**Direction Dependence of Spin Relaxation and Diffusive-Ballistic Crossover**

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**Abstract**

The dependence of spin relaxation on the direction of the quantum wire under Rashba and Dresselhaus (linear and cubic) spin orbit coupling (SOC) is studied using the Cooper equation. Computing the dimensionless relaxation of the wire in the diffusive regime, the lowest spin relaxation and depolarization rates for (001) and (110) systems are found. The analysis of spin relaxation reduction is then extended to non-diffusive wires where it is shown that, in contrast to the theory of dimensional crossover from weak localization to weak quantization in diffusive wires, the relaxation due to cubic Dresselhaus spin orbit coupling is reduced and the linear part shifted with the number of transverse channels $N$. We set $\alpha = 1$.

**Consequence and Spin Diffusion**

The weak localization correction to the conductivity is given by

$$\sigma = \frac{4\hbar}{2e^2} N_{\nu} \sum_{n,m} \epsilon_n \delta_{nm} C_{nm}(\alpha, \beta).$$

where $\alpha$, $\beta$ are the spin indices, and the Cooper propagator $C$ is for $\nu \sigma > 1$ (Fermi liquid), given by

$$C_{nm}(\alpha, \beta) = \frac{1}{1 - \sum_{p \neq m} \epsilon_p}.$$  

Expanding $C$ to lowest order in the generalized momentum $Q$ leads to

$$C_{nm}(Q) = C(Q) = (1 + \alpha Q^2 + 2 \alpha Q^2 H_0).$$

for the Cooper propagator $C$ in (001), with the Baschnagel parameter $\alpha Q$ and the shifted linear Dresselhaus coupling $\alpha = -\Delta_{0}/\epsilon_{F}E_{D}$, $H_0 = \frac{\Delta_{D}}{E_{F}}$.  

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2D spectrum of $H_0 = \sum_{m} l_{m}$ in dashed black and triplet modes

The local corrections given by $C$ can be related to spin relaxation by taking the linear response

$$\sigma_{\nu,\mu} = \langle \nu | \sigma_{\nu,\mu} | \mu \rangle.$$

with the spin diffusion equation for $\nu, \mu$.

$$0 = \frac{\partial \delta_{\nu}}{\partial t} - \frac{\partial}{\partial \nu} \left( - D \frac{\partial}{\partial \nu} \delta_{\nu} - 2 \frac{\partial}{\partial \nu} \left( - D \frac{\partial}{\partial \nu} \delta_{\nu} \right) \right).$$

The effective moment of the electron spin relaxation, whose evolution is described by the spin diffusion equation, Eq. 6.

$$\delta_{\nu} = \frac{1}{\gamma_{\nu}} \left( B_{\nu}(\nu \nu) \delta_{\nu} - B_{\nu}(\nu \nu) \delta_{\nu} \right).$$

**Spin Relaxation**

The eigenvalue of $H_0(\beta)$ which has the eigenvalue

$$E_{\beta}(\beta) = \frac{\gamma^{2}}{2} + \frac{1}{2} \sqrt{\left( \frac{\gamma^{2}}{2} + \frac{1}{2} \right)}$$

is the triplet state $S = 1$, $m = 0$, $J = 1$, $| 1 \rangle | 1 \rangle | 1 \rangle | 1 \rangle = | 1 \rangle | 1 \rangle | 1 \rangle | 1 \rangle$. This leads to the momentum of the triplet state, whose evolution is described by the spin diffusion equation, Eq. 6.

$$\delta_{\nu} = \frac{1}{\gamma_{\nu}} \left( B_{\nu}(\nu \nu) \delta_{\nu} - B_{\nu}(\nu \nu) \delta_{\nu} \right).$$

**Spin Relaxation Anisotropy in the (001) System**

Consider a system featuring scattering at spin-conserving boundaries:

$$\mathbf{n} \cdot \mathbf{j}_{\nu} = 0, \mathbf{n} \cdot \mathbf{j}_{\nu} = -\mathbf{n} \cdot \mathbf{j}_{\nu} = 0.$$  

Using $\mathbf{e}_{\nu}$, we find the BCF for the Cooper and simplify them by applying a second transformation $e_{\nu}$ to the Newman BC.

$$\mathbf{U}_{\nu} = \mathbf{e}_{\nu} \mathbf{B}_{\nu}(\mathbf{B}_{\nu}(\mathbf{k} \times \mathbf{e}_{\nu})) \mathbf{e}_{\nu} = 0.$$  

The dimensionless relaxation of the wire in the diffusive regime, the lowest spin relaxation and depolarization rates for (001) and (110) systems are found. The analysis of spin relaxation reduction is then extended to non-diffusive wires where it is shown that, in contrast to the theory of dimensional crossover from weak localization to weak quantization in diffusive wires, the relaxation due to cubic Dresselhaus spin orbit coupling is reduced and the linear part shifted with the number of transverse channels $N$. We set $\alpha = 1.$

**References**


