Electrical control of drifting spin coherence in GaAs quantum well

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Key technologies for realizing spin-based devices are spin transport and its electrical manipulation in a solid-state device. At the last JSAP meeting [1], we reported the long-distance drift transport of electron spins in GaAs quantum wells (QW) where the spin-orbit interactions (SOI) were set at the exact SU(2) symmetry generating a persistent spin helix (PSH) mode [2]. The next challenge associated with drifting spins is the electrical manipulation of spin degree of freedom during drift transport. Here we report the electrical control of the spin precession and decay length of drifting spins near the PSH condition.

The sample consisted of a 25-nm-thick GaAs QW embedded in a HEMT structure. The wafer was processed into a cross-shaped channel with a top gate electrode (Fig. 1). This structure allowed us to use in-plane voltages V_x and V_y to create drift motion, and a vertical gate voltage V_g to tune the strengths of SOIs. The spatial spin distribution of drifting spins was measured using Kerr rotation microscopy at $T = 8$ K. A circularly polarized pump light from a cw Ti: sapphire laser generates electron spins at a certain position and a linearly polarized light probes the Kerr rotation θ_K, which is proportional to the spin density at the focused position. Figure 2a shows a V_g dependence of the Kerr rotation angle θ_K scanned along the [1-10] direction for $V_x = 50$ mV and $V_y = 0$ mV. Even in the absence of an external magnetic field, we observed spin precession resulting from the effective magnetic field induced by SOIs. By varying the gate voltage, the spatial frequency of the drifting spin precession was continuously modulated via gate control of the Rashba SOI. This behavior was well reproduced by a simulation based on a spin-drift-diffusion model as shown in Fig. 2b. A comparison of the experiment and the simulation revealed that in the present samples a PSH state is achieved around $V_g = -4.4$ V and the spin decay length is maximized near the PSH condition.

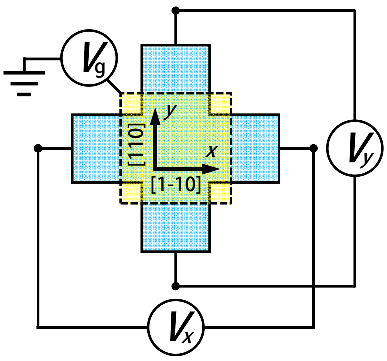

Fig. 1 Schematic of top view of our samples.

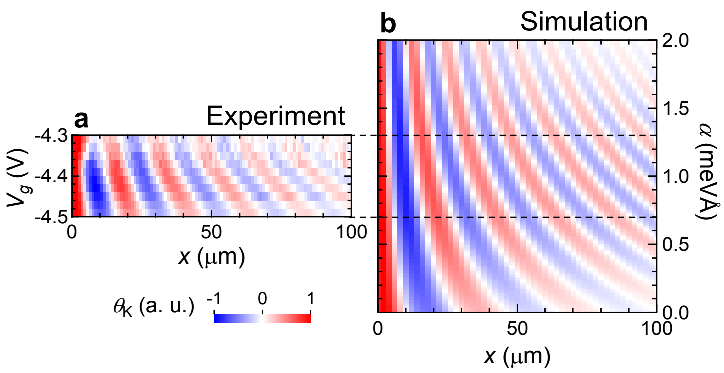

Fig. 2 (a) Gate voltage dependence of the spatial distribution of drifting spins in the [1-10] direction for $V_x = 50$ mV and $V_y = 0$ mV. (b) Simulated spatial distribution of drifting spins as a function of the Rashba SOI parameter α. Dashed lines show the area corresponding to the experimental result.

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