

Ph118c (2014 -- 2015) Course Information & Syllabus “Physics of Measurement”

INSTRUCTOR: Professor Nai-Chang Yeh
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SCHEDULE: Tuesday/Thursday 2:30 – 4:00 PM

LOCATION: West Bridge 57

INFORMATION: http://www.its.caltech.edu/~yehgroup/Ph118c_2014-2015

The third term of Ph118 will focus on the physical principles and applications of several important measurement techniques to modern condensed matter physics research. The course will begin with an introduction of the concept of self-energy and Green function techniques in the descriptions of many-body interactions. Several representative experimental techniques for investigating important physical properties of many-body systems will be discussed, followed by explicit examples for their applications to condensed matter physics research. The measurement techniques will include scanning tunneling microscopy/spectroscopy (STM/STS), angle-resolved photoemission spectroscopy (ARPES), optical measurements, and thermodynamic and electrical transport measurements. Students enrolled in the course will be given reading assignments and a few optional problem sets for their own practice. Each student will be required to give a presentation to the class by choosing a topic among the assigned readings in the end of the term. The course will be graded pass/fail only.

I. Introduction: Green function techniques & the applications to many-body systems.

- Basic properties of Green functions.
- The physical meanings of Green functions.
- Relating Green functions to physical observables.
- Diagrammatic expansions of Green functions; self-energies and Dyson's equation.

II. Scanning Tunneling Microscopy/Spectroscopy (STM/STS) and Related Technology

- Overview of the operation principles of STM/STS.
- Applications to surface science research.
- Applications to condensed matter physics research.
- Applications to high-temperature superconductivity.
- Related scanning probe technology: spin-polarized STM (SP-STM), and ballistic electron emission microscopy (BEEM).

III. Angle-Resolved Photoemission Spectroscopy (ARPES)

- Overview of the operation principles of ARPES.
- Applications of ARPES to determining standard electronic bandstructures.

- Applications of ARPES to studies of pseudogap phenomena in high-temperature superconductors.
- Applications of ARPES to studies of topological insulators.

IV. Optical Measurements

- Operation principles of various optical measurement techniques.
- Applications of infrared and Raman spectroscopy.
- Applications of optical conductivity measurements.

V. Thermodynamic and electrical transport measurements

- Overview of the principles of various thermodynamic measurement techniques.
- Overview of electrical transport measurements.
- Applications of thermodynamic measurements to the studies of different types of phase transitions.
- Application of electrical transport measurements to the studies of Fermi surface properties of condensed matter systems.
- Applications of electrical transport measurements to the quantum Hall, fractional quantum Hall, quantum spin Hall, anomalous Hall and quantized anomalous Hall effects.
- Applications of electrical transport measurements to the studies of localization.

Reference Books:

1. “*Scanning Probe Microscopy and Spectroscopy – Methods and Applications*”, R. Weisendanger, Cambridge University Press (1994). [ISBN 0-521-42847-5]
2. “*Quantum Theory of Many-Particle Systems*”, A. L. Fetter and J. D. Walecka, Dover Publications, Inc. (2003). [ISBN: 0-486-42827-3]
3. “*Quantum Theory of Solids*”, C. Kittel, John Wiley & Sons, Inc. (1987). [ISBN: 0-471-62412-8 (pbk.)]
4. “*Quantum Field Theory of Many-Body Systems*”, X.-G. Wen, Oxford University Press (2004). [ISBN: 0-19-853094-3]