Exciton dynamics in $InAs/In_{0.53}Ga_{0.23}Al_{0.24}As/InP$ quantum dashes

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In this work there are presented the results of photoluminescence (PL) and time-resolved photoluminescence (TRPL) measurements on $InAs/In_{0.53}Ga_{0.23}Al_{0.24}As$ strongly elongated quantum dots called quantum dashes (QDashes), grown by molecular beam epitaxy on (001) InP substrate. The experiments have been performed at low temperature (5 K), both on the ensemble and single dashes. In the case of the emission from the ensemble, a series of structures has been investigated with different cross-sectional dimensions: height and base width changing from 3x12 nm to 5x20 nm, leading to a pronounced spectral shift of PL emission peak from 1.4 to 1.65 μm, due to the increase in their volume. The TRPL experiments use a mode-locked Ti:Sapphire laser with 76 MHz train of 150 fs wide excitation pulses and exploit a time correlated single photon counting technique, thanks to the application of very fast (50 ps) and low dark count (<10 s^{-1}) superconducting single photon detectors with a significant detectivity and quantum efficiency in NIR.

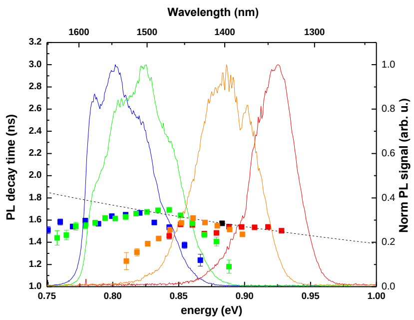

Fig. 1 PL spectra and PL decay time dispersion.

For each of the structures the ensemble PL decay time dispersion vs photon emission wavelength has been recorded. The results are shown in Fig. 1. It shows the PL decay time increase from ~1.5 up to ~1.67 ns with increasing emission wavelength (from ~1.33 to 1.5 μm), which is consistent with the tendency for a strong confinement regime (dotted line). However, for longer wavelengths, the PL decay time starts to decrease. This is interpreted as a transition to the intermediate regime, where Coulomb correlation becomes more important and the transition oscillator strength should depend linearly on the exciton coherent volume, and thus also on the QDash size. The shift occurs for slightly different wavelengths due to the fact that the energy structure of dashes depends not only on their size, but on the strain as well, which very between structures.

Single dash PL measurements were performed on a sample emitting at 1.45 μm, with submicron mesas, to assure small enough probed area to resolve the individual emission lines. Several lines attributed to the emission from excitons and exciton complexes were visible for very low excitation powers. The TRPL spectra revealed two main groups of lines, with lifetimes differing by a factor of two, as is expected for strongly confined excitons and biexcitons. The emissions with longer decay times showed non-exponential behavior, with the maxima of the emission shifting to longer times for higher excitation powers and long rise times, agreeing with the decay constants for the emissions with shorter times, having monoexponential decay for any excitation power. Such a behavior is also consistent with biexciton/exciton cascade. The temperature evolution of the decay curves for excitonic lines was also investigated, showing that they regain exponential behavior at higher temperatures.

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