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Substantial Temperature Dependence of Transverse Electron g^* -factor in Lead Chalcogenide Multi-quantum Wells

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Abstract. We report significant temperature dependence of the transverse electron g^* -factor in symmetric lead chalcogenide multi-quantum wells (MQWs). The g^* -factor values were extracted from the electron Larmor precessions recorded by means of a circularly polarized pump probe technique under the influence of transverse external magnetic field (Voigt geometry) in the temperature range between 10 and 150K. The reported g^* -factor values are in good agreement with theoretical predictions and available low temperature experimental data. Although temperature tuning of lead salt laser emission wavelengths has been the method of choice in these systems for many years, we demonstrate that temperature can also be used to modulate g^* , and hence the spin lifetime in lead salt QW spintronic devices.

Keywords: electron g -factor, lead chalcogenide quantum wells.

PACS: 73.21.Fg, 78.20.Ls, 78.47.jb, 78.47.jm, 75.70.Tj, 75.70.Ej

1. INTRODUCTION

Recently there has been considerable interest in the temperature dependence of the electron g^* -factor in III-V and II-VI semiconductors, prompted by the apparent anomaly in these measurements for GaAs over many years [1, 2, 3]. There are two opposite contributions to the change of electron g^* factor in III-V semiconductors resulting from a) the decrease of energy gap with increasing temperature and b) the thermal spread of electrons at elevated temperatures in a non-parabolic band [1].

By taking advantage of the fact that **k.p** theory is correctly applied only to rigid lattices (i.e. taking only the dilatational contribution to the energy gap change with temperature) we have demonstrated for both GaAs and InSb [2,3] that the experimental temperature dependence of the g^* -factor (up to 300K) is well explained by existing **k.p** theory; and that, in practice, in III-V compound narrow gap semiconductors, the dilatational band gap and non-parabolicity contributions almost cancel each other [2] resulting in very little temperature dependence of g^* .

By contrast, the narrow gap lead salt system is remarkably different from the III-V systems: the bandgap *increases* with temperature i.e. $E_G(300K) > E_G(0K)$. This means that the contributions to g^* add up, so that overall we expect a much larger temperature dependence of g^* than for InSb [2].

2. EXPERIMENT

We have performed a circularly polarization pump-probe technique [4-6]. The light source was the output of a difference frequency generator (DFG) pumped by both the signal and the idler output of an infrared optical parametric amplifier. The DFG provides pulses around 100 fs duration at a repetition rate of 250 kHz. The samples were excited using 3.5-6 μm wavelength for the temperature range of 10 to 300K and therefore, the pump and the probe photon energy was maintained just above the bandgap under all experimental conditions. The power of the laser beam before the beam splitter (BS) was approximately 4mW. The intensity of the probe beam was a few percent of that of the pump beam.

We investigated two symmetric lead chalcogenide MQWs, PbSe/PbSrSe and PbTe/PbSrTe. Both of the samples were grown by molecular beam epitaxy onto (111) oriented BaF_2 substrates [7]. The first sample consisted of 30 periods of 100Å PbSe QWs alternating with 400Å PbSrSe barriers. The Sr content χ_{Sr} was 7.1%. Similar the second sample consist of 50 periods of MQWs and χ_{Sr} was 5.9%. The values of the band gap for both samples were found experimentally using a FTIR technique. In order to investigate the influence of an external magnetic field the samples were placed inside an optical access superconducting split coil magnet.

3. RESULTS AND DISCUSSION

Figure 1 shows examples of the temporal evolution of the optical polarization measured for different temperatures and under perpendicular (Voigt geometry) magnetic fields up to 2T; Fig. 1(a) represents the optical polarization at low temperatures, at 0.2T for sample PbSe/PbSrSe MQWs. Figure 1 (b) represents the optical polarization for sample PbTe/PbSrTe for two different temperatures, 10K (dash lines) and 100K (solid lines) for several external magnetic fields (0.5-2T).

FIGURE 1. Representative data for time resolved Larmor precession; (a) Temperature dependence at constant magnetic field of 0.2T for PbSe/PbSrSe MQW sample and (b) field dependence, at two different temperatures 10K (dash line) and 100K (solid line) for PbTe/PbSrTe, both in Voigt geometry.

The optical polarization oscillates with Larmor precession frequency, from which one can determine the period of oscillation and therefore extract the values of g^* factor by using

$$g^* = \frac{\omega \hbar}{T \mu_B B} \quad (1)$$

where, ω is the Larmor frequency, T is the period of oscillation, μ_B is the Bohr magneton and B is the magnitude of the magnetic field. The results are summarized in Table 1. As expected, g^* exhibits a significant temperature dependence in comparison with InSb, especially for PbSe QWs, which decreases approximately by a factor of 2 in this temperature range. Note that the value of g^* for the case of PbSe QWs at 10K is in good agreement with that of Ref. 8. The general g^* -factor behavior is also in agreement with the six level **k.p** theoretical predictions for the case of $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$ [9]. This work will be continued with quantitative theoretical **k.p** calculations for a range of PbSe and PbTe quantum well samples.

TABLE 1. Determined g^* -factor values.

MQWs Sample	g^* (T(K))
PbSe/PbSrSe	18.6±1.7(10K), 14.6±1.4(100K), 12.4±1.3(150K)
PbTe/PbSrTe	13.6±0.4(10K), 10.0±1.5(100K)

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REFERENCES

1. M. Oestreich and W.W. Ruhle, *Phys. Rev. Lett.* **74**, 2315 (1995).
2. K. L. Litvinenko, et al., *Phys. Rev. B* **77**, 033204 (2008).
3. W. Zawadzki, et al., *Phys. Rev. B* **78**, 245203-1 (2008).
4. K. L. Litvinenko, et al., *New Journal of Physics* **8**, 49 (2006).
5. B. N. Murdin, et al., *Phys. Rev. B* **72**, 085346 (2005)
6. J. M. Kikkawa and D. D. Awschalom, *Phys. Rev. Lett.* **80**, 4313 (1998).
7. G. Springholz, in *Lead Chalcogenides: Physics and Applications*, edited by D. Khokhlov (Taylor & Francis, New York, 2002); G. Springholz, G. Bauer, and G. Ihninger, *J. Cryst. Growth* **127**, 302 (1993).
8. B. Kaufmann, *Phys. Rev. B* **30**, 4640 (1984).
9. R. L. Hota, and G.S. Tripathi, *J. Phys.: Condens. Matter*, **3**, 6299-6311 (1991).