Parametric oscillation in semiconductor microcavities : nonlinear and quantum effects

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Polaritons in high finesse semiconductor microcavities present large nonlinearities coming from the Coulomb interactions between the exciton components. Under resonant pumping, this leads to a parametric process where a pair of pump polaritons scatter into nondegenerate signal and idler modes while conserving energy and momentum. The scattering is particularly strong in microcavities, because the unusual shape of the polariton dispersion makes it possible for the pump, signal and idler to be on resonance at the same time.

In cw experiments, the microcavity can emit strong signal and idler beams above a threshold pump intensity, without any probe stimulation [1]. In this regime a microcavity can be compared with a triply resonant optical parametric oscillator (OPO) [2]. Since OPOs have been extensively studied in the fields of nonlinear and quantum optics, this analogy is useful not only for the interpretation of experiments, but also in the search for novel effects.

I. Optical bistability

We have carried out experiments on III-V microcavity samples provided by R. Houdré's group in Lausanne. Under resonant cw laser excitation, we observed bistability on the signal emission (see Fig. 1), when the microcavity is slightly detuned with respect to the optimal oscillation conditions. A similar effect has been demonstrated in OPOs. A model analogous to those developed in triply resonant OPOs gives good qualitative agreement with our results [3].

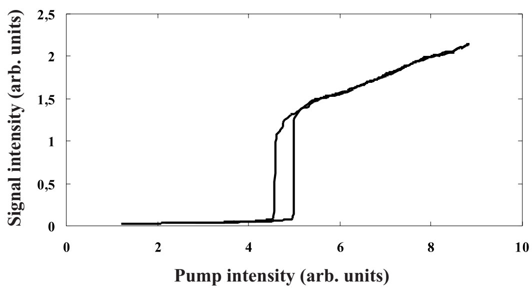

Fig. 1: hysteresis cycle of signal intensity vs pump intensity.

II. Twin polaritons

The strong nonlinearities of cavity polaritons make them attractive for quantum optics. Polariton squeezing was deemonstrated in our group [4] using degenerate polariton four-wave mixing. Knowing that OPOs can produce strongly quantum correlated beams, it is also interesting to study quantum correlations in microcavities. Below the oscillation threshold, strong correlations between the signal and idler polariton fields have been predicted [5]. We have developed a full quantum model which allows to compute the fluctuations of the signal and of the idler light beams produced by a semiconductor microcavity above the oscillation threshold [6]. Strong correlations between the signal and idler polariton modes are predicted. However, the idler mode is in general very weakly coupled to the extracavity field, which leads to a strong reduction of quantum correlations between the outgoing light fields.

References

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