Carrier dynamics in (Al,Ga,In)As/(Al,Ga)As quantum dots: the issue of quantum confinement and lattice temperature

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Self-assembled (Al,Ga,In)As quantum dots (QDs) compatible with the state-of-the-art GaAs-based technology can form an essential platform leading to a development of new nanophotonic devices of unprecedented functionalities. The (Al,Ga,In)As/(Al,Ga)As QDs have several important advantages, i.e.: wide spectral tunability of the emission wavelength [1]; the QD surface density can be tailored in a broad range (10^{10} to 10^{11} cm^{-2}) leading to an isolation of a single emitter [2] or producing a high gain material for a QD laser [3]; the use of an (Al,Ga)As barrier can potentially result in a high temperature operation of a device due to high electron and hole quantum confinement.

In this presentation we show results of time-integrated and time-resolved photoluminescence (PL) experiments performed as a function of temperature on a series of (Al,Ga,In)As/(Al,Ga)As QD structures characterized by various chemical content of the QD material. The last issue leads to the observation of QD emission spanning the spectral range of the photon wavelengths between ~0.67 µm to ~1 µm, which is predominantly determined by changes in the lateral size of QDs and the QD material bandgap, as confirmed by the structural data [1] and performed QD band structure calculations. Within the mentioned spectral range, the ground state exciton lifetime (obtained at T=10 K) undergoes the monotonic increase from ~450 ps at ~0.67 µm up to ~740 ps at ~1 µm. The experimentally determined exciton lifetime suggests that an electron and a hole in these dots cannot be treated as being in the strong confinement regime. This is additionally confirmed by the QD band-structure calculations performed within the eight band **kp** framework which suggest smaller than expected hole bands quantization in these dots, which increase the role of the Coulomb correlation between an electron and a hole.

We demonstrate also the role of the lattice temperature on the PL emission from these dots. For the reference QD structure with a deep confining potential for an electron and a hole [(In,Ga)As/(Al,Ga)As QDs] the PL emission is observed up to the room temperature even for moderate pumping conditions. More importantly, the PL emission intensity is not changing significantly. This observation is repeated for QD structures with low Al content within the (In,Al,Ga)As chemical composition of the dot. However, the increase in the aluminum content results in a faster temperature quench of the PL emission caused by the lowering of the quantum confinement for an electron and a hole. As we show these effects lead to the observation of complicated pattern in the photoluminescence decay process for these structures.

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