REU at U of M

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After writing code for controlling the distance between the pump and probe beams in the pre-existing setup, and helping out around the lab by wiring up samples, analyzing and taking data in the existing setup, I wrote code that simulated spin noise in GaAs.

I. LARGER PICTURE

Professor Vanessa Sih's lab, which I was working in this summer, studies the dynamics of electron spins in semiconductors, ideally to ultimately use the research in applications in spintronics. Spintronics is a method of transporting information in which one uses both the charge of the electron and the spin of the electron as a medium. The charge of the electron as a medium of information is nothing new: all electronic devices are exactly this. It is the use of the spin which is not yet understood enough to manipulate very well.[1] Potential advantages that spintronics may have over conventional electronics include less power consumption [2], and higher processing speeds [3], the two things we are always striving for in our development of newer and more advance technologies. The Sih lab studies the spin dynamics of semiconductors in particular because of the extreme applicability in the long run, due to the infrastructure which already exists for manipulating semiconductors.

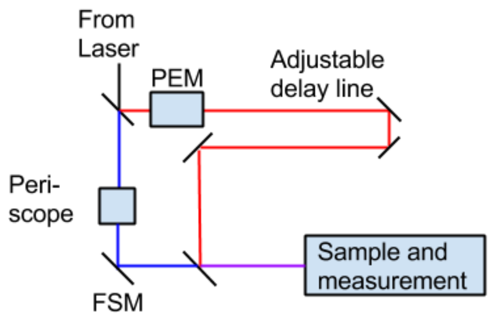

FIG. 1: A slightly inaccurate simplification of the setup. The FSM is the Fast Steering Mirror, used to control the distance of the pump beam (red) from the probe beam (blue). The PEM is a photoelastic modulator, which turns the linearly polarized light into circularly polarized light to pump spins into the sample.

II. PUMP - PROBE MEASUREMENTS

We probed the spin dynamics by inducing a spin polarization using a pump beam, which is a picosecond pulse from a Ti-Sapphire laser tuned to the energy of the band gap of GaAs. Then a probe pulse, linearly polarized, is shot at the sample to probe the resulting spin polarization. A diagram of this setup is shown in Fig. 1. One of my jobs this summer was to write a program to control the fast steering mirror to control the distance that the pump beam was from the probe beam on the sample. In particular, my program is mostly being used to make sure that the pump and probe beams are in the same place on the sample, to calibrate the setup.

After writing that code, I helped in some data runs by wiring up the sample and actually using the setup. I also helped out by analyzing existing data, which did lead to some interesting conclusions regarding the Landé g-factor as a function of voltage in GaAs.

III. SPIN NOISE

Spin noise is random fluctuations in spin. The randomizing processes and the time which it takes for an initial spin polarization to become randomized gives us another window into spin dynamics in semiconductors. The Sih lab plans to start measurements on this soon, and I was asked to create a model for spin noise before they start the measurements, so that they can gain more insight into what they are doing before they jump into it.

Spins in my model were just vectors which precessed about an external magnetic field, and at each timestep, had a probability of randomizing its direction. The total spin polarization considered is just the average value of the z-components of the spins. A sample result is shown in Fig. 2.

[1] The giant magnetoresistance effect has been observed and implemented already, but this is a rather recent development, and marks one of the first big advances in spintronics as a field [1].

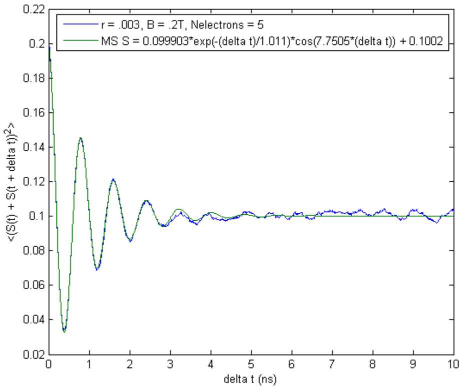

FIG. 2: A sample result from my model. The blue curve is data from my model, and the green curve is the fit curve. The fit works extremely well. This plot is of a quantity called the autocorrelation (offset by a constant), which tells us how the signal at a time t is related to the signal at a time $t + \Delta t$. This is a function of Δt.

While my model was quite simple, it actually captures much of the physics that we wanted to see in my lab group. I would have liked to put much more physics into the simulation, but I was constrained by the time period, and plan to finish this model soon.

[1] S.Yuasa, T. Nagahama, A. Fukushima, Y. Suzuki, and K. Ando, Nature Materials **3**, 868 (2004).

[2] K. Ando, S. Fujita, J. Ito, S. Yuasa, Y. Suzuki, Y. Nakatani, T. Miyazaki, and H. Yoda, J. Appl. Phys **115**, 172607 (2014).

[3] S. A. Wolf, D. D. Awschalom, R. A. Buhrman, J. M. Daughton, S. von Molnár, M. L. Roukes, A. Y. Chtchelkanova, and D. M. Treger, Science **294** 1488 (2001).

[4] B. Norman, Ph.D. thesis, University of Michigan, 2014.