Dispositifs Optoélectroniques et Nanophotoniques (DON)

Université Paris Cité

Surface Plasmon Thermalization and Condensation in 1D

Internship and/or PhD thesis (funding via the doctoral school)

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Context

The internship aims to study **photon Bose-Einstein condensation (BEC)**, a phenomenon in which **an active medium mediates the interaction between photonic modes** in order to thermalize their population, and generate a condensed fraction. This phenomenon is **out-of-equilibrium**: an optical pump continuously generates excitations to compensate for the losses. Photon condensates were first observed in dye-filled optical microcavities[1], before being demonstrated in plasmonic lattices[2] and semiconductor cavities[3].

Their driven-dissipative nature places them between equilibrium condensates and conventional lasing. They present the advantage to preserve **phase coherence** at energy thresholds below those of lasers, without population inversion, making them of great technological interest. Moreover, the emergence of coherence in the presence of dissipation is an inherent to quantum platforms, and mastering its effects would help make robust quantum states.

The photon condensates studied to date are 2D systems. The project implements a 1D system by using **electromagnetic modes** which are guided at the interface between a dielectric and a metal, **surface plasmons**[4]. By confining these modes within a plasmonic Fabry–Perot cavity (Fig. 1a), **one obtains paraxial modes in one dimension**. In 1D, fluctuations and interactions become particularly important due to the reduced dimensionality. **Whether and how this condensation regime develops for photons remains an open question.** The platform used consists of a plasmonic cavity interacting with a polymer film doped with an organic dye (shown in light blue, Fig. 1b). The cavity is defined by two plasmonic Bragg mirrors, which also act as couplers. This platform already allowed to observe **the first evidence of BEC of surface plasmons** (Fig. 1c, unpublished results).

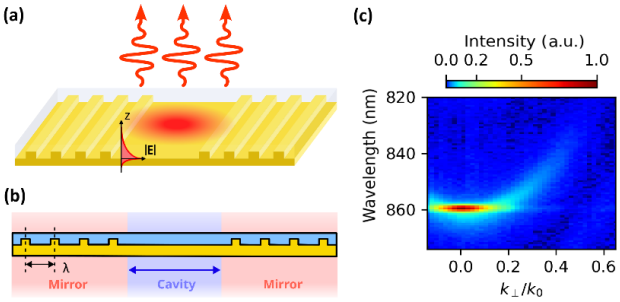


Figure 1: (a) 3D rendering of the plasmonic Fabry-Perot cavity, and (b) cross-sectional view. The organic dye layer in the polymer matrix is shown in light blue. (c) Measurement at room temperature showing the dispersion relation of condensate plasmons as a function of the transverse wave vector. At $k_\perp = 0$, the condensate mode appears under strong optical pumping. The color scale is nonlinear.

Project

The internship project aims to study **the mechanisms by which thermalization and condensation occur** within this system, and will involve an experimental study of the gas's thermodynamic properties and spatial correlations. The intern will join a team involving two experimental researchers (Marin Tharrault and Aloyse Degiron) as well as a theoretican (Alexandre Le Boité), and work in tight collaboration with all its members. He/she will fabricate plasmonic samples in the MPQ's nanofabrication clean room, measure them using advanced optical techniques and analyze the experimental results in close relation with theoretical modelling. The intern will step in a project already in a rather advanced stage, which will allow him/her to **gain insight into the entire process of a research project**.

Profile

We are looking for a student with a background in **quantum mechanics**, **optics** and/or **nanofabrication**, and a taste for experimental work. The ability to generate new ideas by **interacting** with researchers from different fields of expertise will be a strong drive of the intern's work.

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1 J. Klaers *et al.*, *Bose–Einstein condensation of photons in an optical microcavity*, Nature **468**, 545 (2010).

2 T. K. Hakala *et al.*, *Bose–Einstein condensation in a plasmonic lattice*, Nature Phys **14**, 739 (2018).

3 R. C. Schofield *et al.*, *Bose–Einstein condensation of light in a semiconductor quantum well microcavity*, Nat. Photon. **1** (2024).

4 H. Raether, *Surface Plasmons on Smooth and Rough Surfaces and on Gratings*, **111**, (1988).