Ph118c (2015 -- 2016) Course Information & Syllabus "Physics of Measurement"

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

LOCATION: Downs 107

INFORMATION: http://www.its.caltech.edu/~yehgroup/Ph118c_2015-2016

The third term of Ph118 will focus on the physical principles and applications of representative measurement techniques to modern condensed matter physics research. The course will begin with an introduction of the concept and applications 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) and other scanning probe microscopy (SPM), angle-resolved photoemission spectroscopy (ARPES), optical measurements, 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.

- Overview of Green function techniques for many-body physics.
- 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.
- Other scanning probe technology: spin-polarized STM (SP-STM), atomic force microscopy (AFM), ballistic electron emission microscopy (BEEM), near-field scanning optical microscopy (NSOM), and hybrid scanning probe microscopy.

III. Angle-Resolved Photoemssion 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

- Macroscopic theory of optical properties.
- Microscopic theory for dispersion and absorption.
- Photon-phonon interactions.
- Interband transitions and excitons.
- Photon interactions with electrons in good metals – Optical conductivity measurements.
- Applications of infrared and Raman spectroscopy.

V. Electrical Transport Measurements

- Overview of electrical transport measurements.
- 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.*

(*Optional if time permits.)

Reference Books:

1. "*Principles of the theory of Solids*", J. M. Ziman, Cambridge University Press (1972). [ISBN 0-521-29733-8]

2. "*Quantum Theory of Solids*", C. Kittel, John Wiley & Sons, Inc. (1987). [ISBN: 0-471-62412-8 (pbk.)]

3. "*Scanning Probe Microscopy and Spectroscopy – Methods and Applications*", R. Weisendanger, Cambridge University Press (1994). [ISBN 0-521-42847-5]

4. "*Quantum Theory of Many-Particle Systems*", A. L. Fetter and J. D. Walecka, Dover Publications, Inc. (2003). [ISBN: 0-486-42827-3]