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Spintronic Transport: Coherence and Numerical Modeling

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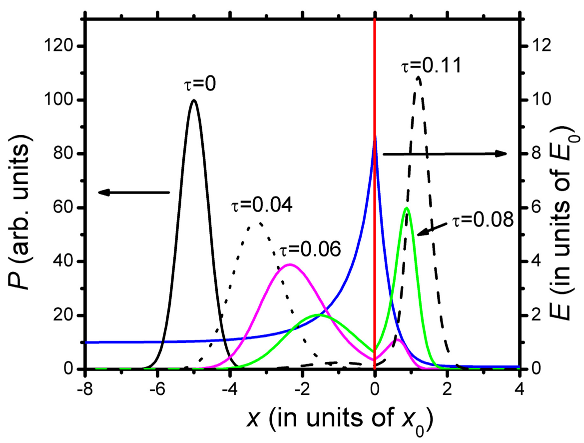
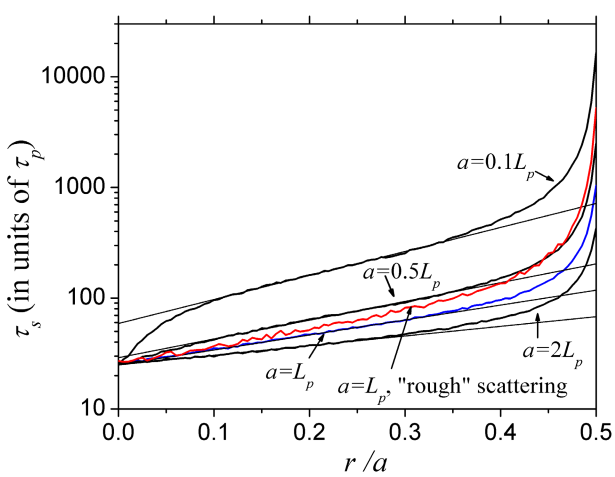
We report extensive studies in the field of semiconductor spintronics with special emphasis on fundamental mechanisms of spin coherence control and numerical modeling of spin-polarized transport. Specifically, we have studied propagation of spin-polarized electrons through a semiconductor with varying doping level [1], and through a boundary between different semiconductors [2]. It was shown (see Figure below) that an initially created narrow region of spin polarization could be further compressed and amplified near the boundary. If the boundary involves only variation of doping but no real interface between two semiconductor materials, no significant spin polarization loss is expected.



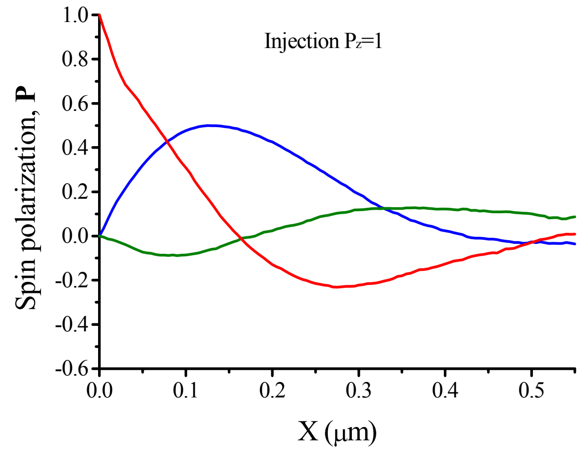
We have investigated the spin relaxation dynamics in two-dimensional electron gas with an antidot lattice [3]. The spin relaxation time was calculated as a function of geometrical parameters describing the lattice, namely the antidot radius and the distance between their centers. It was shown that spin relaxation can be suppressed by the chaotic spatial motion due to the antidots (see Figure).



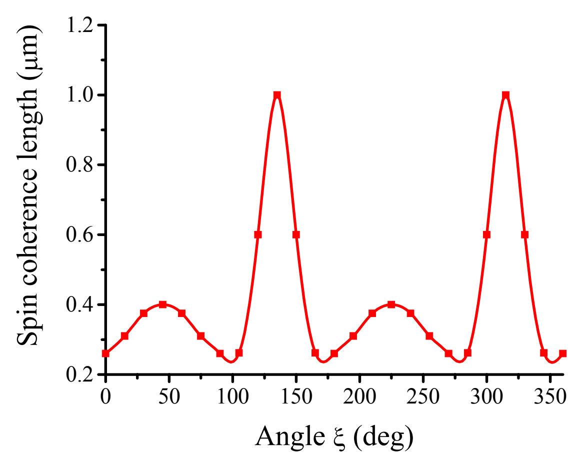
Furthermore, studies of electron spin polarization having initially inhomogeneous direction of the electron spin polarization vector were performed, and a long-lived configuration of spin polarization, namely a spin coherence standing wave, was predicted [4]. The results outlined above offer new approaches to spin coherence manipulation in spintronic devices.

For numerical modeling, we have developed a systematic hierarchy of transport models for spin dependent transport in semiconductor spintronic devices. The long-term goal has been to develop spintronic device simulators at different levels of efficiency and accuracy. In addition to fundamental understanding of the spin dynamics in realistic device structures, we aim at tools to study and optimize spin device characteristics and explore possible applications utilizing quantum spin dynamics.

We applied an ensemble Monte Carlo scheme to simulate transport of spin polarized electrons. The spin dynamics, controlled by the spin-orbit interaction, is incorporated using a spin density matrix approach [5,6]. The model allows studying effects of an applied bias, temperature, finite device size, charge accumulation, transport direction, etc. on the coherent spin dynamics. The figure below shows a typical evolution of the spin polarization vector as a function of distance.



Using the developed model, the problem of a quantum device optimization can be addressed [6]. For example, in the case of spin polarized current propagating along the (1, –1, 0) direction, the spin polarized electrons can maintain spin coherence on the length scale of the order of 1 micron, even at room temperature. The simulated results are shown on the following figure.



We have also studied spin injection into a non-magnetic semiconductor. We have investigated the effect of a metal/semiconductor interface on the spin injection and spin coherent dynamics in a semiconductor heterostructure [7]. It is found that for some orientations of a spin polarization, a strong electric potential at the material interface can destroy spin coherence (cause decay of the transverse spin component) on the very short length scale (~ 0.1 micron). However, decay of the longitudinal component is on the appreciably longer length scale.

References

1. Y. V. Pershin and V. Privman, Phys. Rev. Lett. **90**, 256602 (2003).
2. Y. V. Pershin, Phys. Rev. B **68**, 233309 (2003).
3. Y. V. Pershin and V. Privman, Phys. Rev. B **69**, 073310 (2004).
4. Y. V. Pershin, cond-mat/0311223.
5. S. Saikin, M. Shen, M.-C. Cheng and V. Privman, J. Appl. Phys. **94**, 1769 (2003).
6. M. Shen, S. Saikin, M.-C. Cheng and V. Privman, Math. Comp. Simul. **65**, 351 (2004).
7. S. Saikin, M. Shen and M.-C. Cheng, IEEE Trans. Nanotech. **3**, 173 (2004).