ECE 498KF Quantum Optics and Devices

Instructor:
Prof. Kejie Fang

Time/Location:
80 mins lecture, twice a week.

Office hours
M 11-noon. 2112 MNTL

Course website:
https://courses.engr.illinois.edu/ece498kf4/sp2024/

Textbooks and References:
"Quantum Optics," by D. F. Walls and G. J. Milburn

Pre-requisite:
ECE 305(398), previously ECE487, Quantum Systems I or equivalent

Course Outline:
This course is planned to prepare ECE students with the essential quantum physics and device knowledge for the advent of the quantum technology era. The first half of the course will cover concepts and formalisms developed in quantum optics, which are generally applicable to other quantum systems for design and analysis of quantum devices. The second half of the course will be focused on the application of the theoretical tools to study a variety of quantum device platforms. This will be accompanied by review of classic literatures in the respective fields. Covered topics includes:

Topics

1. Electromagnetic fields quantization; non-classical light; quantum correlations
2. Quantum nonlinear optics
3. Open quantum systems; input-output formalism; Master equation
4. Atom-light interaction; cavity-QED
5. Optical quantum computing
6. Superconducting quantum circuits
7. Mechanical quantum systems
8. Quantum measurement

Learning objectives:
The students are expected to understand basic concepts and formalisms in quantum optics. They should be able to perform analytical calculations involving operators. They should be familiar with several physical quantum platforms and key quantum devices. They will be trained to use quantum optics methods to design and analyze quantum devices.

Grading:
3 credits: 6 homework (70%), final (30%)
4 credits: 6 homework (60%), final (30%), term paper (10%)

Lectures:

Quantum optics

1. Introduction; harmonic oscillator
2. Electromagnetic field quantization
3. Fock states; coherent states
4. Squeezed states
5. Field-correlation functions
6. Photon correlation measurements
7. Beam splitters
8. Nonlinear optics I, single mode quantum correlations
9. Nonlinear optics II, two-mode quantum correlations
10. Input-output formalism
11. Master equation
12. Quantum regression theorem
13. Atom-field interaction I
14. Atom-field interaction II

Quantum devices

15. Optical quantum computing
16. Cavity-QED I
17. Cavity-QED II
18. Superconducting quantum circuits (circuit-QED) I
19. Superconducting quantum circuits (circuit-QED) II
20. Mechanical quantum systems I
21. Mechanical quantum systems II
22. Quantum measurement (weak continuous measurement)
23. Quantum non-demolition measurement