ECE 406 Quantum Optics and Devices

Instructor:
Prof. Kejie Fang

Lectures:
M W F 9-9:50AM

Office hours
W 10-noon. 2112 MNTL

Course website:
http://courses.grainger.illinois.edu/ece406/sp2026/

Textbooks and References:
[1] "Quantum Optics," by D. F. Walls and G. J. Milburn.
[2] "Introductory Quantum Optics," by C. Garry and P. Knight. This book provides more mathematical derivations as compared to [1].
[3] "Quantum Optics: An Introduction," by M. Fox. A more entry-level book. Explains many basic concepts and connects to experiments without involving too much math.

How to use the textbooks: selectively read relevant chapters of [1] and [2], but this is optional if you want to learn more extensively. All HWs and exams are based on lecture notes.

Pre-requisite:
ECE 305 Quantum Systems I or equivalent

Policy on use of AI:
Use of AI is NOT allowed for HWs.

Course outline:
The course will cover concepts and analytical methods in quantum optics, as well as application of these theoretical tools to study several quantum device platforms. 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:

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 quantum devices. They will be able to use quantum optical methods to design and analyze quantum devices. Also see https://ece.illinois.edu/academics/courses/ece406.

Grading:
6 homework (60%), 2 quizzes (10%), final (30%).

Lectures:
1. Introduction; harmonic oscillator
2. Electromagnetic field quantization
3. Fock states; coherent states
4. Squeezed states
5. Beam splitters
6. Field-correlation functions
7. Photon correlation measurements
8. Nonlinear optics I, single mode quantum correlations
9. Nonlinear optics II, two-mode quantum correlations
10. Optical quantum computing
11. Input-output formalism
12. Quantum optomechanics
13. Master equation
14. Quantum regression theorem
15. Atom-field interaction I
16. Atom-field interaction II
17. Cavity-QED
18. Superconducting quantum circuits (circuit-QED)
19. Quantum measurement (weak continuous measurement)
20. Quantum non-demolition measurement