Single photons emitted by quantum dots: towards all-optical q-gates

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Self-assembled quantum dots (QDs) are nanostructures that confine electrons and holes in all three dimensions. This induces a zerodimensional density of states and a discrete spectrum of single-carrier energy levels [1,2]. Recently, we demonstrated that emission wavelength of single InGaAsQDs can be tuned over a wide range of interest for telecommunications (900 – 1300 nm) byan appropriate engineering of the growth conditions [3]. Other than applications in standard optoelectronics, these kinds of QDsare particularly promising for future emitters of single/entangled photons [4,5] and quantum logic elements [6] in quantum information processing and computing.

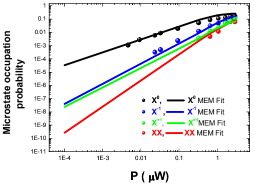

Figure 1: is presented the intensity evolution when exciting. Solid circles correspond to experimental data for the principal excitonic complexes and solid lines correspond to the results obtained with the models.

In this work, we present an adaptation of the Master Equations forthe Microstates (MEM) to reproduce the capture and recombination dynamics of the ground exciton states (quasi particles) confined in a single QD [7].This model considers that QDs are charged via 2D-statesof the wetting layer (WL), where pumping light is producing carriers, in two different ways: exciton capture (correlated e^- - h^+ capture) and uncorrelated (e^-,h^+) capture. The main input parameters of the model are (once considered that capture times are very fast compared to the other time constants): uncorrelated (e^-,h^+) escape times out of the QDs (te_e,te_h), the generation rates of correlated and uncorrelated carriers, G_X and G_{eh}, and the radiativo life times for the different exciton species (τ_r).Not all of these parameters are free and we can fix the experimentally measured radiative lifetimes of the different exciton species (τ_r of neutral and charged excitons, and biexciton).The other parameters (generation rates and escape times) are used as free fitting parameters to reproduce the power evolution of the emission intensity for the different exciton species, as shown in Fig. 1 for fitting parameters listed in Table 1. This procedure can be also applied to different single QDs with different charge environment. The latter condition can be simulated by introducing an extra reservoir of electrons to be transferred into the QD ground states (through an extra generation rate, G_I) if selective pumping is used [8].

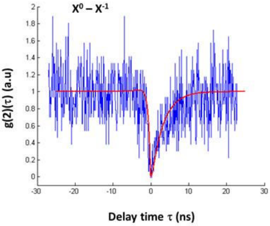

Figure 2: In blue the measured photon correlation function (g(2)(τ)) a single QD for $X^0 – X^{-1}$, and red line correspond the theoretical fit.

The output of the MEM model can be used to quantify the experimentally mesured second-order correlation function, g(2)(τ), both self- and cross-correlations, using the Hanbury-Brown-Twiss experiments, as shown in Fig. 2 for the case of neutral exciton and trioncross-correlations. Finally, we also conducted two-color experiments to measure cross-correlations between neutral excitons and trions, but now generated with different pumping lasers, demonstrating a NANDgate operation using single photons, again quantitatively corroborated byour MEM model.

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te_e	te_h	$\tau_r(X^0)$	$\tau_r(X^{-1})$	$\tau_r(X^{+1})$	$\tau_r(XX)$	G_x	G_{eh}
5.5ns	3.5ns	0.85ns	0.892ns	0.892ns	0.539ns	0.046 excitones ns^{-1}	0.0061 e^- – h^+ ns^{-1}

Table 1: CW fitting parameters corresponding to figure 1 and 2.