OPTI 544: FOUNDATIONS OF QUANTUM OPTICS, SPRING 2024

Homework: One set roughly every two weeks.

Midterms: Mid-March, late April. Exact time and date TBD
Final: Thursday May 13, 10:30am-12:30pm

Grading: Weekly homework 20%
Midterm exams 40%
Final exam 40%

Office hours: Jessen: Tuesdays 2-3:30pm, Thursdays 2-3:30pm. Location: Meinel 604
Jon Pajaud (TA): TBD. Location: TBD

Questions and requests: email jessen@optics.arizona.edu.

Text: There is no designated text for OPTI 544. In the past I have suggested "Lasers", by P. W. Milonni and J. H. Eberly (ISBN 0471627313) to those who ask for one. This book is a good compilation of semiclassical optical and laser physics but lacks any serious treatment of Quantum Optics. It is also out of print, though good second-hand copies have so far been easy to find on the web. I provide extensive class notes for the course, and in recent years all but a few students have found those to suffice. Warning: There is a newer book available by Milonni and Eberly called "Laser Physics". It is not the same book and will not be particularly useful for the course so there is no reason to buy it.

Class notes, problem/solution sets, and lectures (slides and video) will be posted online at

https://wp.optics.arizona.edu/opti544/

Other texts that you may or may not find helpful:

"Quantum and Atom Optics", notes by Daniel Steck. Free download at http://atomoptics.uoregon.edu/~dsteck/teaching/quantum-optics/
"Introduction to Quantum Optics", by G. Grynberg, A. Aspect, and C. Fabre.
"Quantum Optics", by M. O. Scully and M. S. Zubairy.
"Elements of Quantum Optics", by P. Meystre and M. Sargent.
"Photons and Atoms: Introduction to Quantum Electrodynamics", by C. Cohen-Tannoudji et al.
"The Quantum Theory of Light", by R. Loudon.
"Optical Resonance and Two-Level Atoms", by Allen and J. H. Eberly.

OPTI 544. Foundations of Quantum Optics (3). Classical linear optics, interaction of two- and multi-level atoms with light, density matrix and optical Bloch equations, semiclasssical laser theory, quantum theory of the electromagnetic field, quantized light-matter interaction.

Course Outline:

1. Classical linear optics (Review). Maxwell's equations, Lorentz atom, dipole approximation, dipole force. Lorentz atom with damping. Classical theory of absorption. Complex polarizability and index of refraction.
2. Two-level atom and classical electric field. Rabi solutions. Comparison to Lorentz atom.
3. Multi-level atoms, selection rules for electric dipole transitions, Raman coupling in 3-level systems.
4. Density-matrix formalism. Application to two-level atom. Relaxation. Spontaneous emission and collisions.
5. Population rate equations. Einstein A and B coefficients.
6. Optical Bloch equations, Pulse Area Theorem, composite pulses. Maxwell-Bloch Equations, self-induced transparency. Solitons.
7. Semiclassical laser theory, laser threshold.
8. Introduction to Quantum Field Theory. Quantum theory of sound, Phonons.
9. Field quantization in the Coulomb gauge. Field observables, vacuum fluctuations. Number states, coherent states, squeezed states, wave packets. The quantum beam splitter.
10. Atom-field interaction in the dipole approximation. Two-level atom. The Jaynes-Cummings model. Dressed states. Weisskopf-Wigner theory of spontaneous emission.
11. New material, Topics TBD. Possibilities: Theory of Quantum Measurement, Photon counting, Homodyne and Heterodyne detection, Adaptive measurement. Beyond orthogonal measurement.

Prerequisites:
OPTI 570 or similar graduate-level introductory quantum mechanics course. Familiarity with the topics listed under Topics and Activities at this link:

https://wp.optics.arizona.edu/opti570/course-description/

Note: OPTI 511R is not sufficient preparation for OPTI 544.