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Detection of the exact persistent spin helix state using drift spin transport in GaAs quantum well

NTT BRL [1], Tohoku Univ. [2], °Yoji Kunihashi[1], Haruki Sanada[1], Hideki Gotoh [1], Koji Onomitsu [1], Makoto Kohda[2], Junsaku Nitta[2], Tetsuomi Sogawa[1]

E-mail: kunihashi.y@lab.ntt.co.jp

Recently, a lot of attention has focused on the suppression of spin relaxation in two-dimensional electron systems with balanced Rashba and Dresselhaus SOIs [1]. The characteristic spin dynamics in such electron systems result in a long-lasting helical spin mode termed a persistent spin helix (PSH). This spin dynamics near the PSH state has been directly observed with two-dimensional Kerr imaging [2]. In this technique, however, it is difficult to determine the exact PSH state because of short spin transport length originating from the diffusion process of electrons. Here, we report the experimental determination of the strength of Rashba and Dresselhaus SOIs (α and β) by measuring the spin precession frequency of drifting electrons in electric-field-applied QWs. The highly accurate detection of the PSH state has been achieved with employing the long-distance transport of drifting electrons [3].

The samples were GaAs/AlGaAs single QWs (15 and 25 nm thick) embedded in HEMT structures. Each wafer was processed into a cross-shaped channel with a top gate electrode. This structure allows us to apply in-plane electric field for drifting spins, and vertical one for tuning the strengths of SOIs. The spatial spin distribution of drifting spins was measured using spatially-resolved Kerr rotation microscopy with a CW Ti:sapphire laser at $T = 8$ K. The spin distribution of electrons drifting along the [1-10] and [110] directions in the 25-nm-wide QW are shown in Fig. 1. The spin precession frequencies are significantly anisotropic in the two directions. The fast spin precession along the [1-10] direction reflects the strong effective magnetic field caused by the sum of the Rashba and Dresselhaus SOIs, whereas the non-oscillating decay of the spins in the [110] direction indicates a zero effective magnetic field. We extracted the SOI parameters by fitting the experimental data to the drift-diffusion model and obtained $\alpha = \beta = 0.99$ meVÅ. The drift spin transport under the exact PSH state observed in the present work will advance both further research and the application of spins to semiconductor devices.

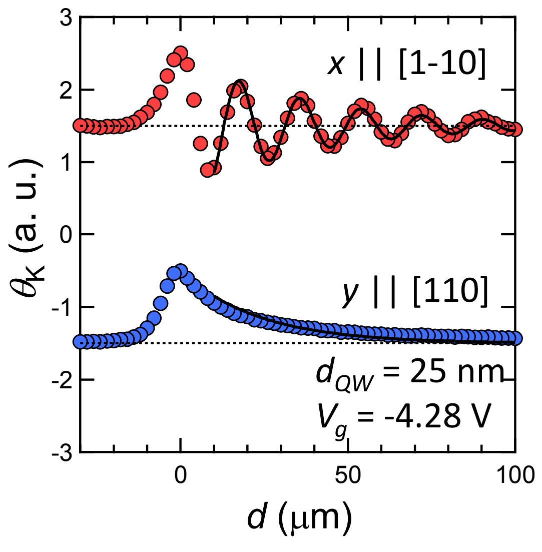

Fig. 1 Spatial spin distribution along the [1-10] and [110] directions. Red and blue plots show experimental data. The solid lines show the best fits with the drift-diffusion model. It should be noted that the 0 to 10 μm region is excluded from the fitting region to avoid the non-equilibrium effect.

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