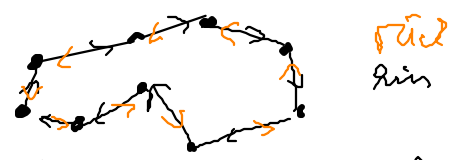


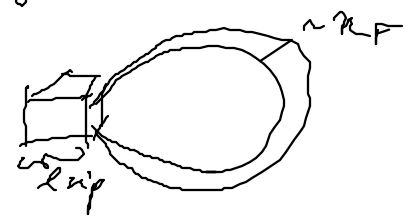
Schwache Lokalisierung

$$L_{imp} < L < L_{\phi}$$



• höchste Rückkehrwahrscheinlichkeit wegen guter Interferenzzeit umgekehrter Wege

• Rückkehrwahrscheinlichkeit für diffusionsproblem

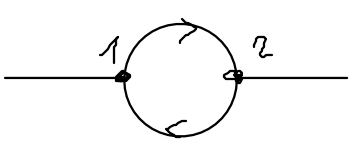


$$\Delta \sigma = -\frac{2e^2}{\pi h} D \int_{t_{imp}}^{\infty} dt \tilde{W}_{\phi}$$

entweder einem Streuzentrum im L_{imp} kann korrekter auftreten

Vergleich

Δ Karbonat-Bolm \Leftrightarrow Shavrin-Shavrin



$$\Delta \theta = 2\pi \frac{\phi}{\phi_0}$$

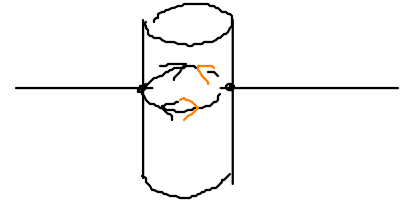
$$\phi_0 = \frac{hc}{e}$$

$$\Delta \theta = 2\pi \frac{2\phi}{\phi_0}$$

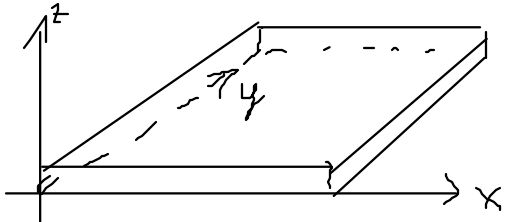
$$\phi_0 = \frac{hc}{e}$$

$$\tilde{\phi}_0 = \frac{hc}{2e}$$

Weg
"ähnliche Supraleitung" $g = 2e$



Schwache Lokalisierung im Magnetfeld (Film)



$$\frac{d}{dt} + D \left((-i\nabla - \frac{2e}{hc} A(\vec{r}))^2 + \frac{1}{L_{imp}} \right) \tilde{W}(\vec{r}, 0^+, 0) = \delta(t) \delta(\vec{r})$$

a) parallel zum Film $\vec{A} = \begin{pmatrix} 0 \\ -Bz \\ 0 \end{pmatrix}$ $\vec{B} = \vec{v} \times \vec{A} = \begin{pmatrix} B \\ 0 \\ 0 \end{pmatrix}$

mitte über z

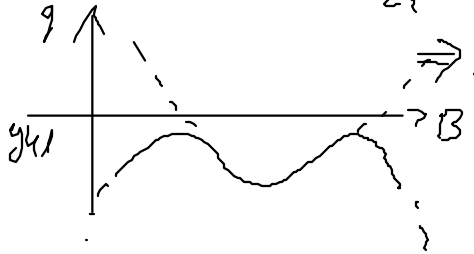
$$\left(\frac{d}{dt} - D \left(\frac{d^2}{dx^2} + \frac{d^2}{dy^2} \right) + \frac{1}{L_B} + \frac{1}{L_{\phi}} \right) \tilde{W} = \frac{1}{a} \delta(t) \delta(x) \delta(y)$$

$$\frac{1}{L_B} = D \left(\frac{2e^2}{hc} \right)^2 \frac{1}{a} \int dz A^2(z) = \frac{1}{3} D \left(\frac{eBa}{hc} \right)^2$$

\Rightarrow Phasenkohärenz wird schneller zerstört $\frac{1}{L_{\phi}} \rightarrow \frac{1}{L_{\phi}} + \frac{1}{L_B}$

$$\Delta \sigma = -\frac{e^2}{h} \ln \left(\frac{L_{imp}}{\frac{1}{L_{\phi}} + \frac{1}{L_B}} \right) \approx -\frac{e^2}{h} \left(\ln \left(\frac{L_{\phi}}{L_{imp}} \right) - L_{\phi} \frac{1}{3} \left(\frac{eBa}{hc} \right)^2 + \dots \right)$$

\Rightarrow anomaler Magnetwiderstand



b) $\vec{B} \perp \vec{v}$ Fikn $\vec{A} = \begin{pmatrix} 0 \\ Bx \\ 0 \end{pmatrix}$ $\vec{B} = \begin{pmatrix} 0 \\ 0 \\ B \end{pmatrix}$

$\frac{d}{dt} + D(-\frac{d^2}{dx^2} + (\frac{1}{i} \frac{d}{dy} - \frac{2eB}{\hbar c} x)^2 + \frac{1}{L_y}) \tilde{W} = \frac{1}{a} \delta(t) \delta(x) \delta(y)$ vgl. Landau Nivaus

$\tilde{W}_{t_0} = \frac{1}{a} \sum_n \int \frac{dy}{2\pi} \psi_n(x_f - \frac{\hbar c y}{2eB}) \psi_n(x_i - \frac{\hbar c y}{2eB}) \exp[ik(y_f - y_i) - \omega_n t_0 - \frac{t_0}{L_y}]$

$\omega_n = \frac{4eB}{\hbar c} (n + \frac{1}{2})$

ψ_n sind Eigenfkt von $D(-\frac{d^2}{dx^2} + (\frac{2eB}{\hbar c} x)^2)$

$\Delta g = -\frac{2e^2}{\hbar} \int_{\text{imp}} dt \tilde{W}_{t \uparrow \uparrow} \xrightarrow{B \rightarrow 0} -\frac{e^2}{2\pi^2 \hbar} (\ln(\frac{E_F}{E_{imp}}) - \frac{1}{6} (\frac{eB D L_y}{\hbar c})^2 + \dots)$



Erhöhung von g durch B macht Δg beobachtbar

Spin-Flip und Spin-Bahn-Streuung

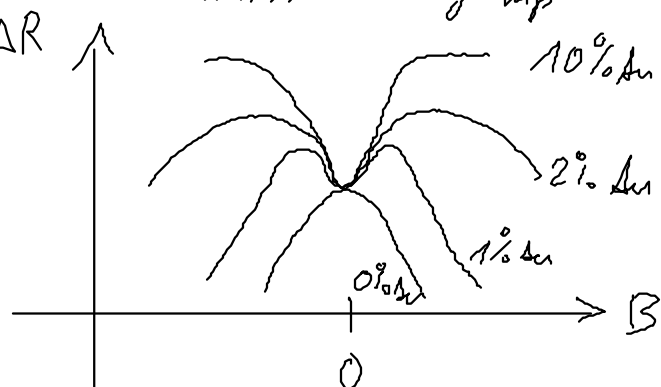
$f(p, p') = \overset{\text{Spinflip}}{U_{sf}} \frac{1}{\sigma} \delta + i \overset{\text{Spinorbit}}{U_{so}} \frac{1}{\sigma} (\vec{p} \times \vec{p}')$

$\frac{1}{U_{sf}} = \pi N(E_F) N_s |U_{sf}|^2 s(s+1)$
 ↑ Konzentration Versunreinigerenspins

$\frac{1}{U_{so}} = \pi N(E_F) N_i |U_{so}|^2 \langle (\vec{p} \times \vec{p}') \rangle$
 ↑ Konzentration der Störstellen

$\frac{1}{U_{sg}} = \frac{2}{U_{sf}} + \frac{1}{U_p}$ $\frac{1}{U_{sp}} = \frac{4}{3U_{sf}} + \frac{2}{3U_{sp}} + \frac{1}{U_p}$

$\Rightarrow \Delta g = -\frac{e^2}{2\pi^2 \hbar} (\ln(\frac{E_F}{U_{sg} E_{imp}}) - \frac{1}{6} (\frac{eB D}{\hbar c})^2 (3U_{sp}^2 - U_{sf}^2) + \dots)$
 ↑ Triplett Singlett



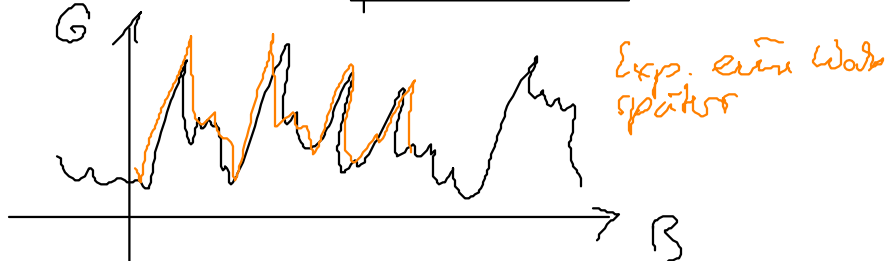
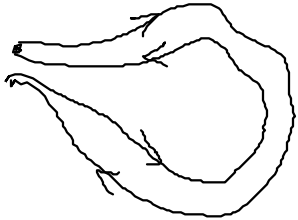
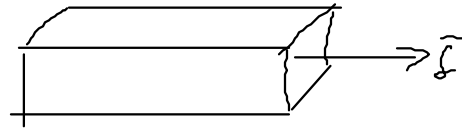
Magnesium führen mit magere hiden Goldverunreinigungen (Bergmann)

Referenzen

- S. Chakravarty und A. Schmid, Phys. Rep. 140, 193 (1986)
- G. Bergmann, Phys. Rep. 107, 1 (1984)

Probenphysikalische Fluktuationen

$$l_{imp} < L < L_{\phi}$$



G weist charakteristische, reproduzierbare Fluktuationen als Fkt von B auf.

Universal conductance fluctuations (UCF)

(Universelle Leitwertfluktuationen)

Metallischer Fall: $G = \frac{2e^2}{h} \sum_{\alpha, \beta=1}^N |t_{\alpha\beta}|^2$

Adm: $G_{class} = \sigma \cdot \frac{W}{L} \left(\frac{Wekt}{Länge} \right) = \frac{e^2}{h} v_F l_{imp}$ $\sigma = \frac{v^{2D} e^2 C}{m}$ $v^{2D} = 2 \frac{\pi v_F^2}{(2\pi)^2}$

Anzahl der Kanäle $N = \frac{W v_F}{\pi}$

$G_{class} = \frac{2e^2}{h} \frac{\pi l_{imp}}{2L} N$ $\langle \dots \rangle = \text{Mittelwert über Störstellen}$

$\sum_{\alpha, \beta=1}^N \langle |t_{\alpha\beta}|^2 \rangle = \frac{\pi l_{imp}}{2L} N$ $\sum_{\alpha, \beta=1}^N |t_{\alpha\beta}|^2 = N - \sum_{\alpha, \beta=1}^N |r_{\alpha\beta}|^2$

Annahme: $\sum_{\alpha, \beta=1}^N \langle |r_{\alpha\beta}|^2 \rangle = N^2 \langle |r_{\alpha\beta}|^2 \rangle$

$\Rightarrow \langle |r_{\alpha\beta}|^2 \rangle = \frac{1}{N} \left(1 - \frac{\pi l_{imp}}{2L} \right)$

$\langle \delta G^2 \rangle = \langle (G - \langle G \rangle)^2 \rangle = \left(\frac{2e^2}{h} \right)^2 \left(\langle \left(N - \sum_{\alpha, \beta} |r_{\alpha\beta}|^2 \right)^2 \rangle - \left(N \sum_{\alpha, \beta} \langle |r_{\alpha\beta}|^2 \rangle \right)^2 \right)$

$\langle G^2 \rangle = \frac{2e^2}{h} \langle \sum_{\alpha, \beta \neq \gamma, \delta} |t_{\alpha\beta}|^2 |t_{\gamma\delta}|^2 \rangle$

$\langle \delta G^2 \rangle = \left(\frac{2e^2}{h} \right)^2 \left(\langle \left(\sum_{\alpha, \beta} |r_{\alpha\beta}|^2 \right)^2 \rangle - \langle \sum_{\alpha, \beta} |r_{\alpha\beta}|^2 \rangle^2 \right)$

$= \left(\frac{2e^2}{h} \right)^2 \langle \delta \left(\sum_{\alpha, \beta} |r_{\alpha\beta}|^2 \right)^2 \rangle = \left(\frac{2e^2}{h} \right)^2 N^2 \langle \delta \left(|r_{\alpha\beta}|^2 \right)^2 \rangle$

$\langle \delta \left(|r_{\alpha\beta}|^2 \right)^2 \rangle = \langle |r_{\alpha\beta}|^4 \rangle - \langle |r_{\alpha\beta}|^2 \rangle^2$

$$|r_{\alpha\beta}|^2 = \sum_{ij} A_{\alpha\beta}^*(i) A_{\alpha\beta}(j) \quad \langle |r_{\alpha\beta}|^2 \rangle = \sum_i |A_{\alpha\beta}(i)|^2$$

$$\langle |r_{\alpha\beta}|^2 \rangle = \langle \sum_{ijkl} A^i A^j A^{*k} A^l \rangle$$

$$= \sum_{ijkl} |A^i|^2 |A^j|^2 (\delta_{ij} \delta_{kl} + \delta_{ik} \delta_{jl}) = 2 \langle |r_{\alpha\beta}|^2 \rangle$$

$$\langle \sigma_G^2 \rangle = \left(\frac{2e^2}{g}\right)^2 N^2 \langle |r_{\alpha\beta}|^2 \rangle \propto \left(\frac{2e^2}{g}\right)^2 \frac{1}{\epsilon_0}$$

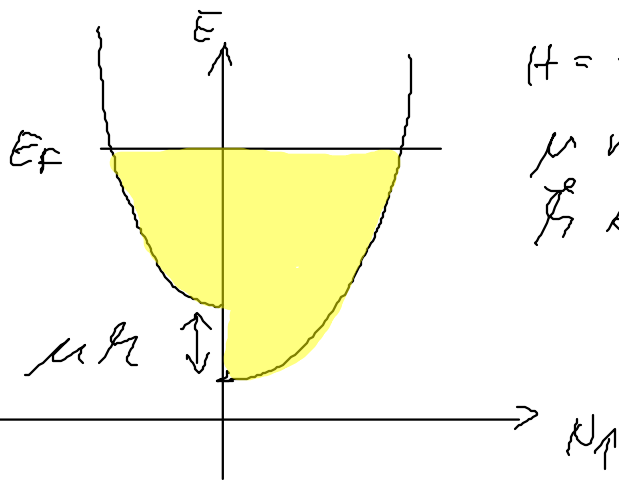
universelle Leitwertfluktuationen $\propto \epsilon_0^{-1}$

• σ_G unabhängig von Dimension $d=1, 2, 3$

6 Spintronik / Spineltronik

Spin-Effekte: Magnetismus

Ferromagnete: Eisen (Fe), Kobalt (Co), Nickel (Ni)



$$H = \frac{p^2}{2m} + U(x) \pm \mu_B \hbar S$$

μ magnet Moment

\hbar Austausch