Imaging Spin Drift and Diffusion in Lateral Fe/GaAs Spin Transport Devices

Scott A. Crooker (NHMFL-LANL); Darryl L. Smith (T-11, LANL); E. Garlid, K. S. M. Reddy, Chris J. Palmstrom, Paul A. Crowell (U. Minnesota)

Using methods for scanning magneto-optical Kerr rotation microscopy, we directly image the electrical injection of spin-polarized electrons from Fe electrodes into n-type GaAs [1] in a series of hybrid lateral Fe/GaAs spin transport devices. Figure 1 shows a photomicrograph of one such device, which consists of five epitaxially-grown Fe electrodes on a low-doped ($n=1\text{-}5\times10^{16}cm^{-3}$) GaAs channel. These electrodes form Fe/GaAs Schottky tunnel barriers having a spin-dependent transmission, allowing for spin injection and extraction [2]. In this experiment, we image the electron spin polarization that accumulates near contact #4. The 65x65 micron region that is imaged is shown by the dotted square in the photo. Electron current can be made to flow from contact #4 to contact #5, in which case the current path lies in the images region. The image on the lower left of Fig. 1 shows this scenario. Spin polarized electrons are observed to emanate from contact #4, drifting and diffusing to the right.

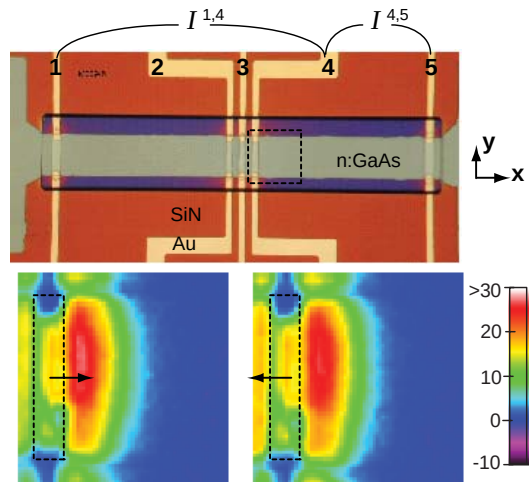

Figure 1: The Fe/GaAs spin transport device. Below left: an image of spin-polarized electrons injected from contact #4 and drifting to the right. Below right: same, but for spins drifting to the left. These spins are diffusing freely "upstream" of the current path.

Alternatively, the electron current can be made to flow in the other direction, from contact #4 to contact #1, in which case the imaged region lies outside of ("upstream of") the current path. The image on the lower right of Fig. 1 shows this situation. Perhaps unexpectedly, this image appears very similar. The spin polarization in this case derives from injected spins that have diffused out from under contact #4, and which are diffusing freely "upstream" of the current path where the electric field is nominally zero. That these two images appear to have similar lengthscales indicates that spin transport at this low current (25 microamps) is dominated by diffusive spin transport rather than by drift.

These measurements were repeated at higher bias (125 microamps), where the effects of drift begin to dominate diffusive spin transport. In addition, similar measurements were made for the case of spin accumulation by spin *extraction* (as opposed to injection) at contact #4. In this case, contact #4 is forward-biased and electron current flows from the GaAs into contact #4.

The results are summarized in Figure 2, which shows the measured spin polarization vs. distance from the contact (green bar), both in the current path (to the right of the contact), as well as "upstream" of the current path where spins can only diffuse (to the left). Both low an high biases are shown (blue and red, respectively). As expected, diffusion alone drives spin transport upstream of the current path, regardless of current magnitude or direction. In the current path, spin drift can either augment or oppose the natural diffusion of spins.

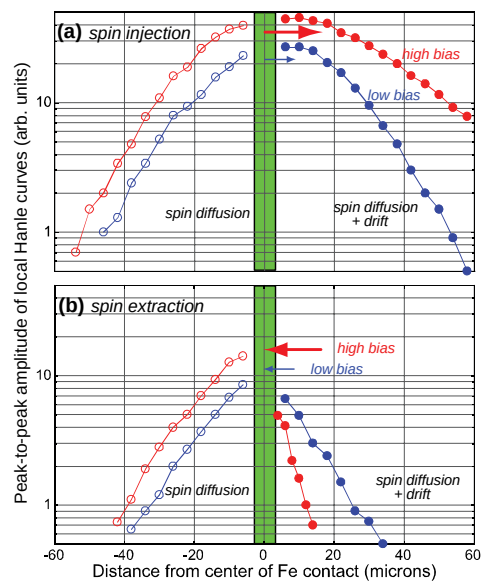

Figure 2: Spin polarization vs. distance from contact #4, for both injection and extraction.

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[1] M. Furis *et al*, New J. Phys. **9**, 347 (2007).
[2] X. Lou *et al*, Nature Physics **3**, 197 (2007).