formation in an exciton-polariton condensate at a bound state in the continuum,* Phys. Rev. B (2024)
7. H. Souissi *et al., Mode-locked waveguide polariton laser*, Optica 11, 967 (2024); arXiv