RydEx 2024, Dortmund, Germany

Hanle Effect and Polarization Recovery on Resident Electrons in Single $MoSe_2$ Layer

Eyüp Yalcin[1], Ina V. Kalitukha[1], Ilya A. Akimov[1,*], Vladimir L. Korenev[1], Olga S. Ken[1], Jorge Puebla[2], Yoshichika Otani[2], Oscar M. Hutchings[3], Daniel J. Gillard[3], Alexander I. Tartakovskii[3], and Manfred Bayer[1]

[1]*Department of Physics, TU Dortmund University, 44227 Dortmund, Germany*
[2]*RIKEN Center for Emergent Matter Science, Saitama, Japan*
[3]*Department of Physics and Astronomy, University of Sheffield, S10 2TN Sheffield, United Kingdom*
**e-mail: ilja.akimov@tu-dortmund.de*

Spin-related phenomena in two-dimensional Van der Waals semiconductors, such as $MoSe_2$, have garnered significant attention due to their distinctive energy structure characterized by spin-valley locking, strong spin-orbit interaction, and exceptional optical properties, which can be exploited for the initialization and readout of carrier spin. Despite the remarkably short exciton recombination times and considerable spin relaxation of excitons attributed to electron-hole exchange interaction in $MoSe_2$, much remains unknown regarding the spin relaxation of resident carriers, namely electrons or holes. Recent demonstrations have shown efficient spin-valley pumping of resident electrons with circularly polarized light, and the spin dynamics of these electrons in Voigt geometry for AB_2 compounds (where A = Mo, W and B = Se, S) have exhibited depolarization even in very weak magnetic fields [1,2].
In this study, we investigated the depolarization (Hanle effect) and recovery of resident electron spins in an external magnetic field in single-layer $MoSe_2$, utilizing a single-beam excitation and detection technique [3]. The single-layer $MoSe_2$ was placed on top of a 10 nm thick EuS film, deposited on a dielectric distributed Bragg reflector. The EuS film served as the source of electrons in the $MoSe_2$ layer, exhibiting a carrier density of approximately $n_e \approx 10^{12}$ cm^{-2} and showing no magnetic behavior [4]. The Hanle effect was measured under resonant optical pumping at the trion resonance using circularly polarized light (laser photon energy at 1.63 eV) at a temperature of approximately 10 K, with the reflected light intensity serving as a monitor of the electron spin density S_z along the z-axis, perpendicular to the sample surface plane. A magnetic field was applied at various angles from $\alpha = 0$ (Faraday geometry) to 90° (Voigt geometry).
The application of an external magnetic field B_{ext} resulted in a variation of S_z depending on α. For $\alpha = 0$, an increase in spin polarization (polarization recovery) was observed, while for $\alpha = 90°$, depolarization (Hanle effect) was evident. The results could be fitted with a single Lorentzian curve with a half-width-half-maximum (HWHM) $B_{1/2}$ of only a few mT. From the angular dependence of the saturation value of $Sz(B \gg B_{1/2})$, we evaluated the magnitude of anisotropy $\gamma_{s,z} g_z^2 = 9\gamma_{s,x} g_x^2$, where $\gamma_{s,x}, \gamma_{s,z}$and g_x, g_z are the spin relaxation rates and g-factor along the x-and z-axes, respectively. Considering $\gamma_{s,x} > \gamma_{s,z}$, we conclude a strong anisotropy of the electron g-factor.

References

[1] C. Robert, S. Park, F. Cadiz et al., Nature Commun.12, 5455 (2021).

[2] P. Dey, Luyi Yang, C. Robert et al., Phys. Rev. Lett. 119, 137401 (2017).

[3] F. Saeed, M. Kuhnert, I. A. Akimov et al., Phys. Rev B 98, 075308 (2018).

[4] T.P. Lyons, D.J. Gillard, C. Leblanc et al., Nat. Photon. 16, 632–636 (2022).