Kinetics of electrons in a quantum well-quantum dot system

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We study theoretically kinetics of conduction band electrons in a coupled quantum well-quantum dot injection structure. The system under consideration might be used to increase efficiency of quantum dot lasers, emitters of high quality coherent light. Experimental data show [1], that additional quantum well reservoir supplies excessive carriers for a quantum-dot-active-media increasing pumping efficiency and modulation frequency, important parameters for telecommunication applications. QW-QD is also an interesting system for theoretical studies of electron relaxation between states of different dimensionality.

Internal dynamics of a nanostructure is strongly determined by electronic states. For a single structure a simple form of wavefunctions like gaussian function (QD) or plane waves (QW) ensures main physical properties, but for coupled structures it does not provide important effects like states overlap. Hence, calculation of wavefunctions within more sophisticated model is obligatory, e.g. by full diagonalization of the system. Since the quantization along z direction is strong, we use adiabatic approximation to separate dimensions for the computation [2]. We take advantage of the cylindrical symmetry of the system, which reduces the complexity even further. The resulting states are grouped according to their orbital momenta and for each subspace matrix elements are found.

In this contribution we focus on the relaxation of electrons from a quantum well to a quantum dot due to the electron-LO phonon interaction. Time dependence of the average number of electrons in all states is calculated with full quantum kinetic treatment. The derivation of evolution equations is done within the correlation expansion method, where hierarchy of second-quantization operators is build with the Heisenberg equation. We study limiting cases of a single electron and a full-band limit and generalize the model for arbitrary initial distribution. We close the set of equations and integrate them to obtain injection rate and time evolution of occupations.

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