Analysis of the Exitation Dynamics in 2D Semiconductor Nanostractures Induced by a Quantum Electromagnetic Field Under the Kerr Phase Modulation

I A Tereshchenko[1,2] and O V Tikhonova[1,2]

[1]*Physics Department, Lomonosov Moscow State University, Leninskie Gory, 1, 119991, Moscow, Russia*
[2]*Skobeltsyn Institute of Nuclear Physics, Leninskie Gory, 1, 119234, Moscow, Russia*
Contact Email: tereshchenko.ia19@physics.msu.ru

The study of nanostructure excitation dynamics is an important scientific field of great interest both from a fundamental and practical point of view. In such nanoscale objects, new physical effects arise due to spatial quantization. The interaction of such systems with electromagnetic fields opens up a wide range of possibilities for controlling their properties and using them for the development of nanoelectronics. Currently, spatially localized excitations in solid nanostructures are considered as promising candidates for the development of various quantum information technologies. Moreover, the interaction with non-classical light and the transfer of non-classical properties and even quantum correlations from photons to the electronic subsystem [1] open up new prospects for the analysis of hybrid electron-photon systems and provide the basis for the development of a fully quantum photon-matter interface, which is very promising, especially in the field of nanosystems. An important aspect of interaction with electromagnetic fields is the presence of nonlinearity, which characterizes most solid-state resonators and has a significant effect on the excitation processes [2].

In this paper, we analyze the dynamics of the formation of Frenkel excitons in a semiconductor quantum well induced by a non-classical electromagnetic field, taking into account the nonlinear effects arising from self-phase Kerr modulation. Similarly [3-5], the manifold excitations of a quantum well are analyzed using the formalism of bosonic ladder operators. An analytical solution of the nonstationary Schrodinger equation is obtained, including both semiconductor and field degrees of freedom. To ensure the effective interaction of the electron with the field, it is assumed that the quantum well is located in the cavity. A significant reduction in the resonator volume makes it possible to observe strong field effects even with a small number of photons in the resonator. In the presence of nonlinearity, a very rich excitation dynamics is detected in the system and it turns out that time separation of excitation channels is possible. It is found that the probability of excitation of different channels significantly depends on the non-linearity parameter, and the maximal probability can be reached not only without nonlinearity. The possibility of controlling the excitation by changing the frequency tuning of the field is demonstrated and analytically proved. The initial states of coherent and squeezed vacuum fields were also considered, for which it was possible to identify optimal conditions for the effective excitation of a certain excitation channel. In this case, it turns out that the excitation of high-order channels is only slightly less than without nonlinearity. In addition, special attention was also paid to the study of the case of cross-phase modulation in the presence of two field modes with symmetrically tuned frequencies from the resonant one. The interplay of the nonlinear cross-phase modulation effects and the induced entanglement of field modes is shown.

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