Non-equilibrium Dynamical Behavior of Exciton/Biexciton in a Diluted Magnetic Semiconductor Asymmetric Quantum Well

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The biexciton formation has been confirmed by a polarization dependent four-wave-mixing (FMW) experiment in an asymmetric quantum well $Cd_{0.9}Mg_{0.1}Te/CdTe/Cd_{0.8}Mn_{0.2}Te$ (the well width, L_z=4.9nm) [1]. However, it is has been remained unsolved why the biexciton photoluminescence (PL) in this system is dominative even under weak excitation intensity at low temperatures. On attempt to clarify this anomalous band edge PL behavior, we applied systematic study on the excitation density and photon energy dependence of luminescence spectra. We have found the co-existence of biexcitons and charged excitons at nearly the same energy position when excited at high photon energies. This feature may occur quite commonly among II-VI diluted magnetic semiconductor quantum wells, where Mn d-d transition contributes to the creation of electrons into the well. We have demonstrated the Mn d-d transition contribution to the charged exciton creation by means of photoluminescence excitation spectra. The time-resolved photoluminescence spectroscopy (TRPL) of excitons and biexcitons have been measured under exciton resonant excitation, of which results showed important role of dark excitons and their spin scattering by Mn localized spins. For a resonant excitation, the biexciton grew super-linearly with respect to the exciton intensity, in contrast to the non-resonant case, where the ratio of the biexciton to exciton intensity showed a linear dependence.

The biexciton TRPL showed a longer lifetime as compared with that of the exciton. These results are in contrast to an exciton-biexciton system in conventional semiconductor quantum structures, such as GaAs quantum wells, where the biexciton PL intensity exhibits quadratic dependence on the exciton PL intensity and the decay of biexciton is two times faster than that of exciton [2]. The rate equations based on our model taking account of the dark exciton level ($J=\pm 2$) were used to analyze the time decay of the exciton and biexciton TRPL in various temperatures and excitation densities. Our analysis leads to a conclusion that the new channel from a dark exciton has an essential role when biexcitons are created in dilute magnetic semiconductor quantum wells containing Mn in the barrier. In this system exciton spin scattering by Mn localized spins are very important.

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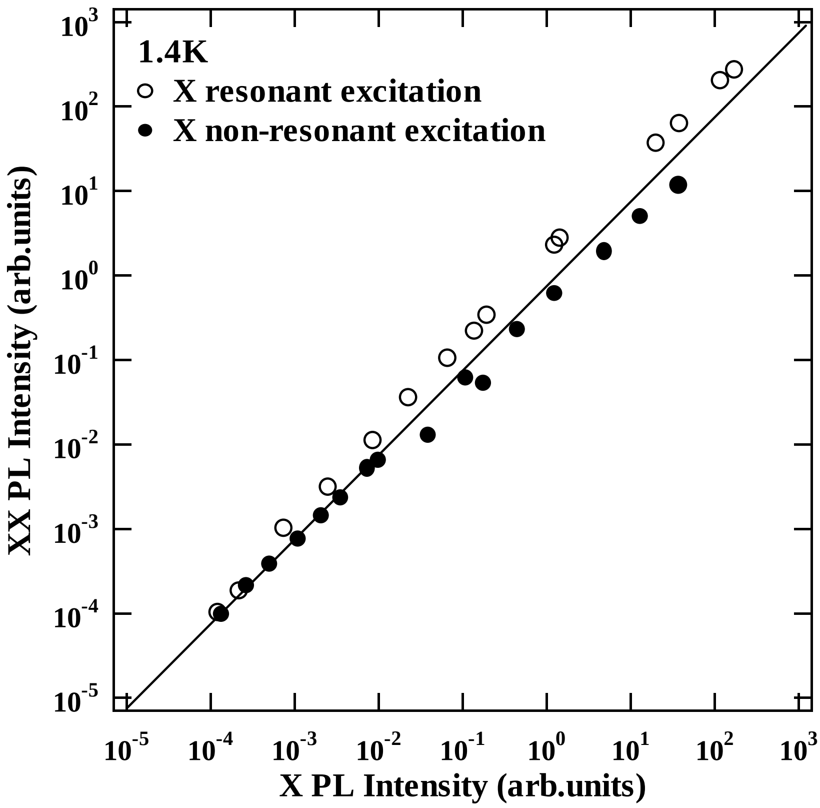

Fig.1. The biexciton (XX) PL intensity against the exciton (X) PL intensity at 1.4K under an exciton resonant excitation (open circles) and a non-resonant excitation (solid circles), respectively.

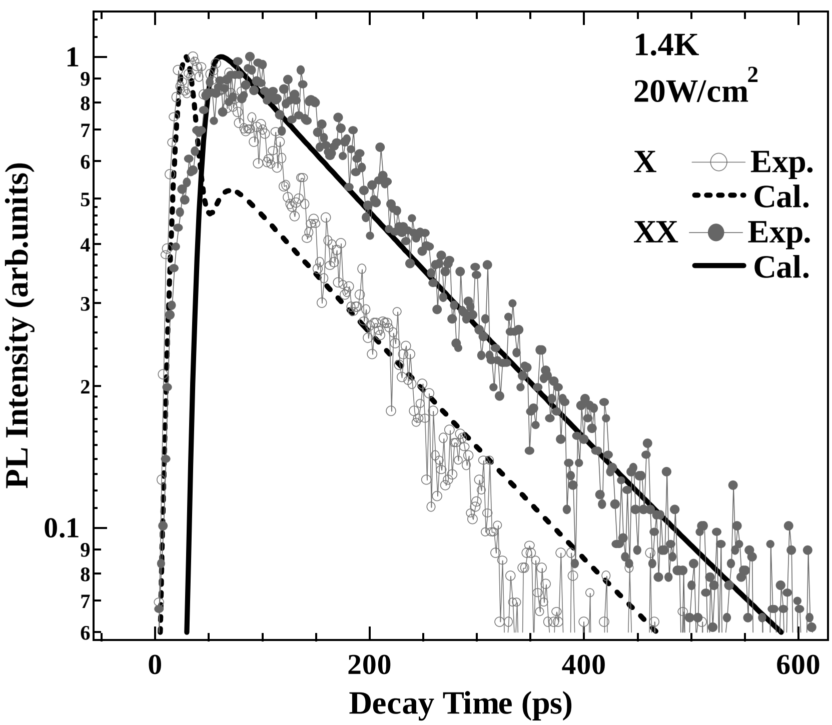

Fig.2. Calculated curves of the exciton (X) and biexciton (XX) luminescence decay profile are compared with those of experimental excited under exciton resonant excitation at 1.4K.