Spin pumping of resident electrons in CdTe quantum wells under resonant excitation of trions with a periodic sequence of optical pulses

M. Kuhnert[1], F. Saeed[3], I. A. Akimov[1,2], V. L. Korenev[2], G. Karczewski[4], T. Wojtowicz[4,5], A. S. Bhatti[3], D. R. Yakovlev[1,2] and M. Bayer[1]

[1] *Experimentelle Physik 2, TU Dortmund, 44221 Dortmund, Germany*
[2] *A.F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia*
[3] *COMSATS Institute of Information Technology, Islamabad, Pakistan*
[4] *Institute of Physics, Polish Academy of Science, PL-02668 Warsaw, Poland*
[5] *International Research Centre MagTop, PL-02668 Warsaw, Poland*

The Hanle effect is widely used for investigation of spin relaxation times of photoexcited and resident carriers in semiconductors [1]. For periodic excitation with optical pulses resonant spin amplification (RSA) occurs in the studied system when the spin lifetime is longer than the pulse repetition rate. Currently RSA is well established in time-resolved pump-probe experiments [2]. Here, we demonstrate an alternative approach for observation of RSA, where a single beam tuned in resonance with the trion transition in a semiconductor quantum well is used for spin pumping of the ground resident electron state, while its absorption is simultaneously used to monitor the spin polarization of the system.

The studied sample was grown by molecular beam epitaxy and consists of five 20nm thick CdTe quantum wells separated by 110nm $Cd_{0.78}Mg_{0.22}Te$ barriers [3], electronically decoupling the quantum wells. The barriers are doped by iodine donors, providing the quantum well with CB electrons with a density of $n_e \approx 1 \cdot 10^{10}$ cm^{-2}. The sample was mounted in a liquid helium bath cryostat with variable temperature inset. An external magnetic field B of up to 0.7T in Voigt geometry, e.g. parallel to the quantum well plane, was applied by an electromagnet. The laser was tuned to the trion resonance and the transmitted light was measured. To detect the difference in absorption caused by optical spin pumping of resident electrons, the laser light was modulated between linear and circular polarization. Experiments with a continuous wave (CW) laser show a single Hanle peak in magnetic field dependent transmission. The half width of this peak depends on the excitation power and decreases linearly for lower powers. The corresponding spin lifetimes are in the range of 15ns to 4ns.

Under pulsed excitation with laser repetition rates of $f_{laser} = 76$MHz and $f_{laser} = 1$GHz, additional peaks appear if the resonance condition $\omega_L = n2\pi f_{laser}$ is satisfied, where $\omega_L = \frac{g\mu_B B}{\hbar}$ is the Larmor precession frequency, μ_B is the Bohr magneton, $\hbar$ the reduced Planck constant and g the g-factor of the optically oriented carrier. We evaluate a g-factor of 1.64, which corresponds to resident electrons. [3]

Such behaviour is observed in RSA measured with a pump-probe technique. However, our approach doesn't require a comprehensive setup with two beams and additional components for recording transient signals.

[1] F. Meier and B.P. Zakharchenya. Optical orientation. Modern problems in condensed matter sciences, North-Holland, 1984.

[2] J. M. Kikkawa and D. D. Awschalom, *Phys. Rev. Lett.* **80**, 4313 (1998).

[3] E. A. Zhukov, D.R. Yakovlev, M. Bayer, M.M. Glazov, E. L. Ivchenko, G. Karczewski, T. Wojtowicz, and J.Kossut, *Phys. Rev. B* **76**, 205310 (2007).