Pittsburgh University **Physics 3101 (11241)** **Fall 2014**

Special topics – Atomic, Molecular and Optical physics

Instructor: David Pekker
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Class meets: Tuesday/Thursday 11-12:15, 219 Allen Hall
Office hours: By appointment

Grading: Grades will be based on homework (75%) and final project (25%)

Course description:
This course will focus on the recent progress in realizing many-body physics in the setting of atomic, molecular and optical (AMO) experiments. Topics to be covered will include atom trapping, Bose-Einstein condensation, Feshbach resonances, the BEC-BCS crossover, optical lattices, and low-dimensional physics. The course will highlight the unique features of AMO systems such as the possibility to study isolated quantum many-body systems and their dynamics.

Prerequisites:
The course will assume knowledge of quantum mechanics, statistical physics and condensed matter physics.

Homework:
For the first half of the class homework will consist of problem sets that will be due every two weeks. For the second half homework will consist of writing a one-page summary of a recently published research article, also due every two weeks.

Final project:
Final project will be a 30-minute presentation to the class about a topic chosen by the student. The presentation should cover one or several recently published research papers, with the aim of informing the class about the subject described in the papers. Please see me about choosing a topic by end of October.

Tentative list of topics to be covered:
(1) Intro to BECs, interaction of atoms with light
(2) Atom trapping with optical molasses, magneto-optical traps, magnetic traps, and dipole traps
(3) BECs I: principals of evaporative cooling, superfluidity & Bogoliubov theory of weakly interacting atoms
(4) BECs II: time of flight "momentum space" imaging, excitations in trap, atom "lasers"
(5) Optical lattices, Hubbard model, Mott-SF transition
(6) Quantum gas microscope, single site imaging, Higgs mode
(7) Feshbach resonance — single channel model
(8) The BEC-BCS crossover
(9) Modulation spectroscopy: Pairing gap & shiba states
(10) Double occupancies in cold fermions — birth and death
(11) Stability of the Fermi sea following a quench to strong interactions
(12) Many-body localization — a theoretical perspective on the breakdown of thermalization
(13) Topological band structures & Bloch oscillations
(14) Periodic driving, synthetic gauge fields & Floquet topological matter
(15) A crash course on the renormalization group (using OPE instead of k-space)
(16) Superfluidity in two dimensions — the Berezinskii-Kosterlitz-Thouless transition
(17) Ramps and quenches across QCPs: universal dynamics
(18) Simulating the electronic Hubbard model I: Hubbard model physics and current efforts
(19) Simulating the electronic Hubbard model II: Origin of HTC and plaquette model
(20) Luttinger-Tomonaga liquid theory of 1D systems
(21) Driving & Quenching of 1D systems
(22) String order parameter, Bloch lab
(23) Introduction to polaritons & polariton condensation