Physics 1415 Fall 2017
Quantum Physics at the Nanoscale

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NFCF (cleanroom):
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Summary : This is an advanced laboratory course focused on the experiments first performed in the XXI century in the field of quantum computing, nanoscience and mesoscopic physics. The class will closely mimic a real physics research project, and thus it can be used as a first undergraduate research experience. This is an inquiry-based laboratory course without a laboratory manual to follow. Students will work in groups of up to five, each group will pursue a single project during the entire semester. Projects will be chosen by the students together with the instructor during the first week. During this pilot offering of the course, the project chosen by the instructor is the fabrication and experimental investigation of a semiconductor nanowire-based quantum device.

The project will follow three main stages. Stage 1 will be based at the Nanofabrication and Characterization Facility (NFCF, http://nano.pitt.edu/) at the sub-basement level of Benedum Hall. At this facility often referred to as 'the cleanroom', students will learn methods of nanofabrication, receive training on equipment such as an electron beam microscope, electron beam evaporator, optical lithography tools; Students will fabricate their own nanoscale samples for their project. Stage 2 will involve measurements of samples created during stage 2 at the instructor's laboratory in the Old Engineering Hall (room B05) equipped with the nanowire positioning setup, a wirebonder, and the low-temperature electrical transport measurement setup. Stage 3 will be dedicated to the analysis of the gathered data, possibly including numerical simulations using a python-based KWANT code, and the writing of a final report.

Learning Goals: A student is expected to learn how to perform optical lithography, position semiconductor nanowires on silicon substrates, image nanowire devices in an optical and scanning electron microscopes, design electrical contacts to semiconductor nanowires, evaporate thin films of metal, measure electrical conductivity in nanowire devices at room temperature, measure gate effect in nanowire devices at liquid helium temperature, model a nanowire device using KWANT, write a Physical-review style paper summarizing the project.

Pre-requisites: PHYS 174 (or 475), PHYS 175 (or 476), PHYS 219 (or 520)

Textbook : None required. Textbooks, Review Articles and Lecture Notes will be provided based on the chosen experiment.

Laboratory : Time in various laboratories will be scheduled weekly based on the team's progress and to accommodate the schedules of all team members. Thus, course hours may deviate from the hours listed in the Student Center. At NFCF, students will first attend the orientation and a safety session, after which they will attend a number of training sessions for each piece of equipment and process to be used in the course. Training will be provided by NFCF staff. Training will be followed by hands-on sessions supervised by the TA. At Physics labs, students will first attend safety and equipment orientation followed by measurement sessions supervised by the instructor, TA and graduate students in the lab. Weekly commitment will be commensurate with the number of credits for the course. Spending additional time in the lab and the cleanroom will be welcome.

Lecture: Students will meet with the instructor and the TA once a week for 1 hour during a lecture that will be organized as a research group meeting. During the meeting, students will present their progress over the past week in short 5 minute presentations. The instructor will explain concepts important for the activities of the upcoming week. The entire class will formulate the goals and make a schedule for the next week.

Homework: None

Courseweb: There is a Courseweb site associated with this course. It can be accessed through your http://my.pitt.edu account. This site will be used to make important announcements and to make materials available such as instructional slides and notes.

Examinations: Final examination will consist of the preparation of a written report summarizing the project in a Physical Review-style paper. The project will also be presented by students during the last meeting of the term.

Grading: Laboratory notebooks 60% (20% nanofabrication; 20% data acquisition; 20% data analysis). Final report and presentation 40%.

Semester Schedule Week-by-Week: Tentative training schedule is provided below. Training is required to complete the semester project, but work on the project will be done outside of training. Work on the project involves moving back and forth between modules learned during the training until goals are achieved.

Week	Module	Location
1	Cleanroom Orientation	NFCF (Joanna Barr)
2	Optical Lithography (Microscope, Profilometer, Lithography Hood, Mask aligner)	NFCF (Jun Chen)
3	Lab safety and nanowire positioning	Frolov lab
4	Thin Film Technology (evaporator, reactive ion etching)	NFCF (Esta Abelev)
5	Electron Microscopy (scanning electron microscope)	NFCF (Esta Abelev)
6	Room temperature electrical characterization (probe station, wirebonder)	Frolov lab
7	Data acquisition (IVVI, Optodac)	Frolov lab
8	Liquid helium safety and cryostat operation	Frolov lab
9	Nanowire device simulation (KWANT, Poission-Schroedinger)	Frolov lab
10	Introduction to TeX	Frolov lab
11-13	Work on the project	Frolov lab and NFCF
14	**Final report and presentation**	

Academic Integrity:
Students in this course will be expected to comply with the University of Pittsburgh's Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity.

Disabilities:
If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services (DRS), 140 William Pitt Union, (412) 648-7890, as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.