OPTI 544: FOUNDATIONS OF QUANTUM OPTICS

SPRING 2020

Homework: Approximately every two weeks, usually distributed on a Friday and due the following Friday.

Midterms: TBD
Final: Friday May 8, 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
Kuper: TBD
Email questions to poul.jessen@optics.arizona.edu.

Text: "Lasers", by P. W. Milonni and J. H. Eberly (ISBN 0471627313). This is a good compilation of basic optical and laser physics, but lacks any serious treatment of quantized electromagnetic fields. It is also out of print, though good second-hand copies have so far been easy to find on the web. We will supplement it with extensive class notes. In past years many students have made do with these notes and not purchased the text. 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 lecture reviews will be posted online at

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

Other recommended texts:

"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. Optical Physics (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. 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. Photon echoes, free-induction decay, self-induced transparency. Maxwell-Bloch equations. Solitons.
7. Introduction to semiclassical laser theory. Fundamental laser equation. Stability analysis, laser threshold, frequency pulling. Small signal and saturated gain. Laser linewidth.
8. Field quantization in the Coulomb gauge. Field observables, vacuum fluctuations. Number states, coherent states, squeezed states, wave packets. The quantum beam splitter.
9. Atom-field interaction in the dipole approximation. Two-level atom. The Jaynes-Cummings model. Dressed states. Weisskopf-Wigner theory of spontaneous emission.

<u>No longer covered</u>

10. Quantum theory of photodetection. Classical and quantum theories of optical coherence. Correlation functions. Hanbury Brown and Twiss interferometry. Photon antibunching. Two-photon interferometry.