Novel insights into the spin-flip Raman scattering of Mn^{2+} ions

Henning Moldenhauer[1], Carolin Lüders[1], Philipp Waldkirch[1], Dennis Kudlacik[1], Victor Sapega[2], Jörg Debus[1], Andreas Waag[3], Dmitri Yakovlev[1,2], and Manfred Bayer[1,2]

[1] *Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany*
[2] *Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia*
[3] *Institut für Halbleitertechnik, TU Braunschweig, 38016 Braunschweig, Germany*

Diluted magnetic semiconductors (DMS) are promising materials for devices based on the tailoring of their spin properties leading to the field of semiconductor spintronics. Even though there has been a continuous study on Mn-based DMS during the last decades, several questions on the carrier-Mn ion interactions are still unanswered [1,2]. In that context, we investigate the spin-flip Raman scattering (SFRS) of the Mn^{2+} ions in (Zn,Mn)Se/(Zn,Be)Se quantum wells with Mn ion concentrations below 4 % by precisely analyzing the dependence on the magnetic field geometries.

For tilted geometries, Stühler et al. observed up to fifteen Mn^{2+} SFRS lines [3], which could not be explained by the spin multiplicity of six of the Mn system [4]. It was described in the framework of a collective effect involving several Mn ions, where the decrease in magnetization corresponds to the multiple spin-flips, as observed in the Stokes regime. We measure multiple Mn^{2+} spin-flips also on the anti-Stokes side, which is one argument to extend the proposed model.

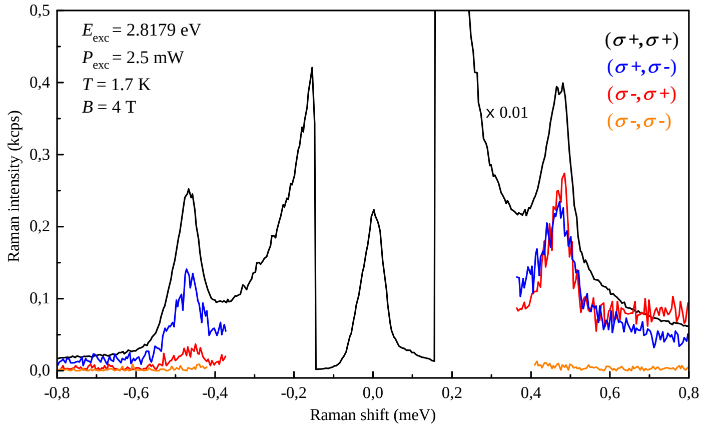

Figure 1: Mn^{2+} SFRS spectra for a $ZnMn_{0.004}Se$ quantum well measured in different circular polarization configurations. The neutral exciton was resonantly excited.

Another argument to reconsider the mechanism of the Mn^{2+} SFRS arises during its study in the Faraday geometry for different circular polarization configurations. As shown in Figure 1, the intensities of the Stokes and anti-Stokes Mn^{2+} SFRS lines are highest for copolarized (σ^+, σ^+) configuration. Moreover, it is dominant for the excitation of the neutral exciton, while at the trion its intensity is negligible. We suggest that the Mn^{2+} SFRS resonance is caused either by anisotropic flip-stop exchange interaction with the electron of the neutral exciton or by a scattering process including isotropic exchange and hyperfine interaction with a nuclear spin. To verify this mechanism we apply radio-frequency fields, combined with resonant SFRS, to observe an impact of the nuclear spin depolarization on the Mn^{2+} SFRS signal.

[1] A. D. McCarty, A. K. Hassan, L.-C. Brunel et al., *Phys. Rev. Lett.* **95**, 157201 (2005)
[2] C. Kehl, G. V. Astakhov, K. V. Kavokin et al., *Phys. Rev. B* **80**, 241203(R) (2009)
[3] J. Stühler, G. Schaack, M. Dahl et al., *Phys. Rev. Lett.* **74**, 2567-2570 (1995).
[4] L. C. Smith, J. J. Davies, D. Wolverson et al., *Phys. Rev. B* **77**, 115341 (2008)