Four-Wave-Mixing Transient Spectroscopy on Exciton Complex States in $CdTe/Cd_{1-x}Mn_xTe$ Quantum wells

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$CdTe/Cd_{1-x}Mn_xTe$ is a prototype of a dilute magnetic semiconductor quantum well with its barrier containing Mn localized spins. Substantial number of papers has been reported so far for the electronic and spin states of excitons and the exciton magnetic polarons in this system, where the exchange interaction between the carriers and the localized Mn moment underlies the spin dependent properties.

Exciton complexes such as a charged excitons (trion) or biexcitons were, however, behind the intensive and advanced studies in this peculiar system, partly because of a difficulty for controlling sample quality, and partly because of diversity of the origin of the photoluminescence spectral features. Recently we have successfully applied the four-wave-mixing (FWM) spectroscopy to identify the biexcitons and a charged exciton complexes by means of a quantum beat in various combination of polarization of the incident laser light.

We have performed the polarization dependent FWM spectroscopy on $CdTe/Cd_{0.88}Mn_{0.12}Te$ with various quantum well sizes at low temperatures and in magnetic fields. Two patterns of quantum beat have been observed with different period, one from an exciton-trion (the frequency equivalent to 3.8 meV), and the other from an exciton-biexciton (the frequency: 5.6 meV). An exciton-trion quantum beat became more pronounced when two-incident light is left co-circular polarization, whereas the discernible beat structure appeared in cross-linear (at high density region) and in cross-circular polarization, indicating the exciton-biexciton as its certain origin. The laser power dependence has clearly shown the interplay between the charged exciton and biexciton contribution to the quantum beat structure especially in co-linear polarization.

In the time-integrated FWM measurement there observed a clear signal at negative delay time region, which is a typical of biexciton contribution, and increased its intensity on increasing incident laser power resulted from the increased number of biexcitons. The spectrally resolved FWM showed spectra at each polarization configuration, corresponding to the energy position of the charged exciton and the biexciton (singlet and triplet), respectively. We also have found the important fact that the high energy excitation photoluminescence (above a Mn d-d transition) resulted in charged exciton photoluminescence structure dominative in dilute magnetic semiconductor quantum wells.

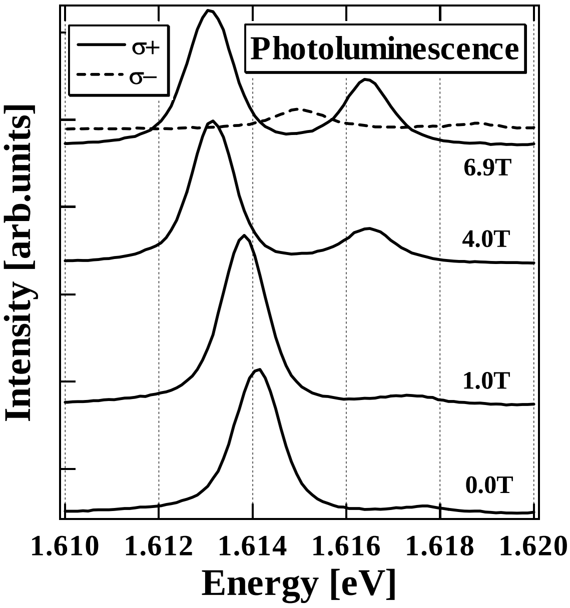

Fig.1(a)

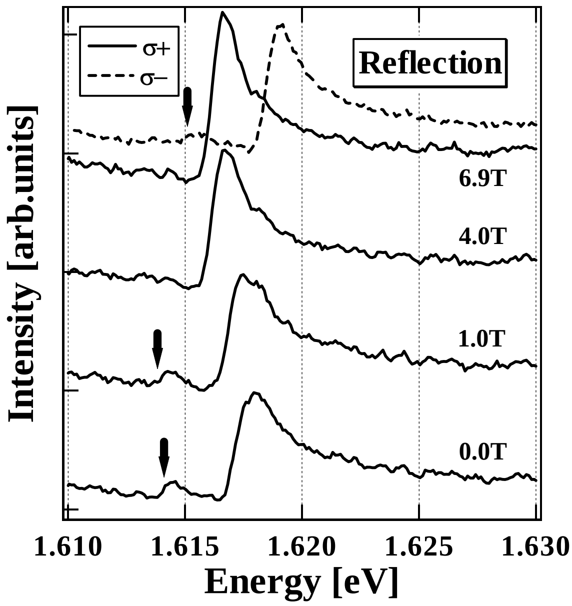

Fig.1(b)

Fig.1. (a) Photoluminescence (excited by 750 nm) and (b) reflection spectra in magnetic fields at 4.2 K. A strong peak in PL spectra is contributed by both a charged exciton and a biexciton. In the reflection spectra the low-energy structure at 1.615 eV (b) is understood as an origin of a charged exciton judged from the polarization dependence.

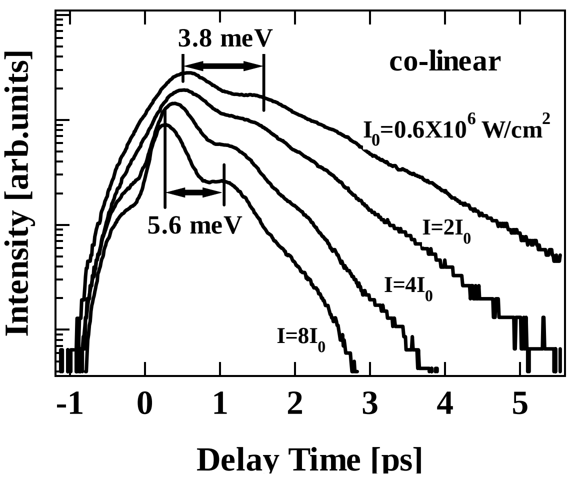

Fig.2(a)

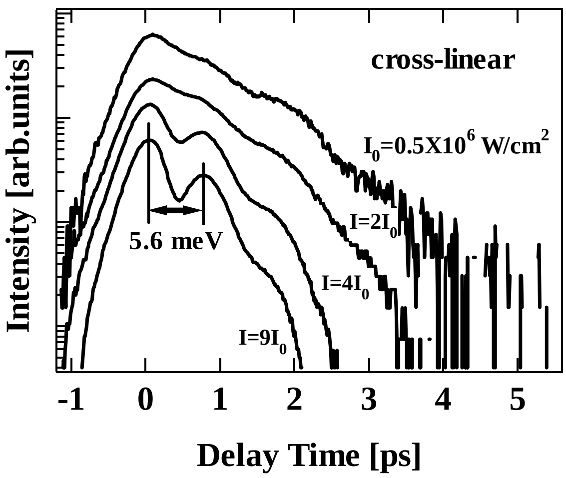

Fig.2(b)

Fig.2. The excitation power dependence of TI-FWM (a) under co-linear, and (b) under cross-linear polarization, respectively. In the case of co-linear polarization (a) an exciton-charged exciton quantum beat was dominative under low power excitation (the beat period: 3.8 meV matching to a charged exciton binding energy), whereas the beat from biexcitons became more pronounced on increasing the laser power. In cross-linear polarization, as one expects, the biexciton contribution was more enhanced, showing the strong beat corresponding to a biexciton binding energy (5.6 meV). The negative delay signal is also typical of a biexciton.