Transport Simulation of Precessing Spin Distribution across Semiconductor Heterojunctions

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Electric Field Dependent Spin Dynamics

Larmor frequency: \( \omega_L = \frac{geB}{2m} \)

Landé factors: \( g_{GaAs} = -0.44 \)
\( g_{ZnSe} = 1.1 \)

Spin dynamics:
zero bias: ZnSe-like
non-zero bias: GaAs-like

Why is Lande factor GaAs-like at E>0?

The Landé factor is a local material property:
   The Landé factor describes how the band energies vary with B in the material where the electron is located.

Therefore, it is expected that the spin will start precessing at the ZnSe Larmor frequency as soon as the electron enters the epilayer.
However, at non-zero bias experiments show that the GaAs spin parameters determine the spin dynamics in the ZnSe epilayer.

The apparent contradiction is lifted by examining simultaneously the transport and precession dynamics.
Spin Diffusion Model

Continuity equation for spin accumulation

\[
\frac{\partial m_i}{\partial t} = -\frac{m_i}{\tau} + \frac{\partial}{\partial x_k} \left( D \frac{\partial m_i}{\partial x_k} \right) + \frac{ge}{2m_e} (m \times B)_i
\]

Space dependent material parameters:
spin relaxation time \( \tau \), Landé factor \( g \) and diffusion coefficient \( D \)

Reflection at interface:
diffusion coefficient at one grid point reduced by a time dependent transmission factor \( T = T_0 e^{-\frac{t}{\tau_d}} \) where \( \tau_d \) is the accumulation lifetime

Spin Transfer at Zero Bias and Zero Magnetic Field

Experiment

Simulation

Simulations:
- Accumulation lifetime $\tau_d$ is finite
- Fraction transferred is within experimental range 5-10%
- Large times: exponential decay with lifetime $\tau_{ZS}$
- Larger $\mu$(GaAs) induces larger transfer
Spin Precession – No Bias

Simulations:
- Spin dynamics is ZnSe-like
- Spin coherence decreases as magnetic field increases
- Phase shift increases as magnetic field increases
Spin Precession – With Bias

Experiment

Simulation

Spin dynamics is GaAs-like
Conclusion

1. Spin density diffusion model reproduces experimental data for biased and unbiased samples.

2. Switch from ZnSe-like to GaAs-like spin dynamics is explained by fast transit times through ZnSe epilayer and barrier at interface.

3. Decay of spin transfer is slow compared to thermalization times.