This course is about the use of optical spectroscopy for the investigation of various solids, but it is also a review of some of the exciting concepts in condensed matter physics.

First we will discuss the fundamental interactions between the electromagnetic radiation and condensed matter. We will then consider the simplest metals, semiconductors and insulators, and compare experiments and calculations of their optical properties. A large part of the course will be the discussion of electronic systems with various interactions, leading to strong electron correlations (see details below). In each case, there will be a quick introduction to the relevant theoretical model, and then the actual optical experiments are discussed. Finally, we will discuss experimental methods, we dissect a working FT-IR spectrometer, and we will possibly visit Brookhaven Lab.

There is no single recommended book. "Solid State Spectroscopy" (Springer, 1998) by Hans Kuzmany is helpful in terms of the experimental techniques. "Solid State Physics: Problems and Solutions" (Wiley, 1996) by L. Mihály (me) and M.C. Martin (my former Ph.D. student, currently staff scientist at the Advanced Light Source, Berkeley) has a relevant Chapter. Most of the discussions will be based on papers published in Phys. Rev. B, Phys. Rev. Letters and other journals. Critical reading of those publications will be part of this course.

Grading is based on about 5 homeworks (50%) and a final exam (50%).

- A quick summary of basic E&M (Lecture 1)
  - Maxwell equations in free space and medium
  - Interfaces
  - Kramers-Kronig relations (Lecture 2)
- Classical models for metals and insulators
  - Drude model
  - Oscillator model
- Beyond classical: Band electrons and Boltzmann equation (Lecture 3)
  - Direct and indirect gap
  - Semi-classical calculation in a two dimensional band
  - Doped silicon
- Metal-insulator transitions (Lecture 4)
  - Optical conductivity in the Hubbard model
  - Spin and charge density waves
  - Polycrystalline
- Superconductivity (Lecture 5)
  - BCS theory and experiment
  - Beyond weak coupling: the Eliashberg theory and the Allen formula
- High Tc superconductivity
  - Experimental search for the gap
  - High Tc phase diagram
- Heavy Fermions (Lecture 6)
  - Anderson Hamiltonian and the periodic Anderson model
  - Kondo alloys
  - Heavy Fermions
- Colossal magnetoresistance: the physics of perovskites
- Optical spectroscopy methods (Lecture 7)
  - Coherence and interference
  - Light sources
  - NSLS: an example for the synchrotron source
  - Taking light from one place to another (Lecture 8)
  - Detecting light
- Comparing spectrometers: intensity, brightness and throughput
- The operation of an FT-IR spectrometer

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