Transport Simulation of Precessing Spin Distribution across Semiconductor Heterojunctions

NOTE: CORRECT TITLE ON B30 FORM. 11/1 KW

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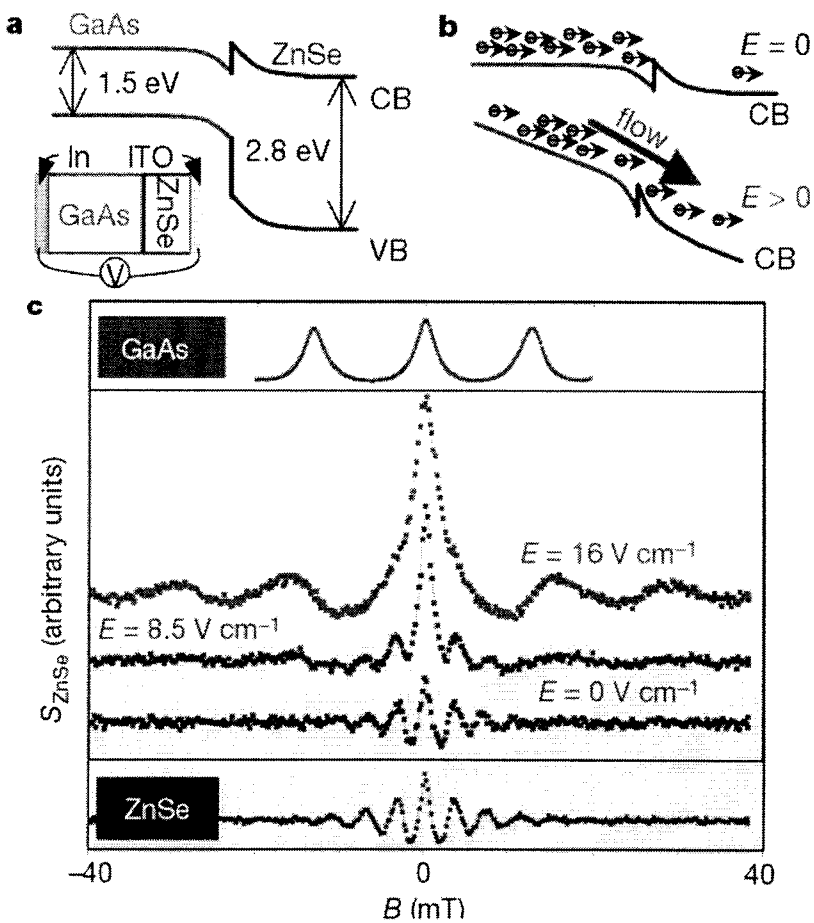
Electric Field Dependent Spin Dynamics



Larmor frequency: $\omega_L = \dfrac{geB}{2m}$

Landé factors: $g_{GaAs} = -0.44$ $g_{ZnSe} = 1.1$

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

I. Malajovich, J.J. Berry, N. Samarth and D.D. Awschalom, Nature 411, 770 (2001)

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 τ, Landé factor g and diffusion coefficient D

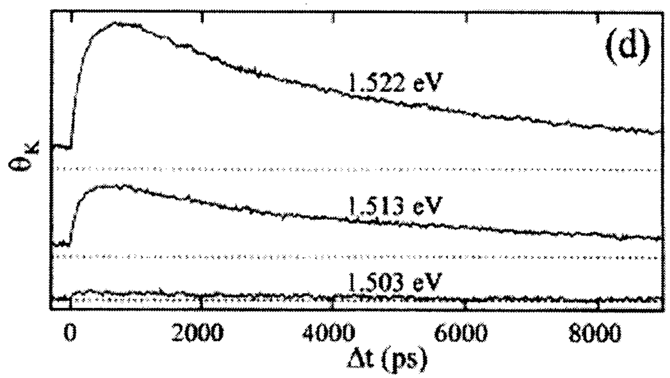
Reflection at interface:

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

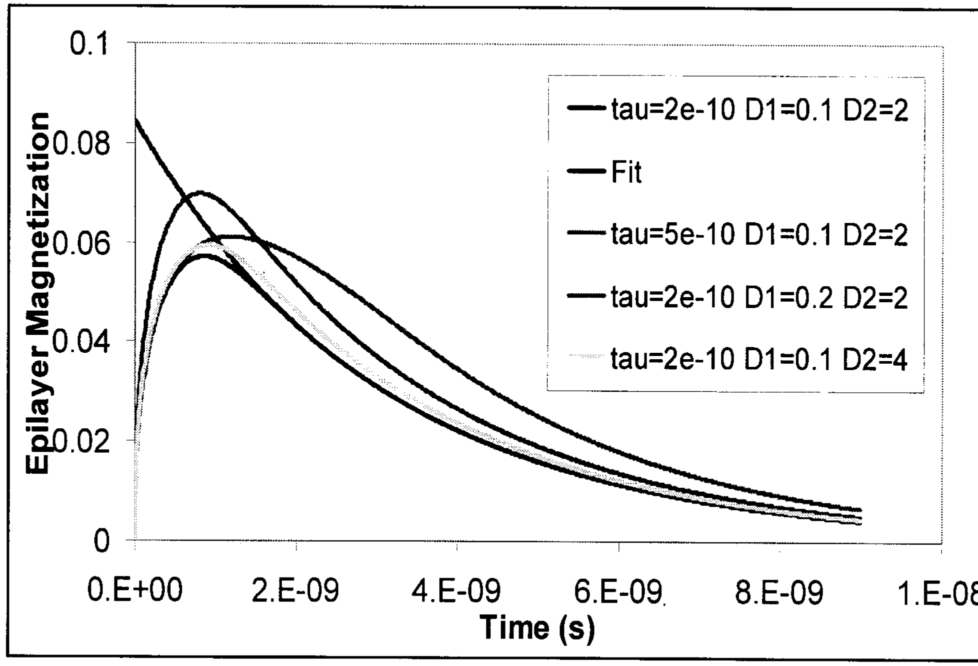
M.D. Stiles and A. Zangwill, preprint (2002)

Spin Transfer at Zero Bias and Zero Magnetic Field

Experiment



Simulation

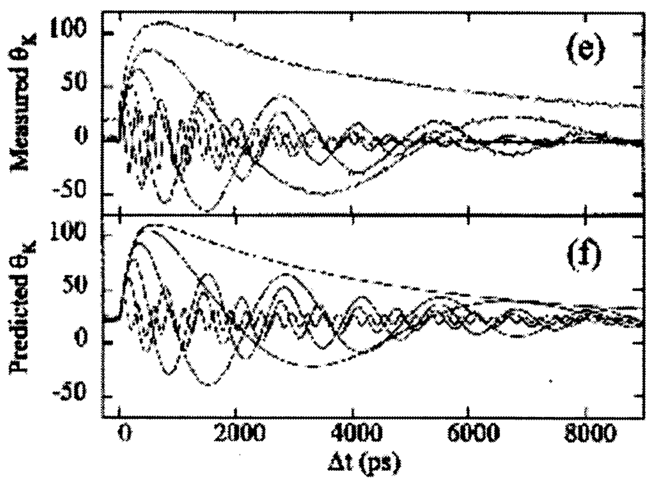


Simulations:

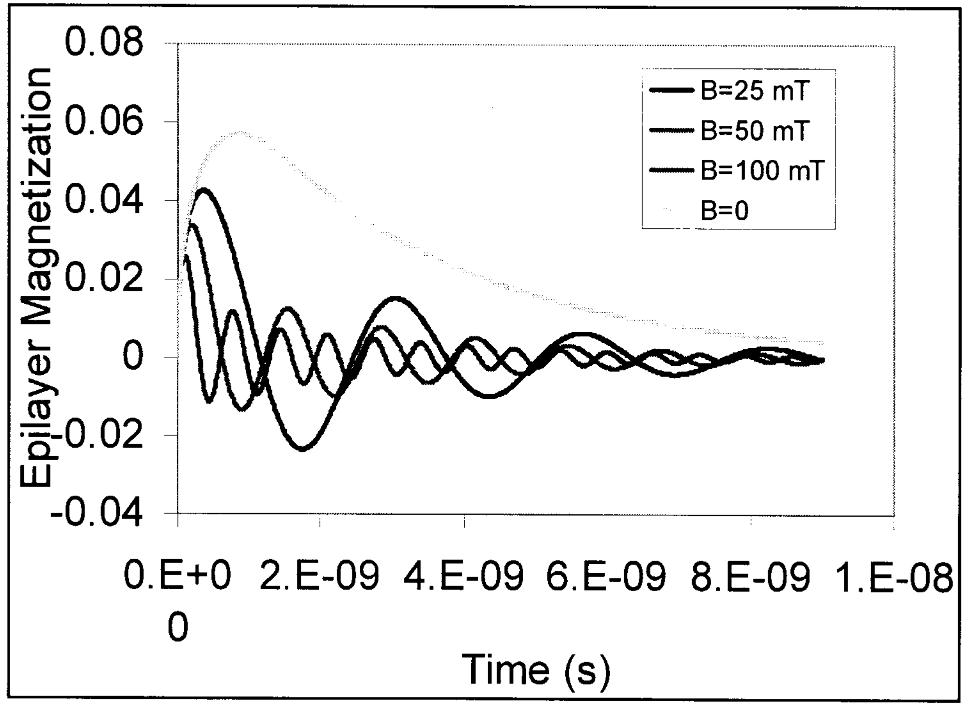
- Accumulation lifetime τ_d is finite
- Fraction transferred is within experimental range 5-10%
- Large times: exponential decay with lifetime τ_{ZS}
- Larger μ(GaAs) induces larger transfer

Spin Precession – No Bias

Experiment



Simulation

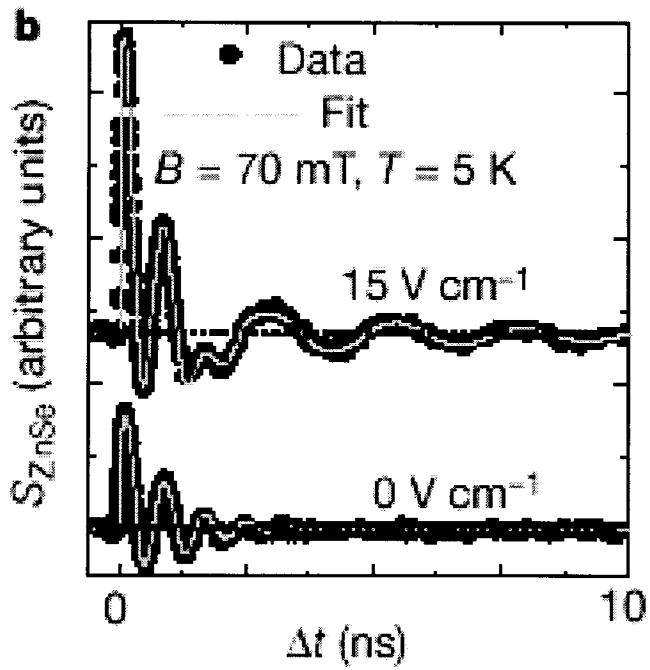


Simulations:

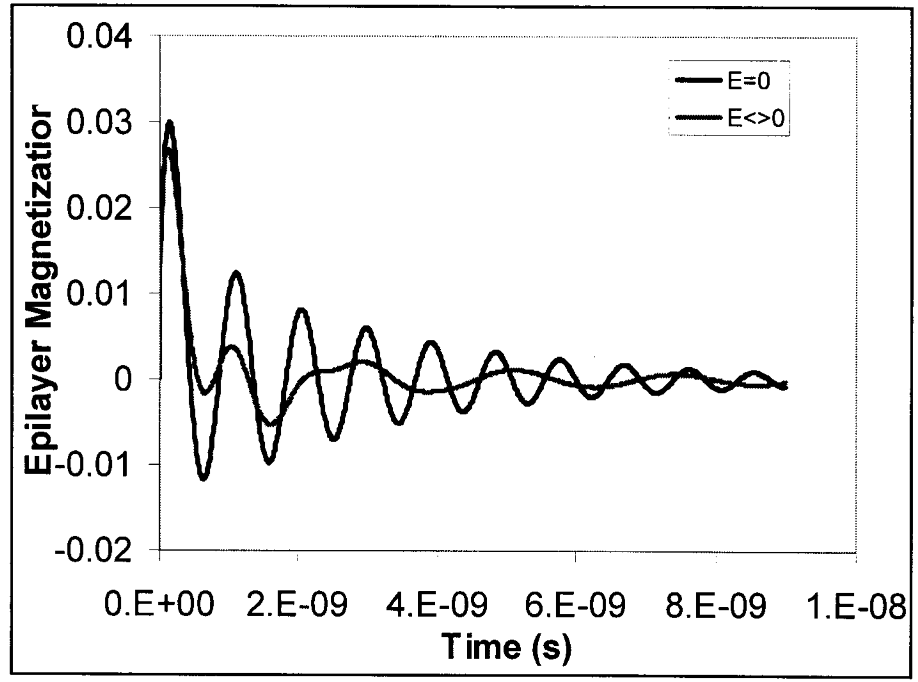
- Spin dynamics is ZnSe-like
- Spin coherence decreases as magnetic field increases
- Phase shift increases as magnetic field increases

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.