PhD position

Waveguide Polariton Lasers: quantum fluids of light for integrated photonics

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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. Quantum fluids of polaritons are widely investigated as a candidate platform for nonlinear integrated photonics, and for quantum simulations. Indeed polaritons allow both for a careful engineering of the potential energy and strong nonlinear interactions, two major ingredients of nonlinear optics on the one hand, quantum simulators on the other hand.

Within a collaboration with C2N (Saclay), CRHEA (Valbonne) and IP (Clermont-Ferrand), we have been developping an alternative platform based on polaritons in GaN ridge waveguides [2-5], dedicated to laser physics at small photon numbers, nonlinear photonics and soliton physics [6]. Interestingly it allows a much easier electrical injection compared to vertical cavities. Within the ANR-funded project NEWAVE5, we will shape 1D photonic crystals in order both to control the polariton laser dynamics, i.e. the polariton condensation dynamics, and to couple neighboring cavities.

The foreseen PhD project is devoted to the design and characterization of the polariton dispersion in patterned GaN ridge waveguides, and the spectroscopic investigation of the dynamics of polaritons in these structures. After our recent demonstration of polariton lasing in a GaN polariton waveguide [5], we plan to control the operation of the laser under electrical injection and to discriminate continuous versus pulsed operation regimes. This last transition is related to the non-linear formation of polariton condensates and associated solitonic phases in polaritonic waveguides, inspired from the atomic physics community, at the frontier between non-linear optics, quantum optics and condensate physics.

We are looking for a motivated PhD student interested in optical experiments. The applicants are expected to have a background in semiconductor physics, quantum mechanics and optics. This project is part of the ANR-funded NEWAVE program [7], starting in January, 2022.

References

1. Kasprzak, J. et al., *Bose-Einstein condensation of exciton polaritons,* Nature **443**, 409 (2006).
2. Li, F. *et al.*, *From Excitonic to Photonic Polariton Condensate in a ZnO-Based Microcavity*, Phys Rev Lett **110**, 196406 (2013).
3. Hahe, R. *et al.*, *Interplay between tightly focused excitation and ballistic propagation of polariton condensates in a ZnO microcavity*, Phys. Rev. B **92**, 235308 (2015).
4. C. Brimont *et al.*, *Strong coupling of exciton-polaritons in a bulk GaN planar waveguide: quantifiying the Rabi splitting,* Phys.Rev. Applied **14**, 054060 (2020); arXiv:1902.02974
5. H. Souissi *et al.*, *Ridge polariton laser: different from a semiconductor edge-emitting laser*, Arxiv:2201.04348 and T. Guillet *et al.*, *Demonstration of a GaN waveguide polariton laser, so different from a ridge laser*, Presentation at the PLMCN conference (video), 10/2020
6. Walker, P. M. *et al.*, *Ultra-low-power hybrid light–matter solitons*, Nat. Commun. **6**, 8317 (2015).
7. NEWAVE project: https://coulomb.umontpellier.fr/-NEWAVE-