Enhancement of spin transport length with tailored spin-orbit interaction

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Recently, a lot of attention has focused on the suppression of spin relaxation in two-dimensional electron systems with balanced Rashba and *k*-linear Dresselhaus spin-orbit interactions (SOIs) [1]. The characteristic spin dynamics in such electron systems result in a long-lasting helical spin mode termed a persistent spin helix (PSH). However, spin coherence in the PSH state is inevitably destroyed by the *k*-cubic term of the Dresselhaus SOI in a realistic material. Here, we report that spin coherence is enhanced by an electrically controlled cubic Dresselhaus SOI. We found that spin coherence can be improved by balancing a Rashba SOI and all the terms of a Dresselhaus SOI. This technique will provide a new way of both suppressing spin relaxation and controlling spin precession frequency when using the cubic Dresselhaus SOI.

The sample was a GaAs/AlGaAs single quantum well (QW) (25 nm thick) embedded in high-electron mobility structures in which SOIs were set near to the PSH condition. An epitaxial wafer was processed into a cross-shaped channel with a top gate electrode. This structure allowed us to apply in-plane and vertical electric fields. 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 in the [1-10] direction in a 25-nm-wide QW is shown in Fig. 1. We observed that the electron spins drifted over 100 μm with spin precession due to the effective magnetic fields induced by the SOI. To extract the decay length of the drift spin transport, we fitted the model function,

$$\theta_K = A\exp(-x/\lambda_{SO})\cos(k_{SO}x),$$

where λ_{SO} and k_{SO} indicate spin decay length and spin precession frequency, respectively, to the experimental results. The in-plane electric field (E_{in}) dependence of λ_{SO} is shown in the inset in Fig. 1. In the lower electric field region, λ_{SO} decreases with increasing E_{in}, which is due to the spin decoherence caused by increasing the electron temperature with an applied in-plane electric field. In contrast, in the higher electric field region, λ_{SO} increases with E_{in}. This λ_{SO} enhancement indicates an improvement of spin coherence by an electrically modulated cubic Dresselhaus SOI in the present sample. This work was supported by JSPS KAKENHI (No. 24686004 and 23310097).

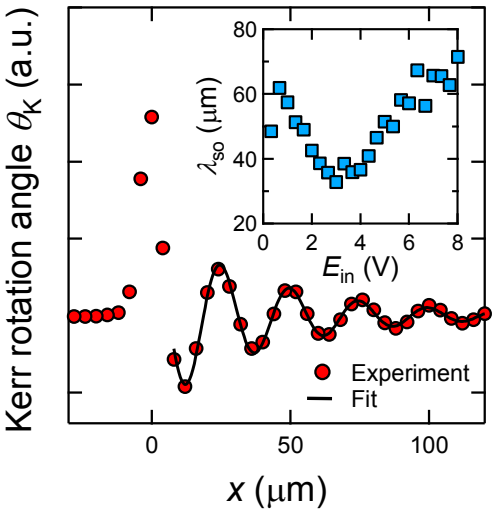

Fig. 1 Spatial spin distribution in the [1-10] direction when applying E_{in} = 200 mV. The solid line indicates the fit of the model function described in the text. The inset is the in-plane electric field dependence of the spin decay length.

[1] J. Schliemann *et al.*, PRB **68**, 165311 (2003).