Fine Structure of Photoluminescence Spectra in a Modulation-doped n-CdTe/(Cd, Mg, Mn)Te Quantum Well

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Fascinating natures of electrons interacting each other, including charged exciton (trion) [1], combined exciton-cyclotron resonance [2], spin shakeup process [3], have been revealed in magneto-optical studies of electron gases in semiconductor quantum structures. Compared to III-V systems, such as GaAs/(Ga, Al)As quantum wells, II-VI systems have the following features, a larger effective electron Lande g factor and a stronger electron-hole Coulomb binding. In modulation-doped CdTe quantum wells with relatively high carrier sheet densities ($>2\times10^{11}$ cm^{-2}), complex behaviors of photoluminescence emissions around the Landau filling factor $\nu\sim1$ have been reported [4, 5]. Comprehensive explanation of the observations has not been available yet due to a shortage of experimental evidences. We report photoluminescence studies in tilted field configurations as well as temperature dependence of the emission profiles, and attempt a consistent illustration of the observations in this work. It is also interesting to examine the validity of the trion picture in the Fermi sea.

We have obtained very detailed photoluminescence spectra in modulation doped n-CdTe/(Cd, Mg, Mn)Te quantum well with the width of 10 nm and the carrier sheet density of 5.7×10^{11} cm^{-2} at low temperatures, using a two-second 60 T long pulsed magnet and a 40 T short pulsed magnet. Figure 1 shows streak image view of obtained emission spectra versus magnetic field for the $\sigma-$ and $\sigma+$ polarizations at 1.5 K. The Landau filling factor ν became one at 22.8 T, where the intensity of the $\sigma+$ emission had a maximum. In the $\sigma-$ spectra, a new peak A emerged on the higher energy side of the main peak B around ν=1. The peak B exhibited a step-like behavior below ν=1 as shown in Fig. 2 and the behavior vanished with tilting the field direction (Fig. 3). With tilting the field direction, the Zeeman gap at the same ν is enlarged, which is unfavorable to the spin-singlet charged exciton. This suggests that the origin of the peak B is the spin-singlet charged exciton. With increasing temperature to 20 K, the peak A lost its intensity. Taking into account the energy jump at ν=1 and temperature dependence of the emission intensity, we have assigned the peak A to the spin-triplet charged exciton. At 10 and 20 K, the peak B gained its emission intensity in the higher field region in contrast to the results below 4.2 K. The $\sigma+$ emission also lasted to higher fields with increasing temperature. We interpret these two phenomena were caused by the thermal excitation of electrons from the +1/2 state to the –1/2 state. The step-like part in the field dependence of the energy of the peak B disappeared at 10 and 20 K, and the peak B had a local minimum in the corresponding field region. Emission from the spin-triplet charged exciton also disappeared at these temperatures. This suggests the possibility of the coexistence of the step-like behavior with the spin-triplet charged exiton state.

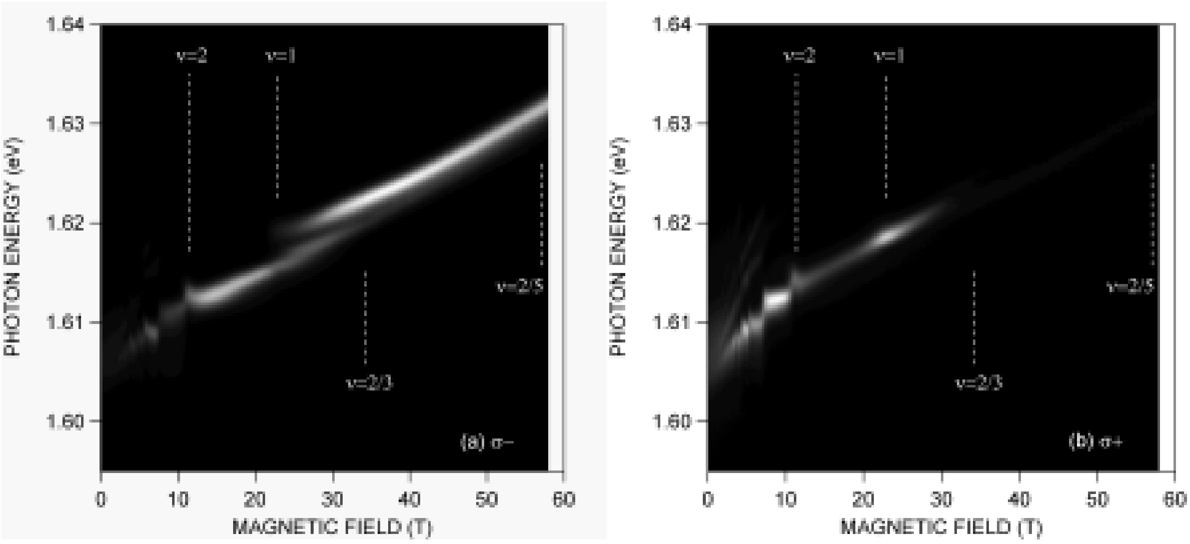

Fig. 1. Streak image view of photoluminescence spectra vs. magnetic field in the modulation-doped n-type CdTe/(Cd, Mg, Mn)Te quantum well at 1.5 K for a) σ− polarization and b) σ+ polarization.

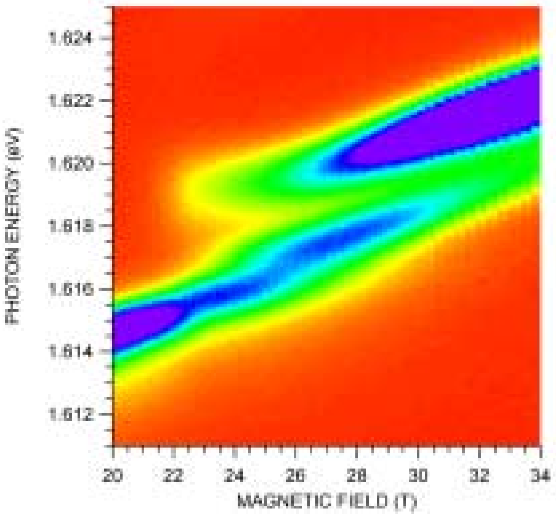

Fig. 2. Enlarged streak image of Fig. 1(a) around ν=1.

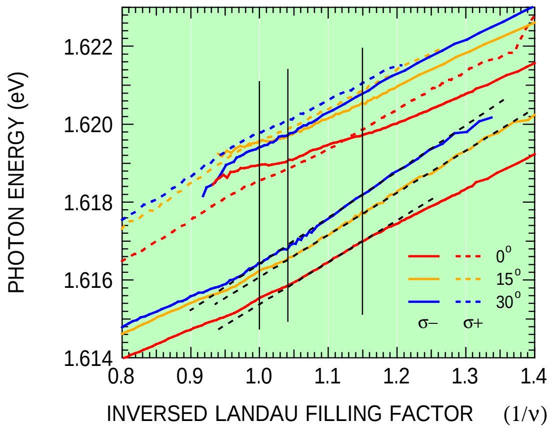

Fig. 3. Inversed Landau filling factor dependence of emission peak energies in tilted field configuration for both circular polarizations.

References

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[1] K. Kheng et al., Phys. Rev. Lett., **71**, 1752 (1993).
[2] D.R. Yakovlev et al., Phys. Rev. Lett., **79**, 3974 (1997).
[3] F. Plentz et al., Phys. Rev. B **57**, 1370 (1998).
[4] H. Yokoi et al., phys. stat. sol. (b) **229**, 681 (2002).
[5] Y. Imanaka et al., phys. stat. sol. (b) **229**, 745 (2002).