ADVANCED EXPERIMENTAL PHYSICS

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Subject fundamentals

The course provides theoretical and experimental tools for understanding the properties of solid-state quantum systems with a huge number of particles. Part of the topics (crystal lattice structure both in real and reciprocal space, electronic bands and phonons, electric transport and Hall effect, superconductivity) are also subject to direct investigation by specific laboratory activities carried out personally by students and/or by advanced computational tools for their analysis or prediction, including Density Functional Theory.

Contents

1. The variables of experimental physics and their control: temperature (cryogenic, high temperatures), pressure (vacuum, high pressures), electromagnetic shielding, high electric and magnetic fields.
2. Scattering phenomena from atomic structures for particles and radiation: elastic scattering of X-rays, electrons and neutrons. Real-space visualization of structures (atomic or not): SEM, TEM, FIB, AFM and STM. Inelastic scattering and determination of the phonon modes: photons in the visible range (Raman), X-rays and neutrons.
3. Experimental determination of the electronic bands and the Fermi surface: De Haas-van Alphen effect and angle-resolved photoemission spectroscopy (ARPES). The ab-initio calculation of the electronic and phonon properties by using Density Functional Theory (DFT).
4. Diffusive, ballistic and quantum transport phenomena: Allen theory of resistivity and spectral function of electron-phonon interaction, Andreev reflection and determination of the superconducting gap, weak localization, Kondo effect.
5. Advanced experiments of Solid State Physics with the goal of a coordinated and integrated study of some normal metallic, superconducting or semiconducting materials: X-ray spectroscopy, SEM and AFM microscopy, resistivity as a function of temperature, Andreev reflection spectroscopy, Hall effect measurements, magnetotransport, transport under electrochemical gating, etc.

Expected learning outcomes

The experimental activity described at point 5 of the previous section has the aim to be a coordinated and integrated study over some test materials which, starting from the original sample, will arrive to determine the main variables that describe the electron and phonon systems as well as their interaction, thereby enabling a comparison with ab-initio calculations of the same properties obtained by the DFT technique. As a consequence the main expected outcomes of the course are the ability to apply experimental and analytical tools to an integrated study of the key quantum phenomena in condensed matter physics as well as the development of specific skills for the scientific teamwork activity.

Assessment and grading criteria

The evaluation of a detailed final group report on the experimental measurements, their analysis and ab-initio calculations and a subsequent individual discussion will contribute to the final grade.