Electrons in Solids: Fundamentals and Experiments

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ECTS credits: 6

Language of instruction: English

Examination: written exam (60%), laboratory reports (40%)

Description:
The main goals of this course are to cover the fundamentals of the electronic properties of solids, and to provide the conceptual basis of selected modern experimental techniques used to investigate such properties. The course will be closely connected with the formalisms and topics introduced in the "Theory of Condensed Matter" lectures. We will illustrate the essential concepts and experimental tools with a few representative research subjects of current interest: strongly correlated materials, high-temperature superconductivity, low-dimensional electronic systems, topological systems, etc. In addition, practical sessions in the lab or at Synchrotron SOLEIL will provide hands-on experience on the themes and materials discussed in the lectures.

Overview of the contents of the course:

1. **Free electrons: joys and pitfalls of the naivest approach.** Elementary concepts: Sommerfeld theory, density of states, electronic specific heat, paramagnetism.
2. **Direct and reciprocal lattices: breaking symmetries of free empty space is funnier!** Concepts, X-ray and neutron diffraction, phonons (dispersion, interaction with electrons).
3. **Bloch's theorem: consequences of living in a periodic world.** Periodicity and emergence of energy bands in the single-electron approximation.
4. **Tight-binding approach: hop between neighbors and create your own band.** Paradigmatic examples: cuprates, graphene.
5. **Surface effects: the restaurant at the edge of the Universe.** Surface states, breaking of inversion symmetry, Rashba effect.
6. **Basics of superconductivity: all together now!** Electronic structure of a BCS superconductor, macroscopic consequences: specific heat, optical gap.
7. **Elements of topology and strong spin-orbit coupling.**
8. **Experimental techniques.**
   a. Reminders of light-matter interaction.
   b. X-ray diffraction, elastic and inelastic scattering
   c. STM
   d. Quantum oscillations
   e. ARPES: electronic band structure and many-body correlations visualized.
   f. Dynamical conductivity.