Nanostructured Waveguide for Low-Density Polariton Bose-Einstein Condensation

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Exciton-Polaritons are elementary excitations arising from the strong coupling between a photonic cavity mode and an excitonic resonance. To date, these particles have been widely studied[1] in vertical microcavities composed of an active material. Embedding the device between two highly reflective mirrors, usually made of GaAs and AlGaAs layers, leads to new properties because of the hybrid light-matter inner structure. However, microcavities do not guarantee a facile manipulation of the photonic mode. In fact, a deep etching process is required to get access to the active material where light is confined.

An alternative interesting platform is constituted by horizontal waveguides[2], whose core can be easily patterned with a shallow etching to introduce new functionalities. Here we present the fabrication and characterization of patterned waveguides composed of GaAs quantum wells and AlGaAs barriers. The patterning consists of linear gratings 90nm deep where the control over periodicity and the grating filling factor were found to be of the utmost importance to introduce new properties in our polariton system.

The realization of the linear grating induces special points in the dispersion observed in a variety of physical systems with specific periodic structuring, ranging from photonics to acoustics. In photonic systems, these states have usually been used to show very long lifetime, lasing and polarization rotation of the emission. However, they have never been exploited for the observation of phase transition into Bose-Einstein condensates (BEC). Indeed, here we show, for the first time ever, that exciton-polariton condensation is reached at this critical point with a record low excitation energy density, considerably lower than conventional photon lasers or polariton condensation in standard microcavity samples. In this framework, we will present how a shallow etched 1D grating and its fabrication control allowed us to drastically reduce the power needed to undergo a BEC.

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[1] D. Sanvitto, Stéphane Kéna-Cohen. The road towards polaritonic devices. Jul 2016

[2] D. G. Suarez-Forero, F. Riminucci, V. Ardizzone, M. de Giorgi, L. Dominici, F. Todisco, G. Lerario, L. N. Pfeiffer, G. Gigli, D. Bagarini, and D. Sanvitto. Electrically controlled waveguide polariton laser. Optica Nov 2020

In turn, we assess the impact of the designed pattern over the polariton condensation threshold and the characteristics of its emission. Furthermore, we show the importance of atomic layer deposition as a passivating layer of the etched QWs, resulting in a lower non-radiative exciton recombination, and therefore a lower exciton-polariton condensation threshold.