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/sp2022/

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 physics and device knowledge for the advent of quantum technology era. The first half of the course will cover concepts and formalisms of quantum optics. Though developed initially in the context of quantum optics, these techniques are generally applicable to other quantum systems and are now essential for design and analysis of quantum devices. The second half of the course will thus 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. Integrated quantum photonics
6. Superconducting quantum circuits
7. Mechanical quantum systems
8. Quantum measurement
9. Other quantum devices: quantum transducers, quantum memory, quantum repeaters

Learning objectives:
The students are expected to understand basic concepts and formalisms in quantum optics. 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: homework (70%), final (30%)
4 credits: 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. Representation of electromagnetic fields
6. Field-correlation functions
7. Photon correlation measurements
8. Linear optics, beam splitters
9. Nonlinear optics, single mode quantum correlations
10. Nonlinear optics, two-mode quantum correlations
11. Input-output formalism I (w/ photonics basics)
12. Input-output formalism II (application to SHG, SPDC)
13. Master equation I
14. Master equation II
15. Quantum regression theorem
16. Atom-field interaction I
17. Atom-field interaction II

Quantum devices

18. Quantum photonic devices I (linear devices)
19. Quantum photonic devices II (nonlinear devices)
20. Cavity-QED I
21. Cavity-QED II
22. Superconducting quantum circuits (circuit-QED) I
23. Superconducting quantum circuits (circuit-QED) II
24. Mechanical quantum systems I
25. Mechanical quantum systems II
26. Quantum transducers
27. Quantum measurement (weak continuous measurement)
28. Quantum non-demolition measurement
29. Quantum memory, quantum repeaters