Branch-entangled polariton pairs: planar microcavities versus photonic wires

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The generation of entangled states is one of the most fascinating aspects of quantum mechanics. In quantum optics, parametric sources of entangled photon pairs have been attracting great interest due to their remarkable non-classical applications. In particular, polarization-entangled pairs of photons [1] are an essential ingredient for quantum cryptography, while frequency-entangled pairs have been recently exploited for the so-called quantum optical coherence tomography [2]. Recently, semiconductor quantum microcavities in the strong exciton-photon coupling regime have been shown to provide very rich parametric phenomena based on polariton-polariton coherent scattering [3]. Interestingly, planar microcavities can be laterally patterned with the possibility of creating one-dimensional polariton systems with controllable parametric properties. Efficient inter-branch parametric scattering has been demonstrated in one-dimensional microcavities, where the presence of several polariton sub-branches provides the opportunity of tailoring the parametric processes in a remarkable way [4]. While the outstanding optical gain properties of polariton parametric amplifiers are largely investigated, the study of the genuine quantum properties is still in its infancy. One intrinsic limitation of the process involving only the lower branch in planar microcavities is the weak radiative coupling of the idler polariton mode to the extra-cavity field. One important issue yet to be explored is the possibility of creating Einstein-Podolski-Rosen (EPR) pairs of polaritons, which are entangled with respect to a certain degree of freedom (not necessarily the polarisation) and which can be efficiently transferred out of the microcavity. In this contribution, a scheme is proposed for the generation of branch-entangled pairs of microcavity polaritons through spontaneous inter-branch parametric scattering [5]. Branch-entanglement is achievable when there are two twin processes, where the role of signal and idler can be exchanged between two different polariton branches. Branch-entanglement of polariton pairs can lead to the emission of frequency-entangled photon pairs out of the microcavity. In planar microcavities, the necessary phase-matching conditions are fulfilled for pumping of the upper polariton branch at an arbitrary in-plane wave-vector. The important role of nonlinear losses due to pair scattering into high-momentum exciton states is evaluated. The results show that the lack of protection of the pump polaritons in the upper branch can be critical. In photonic wires, however, branch-entanglement of one-dimensional polaritons is achievable when the pump excites a lower polariton sub-branch at normal incidence, providing protection from the exciton reservoir.

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