The evolution of spatial coherence in double quantum dots under the influence of phonons

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The experimental evidence of collective effects in the emission from quantum dot (QD) samples suggests that such systems cannot be treated as ensembles of independent emitters [1]. The enhanced, "superradiant" emission from the ground state of a QD ensemble has been successfully modeled [2] under assumption that the QDs are coupled not only by long-range dipole interactions but also by short range ones (e.g. due to tunneling). This model accounted for the experimentally observed system evolution as a function of the number of QDs and detection energy with respect to the maximum of the ensemble photoluminescence. However, the striking difference between the time-resolved ensemble emission under quasi-resonant excitation (optical transition to higher confined shells, leading to a collective enhancement of emission) and non-resonant excitation (transition to wetting layer or bulk states with no enhancement of emission observed) has not been discussed.

In this presentation, we make the first step towards understanding of this dependence on the excitation conditions. As the collective emission requires that a spatially delocalized superposition of exciton states in various dots exists in the system, the most likely explanation of the observed facts is that spatial coherence is preserved during exciton relaxation between confined shells but lost upon trapping from wetting layer or bulk states. Therefore, we study the evolution of the spatial coherence during relaxation between delocalized exciton states in the simplest case of a double quantum dot (DQD) coupled to acoustic phonons. We investigate under what conditions (alignment of energy levels, coupling, inter-dot distance) the spatial coherence is preserved during the relaxation between these states in a DQD system. In addition, we study the effect of thermalization of occupations and dephasing on the collective emission.

Our description of the system kinetics is based on a few-level description of two coupled QDs and a Markovian Lindblad equation for carrier-phonon dynamics with transition rates derived from standard carrier-phonon couplings. Using this model, we show that no coherence can appear in the ground state manifold for uncoupled QDs in the absence of degeneracy of the intraband transition energies. However, either degeneracy or coupling between the dots can lead to coherence transfer, similar to the exciton-biexciton case [3]. Thus, the interplay of the coupling strength and energy degeneracy is crucial not only for the appearance of collective emission itself [3,4] but also for the coherence transfer during relaxation that is needed for the appearance of a "superradiant" superposition in the ground state.

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