Biexciton-exciton radiative cascade in single InAs/InGaAlAs/InP quantum dashes emitting near 1.55 μm

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At the cross point between quantum information processing and fiber-based optical communication technologies there emerges the necessity of developing new devices, with specific requirements. Especially interesting could be a true single photon source or a quantum repeater operating in the spectral range near 1.55 μm, allowing the transport of quantum coded information over long distances. It has been well established that a self-assembled semiconductor quantum dot (QD), thanks to its properties, can constitute the key element of the above mentioned devices [1]. However, it is still a challenge to achieve single photon QD emission at 1.55 μm. In this respect the real alternative can be a self-assembled InAs/InGaAlAs quantum dash (QDash) grown on InP substrate. Although some of the emission properties of single QDashes have already been studied [2], the exciton and biexciton dynamics and the characteristic time of the biexciton-exciton cascade evolution in such structures are still unknown.

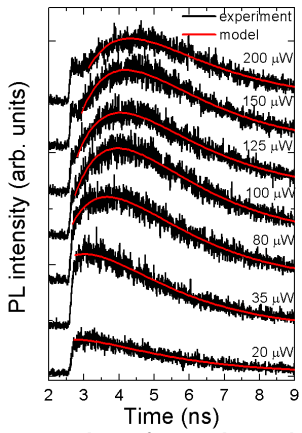

Fig.1. PL decays from single QDash at excitation powers ranging from 20 to 200 μW (black solid line) and modeled X recombination decay in XX-X radiative cascade (red solid line) assuming τ_X=2.4 ns τ_{XX}=1.2 ns.

In this work we present experimental and theoretical studies focused on the exciton (X) and bi-exciton (XX) kinetics in single, self-assembled InAs/$In_{0.53}Ga_{0.23}Al_{0.24}As$ QDashes. The X and XX kinetics have been measured in the time-resolved micro-PL (TRμPL) experiment at T=4.2 K, utilizing the time-correlated single photon counting technique. The key element of the setup was fast (50 ps) and low dark count (<10 c/s) superconducting NbN single photon detector. The analysis of the TRμPL traces allows determining the X and XX decay time constants of 2.4±0.2 ns, and 1.2±0.2 ns, respectively. It shows clearly, that in spite of a high QDash spatial asymmetry, which should lead to the weakening of the confinement regime, the X to XX lifetimes ratio can be very similar to that observed for QD structures being in the strong confinement limit. In order to obtain more insight into the X-XX cascade emission process, the excitation power dependent TRμPL experiment has also been performed. The time evolution of the X emission demonstrates characteristic slowdown of its initial relaxation with the excitation power density. This process is controlled either via the relaxation from QDash higher confined states or the internal XX-X cascade relaxation. The latter one has been confirmed by applying the two level rate equation model, which directly reproduced the experimental data (see Fig. 1).

[1] S. M. Ulrich et al., Phys. Rev. Lett. **98**, 043906 (2007).
[2] N. Chauvin et al., Phys. Rev. B **80**,0 45315 (2009).