Effect of electronic temperature on spin dynamics for drifting spins

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Electrical transport of electron spins in a semiconductor device is one of the essential technologies for future spintronics. By suppressing the spin relaxation with balanced Rashba and Dresselhaus spin-orbit interaction (SOI), namely persistent spin helix state, we demonstrated long-distance spin transport over 100 μm [1]. Application of drift voltages gives energy for the electronic system, resulting in increase in electronic temperature. In such a warm electronic state, effective magnetic field induced by the cubic Dresselhaus SOI is modulated [2]. As this effect changes spatial period of spin precession, comprehensive understanding of electronic temperature dependence of spin dynamics is very important. Here, we report numerically calculated spatial distribution of drifting spins for different electronic temperatures. Electric temperature is taken into account as a consequence of inelastic scattering. We found that spatial period of spin precession becomes longer at higher electronic temperature. This is because enhancement of the cubic Dresselhaus SOI by increase in electronic kinetic energy compensates the effective magnetic field originated from linear term of SOIs. Our results give beneficial knowledge for device application in future spintronics.

The numerical calculation performed in this study was based on the Monte Carlo simulation, which mimics spatially resolved Kerr rotation measurement with pump-probe technique in GaAs quantum well at low temperature. Initial Gaussian distribution (FWHM = 7μm) of spin polarized electrons were randomly scattered by following the Poisson process in which elastic scattering by ionized impurities and inelastic scattering due to acoustic phonons are included. Electrons' motion was limited in two-dimensional space and acceleration due to in-plane electric field was expressed by shift of Fermi circle. Electric temperature is taken into account via inelastic scattering rate depending on the temperature. Spin precession angle about an effective magnetic field during free flight was calculated by Bloch equation, $d\mathbf{S}/dt = \mathbf{\Omega} \times \mathbf{S}$, where $\mathbf{\Omega}$ and $\mathbf{S}$ are precession frequency vector and spin vector, respectively.

Spatial distribution of drifting spins at T_e = 10 K and 30 K are shown in Fig. 1. It is found that spatial period of spin precession increase by increasing T_e. This slower spin precession observed at higher electronic temperature indicates weakened effective magnetic field and qualitatively agrees with our previous experimental result [2]. This work was supported by JSPS KAKENHI Grant Numbers JP20H02563 and JP20H05670.

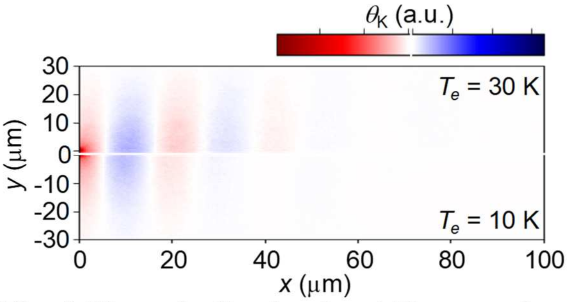

Fig. 1 Numerically simulated Kerr rotation mapping of electron spins at electronic temperature T_e = 10 K and 30 K. Red and Blue indicate up and down spins. Spin polarization in the z direction is initially prepared at the origin. The electric field is applied in the *x* direction.

[1] Y. Kunihashi *et al.*, Nat. Commun. **7**, 1 (2016).
[2] Y. Kunihashi *et al.*, PRL **119**, 187703 (2017).