Single and double photon emission from quantum dots embedded in optical microcavities

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We study the dynamics of a quantum dot (QD) embedded in a three-dimensional semiconductor optical microcavity. The lowest excited state (labeled as exciton) of the QD has the third component, M, of the angular momentum as a degree of freedom. Since we are interested in the coupling with cavity photons, we only consider the two bright excitons with $M=\pm 1$ as well as the biexciton. We work in the strong coupling regime in two different cases:

i) the QD exciton has an energy close to the frequency of a photon cavity mode. This is the adequate situation for single photon emission.

ii) the energy separation between the QD ground state and the biexciton (different from twice the exciton energy due to the Coulomb interaction between electrons and holes) is close to twice the cavity mode frequency. In this case, one can expect the emission of two photons (with a certain degree of entanglement) being much more probable than the single photon emission.

We have considered both continuous and pulsed pumping of the system. Electrons and holes can recombine either by spontaneous emission through leaky modes or by stimulated emission of cavity modes that can escape from the cavity. The numerical integration of a master equation including all these effects gives the dynamics of the density matrix. By using the quantum regression theorem, we have computed the first and second order coherence functions required to calculate the photon statistics and the spectrum of the emitted light.

Pumping and emission rates define different regimes characterized by poissonian or gaussian cavity photon distributions. Sub-poissonian distributions can be obtained for a range of parameters in which the pumping rate is very small, and, the quantum nature of the QD-cavity system manifests in the emitted light.

Our main result is the determination of the conditions for emission of pairs of photons as well as its degree of entanglement visibility. The spectrum of the single (case i) or double (case ii) photon emission has been obtained for different regimes of parameters.