Physics 1415 Fall 2025
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. The research goal of this course is the fabrication and experimental investigation of a superconductor-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 109) equipped with sample packaging equipment, and the low-temperature electrical measurement setups. Stage 3 will be dedicated to the analysis of the gathered data, possibly including numerical simulations and the writing of a final report.

Learning Goals: A student is expected to learn how to perform optical lithography, deposit superconductor films, image semiconductor chips, design microwave circuits, operate cryogenic equipment such as dilution refrigerators, perform microwave domain measurements using vector network analyzers, analyze experimental data and extract physical properties such as quality factors of resonators, 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.

Slack: There is a Slack workspace associated with this course. All students will receive invitations to the workspace. This workspace will be used to make important announcements and to make materials available. Slack will also be where discussions can take place between the students and the instructors.

Homework: Each student will provide the instructor with thorough notes taken during each training session. The notes should be sufficiently detailed to operate the advanced equipment based on the notes by the student who took the 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: Course is graded on pass/fail basis.

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 (Aug 25)	Cleanroom Orientation	NFCF (JosephAnna Barr)
2	Optical Lithography-I (Microscope, Profilometer, Lithography Hood)	NFCF (Jun Chen)
3	Optical Lithography-II (Maskless Aligner, development)	NFCF (Jun Chen)
4	Lab safety and microwave design software	WPQIC
5	Superconductor thin film deposition	WPQIC
6	Reactive Ion Etching	NFCF (Matthew France)
7	Room temperature electrical characterization (probe station, wirebonder)	WPQIC
8	Dilution refrigerator operation	WPQIC
9	Microwave measurements	WPQIC
10 and beyond	Work on the project	NFCF and WPQIC
Finals week	**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.

Title IX:
Your instructor is considered a mandatory reporter by University Policy and is required to report violations of Title IX that he/she observes or is made aware of to the Title IX office. Title IX violations include, but are not limited to, sexual harassment, sexual violence and verbal or sexual abuse. The instructor's capacity and obligation to report does not end at the classroom. The students are welcome to discuss any issues with their instructor, but please be informed that, due to mandatory reporting, the instructor will not be able to keep the information they share confidential and will have to share it with the Title IX office.

Social Media Statement:
While the instructors may be present on social media, they are not likely to engage with students there. Students are advised to use the class Slack, email or in-person meetings to discuss with instructors.