Dynamics and Effective Interactions of a Photonic Condensate in an Optical Trap

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The bosonic nature of both polaritons and photons allows them to achieve Bose-Einstein condensation (BEC), forming a macroscopically coherent state. Polariton and photon condensates are intensively studied systems, where the nature of equilibrium and non-equilibrium BEC is explored. In high density regime, the strong coupling between excitons and photons is lost, and the system undergoes a crossover into the weak coupling, where one can observe a photonic condensate. On one hand, exciton polaritons interact with each other because of the excitonic component. On the other hand, interactions within the photonic condensate may originate from nonlinearities of the active material itself, e.g. via nonlinear refractive index, which has not been reported yet, especially using the geometry of an optical trap. These interactions are expected to manifest as collective Bogoliubov spectrum of excited states.

In this contribution, by using a GaAs-based microcavity sample, we experimentally study dynamics of photonic condensate in an optically induced trap and the effects of photon-photon interactions by measuring the momentum dispersion using the time-resolved spectral tomography on a streak camera. The sample is excited with the pumping pulsed laser shaped into a ring to obtain an effective potential created by the photo-excited reservoir. In the weak coupling regime, the effective potential results from local changes of the cavity's refractive index induced by excessive carriers, which act at the same time as the photon gain [1]. At strongest pumping powers - which correspond to the highest particle densities in the system - modification of the photon condensate dispersion is clearly visible, which can be a signature of effective photon-photon interactions. The photonic condensate is driven-dissipative in nature, hence in the experiment we observe a shape resembling the dissipative Bogoliubov spectrum, Figure 1 [2]. Our results are important in further understanding of the nature of photonic condensates as well as in their undiscovered dynamics.

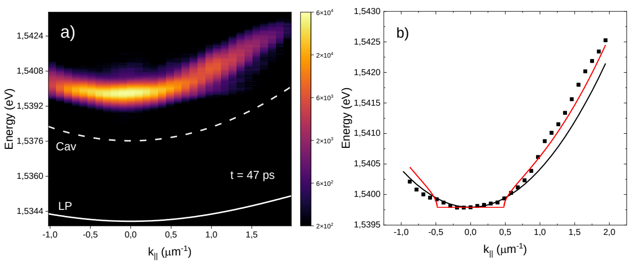

Figure 1. (a) Measured dispersion of a photonic condensate at highest pumping power at time after pulse corresponding to the highest photon density. Theoretical photon and polariton curves are marked with Cav and LP. (b) Extracted energies from (a) (squares), with blueshifted theoretical cavity mode (black line) and fit with the dissipative Bogoliubov dispersion (red line).

[1] M. Pieczarka et al., *Opt. Express* **30**, 17070 (2022).
[2] J. Bloch, I. Carusotto and M. Wouters, *Nat. Rev. Phys.* **4**, 470-488 (2022).