Spatial Diffusion of Photogenerated Carriers in Coupled Quantum Well - Quantum Dot Structures

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A semiconductor quantum well (QW) separated from a sheet of quantum dots (QDs) by a thin potential barrier can act as a large reservoir and transport channel of carriers that subsequently populate QDs' states. As it has been proposed previously, such a tunnelling scheme can be beneficial for high modulation rate QD-based semiconductor lasers [1] or memory devices [2], however, the carrier diffusion in this complex structure has not been investigated so far. In this approach one has to take into account not only a classical physical phenomenon related to spatial distribution of carriers, their concentration's gradient and mobility but also quantum mechanical processes accounted for tunnelling of carriers through a thin potential barrier and additional energy relaxation processes.

In this work we investigate spatial diffusion of photogenerated carriers in a system of coupled QW-QDs layers for a set of structures consisted of a 7-nm-wide or 15-nm-wide $In_xGa_{1-x}As$ QW separated from $In_{0.6}Ga_{0.4}As$ QDs by a 2-nm-wide barrier made of GaAs. The electronic coupling between QW and QDs is tailored by changes in indium content in the QW. [3]. In the experiment, the initial population of carriers is created locally by irradiating the structure with a laser beam, and a subsequent carriers' diffusion process at 5 K is monitored by spatially-resolved micro-photoluminescence technique with 2D imaging. The diffusion is considered in different regimes: varying the excitation density as well as the excitation wavelength, tuning it to the resonance with characteristic energies of the QW or the QD ensemble. Carrier diffusion coefficients are determined from analysis of spatially-resolved photoluminescence intensity profiles. The results show that (i) the diffusion process in the structure with QDs only and weakly-coupled QW-QDs system is quite similar pointing to a typical carrier redistribution process within 2D electronic states, and (ii) with increasing of the coupling strength between the QW and QDs the diffusion is slowing down. This latter effect can be related to (a) elongation of the carriers' transfer time between QW and QDs' states in respect to the interband relaxation time, (b) selectivity of the transfer process due to electronic coupling, and (c) effective trapping of carriers by QDs after the transfer process.

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