INFRARED OPTICAL STUDY OF NEW MAGNETIC MODES IN DILUTE $Cd_{1-X}Mn_XTe/Cd_{1-Y}Mg_YTe$ QUANTUM WELL STRUCTURE AT HIGH MAGNETIC FIELDS

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Introduction

There has been great interest over the past 20 years in diluted magnetic semiconductors (DMS) because of abundant physics phenomena and possible applications of spintronic devices made with these materials. $Cd_{1-x}Mn_xTe$ is one of these DMS compounds that has been very extensively studied both theoretically and experimentally.

Experimental

A systematic optical study has been carried out on a series of modulation-doped dilute $Cd_{1-x}Mn_xTe/Cd_{1-0.12}Mg_{0.12}Te$ (0.7% < x < 2 %) quantum well (QW) samples at liquid helium temperatures and at magnetic fields up to 32 T at Tallahassee's DC facility. All the samples studied were grown by MBE on hybrid CdTe/GaAs (100) substrates and have high electron mobility on the order of $10^5 cm^2/V$ s. All samples have 120 Å QW, and their electron concentrations ranged from 1.0 to 3.0 $x10^{11}$ cm^{-2}.

Results and Discussion

The infrared transmission measurement results have revealed several new magnetic modes in this material.

A representative summarized plot (for sample 012705B) of the observed resonances in these samples is presented in Fig. 1. In addition to the electron cyclotron resonance (CR) represented by symbol +, three new magnetic modes have been observed. The observed narrow CR linewidth is consistent with the high quality of the sample. The position of the resonance occurring at close to 126 cm^{-1} hardly moves with the applied field, B, but its intensity increases monotonically with B. The positions of the other two resonances, whose frequencies are close to that of the CdTe longitudinal optical (LO) phonon, slightly increase with B. The slope of the lower branch (A1) is about 1cm^{-1}/T, and the higher branch (A2) less than 2 cm^{-1}/T. These new modes are not unique for this sample; we have actually observed similar modes in all nine measured samples, which were grown on several separate runs. The strongest feature, A2, becomes stronger with increasing B. A2 is observable all the way down to 0.5 T, and the extrapolation to zero field leads its transition energy at zero field to the CdTe LO phonon frequency. This suggests that this resonance is likely phonon-related. It is well known, however, that the electron phonon (e-ph) interaction can only be observed when the electron CR energy is close to and/or resonant with the phonon energy. The difference between this DMS and other materials is that the s-d exchange interaction between a 2D free electron and a localized d state of M_n^{2+} ion plays an important role in DMS. The manganese concentration is very low in our samples; it is conceivable that these Mn ions can form localized regions that interact very strongly with the CdTe LO phonon via the exchange interaction. Due to the exchange interaction, either the e-ph Fröhlich interaction strength in these localized regions has been greatly enhanced or the optical vibrational mode itself has become magnetic which gives rise to the feature A2. This conjecture is consistent with the temperature dependence of A2. The intensity of A2 decreases with increasing temperature, and from 4.2 K to 10 K, its resonance intensity has reduced more than half.

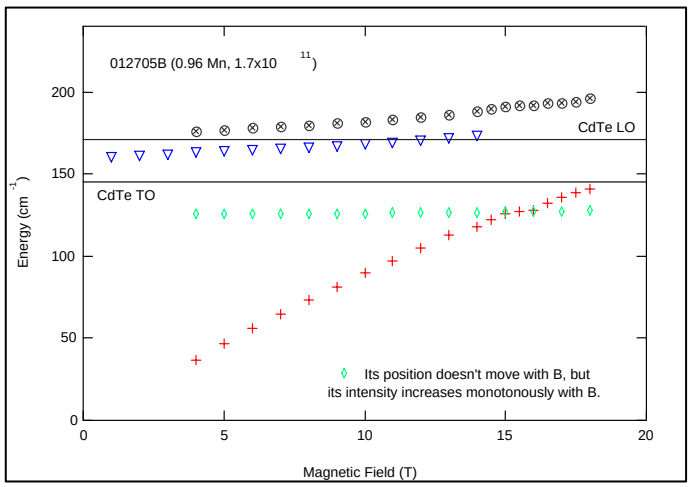

Fig. 1. Summarized plot of transition energy vs. field for all the resonances observed in sample 012705B.

References

[1] See, *e.g.*, Furdyna, J.K., J. App. Phys., **64**, R29, (1988); Haury, A., *et al.*, PRL **79**, 511 (1997) and references therein.