Excitation of Semiconductor Nanosystems by Multy-Frequency Quantum Field

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The study of the interaction of electromagnetic fields with atomic-molecular and nanostructured systems is an important task and is of great scientific interest, not only from a fundamental point of view but also taking into account a wide range of practical applications. In such systems, new physical effects arise due to nanoscaled size and spatial quantization. At the same time, the interaction with electromagnetic fields opens up a wide range of possibilities to develop methods for controlling spatially localized excitations and current in such structures and to use them for purposes of nanoelectronics. One of the relevant areas of such research is the investigation of the impact of non-classical fields. An important aspect, in this case, is the analysis of the effects of a set of frequency components of the quantum field, which represent a spectral field mode (often the Schmidt mode) and are connected to each other through interaction with the electronic subsystem of a semiconductor.

In this paper, the problem of the interaction of a semiconductor quantum well with a quantum field characterized by a certain spectral distribution (the Schmidt mode) is analytically solved. The case of simultaneous influence of two and three spectral components of the field is considered, and the formation of multiple excitations (excitons, biexitons, *etc.*) in a semiconductor structure is investigated. Similar to [1-3], the manifold excitations of a quantum well are analyzed using the formalism of bosonic ladder operators. An analytical solution of the non-stationary Schroedinger equation, including both the semiconductor and field degrees of freedom, is obtained. To provide efficient electron-field interaction, the quantum well is supposed to be placed in a cavity. A significant decrease in the cavity volume allows observing strong field effects even for the low number of photons in a cavity.

A detailed analysis of the time-dependent energy exchange between a semiconductor system and a quantum field is carried out. The dynamics of the probability of excitons and biexitons depending on the initial distribution of photons in the frequency components of the field are obtained. The control of the dynamics of excitations in a nanostructure is demonstrated by varying the spectral profile of the Schmidt frequency mode of the acting quantum field. Interaction with two non-resonant modes is shown to lead to suppression or enhancement of some excitation channels depending on the initial energy distribution over the spectral components of the quantum field. The regimes of either constructive amplification of excitation of the nanosystem or efficient energy exchange between the frequency modes are found. In the letter case, the spectral field components are found to be connected to each other through interaction with the electronic subsystem. The detected effect of correlation or anticorrelation of spectral components is confirmed by calculations of the covariance of the number of photons in these frequency field modes. The formation of a certain eigenstate of the system is found and is shown to limit the maximal energy transferred to the excitation.

References

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