M2 Internship offer 2023/2024

Departement/Team: Photonique/ODIN
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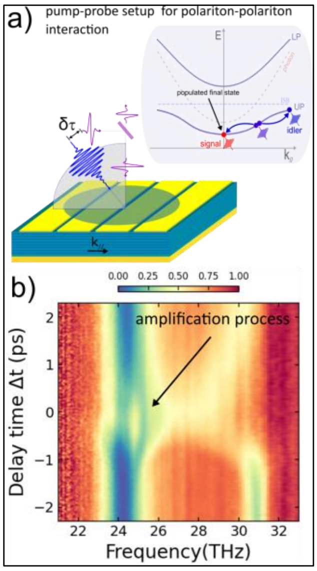
Mid-infrared ultrafast pump-probe spectroscopy of the saturation process in bound-to-continuum polaritons

Scientific project: Non-equilibrium Bose-Einstein condensation of exciton-polaritons have become a vast playground for fascinating phenomena previously reserved to ultracold atomic gases. In particular, it has led to the demonstration of superfluidity, topological lasing and non-Hermitian effects. In these polaritonic systems the fundamental energy scale is intrinsically fixed by the interband transition of the underlying material, limiting flexibility and also the magnitude of the Rabi splitting. Conversely, the transition energy of intersubband (ISB) polaritons in doped semiconductor quantum well (QW) structures can be freely tuned by varying the QW width and doping to reach the mid-IR and Far-IR range of the electromagnetic spectrum. As their excitonic counter-part, it has been predicted that they can show exotic quantum behavior such as final state stimulation and condensation. This would open interesting perspectives of a condensate operating at much lower energy scale and interacting with a 2D gas of electrons to form Fermi-Bose mixtures. Our team has made major progresses towards that goal in the recent years. Starting with dispersion engineering [1], we developed a clear roadmap towards condensation [2] and confirmed the existence of a spontaneous process based on ISB polariton - LO phonon scattering [3]. More recently, in the frame of an international collaboration, we demonstrated for the first time polariton-polariton interaction in the regime of final state stimulation (see figure) [4]. In this pump-probe experiment, we have shown an amplification process occurring on an ultrafast time scale; this is the key ingredient towards condensation.



In this continuity, this internship aims at exploring the nonlinearities of a novel polaritonic scheme based on the strong coupling regime of bound-to-continuum transition and a microcavity [5]. Such novel polaritonic scheme has been demonstrated recently by our team and hold great promises for the demonstration of condensation with polaritons issued from a 2D gas of electrons. The main task of the candidate will be the exploration of the saturation process in such systems, using already existing samples. The candidate will have to use the optical MIR pump-probe setup recently built in the team and characterized the reflectance of the system as a function of the pump fluence. The candidate will then record the dynamic of the system on an ultrafast time scale to fully capture the nonlinearities at play. Finally, she/he will use an in-house numerical code to simulate the polaritons scattering dynamic and amplification process within the novel polaritonic architectures that was characterized earlier on.

Furthermore, and if time allows, the candidate will also be invited to follow the different steps of the fabrication process of the samples in clean room. The project offers a global view of the different activities led in our team from the numerical design, the fabrication in cleanroom and the optical characterization.

[1] J.-M. Manceau et al., *Mid-Infrared Intersubband Polaritons in Dispersive Metal-Insulator-Metal Resonators*, Appl. Phys. Lett. **105**, 8 (2014).
[2] R. Colombelli and J.-M. Manceau, *Perspectives for Intersubband Polariton Lasers*, Phys. Rev. X **5**, 1 (2015).
[3] J.-M. Manceau et al., *Resonant Intersubband Polariton-LO Phonon Scattering in an Optically Pumped Polaritonic Device*, APL. **112**, 19 (2018).
[4] M. Knorr, J.-M. Manceau et al., *Intersubband Polariton-Polariton Scattering in a Dispersive Microcavity*, Phys. Rev. Lett. **128**, 247401 (2022).
[5] E. Cortese, et al., "Excitons bound by photon exchange," Nat. Phys., (2020)

Methods & techniques: Non-linear ultrafast optics, data processing, instrument control (Python).
Possibility to go on a PhD: Yes
Funding: Doctoral school scholarship or research grant