INVITED

Magnetic-field-free electron spin resonance in winding GaAs channel

Haruki Sanada[1], Yoji Kunihashi[1], Hideki Gotoh[1], Koji Onomitsu[1], Makoto Kohda[2], Junsaku Nitta[2], Paulo V. Santos[3], and Tetsuomi Sogawa[1]

[1] *NTT Basic Research Laboratories, NTT Corporation, Atsugi, Japan*
[2] *Department of Materials Science, Tohoku University, Sendai, Japan*
[3] *Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany*

Electron spin resonance (ESR) has the potential for use in manipulating individual spins for quantum information technologies. In general, ESR requires two external magnetic fields: a static field ($\mathbf{B}_0$) and oscillating one ($\mathbf{B}_1$). However, approaches relying on real magnetic fields, which are generated in much broader spaces than the size of individual electrons, are energetically inefficient for spin-information processing on a chip. Here we demonstrate magnetic-field-free ESR achieved by using spin-orbit interaction (SOI) [1]. Because a moving electron experiences a spin-orbit effective magnetic field $\mathbf{B}^{SO}$ that depends on the moving direction, we expect both the static and oscillating fields needed for ESR to be replaced with effective fields ($\mathbf{B}_0^{SO}$ and $\mathbf{B}_1^{SO}$) by controlling the trajectory of travelling electrons [Fig. 1(a)].

The sample was an undoped 20-nm-thick GaAs/AlGaAs (001) quantum well. A surface acoustic wave (SAW) beam propagating along [-110] produces an array of potential wires moving with the velocity v_{SAW} ~ 2.97 km/s [2]. A Ti film with 3-µm-wide slits deposited on the wafer partially screens the piezoelectric field and produces moving dots that travel along the channels formed beneath the slits [Fig. 1(b)]. We performed Kerr microscopy to investigate spin transport along straight and winding channels, the latter of which was designed to be close to the resonance condition.

Figure 2 shows a Kerr image measured for the two channels in the absence of external magnetic field. The Kerr rotation is proportional to the spin density at the probe position. The oscillations observed for the straight channel [Fig. 2(a)] are attributed to the spin precession induced by $\mathbf{B}_0^{SO}$. The effects induced by $\mathbf{B}_1^{SO}$ appear in the data for the winding channel [Fig. 2(b)]; the spin precession phase inverts when the probe position crosses y ~ 30 µm. The Bloch simulations of the spin dynamics under $\mathbf{B}^{SO}$ well reproduce the experimental results, and this proves the feasibility of the magnetic-field-free ESR. This technique will provide an efficient and flexible approach for the coherent control of flying spin information in solid-state devices.

[1] H. Sanada *et al.*, Nature Physics, *to be published*.
[2] H. Sanada *et al.*, Phys. Rev. Lett. **106**, 216602 (2011).

This work was supported by JSPS KAKENHI (No. 24686004 and 23310097).

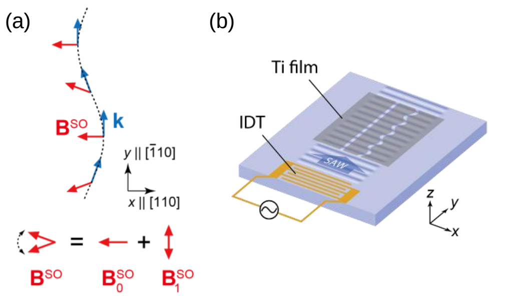

Fig. 1 (a) **k**-vectors and Dresselhaus fields ($\mathbf{B}^{SO}$) for electrons moving along a sinusoidal channel. The electrons experience static ($\mathbf{B}_0^{SO}$) and oscillating ($\mathbf{B}_1^{SO}$) fields. (b) Sample schematic. The winding channel has a sinusoidal shape with a period of 23 µm and amplitude of 2 µm.

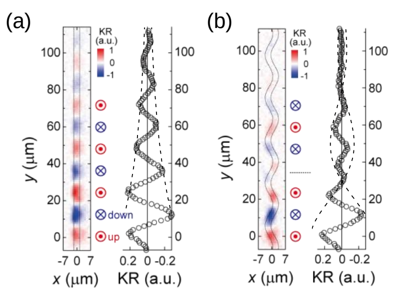

Fig. 2 Kerr images of the straight (a) and winding (b) channels. The same data averaged along the x axis are plotted on the right side of each image. The dashed lines are guides to the eyes.