Acoustic Spin Control Gate

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Even before the term "spintronics" was coined, the idea of controlling and using spin in a logic-type device was introduced by Datta and Das.[1] While electrically-gated semiconductor spintronic devices have not developed as quickly as originally envisioned, coherent manipulation of information encoded on electron spins continues to be an important avenue of research. Successful schemes open potential spin-based logic paradigms for either conventional or even quantum information processing in semiconductor systems.

The novel device introduced by Datta and Das relied on the structural inversion asymmetry induced by an electrostatic gate across a semiconductor quantum well. One is then able to modify the Rashba spin-orbit interaction (SIO), which in turn, controls the precession frequency of the electrons spins travelling under the gate. The final orientation of the electron spins is thus controlled by the gate voltage. There are, however, additional spin-orbit contributions to influence electron spin precession. By exerting a static, uniaxial strain on a semiconductor chip, strain fields were shown to manipulate the precession frequency of electron spins in GaAs in a manner similar to using an electrostatic gate. For dynamic strain fields, transporting electron spins using surface acoustic waves (SAWs) provides a system in which strain is inherent and that can coherently transport spins over large distances.[2] While the first experimental reports indicated that strain fields from SAWs may be a useful tool for spin manipulation,[3] contributions to the SOI were smaller than the bulk inversion asymmetry (the Dresselhaus SOI).

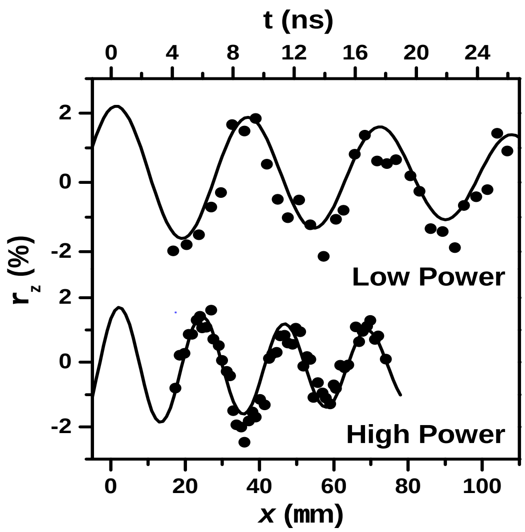

Fig. 1. Spin polarization ρ_z during transport along the [100]-direction of a GaAs (001) quantum well using dynamic quantum dots. The curves correspond to different powers of the surface acoustic wave that both transports the carriers as well as provides a mechanism to control their precession frequency.

Nevertheless, coherently manipulating spins using acoustic strain during the transport of electron spins by SAWs is possible. Figure 1 shows the electron-spin polarization during transport within dynamic quantum dots (DQDs) from a GaAs/(Al,Ga)As (001) quantum well. Lateral confinement of the DQDs is created by the superposition of piezoelectric fields from two orthogonal SAWs propagating along the $[110]$- and $[1\bar{1}0]$-directions. Comparing low and high power acoustic excitation, the strain of the SAWs is controlled such that the precession frequency of the spins is changed. As a result, a full π-rotation of the spin orientation can be achieved that is well within the coherence lifetimes of the spins. While there are multiple components to the SOI, it is the strain term from the SAW that dominates the interaction at higher powers, which will be discussed. This system is therefore particularly interesting given the SAWs act as both the "carrier wave" of the signal, which is coherently transporting the spins, as well as a flying logic gate, which can coherently manipulate the spins during transport. This acoustically-enabled spin gate could therefore permit the realization of a strain-based analog of the Datta-Das modulator.

References

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