All-optical controlled polariton Mach-Zehnder interferometer

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Optical switches and modulators are key components in the next generation of all-optical logic elements. One of the main ingredients in their implementation is the achievement of the phase control of the optical signal. This can be done by modulating the optical index of the guiding material and using slow light effects, for instance in photonic crystal structures [1,2]. However, non-linearities are small in conventionally used materials and architectures, and phase modulations require high optical powers. In this work we show that a giant phase modulation can be achieved using both the strong non-linearity of cavity polaritons and their small in-plane group velocity. These effects are used to implement the first exciton-polariton Mach-Zehnder interferometer (MZI), based on a 1D waveguide structure etched on a high quality GaAs microcavity (Fig.1a) [4].

A coherent polariton flow is resonantly injected in the input waveguide of the MZI at T = 10K. This splits in two in the arms of the interferometer, which are then rejoined and interfere at the output (Fig. 1b). The relative phase between the two arms is controlled by a non-resonant laser placed on one of the arms. This control beam locally creates an exciton population, inducing a local blueshift of the polariton bands due to the exciton-polariton repulsive interaction [6-8] and slowing down the polariton flow. Therewith, this control beam induces a phase shift $\delta\phi$ with respect to the other arm (Fig.1a).

A phase shift up to 2π is obtained in a region of a few µm, that allows switching off and on the output (Fig. 1c), allowing to modulate the transmission by one order of magnitude. The figure of merit for this prototype MZI, the modulated region length times the power for a π phase shift, is significantly lower than for conventional already optimized systems based on photonic crystals. Beside the modulation of the transmission, also the linear degree of polarization of the output can be controlled by the presented polariton MZI.

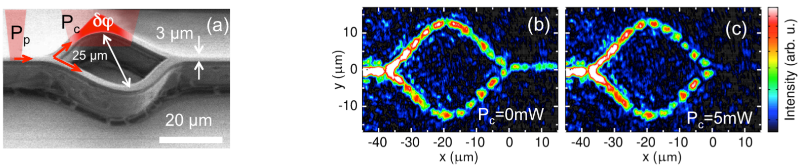

Figure 1 a) Scanning electron microscopy image of the MZI. The excitation laser and control laser are denoted by P_p and P_c, respectively, whereas the arrows indicate the polariton flow. (b and c) Spatially resolved polariton emission for different powers of the control laser.

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