Collective optical effects in multiple quantum dots

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We study the effects resulting from the collective coupling of excitons residing in systems of two to four quantum dots to their radiative environment. The coupling to common photon reservoir leads to the appearance of rapidly decaying states and dark states which do not undergo radiative decoherence. The consequence of the co-existence of bright and optically inactive states is the vacuum-induced coherence effect which consists in a coherent excitation transfer from a bright state to the delocalized and decoherence-resistant one. In this presentation we specify the rapidly decaying states and amplitude combinations which form optically inactive superpositions, we also analyze the role of energy mismatch, coupling between the dots and dipole moments in the dynamics of excitons induced by collective coupling to the photon reservoir. We show that the destructive effect of the transition energy splitting can be overcome by an appropriate interplay of dipole moments which allows to observe perfectly stable states and thus spontaneous trapping of excitation in systems with technologically realistic energy mismatches even if the coupling between the systems does not exceed the transition energy difference by far [1].

Multiple quantum dots composed of two or more coupled quantum dots attract much attention due to the richness and complexity of their optical properties which have been manifested in many optical experiments [2]. One of the factors that affects the evolution of excitons confined in such structures is the collective coupling to the photon environment (superradiance) [3]. The investigation of these phenomena in quantum dot systems is essential for application of quantum information processing, since the dark superpositions do not undergo radiative decoherence and thus may be used for noiseless encoding of quantum information [4], while the short-living states show promise for optimization of lasers [5]. The collective effects are very sensitive to the homogeneity of the transition energy mismatches and may be destroyed in systems with energy splitting of the order of micro-electron-Volts which is below present technological feasibility. This effect may be considerably reduced by sufficiently strong coupling between the systems [6], but full stabilization of the collective effects in technologically realistic ensembles is possible only in systems with different dipole moments [1].

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