

NOME DA DISCIPLINA : TRANSPORTE QUÂNTICO EM NANOESTRUTURAS (PGF5281)

3a. feira - Das 10 às 12 horas

5a. feira - Das 10 às 12 horas

Local: Sala 206-Ala Central

Programa

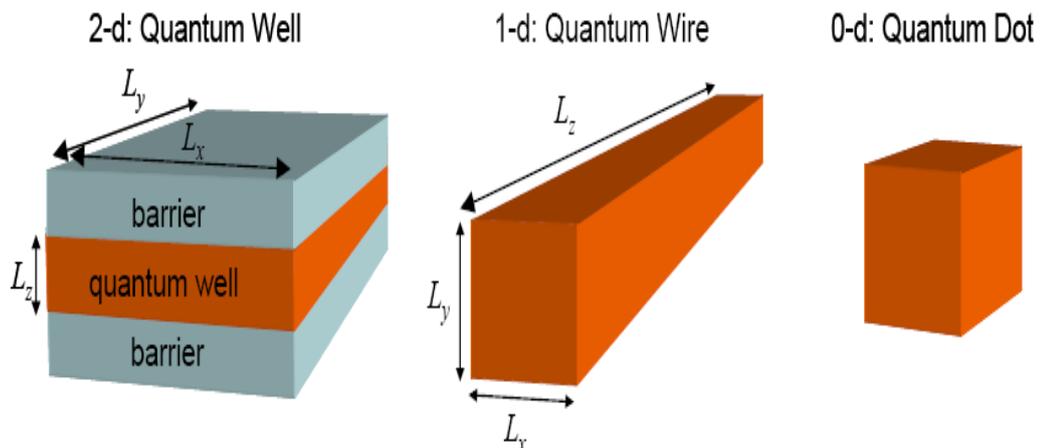
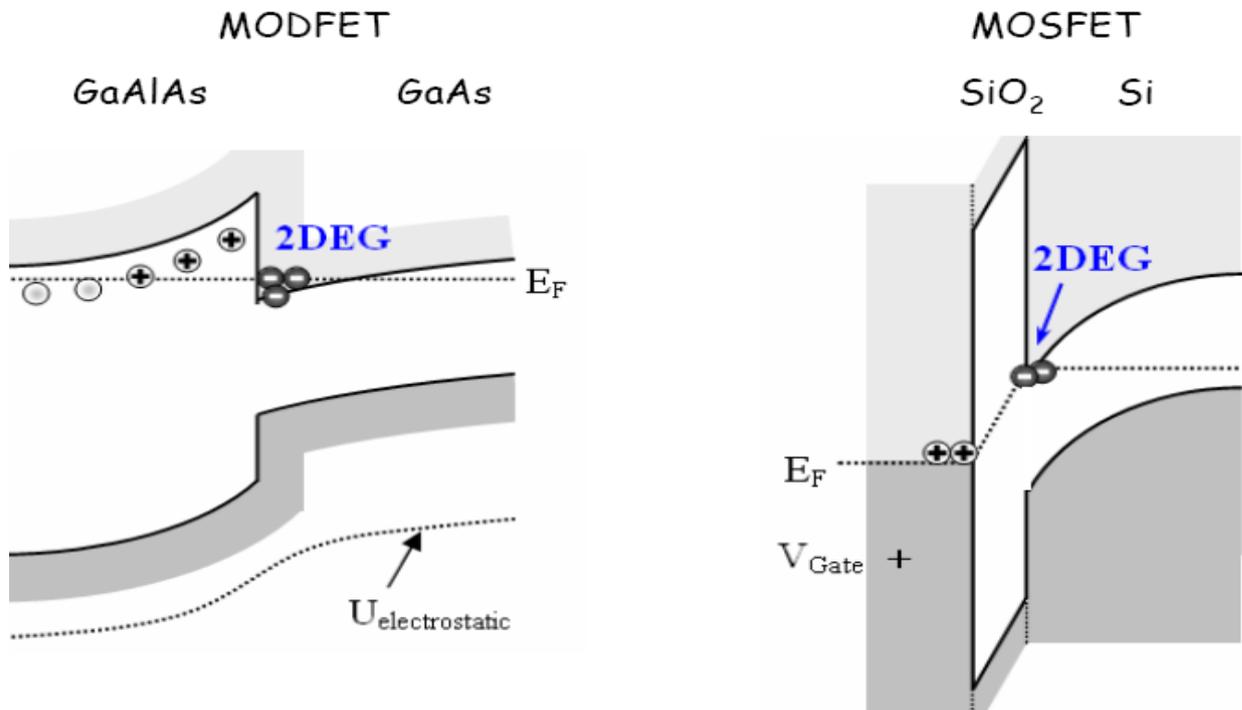
9.08.2016	Introdução a nanociencia
11.08.2016	Nanoestruturas semicondutoras. Gás bidimensional.
16.08.2016	Introdução a nanoeletronica. Nanoeletronica e tecnologia CMOS. FINFET.
18.08.2016	Fios quânticos, pontos quânticos. Fabricação, densidade de estado.
23.08.2016	Dispositivos com um único elétron. Bloqueio de Coulomb, efeitos nonlineares. Efeito Kondo.
25.08.2016	Transporte classico, equação de Boltzmann.
30.08.2016	Transporte, magnetoresistencia
1.09.2016	Transporte, efeito Hall
05-10.09.2016	Semana da Pátria. Não haverá aula
8-12.09.2016	Proclamação da Independência.
13.09.2016	Não haverá aula
15.09.2016	Transporte quântico, efeitos mesoscopicos
20.09.2016	Efeitos mesoscopicos , equação de Landauer, condutância.

22.09.2016	Interferência, efeito Aharonov-Bohm, localização fraca, magnetoresistencia quântica
27.09.2016	Flutuação da condutância universal.
29.09.2016	efeito termoelétrico, lei de Mott, lei de Wiedemann Franz
04.10.2016	niveis de Landau, oscilações quânticos
06.10.2016	Efeito Hall quântico inteiro.
11.10.2016	Efeito hall quântico fracionario, fermions Compostos
12-13.10.2016	Dia da Padroeira do Brasil, Nossa Senhora Aparecida. Não haverá aula.
18.10.2016	Nanoestruturas de Carbono estruturas de banda, crescimento dopa defeitos, dispositivos nanoeletronica de Carbono
20.10.2016	Grafeno, transporte quântico em grafeno.
25.10.2016	Grafeno, fase Berry, efeito Hall quantico
27.10.2016	Spin, equação de Dirac, equação de Dirac não relativística em campo magnético.
1-2.11.2016	Finados. Não haverá aula.
3.11.2016	Ferromagnetismo, paramagnetismo e Diamagnetismo.

8.11.2016	Spintronica. Magnetoresistencia gigante
10.11.2016	Spintronica de semicondutores, efeito Rashba, Datta transistor
14-15.11.2016	Proclamação da República. Não haverá aula.
17.11.2016	Efeito Hall de spin
22.11.2016	Efeito Hall de spin quântico, Isolantes topologicos
24.11.2012	Seminarios
29.11.2012	Seminarios, Avaliação Final
05.12.2008	ENCERRAMENTO DAS AULAS

The Two-Dimensional Electron Gas (2DEG)

Producing a 2DEG in a Field Effect Transistor (FET)



Nanoeletronica e tecnologia CMOS. FINFET.

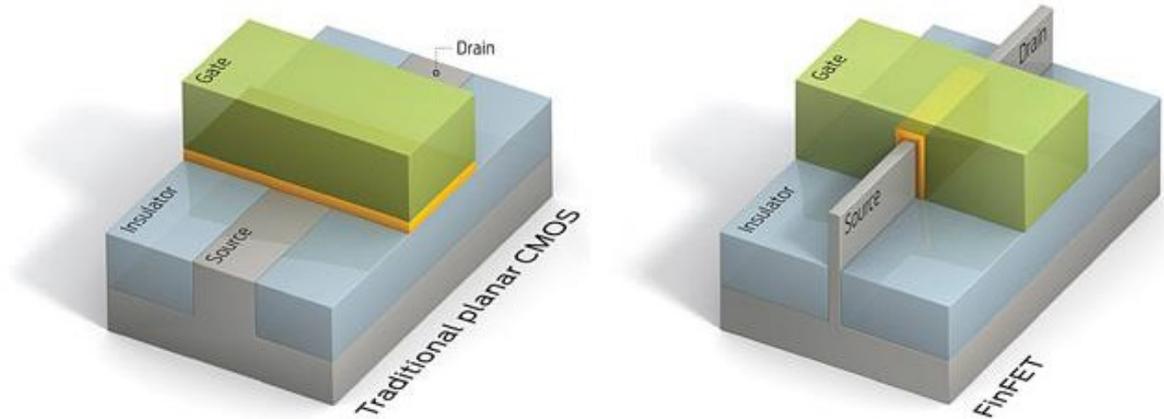
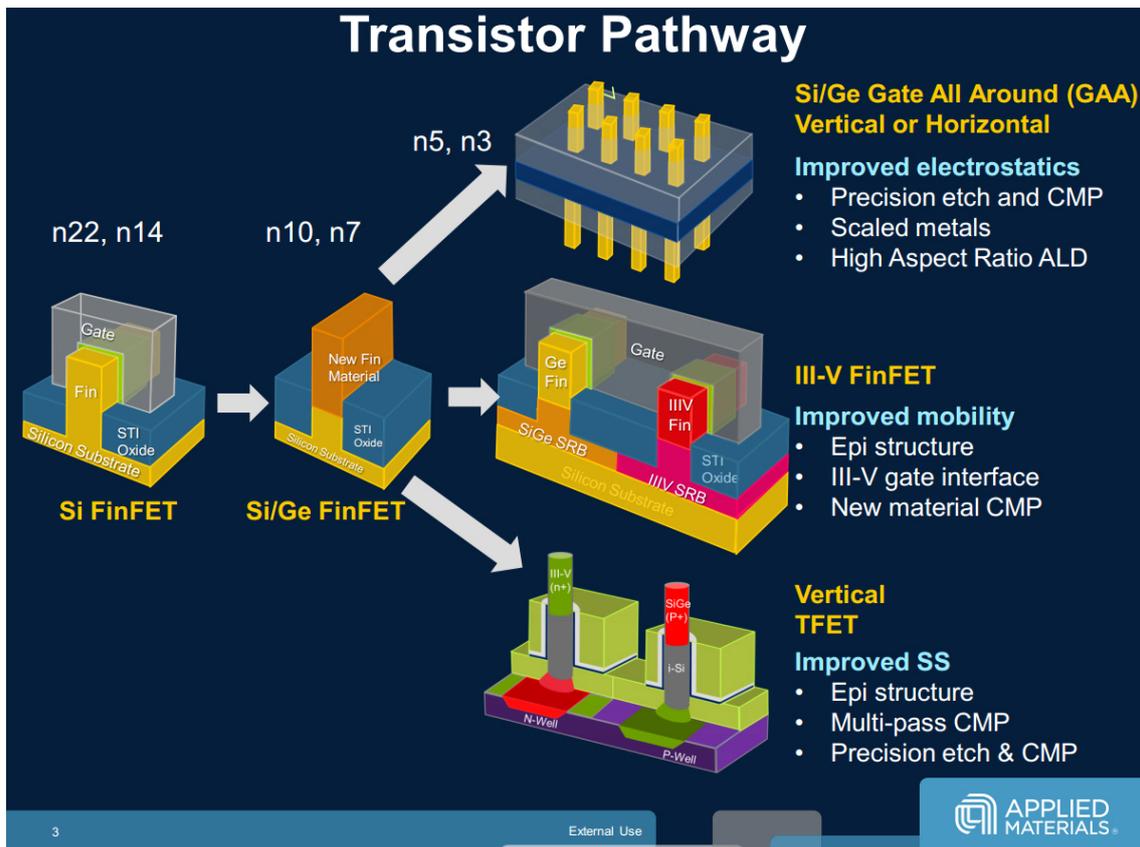
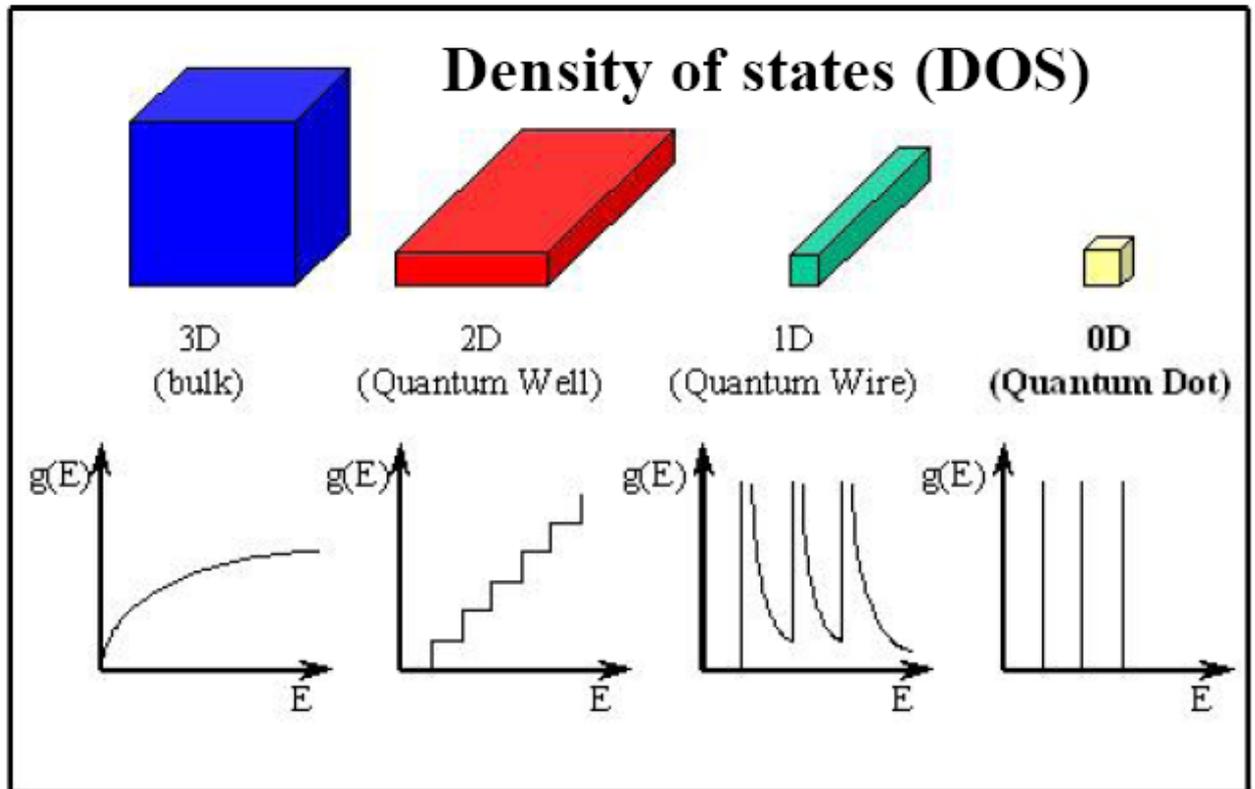
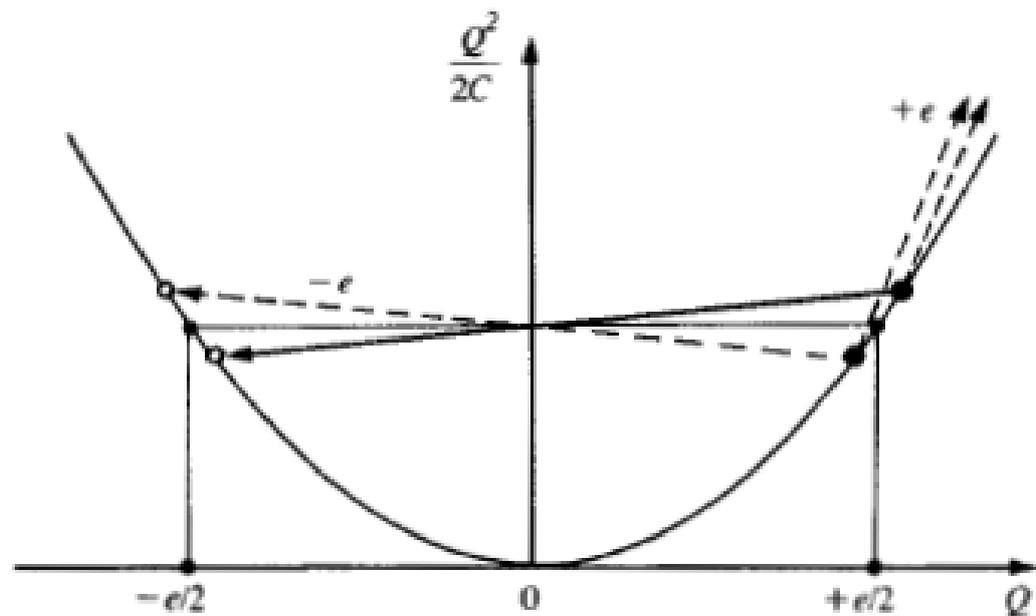


Figure 1: Planar CMOS and FinFET¹





Bloqueio de Coulomb



The principle of the Coulomb blockade

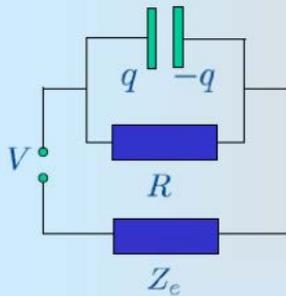


Why R matters?

time delay $\delta t = eR/V$

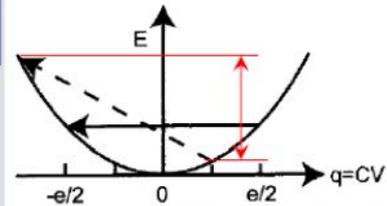
duration $\tau \sim \hbar/eV$

$\delta t \gg \tau \rightarrow R \gg \hbar/e^2$



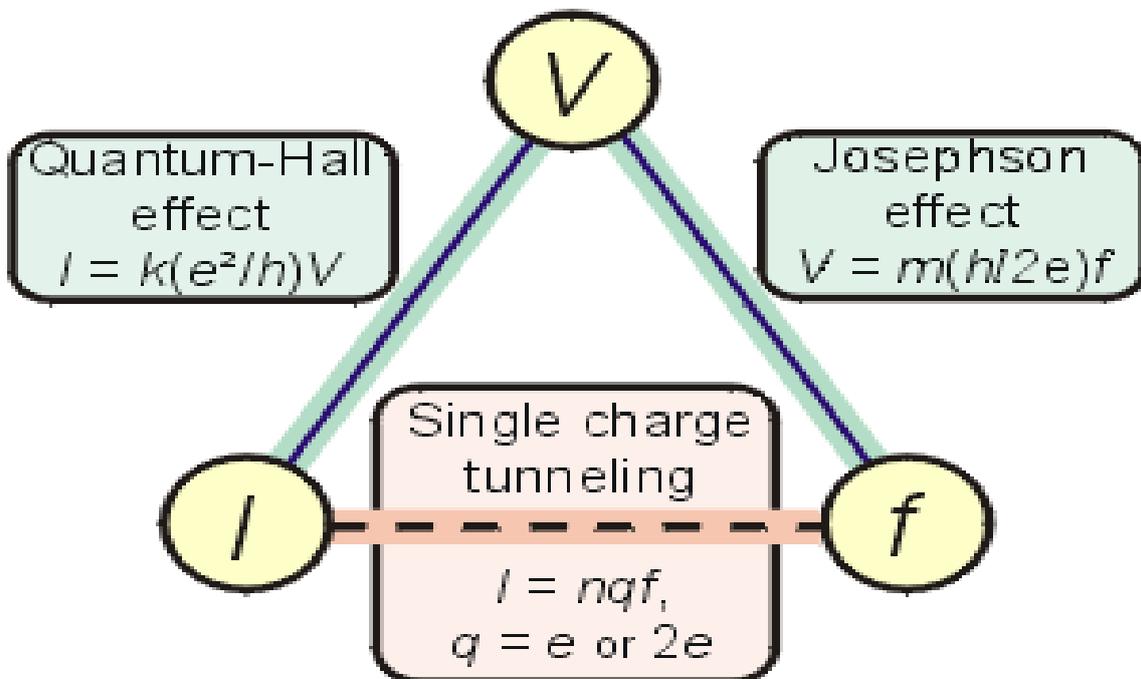
Because of environment capacitances it is difficult to observe CB in single junctions

Energy stored is $q^2/2C$

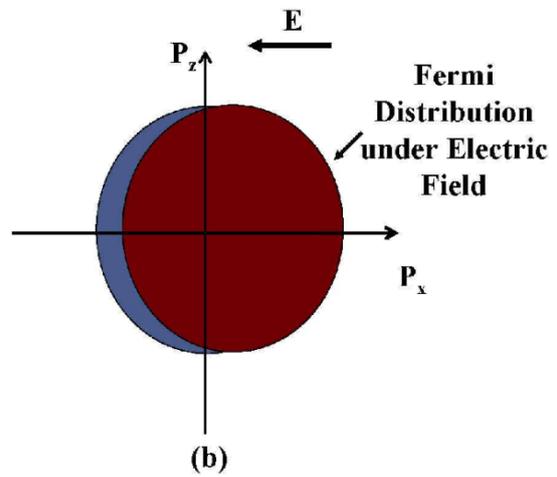
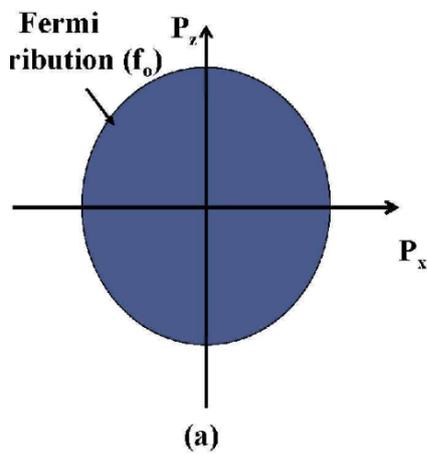
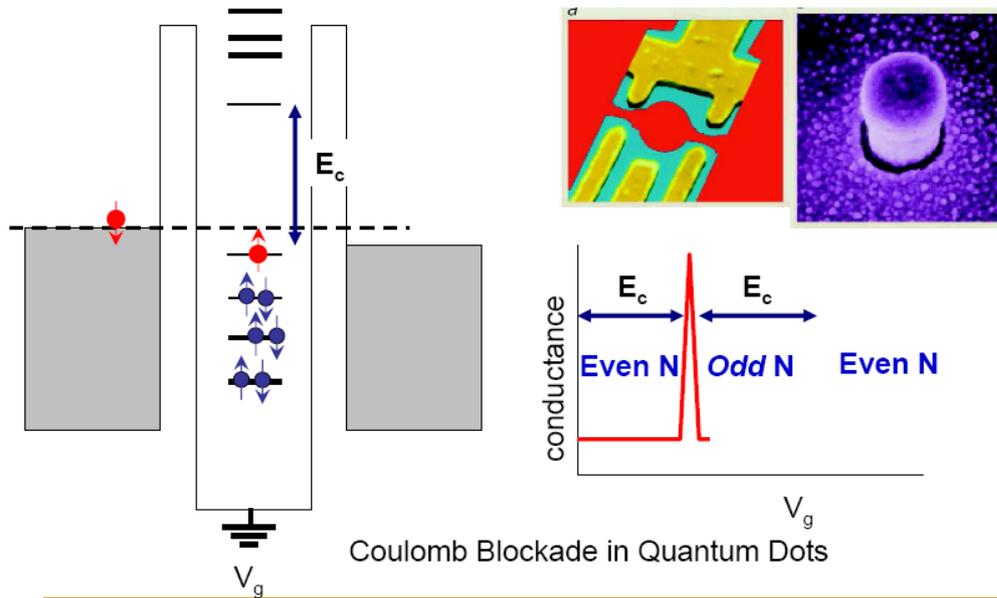


At $|q| < e/2$ the electron tunneling will increase the energy stored in the barrier - one has to pay for the tunneling by the bias voltage

The Metrology Triangle

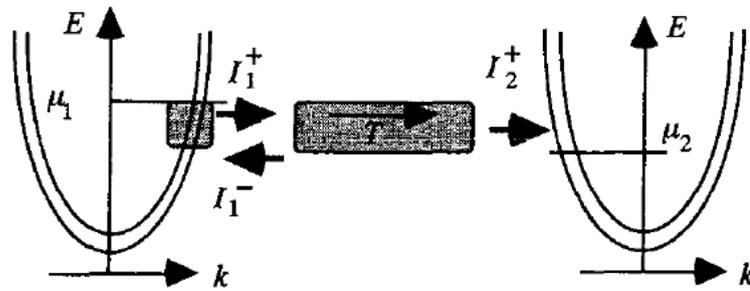
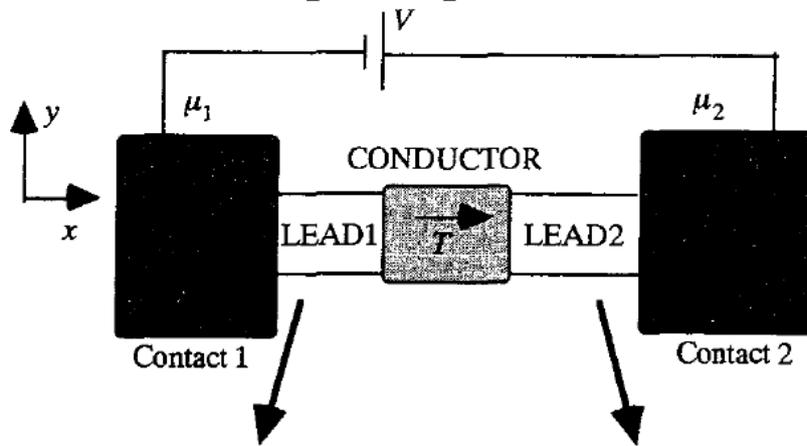


Coulomb Blockade in Quantum Dots



$$\frac{\partial f_v(\mathbf{k})}{\partial t} + \boldsymbol{\Omega} \cdot \nabla f_v(\mathbf{k}) = \left[\frac{\partial f_v(\mathbf{k})}{\partial t} \right]_{sc} + \left[\frac{\partial f_v(\mathbf{k})}{\partial t} \right]_{abs}, \quad (1)$$

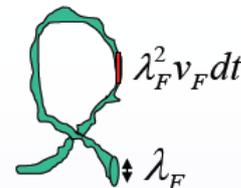
Transporte quântico



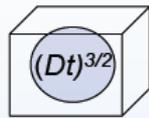
Localização fraca

Different dimensionalities:

The dimensionality of a conductor: $L \leftrightarrow L_\phi(T) \ll \xi$



3D:



$L_\phi < \text{all dimensions}, \xi$

the upper cutoff - τ_ϕ , the loops with $L > L_\phi(T)$ do not contribute to $\Delta\sigma_{WL}$

$$\Delta\sigma_{WL} \propto \int_{\tau}^{\tau_\phi} \frac{\lambda_F^2 v_F}{(Dt)^{3/2}} dt \propto \frac{e^2}{h} \left[\frac{1}{L_\phi(T)} - \text{const} \right]$$

2D:

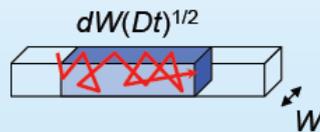
$d < L_\phi \ll \xi$



$$\int_{\tau}^{\tau_\phi} \frac{\lambda_F^2 v_F}{dDt} dt \propto -\frac{e^2}{h} \ln \left[\frac{L_\phi(T)}{l} \right]$$

Quasi-1D:

$d, W < L_\phi \ll \xi$

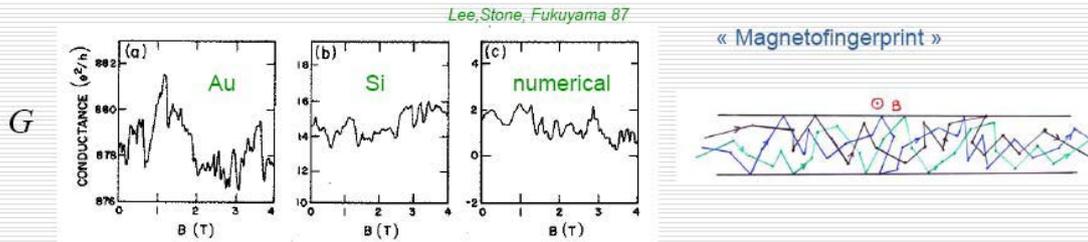


$$\int_{\tau}^{\tau_\phi} \frac{\lambda_F^2 v_F}{dW(Dt)^{1/2}} dt \propto -\frac{e^2}{h} L_\phi(T)$$

Though these QC are small at $L_\phi \ll \xi$, they diverge in low dimensions as T decreases (and L_ϕ increases), and eventually they drive the system into the SL regime.

Universal conductance fluctuations

Reproducible « fluctuations » as a function of an external parameter



The amplitude of fluctuations is universal

$$\frac{h}{e^2} = 25800 \Omega$$

$$\delta G = \sqrt{\delta G^2} = \sqrt{G^2 - \bar{G}^2} \sim \frac{e^2}{h}$$

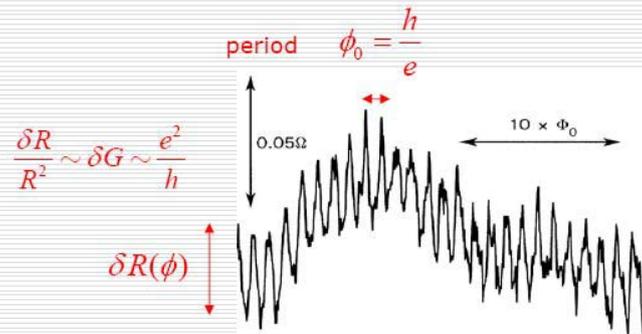
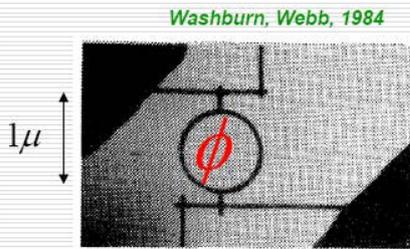
$$\text{if } L \ll L_\phi$$

quantum coherence

In a good metal, $\delta G \ll G$

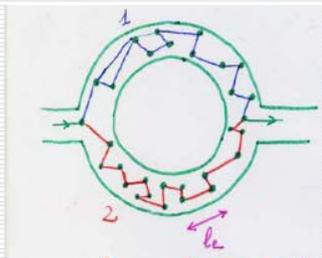
efeito Aharonov-Bohm

Magnetoresistance of a gold wire



$$\delta \varphi_{12}(\phi) = \delta \varphi_{12}(0) + 2\pi \frac{\phi}{\phi_0}$$

PHASE COHERENCE : $L < L_\phi$

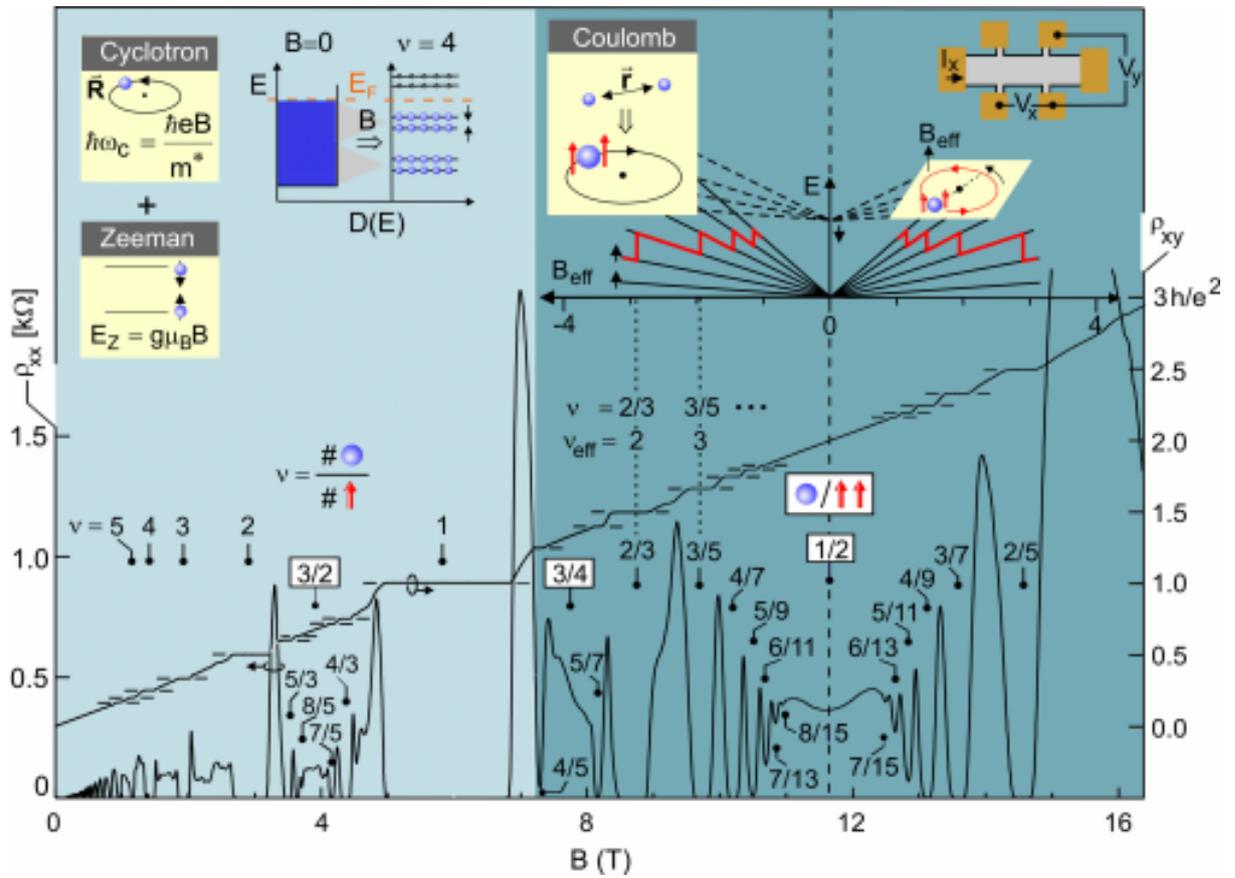
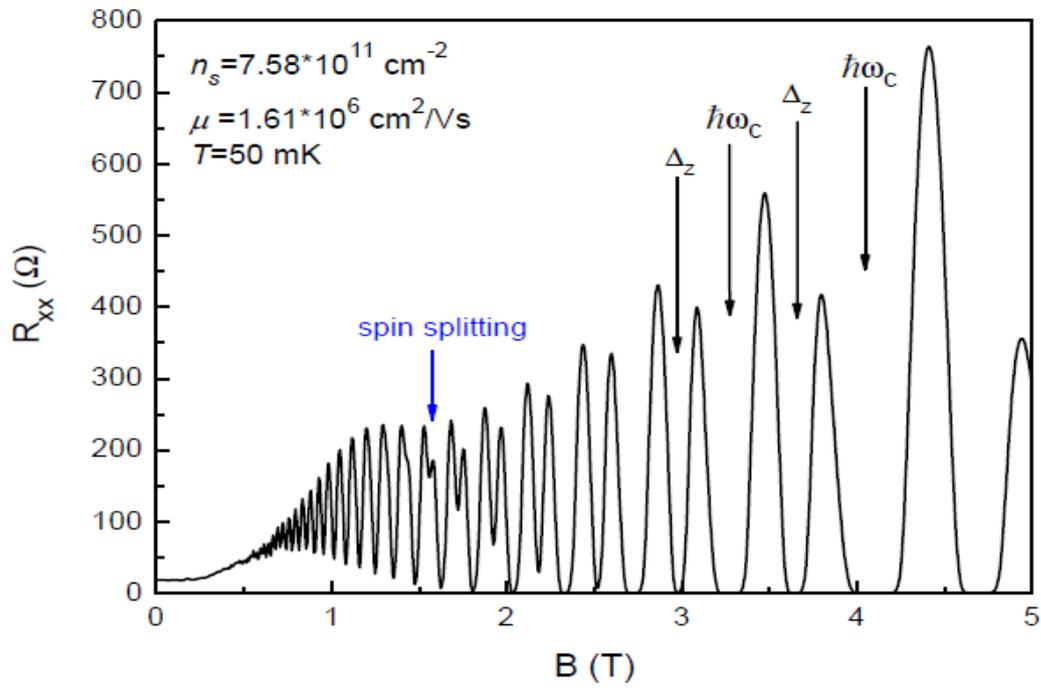


$$L_\phi \text{ phase coherence length } L_\phi \sim 1 \mu\text{m} \quad T \sim 1\text{K} \quad l_e \sim 10\text{nm}$$

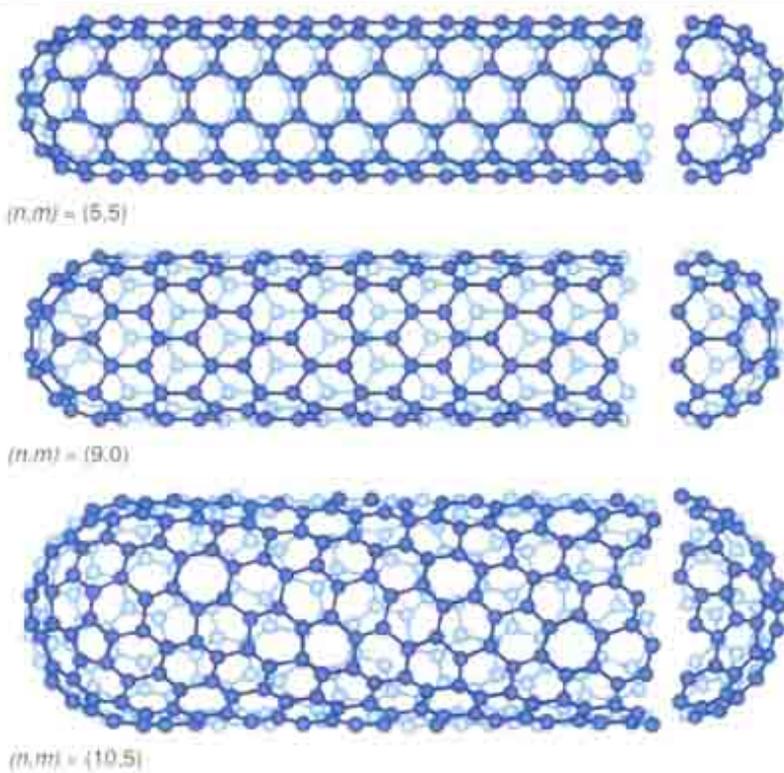
l_e elastic mean free path

$$l_e \ll L < L_\phi(T)$$

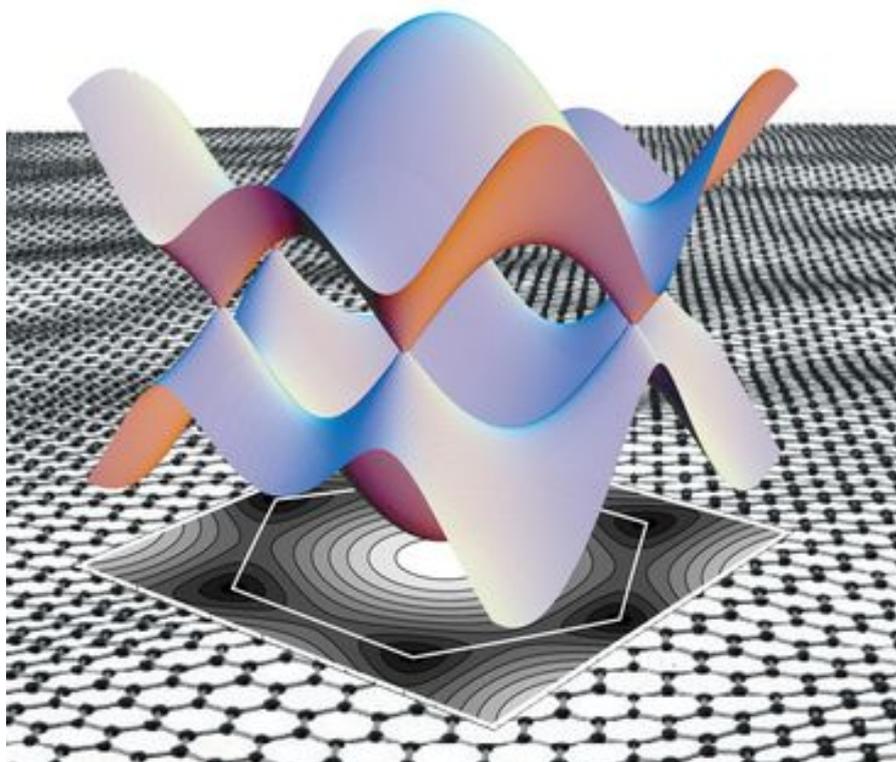
Efeito Hall quântico



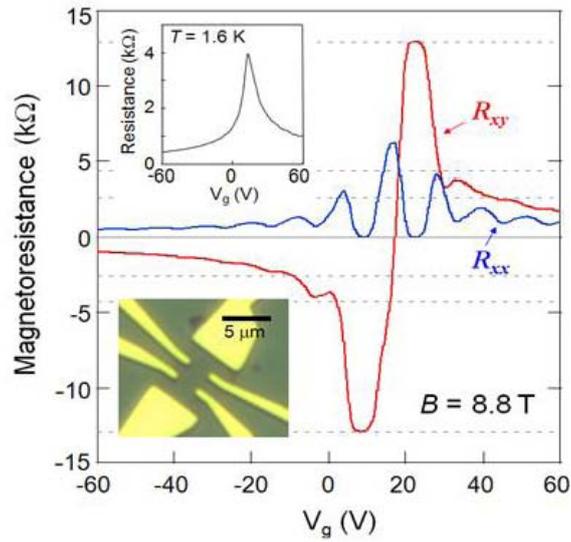
Nanotubos de carbono



Grafeno

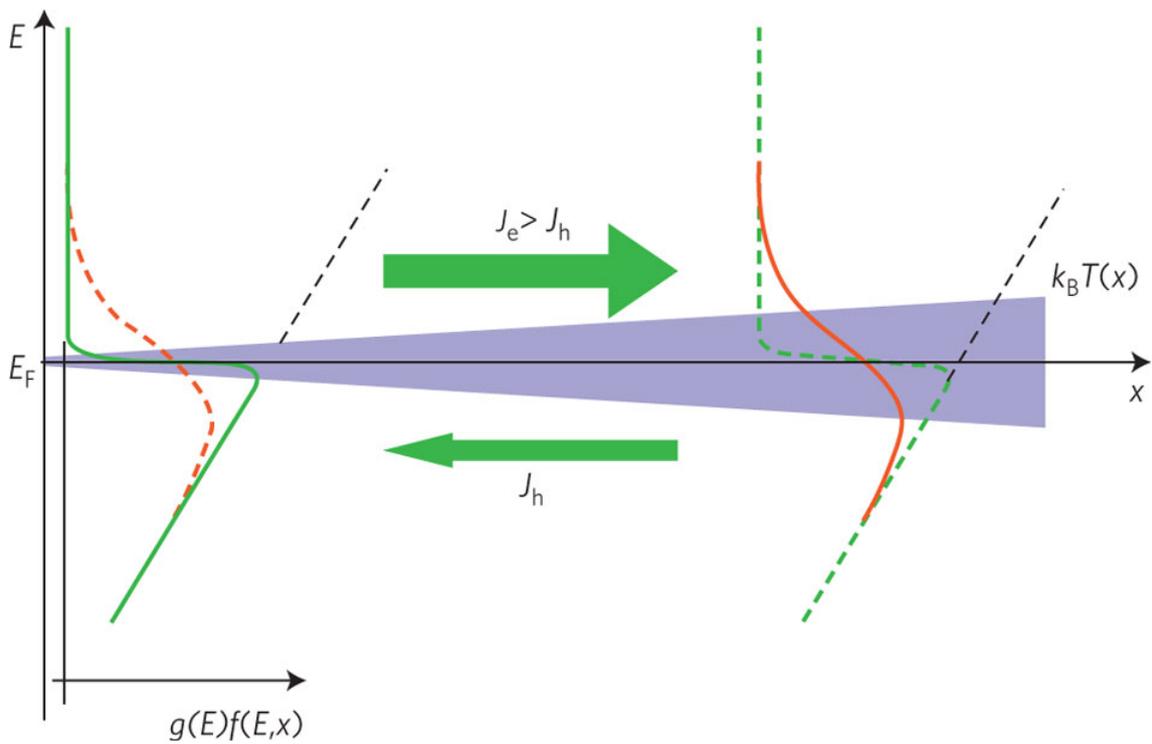


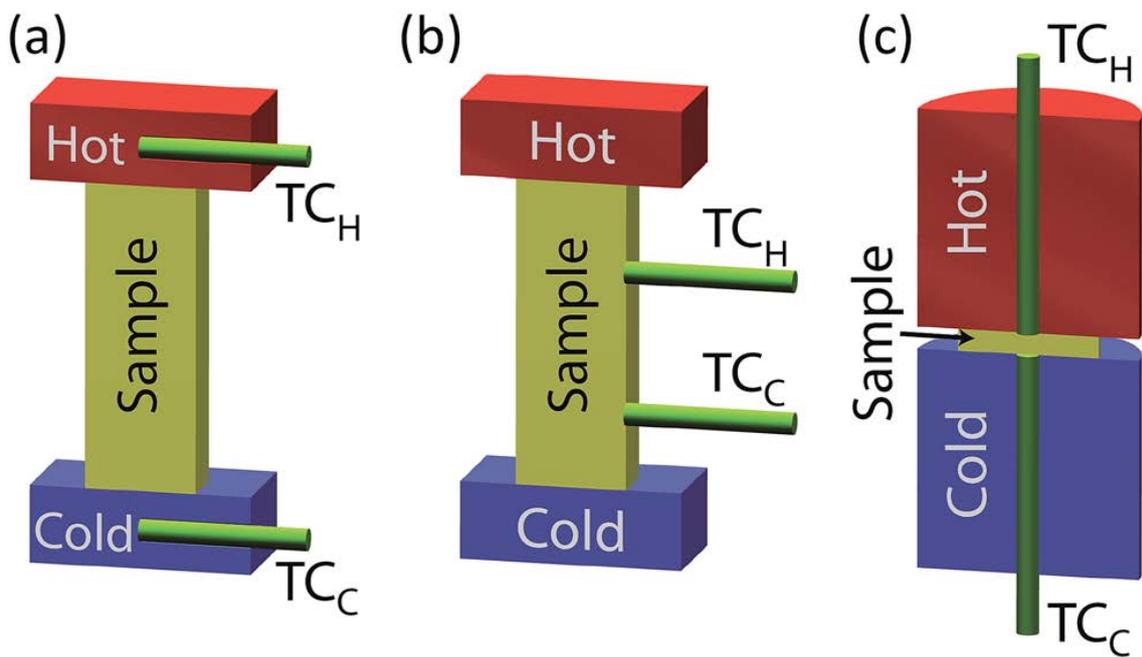
Quantum Hall effect



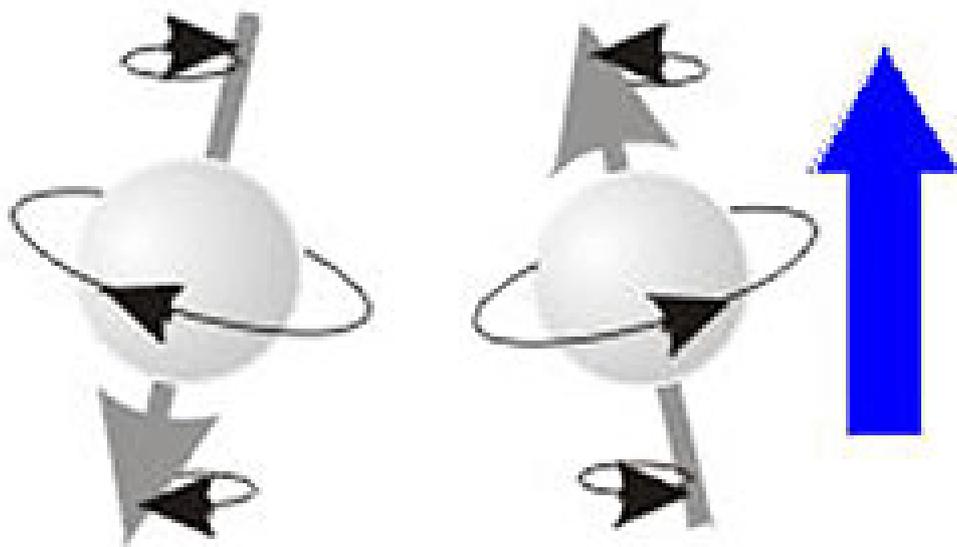
Nature 457, 706 (2009).

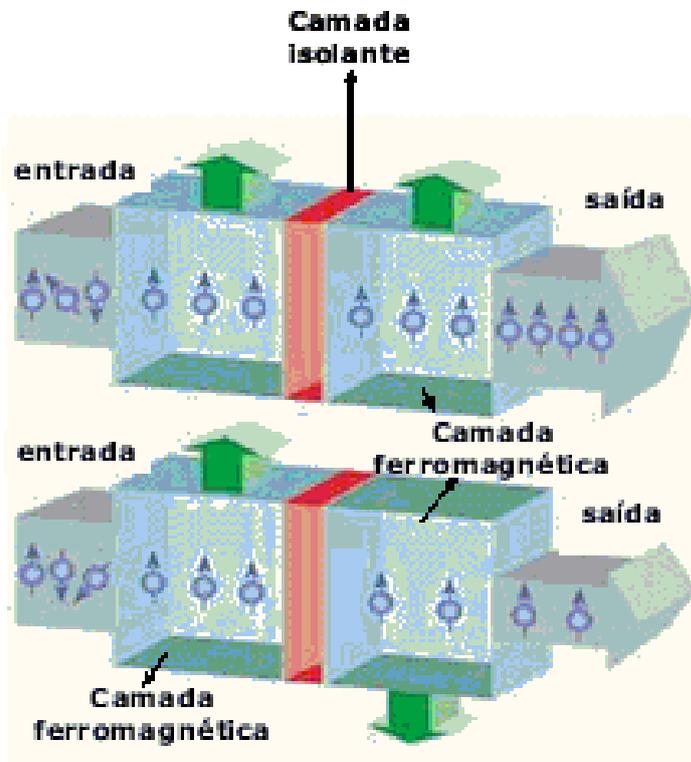
Efeitos termoeletricos



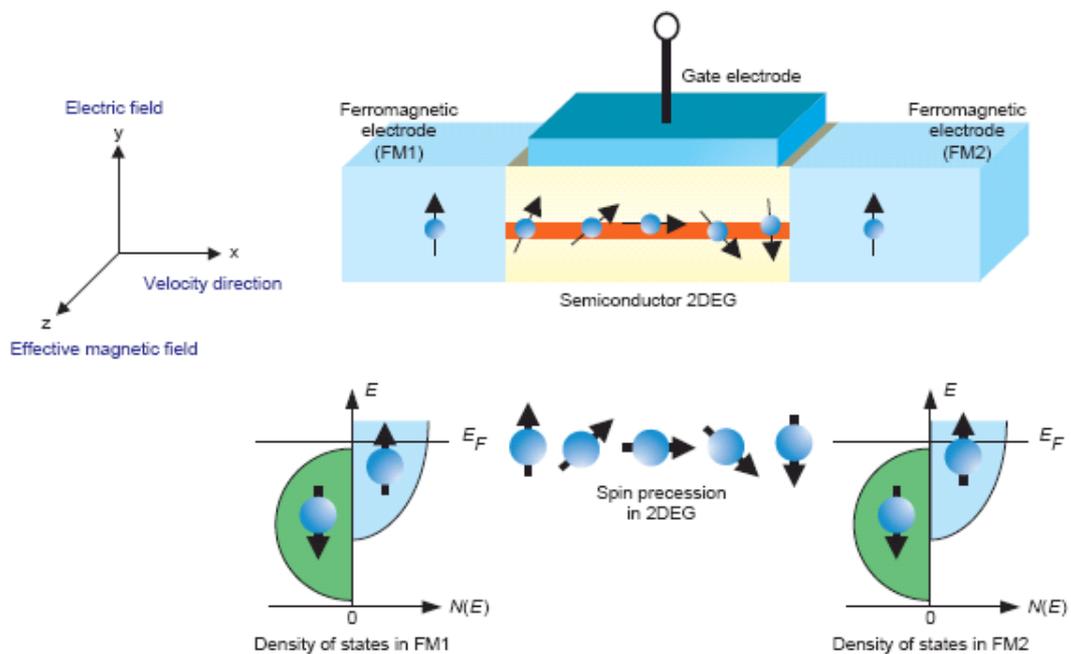


Spintronics





Semiconductor Spintronics



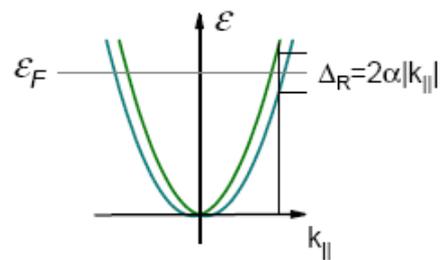
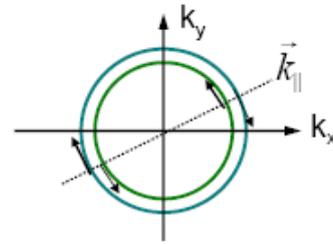
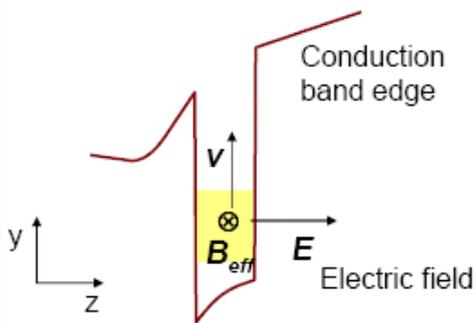
Spin Relaxation

- Dissipation of initial spin state
 - “Spin decoherence”
- The result of fluctuating action in time magnetic fields
 - Effective (not “real”) fields
 - Amplitude, or the precession frequency ω
 - Correlation time, τ_c



Rashba Spin-Orbit Interaction

2D Electron Gas

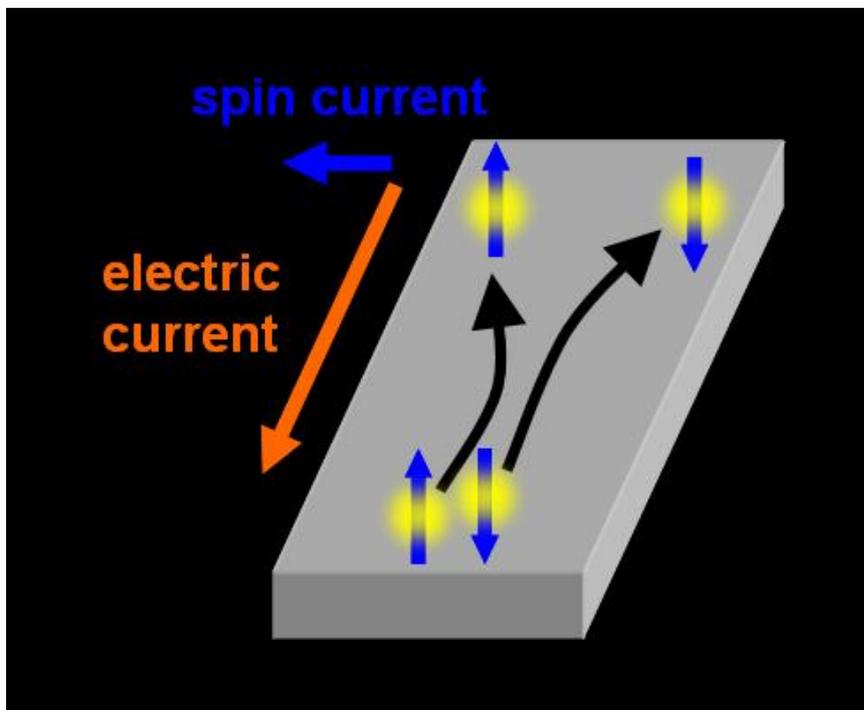


Dispersion relation

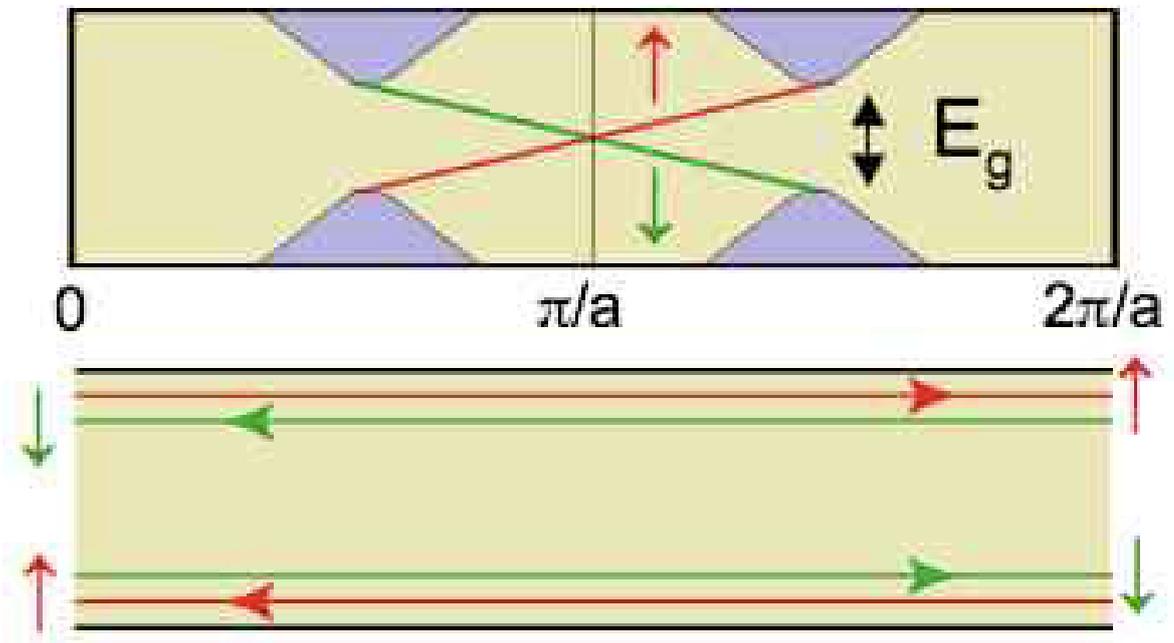
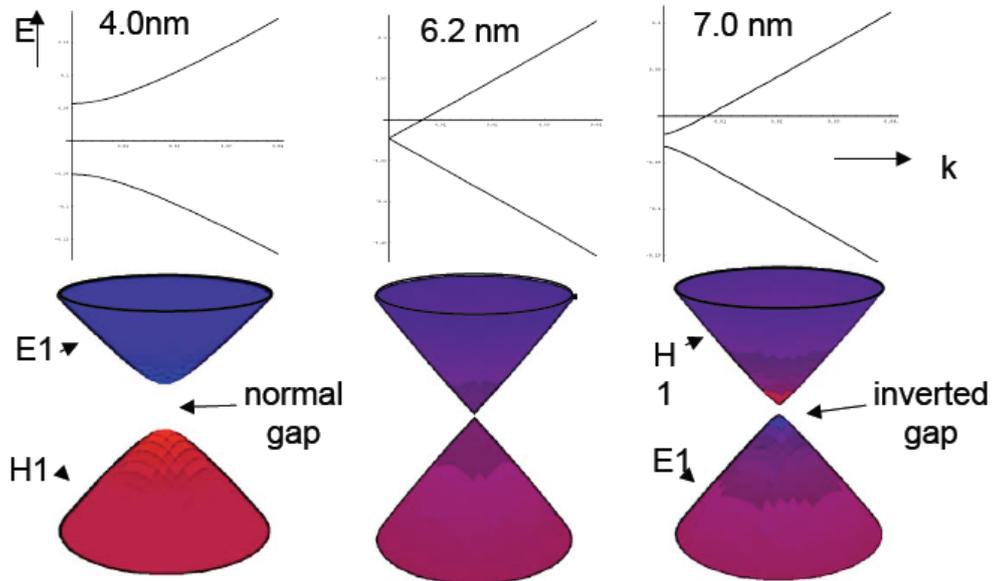
$$\epsilon = \frac{\hbar^2 k_{||}^2}{2m^*} \pm \alpha |\vec{k}_{||}|$$

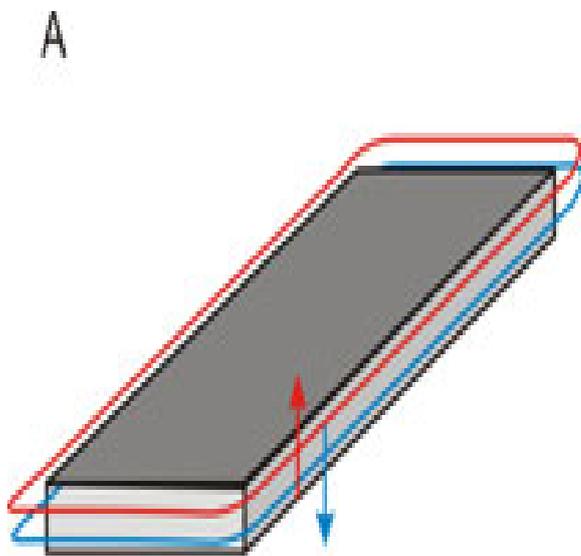
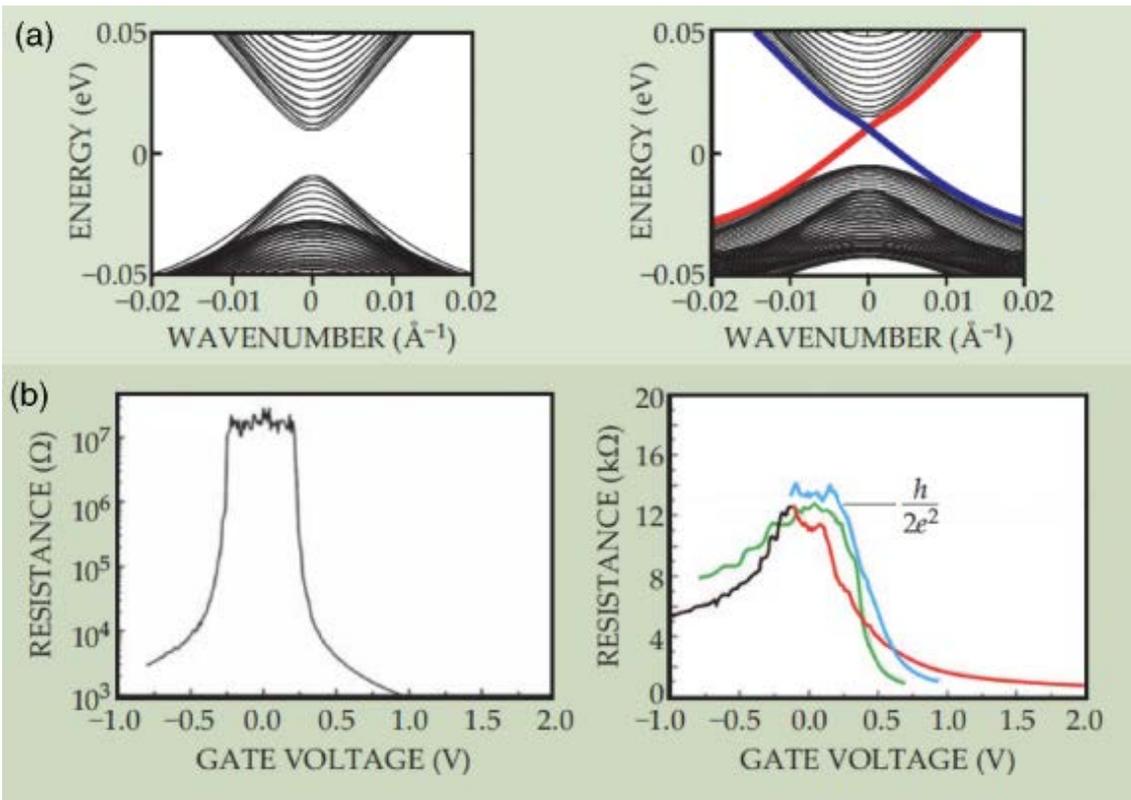
$\vec{k}_{||}$: wavevector in 2D plane

Efeito Hall de spin

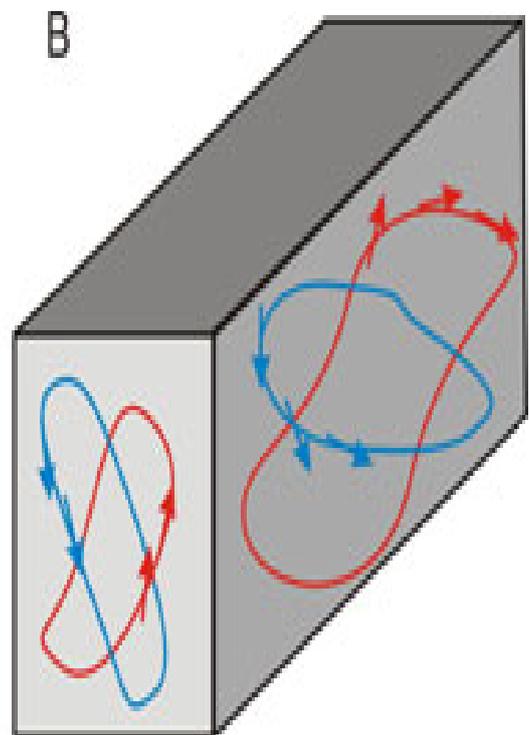


Isolantes topológicos





2D topological insulator



3D topological insulator

