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KPS

Quantum transport through an Aharonov-Bohm ring

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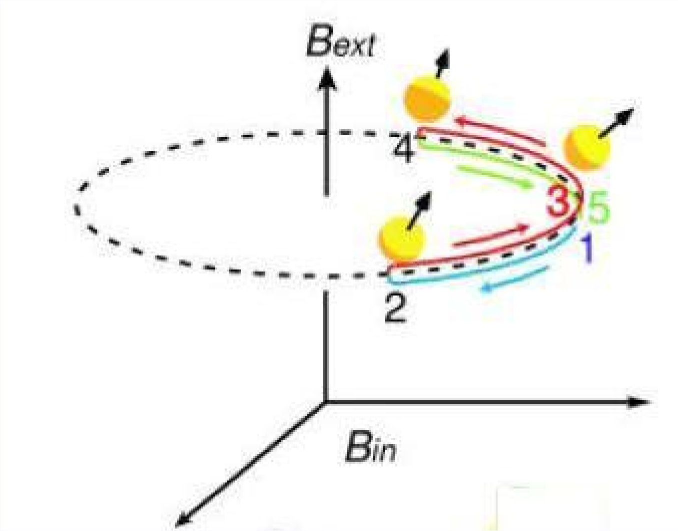
The Model
The Wavefunction
Quantum Transport
Diode
Spin Flip
The practical implications

1 The Model

- 

The ring is embedded in an inhomogeneous time-dependent magnetic field. The Hamiltonian for this system is taken to be,

- $$\widehat{H}(t) = \frac{1}{2ma^2}[\widehat{P}_\theta - ea\mathbf{A}_\theta(t)/c]^2 + \mu\mathbf{B}(t)\cdot\widehat{\sigma} \quad (1)$$

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2 The Wavefunction

- After using the algebraic dynamics [details in *J. Phys.:Condens. Matter,* ***16****,2043 (2004)*], the exact wavefunction of the system was obtained

$$|\Psi(\theta,t)\rangle = \sum_{n,m} C_{n,m}|\Psi_{n,m}(\theta,t)\rangle \tag{2}$$

where $|\Psi_{n,m}(\theta,t)\rangle$ is the diabatic Bases for original Schröinger equation.

$$|\Psi_{n,m}(\theta,t)\rangle = e^{-i\Theta_{n,m}(t)} \cdot e^{in\theta} \sum_{m'} D^{1/2}_{m'm}[v_r(t)]e^{im'v_z(t)}\,|m'\rangle \tag{3}$$

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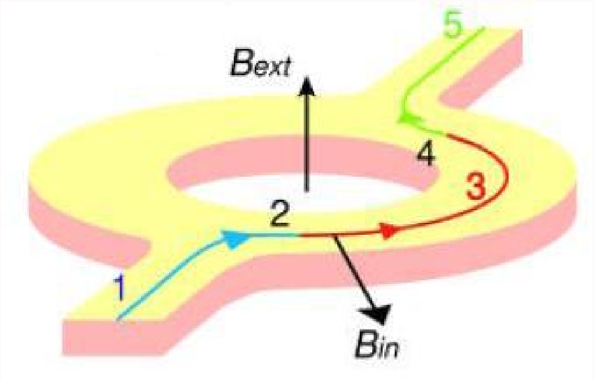
3 Quantum Transport

- 

  – According to Landauer Formula, at the strong coupling limit,and the two leads support only one open channel. The conductance reads,

$$G = \frac{e^2}{h} \sum_{s,s'} T_{s's} = \frac{e^2}{2h} \sum_{s,s'} |\sum_{i} A^i_{s's}|^2 \tag{4}$$

  $A^i_{s's}$ denotes the probability amplitude of the $i - th$ Feynman path from an incoming quantum channel with spin s to an outgoing channel with spin s'.

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3.1. The Transmission

- The transmission is given as: ($\kappa = \uparrow, \downarrow$)

$$T_{\kappa s}(\tau) = \frac{1}{2} \left| \sum\nolimits_{\lambda,m} \langle \kappa | \Psi_{n_m^\lambda, m}(\pi, \tau) \rangle \right|^2 \tag{5}$$

where n_m^λ are determined by the equation $E_F = E_{n,m}$, and are four approximate integer number.

- If the four Feynman pathes have same spin tilt angle, then

$$T_{\uparrow s}(\tau) = C_\uparrow^2 \cos^2 v_r(\tau)[1 + \cos(\Delta\phi_{n_\uparrow^+ - n_\uparrow^-})] + C_\downarrow^2 \sin^2 v_r(\tau)[1 + \cos(\Delta\phi_{n_\downarrow^+ - n_\downarrow^-})]$$
$$T_{\downarrow s}(\tau) = C_\uparrow^2 \sin^2 v_r(\tau)[1 + \cos(\Delta\phi_{n_\uparrow^+ - n_\uparrow^-})] + C_\downarrow^2 \cos^2 v_r(\tau)[1 + \cos(\Delta\phi_{n_\downarrow^+ - n_\downarrow^-})]$$

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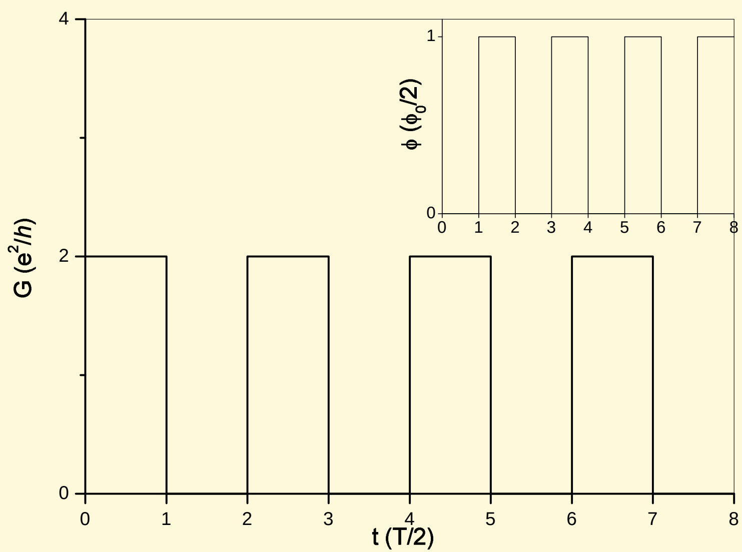
4 Diode

✠ After summation over the spin indices κ and s, the total conductance is

$$G = \frac{e^2}{h}[1 + \cos 2\pi\phi(t) \cos \pi(1 - \cos 2v_r(0))] \tag{6}$$

✠ If the initial spin states is $z - polarized$, i.e. $v_r(0) = 0$ or $\pi/2$, in a rectangularly oscillating perpendicular magnetic field $B_z(t)$ (inset, $\phi(t) = B_z(t) \cdot \pi a^2$) with period T, such a system acts as a ideal diode.



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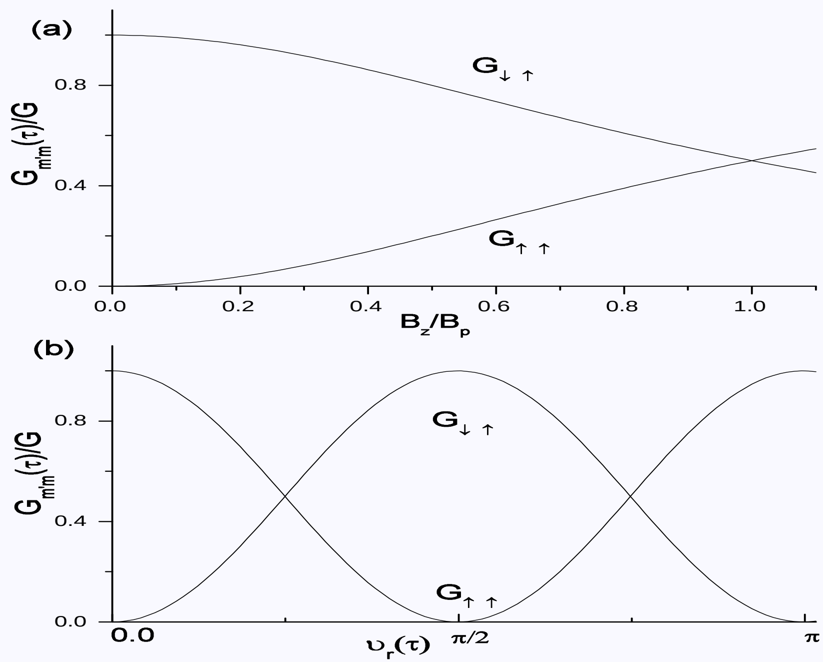
5 Spin Flip

- At the adiabatic Limit [*PRL.* ***87***, *256602(2002)*]: the Larmor frequency of spin precession, $\omega_s = 2\mu|B|/\hbar$, must be larger compared to the frequency $\omega_F = v_F/a$ of orbital motion with the Fermi velocity v_F around the ring, *i.e.* $\omega_s/\omega_F \gg 1$, the spin direction can be completely reversed.



(a) Counter-clockwise rotating magnetic field; (b) Resonant magnetic field.

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6 The practical implications

- A mesoscopic magnetic flux “diode”： Via an rectangularly oscillating perpendicular magnetic field.
- Spin swich, spin transistors, filters, and so on: In the a ”weak” magnetic field $B_z \approx 0$ and the adiabatic limit

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Thank you!

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