Lectures on the Frontiers of Physics

we.taper

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Abstract

This is notes of lectures given by (assistant/)professors of physics in SUSTC, each talking about their own researches. Since they are generally boring (targeted at first/second year students), I omitted many of them.

Contents

1 By JQ. He.

Thermal electrics

2 By Lang. Chen

Grow thin films.

- Rheed-Assited PLD/MBE. (Ray as an exmination).
- orbital contral of electrons -> orbitronics -> Control of Spin orbital coupling.
- Multiferroics -> multiple order parameters, and the interaction between them. E.g. $BiFeO_3$.
- Ferrotorodicity: Spontaneous Toroidal Momennt. Time and spacial symmetries simultaneous broken.
- What is a iridates $Ir_2(X)O_4$, (e.g. Sr_2RuO_4) exactly in theoretical physics?
- H_2S: 200K superconductor?
- The Double Exchange effect of oxygem -> Half-metal, phase transition.

3 By Alan

Photocatalysis: TiO_2. Hongkong has TiO_2 spurred on the keys.

4 By Li, Huang

- Computational Physics
- Surface Dynamics
- Structural factor from 2D to 3D.
- Finding Order Amid the Chaos. amorphous -> spatially resolved distributed function.
- ?: What is genetically algorithm.

Computational and theoretical studies of Surface dynamics

- Surface atoms is immersed in a very different environment compared with the bulk atoms.
- First-principle calculations
- DFT + LDA -> Conser equation
- Plane wave basis + Ultrasoft pseudopotentials to solve the Conser equation
- Continumm method ?

5 By Junfen, Liu

- electronic transport in mesoscopic systems:
- Spintronics
- Graphene eletronics
- Superconductors etc.

Quantum wire conductiing The conduction channel in quantum wire is quantized, with discrete value of conductance.

- λ_F Fermi wavelength
- L_m Momuntum relaxation length $<-$ impurities.
- L_ϕ Phase relaxation length $<-$ memory of phase, related to energy $\omega = E/\hbar$.
- L Sample length
- Ballistic transport: $L << L_m$ No scattering.
- Diffusive $L > L_m$, scattering, reduced transmission.
- Localization $L_m << L << L_\phi$ -> Prof. Haizhou Lu.
- Classical. (Omitted)

Conductance No back-scattering

$$G = \frac{I}{V} = \frac{2e^2}{h}$$

Landauer formula $G = \frac{2e^2}{h} \cdot T$, T is some coefficient accounting for the back scattering, perhaps the transmission probability. In reality, $G = \sum_{\text{Different channels}} G_i$,

We can turn the G into resisivity:

$$\text{Resistance} = \frac{h}{2e^2} + \frac{h}{2 * e^2}\frac{R}{T}$$

$R + T = 1$

5.1 Resonate Transmission

(Omitted)

5.2 Spintronics

Use the extra freedom of Spin.

Spin field eletroncis: Datta and Das, Appl. Phys. Lett. 56, 665(1990)

GMR: 2007 Nobel prize in Physics.

Hall Effect (Omitted) Spin Hall Effect: S. murakami, et.al. Science 301 1348(2004);

J. Sinova et.al. Phys.Rev.Lett. 92, 126603 (2004). (Omitted)

5.3 Graphene

Carrier -> Relativistic Dirac fermions. **Klein Paradox**

5.4 Josephson Junction

A phase difference could conduct electricity in Superconductors.

6 By Haizhou, Lu

6.1 Quantum Anomalous Hall Effect

Requires strong magnetic field: ≈ 10 Tesla.

Anomalous Hall Effect: Without magnetic field. $R_H = R_0 B + R_A M$ where M is the magnetic susceptibility. Two-factors: SO coupling. Spin-dependent Hall Effect.

An excellent illustrations is found in [1]:

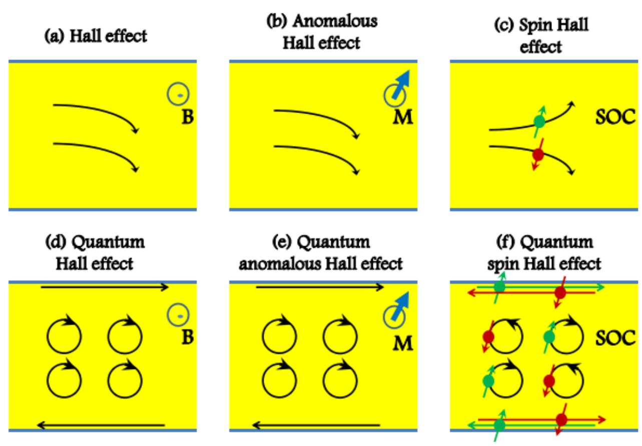

FIG. 1. (Color online) Six members in the family of Hall effect. (a) Hall effect; (b) Anomalous Hall effect; (c) Spin Hall effect; (d) Quantum Hall effect; (e) Quantum anomalous Hall effect; and (f) Quantum spin Hall effect.

Figure 1: Illustration

7 By Kedong Wang

Tunneling current $I \propto Ve^{-2kz}$, where $k = \frac{\sqrt{2m\phi}}{\hbar}$, ϕ is the Work function. I is very sensitive to the distance z.

7.1 Work function

ϕ characterize the obstruction that prevents electron from escaping the sample.

8 By Mingyuan Hunag

Not insterested.

9 By Wenkang Wong

9.1 Non-clone Theorem

We can easily see that there is no universal copy operators in Quantum Mechanics.

Proof. We proove it by contradiction. Let U be the copy operator. By definition, we have

$$U|\psi\rangle|0\rangle = |\psi\rangle|\psi\rangle$$

For any $|\psi\rangle$. Then, let try copying the state $|\psi\rangle = |0\rangle + |1\rangle$. We have

$$\begin{aligned}(|0\rangle + |1\rangle)(|0\rangle + |1\rangle) &= U(|0\rangle + |1\rangle)|0\rangle \\ &= U(|0\rangle|0\rangle + |1\rangle|0\rangle) \\ &= |0\rangle|0\rangle + |1\rangle|1\rangle\end{aligned}$$

This is a contradiction. □

Remark 9.1. *We assume that the copier is universal. This might seems to be too strong. However, if we assume that the copyer only works for certain states $|\phi\rangle$, then with the knowledge of these certain states, we could in principle create an exact copy of these states. This copy ,in the sense of another instance of the same object, of original state should not be considered to be an copied version of the original state.*

10 By Liyuan Zhang

Not insterested.

11 License

References

[1] `http://arxiv.org/abs/1508.07106v1`