Tuning the Sign and Magnitude of the Spin Detection Sensitivity in Fe/GaAs Spin Detectors

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Together with electrical spin injection and manipulation, an all-electrical scheme for spin *detection* in semiconductors is an important and necessary component of many 'semiconductor spintronic' device proposals. In such devices, spin-dependent electrical signals are expected upon reversing the magnetization of a ferromagnetic detection electrode, or when manipulating the electron spin orientation in the underlying semiconductor. Using epitaxially-grown Fe/GaAs Schottky tunnel-barrier contacts on a lateral GaAs channel, we experimentally confirm spin-dependent electrical detection using these two methods. More strikingly, we also demonstrate the ability to continuously tune both the magnitude *and sign* of the intrinsic spin-dependent electrical sensitivity, via the voltage bias applied across the Fe/GaAs detection electrode. Bias control of the sign and magnitude of electrical spin detection offers an alternative method of achieving functionality in spin-transport devices.

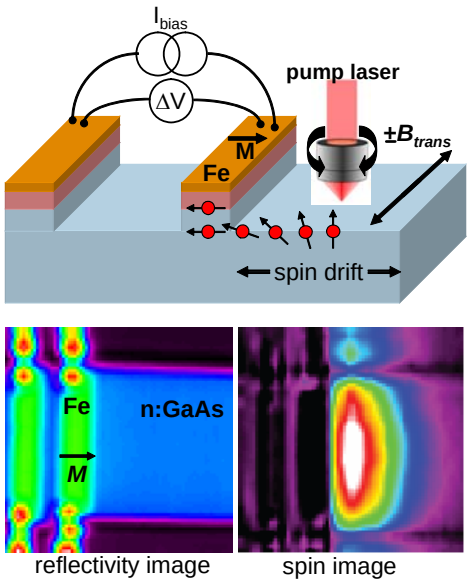

Figure 1:Experimental setup. Below: a reflectivity image showing sample features, and a spin image showing injected spins diffusing.

Using scanning magneto-optical techniques at low temperature [1], we first measure the spin polarization (P_GaAs) that is electrically *injected* into a lateral GaAs channel from a Fe/GaAs contact as a function of voltage bias. Both images and Hanle depolarization curves reveal that P_GaAs inverts sign when sweeping from small reverse bias (electrons flowing into GaAs) to small forward bias (electrons flowing into Fe), as expected from linear response. Surprisingly, P_GaAs also inverts sign again at higher bias across the Fe/GaAs contact. This crossover bias (< 0.2 V in the structures studied) can occur under either forward- or reverse-bias conditions, depending on the details of the Fe/GaAs interface. These data concur with recent all-electrical studies of P_GaAs in lateral spin transport devices having a source, drain, and a third 'non-local' detection electrode [2].

Inverting the experiment, we then optically inject spin polarized electrons into the GaAs channel near a Fe/GaAs detection electrode. These spins diffuse under the electrode (see Fig. 1), and their spin orientation is tipped either parallel or antiparallel to the electrode magnetization using small applied fields. The difference between parallel and antiparallel configurations is the spin detection sensitivity of the Fe/GaAs electrode. We show that both the sign and magnitude of its spin-sensitivity can be continuously tuned through zero in similar fashion with applied bias. The spin-detection sensitivity (see Figure 2) of some Fe/GaAs structures can be tuned by over an order of magnitude from the nominal zero-bias sensitivity, effectively turning a 'poor' spin detector into a reasonably sensitive spin detector.

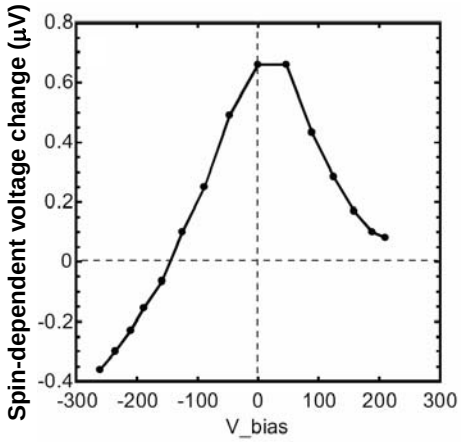

Figure 2: The spin-dependent voltage sensitivity of the Fe/GaAs electrical spin detector. vs. voltage bias.

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[1] S. A. Crooker *et al.*, Science **309**, 2191 (2005); M. Furis *et al*, New J. Phys. **9**, 347 (2007).
[2] X. Lou *et al*, Nature Physics **3**, 197 (2007).