LA-UR- 97-2815

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CONF-970713--

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Submitted to: INTERNATIONAL CONFERENCE ON MAGNETISM, 1997
JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS

Los Alamos
NATIONAL LABORATORY

March 26, 1997

The Faraday effect in $Cd_{0.57}Mn_{0.43}Te$ in high magnetic field

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Abstract

The experimental results of Faraday rotation (FR) measurements in dilute magnetic semiconductors in high magnetic field are presented ('Dirac Series' - Los Alamos). The magnetic field is produced by an explosive-driven flux-compression generator (150 T). Measurements have been carried with samples of $Cd_{1-x}Mn_xTe$ with x=0.43 using 633nm light at liquid helium temperature. The FR increases in such samples when the magnetic field exceeds 60T. Interband exchange interaction and the direct influence of the external magnetic field on the exchange interaction must be considered to interpret the experimental results.

Key words: semiconductors, semimagnetic, $Cd_{1-x}Mn_xTe$, Faraday rotation, g-factor, exchange splitting, high magnetic field.

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Currently much attention is paid to the study of dilute magnetic semiconductors (DMS), which contain magnetic ions as impurity atoms [1,2]. An example of such compounds may be the wide gap semiconductor $Cd_{1-x}Mn_xTe$, where manganese replaces the cation in the CdTe crystal lattice and is in a state of Mn^{2+} with $3d^5$ configuration. Mn presence results in interesting electric and optic phenomena, appearing as a result of spin-spin exchange interaction between the d electrons of the Mn^{2+} ions and the s(p) conduction band and valence band electrons.

The most known manifestation of this interaction is the giant Faraday rotation (FR), observed in DMS near the absorption edge. It results from exchange enhancement of exciton level Zeeman splitting. Ref. [3] mentions an uncertainty in the definition of a spin eigenvalue of zone electrons. Movable p, valence band electrons in semimagnetic semiconductors with the zinc-blende structure are subject to a high spin-orbital interaction. Therefore, it is necessary to use the values of a total angular momentum, *j*, instead of just spin, *s*, in the integral of exchange interaction. If so, then in magnetic fields comparable with the energy of the spin-orbital interaction, the *g*-factor must change and the Zeeman splitting of exciton levels has to depend on magnetic field nonlinearly. So, in this work we measured FR of plane polarized light in magnetic fields up to 150 T.

FR measurements were done using $Cd_{1-x}Mn_xTe$ samples with Mn concentration $x = 0.43$. Magnetic fields were generated in an explosive-driven single-turn flux compression generator[4].Liquid helium was used to cool the samples to 4K in and all-glass flow-through cryostat. Each sample was located within a ceramic tube. The integrated optical probe contained a sample, polarizers, GRIN lenses and held the input and output fibers. A HeNe laser (633nm) was used as a source.

Fig. 1 shows the FR signal in the sample $Cd_{0.57}Mn_{0.43}Te$ at T=4.0 K. As the magnetic field grows, light absorption increases, which prevents determination of FR beyond 100 T. The curve of $\theta(H)$ is shown in Fig. 2. At low temperature it reaches saturation at approximately 15 T, which corresponds to the orientation of the Mn^{2+} ion spins mostly along the field direction. The further gradual growth is usually associated with antiferromagnetic interaction between the nearest neighbors in the manganese clusters [5,6]. An unusual growth of $\theta(H)$ is observed in the field range above 60 T.

In DMS the Faraday rotation in the region of fundamental absorption edge is determined by the transitions between the states $\tilde{A}_8$ and $\tilde{A}_6$ of the valence band (p) and the conduction band (s) [7,8]. The splitting of these zones depends both on the direct effect of the magnetic field on carrier states on the exchange interaction H_{ex}. In low fields the exchange energy $N_0(J_c - J_v)$ in $Cd_{1-x}Mn_xTe$ significantly exceeds the energy of Zeeman splitting and is responsible for enhancement of spin splitting of an exciton band, which results in the giant FR.

Exchange and Zeeman terms have the opposite sign. The combination of low temperatures and high Mn^{2+} ion concentrations results in negative FR [2]. With increasing magnetic field, $\theta(H)$ has to have a maximum, and if the terms are equal it has to change sign, because the exchange term reaches saturation and the Zeeman term continues to grow linearly. Compensation of FR was observed in a semimagnetic semiconductor $Pb_{1-x}Mn_xI_2$, which has a smaller exchange interaction [5]. In $Cd_{1-x}Mn_xTe$, compensation has to take place in a magnetic field near 100 T. However, compensation is not only absent, on the contrary, FR in the fields exceeding 50 T increases. Similar dependence usually takes place during resonant light absorption.

It is presumed [9] that in the increasing magnetic field the average energy of all optic transitions has a red shift. It results from an increasing exciton bond energy or from decreasing of the interband transition. To interpret the experimental data it is necessary that the energy of interband transition, E_g, or the exciton bond energy has changed by approximately 150 meV. This value is high enough, so red shift only partially explains the results obtained. The dependence obtained may be explained by inversion of the sign g-factor of electrons in high magnetic fields. The best agreement with experimental results is got for general $g_{vc} = (g_c + g_v)$ - factor, depended on the magnetic field as $g_{vc}(H) = g_{vc}^{o} + C \cdot M(H)$, were C is constant. Calculations are performed using the following parameters $E_g = 2.1$ eV, for heavy holes $g_v = 0.15$, $m_v = 0.65 \cdot m$, for light holes $g_v = 0.15$, $m_v = 0.12 \cdot m$, for conduction electrons $g_C = -5$, $m_c = 0.095 \cdot m$. We took into consideration transitions only for the first Landau level.

The Russian authors acknowledge the support of the International Science and Technology Center, Grant. 238-97 and of the US Department of Energy. The Los Alamos contributors are supported by the US Department of Energy.

References

1. Diluted Magnetic Semiconductors, ed. by J.K.Furdyna and J.Kossut, Academic Press, N.Y., 1988.
2. P.I.Nikitin and A.I.Savchuk, Sov. Phys. Usp., **33**, 1990, p.974
3. J.Kossut, in Ref.1., p.201
4. C.M.Fowler, R.S.Caird, D.J.Erickson et al., Proceedings of the Oji International Seminar,Springer-Verlag, Berlin, 1981, p.54
5. P.I.Nikitin, A.I.Savchuk and B.E.Derkach, ZETF Lett., **52**, 1990, p.274
6. P.I.Nikitin, O.Tatzenko, V.V.Platonov, A.I.Savchuk, IEEE., Trans. Magn., **29**, 1993, p.25
7. S.Hugonnard-Bruyer, C.Buss, F.Vouilloz, et al., Phys.Rev.**B50**, 1994, p.2200
8. D.U.Bartholomew, J.K.Furdyna, A.K.Ramdas, Phys.Rev.**B34**, 1986, p.6943
9. P.Byszewski, M.Z.Cieplak and M.Romanis, J.Phys.C, **12**, 1979, p.L941

Figure captions:

Fig.1. Signal of light intensity passes through $Cd_{1-x}Mn_xTe$ samples ($x = 0.43$, $\lambda = 633nm$) in the Faraday geometry at the temperature 4.0K. The drop in light intensity in high magnetic fields results from the shift of an absorption edge in the sample. Absorption oscillations appear as a result of increasing Faraday ellipticity near the absorption edge.

Fig.2. Magnetic field dependence of Faraday rotation angle in $Cd_{1-x}Mn_xTe$, $x = 0$. The points show experimental data for the temperatures (1) 4K and (3) 300K. A solid line is a calculated curve which assumes the electron g-factor depends on the magnetic field. A dashed line is a calculated curve for g-factor non depends on the magnetic field, g_{vc} = constant.

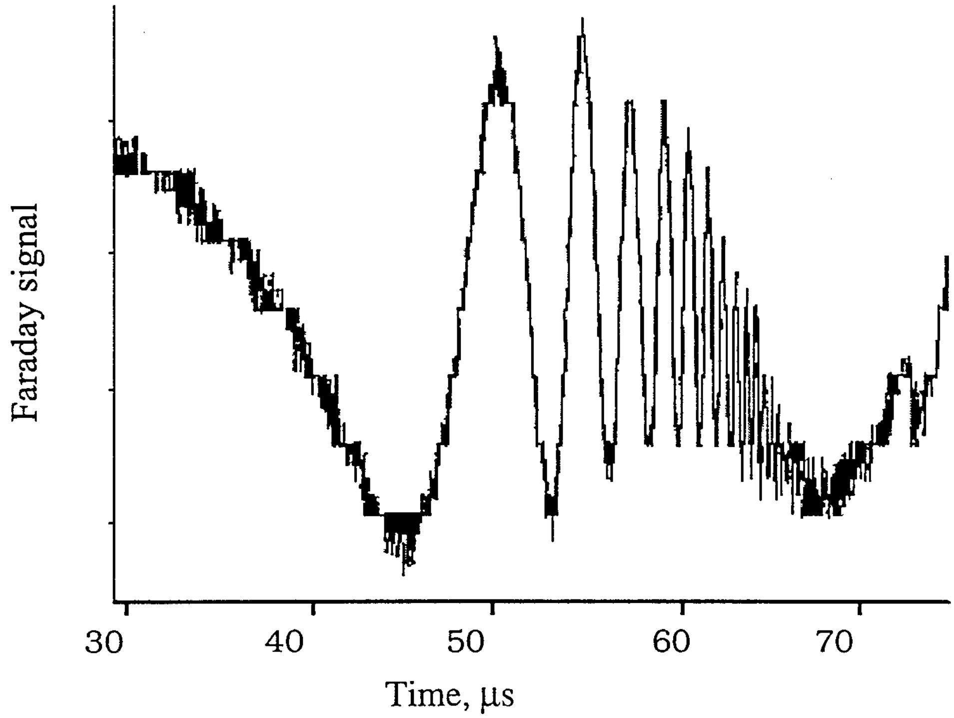

Fig 1
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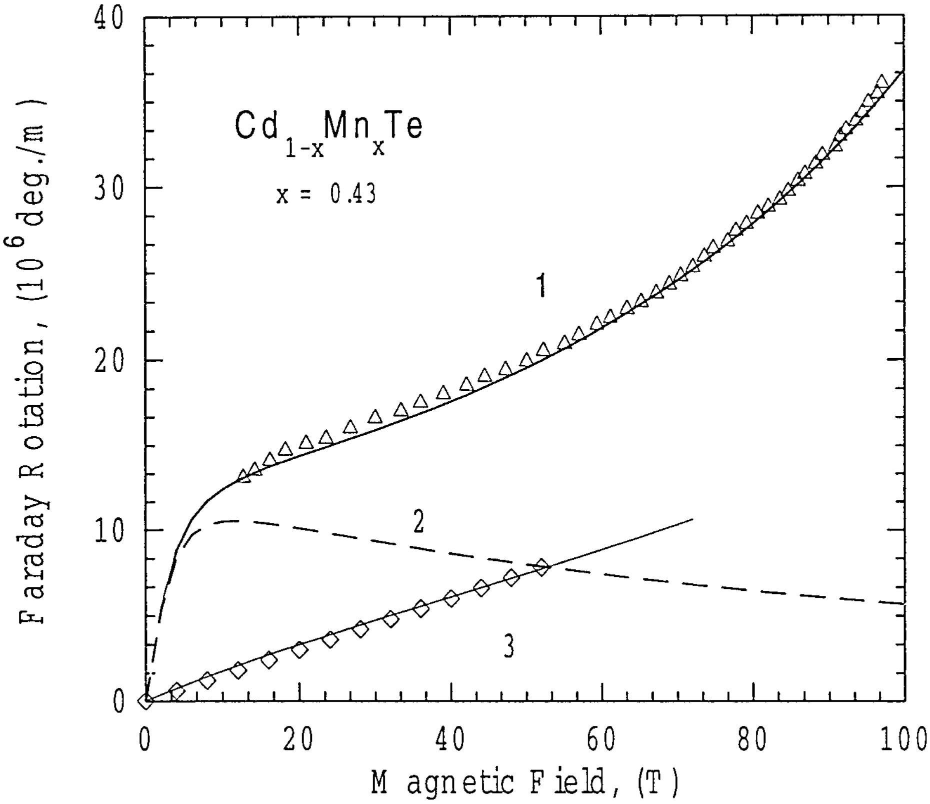

Cd1-xMnxTe
x = 0.43
1
2
3
Faraday Rotation, (10^6 deg./m)
Magnetic Field, (T)
0
10
20
30
40
0
20
40
60
80
100

Fig. 2
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M98000827

Report Number (14) LA-UR--97-2815

CONF-970713

Publ. Date (11) 199703

Sponsor Code (18) DOE/MA, XF

UC Category (19) UC-906, DOE/ER

DOE