

OPTI 544: FOUNDATIONS OF QUANTUM OPTICS, SPRING 2023

Homework: One set roughly every two weeks.

Midterms: Mid-March, late April. Exact time and date TBD

Final: Thursday May 11, 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
Ian Marsh (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, semiclassical 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.

Lectures 2021 – 2022

1 Jan 13 Start Classical	1 Jan 12 Start Classical
2 Jan 15	2 Jan 14
Jan 18 MLK Day	Jan 17 MLK Day
3 Jan 20	3 Jan 19
4 Jan 22	4 Jan 21 End Classical
5 Jan 25	5 Jan 24 Start SemiClassical
6 Jan 27 End Classical, start SemiClassical	6 Jan 26 Start 2-Level
7 Jan 29	7 Jan 28
8 Feb 1	8 Jan 31
9 Feb 3 End 2-level	9 Feb 2 End 2-level, Start MultiLevel
10 Feb 5 Begin MultiLevel	10 Feb 4 HW2 Posted
11 Feb 8	11 Feb 7
12 Feb 10 End Multilevel HW 2 posted	12 Feb 9 End Multilevel,
13 Feb 12 Begin Raman	13 Feb 11 Begin Raman HW2 due
14 Feb 15 End Raman, Begin Density	14 Feb 14 End Raman
15 Feb 17	15 Feb 16 Begin Density
16 Feb 19 HW 2 Due	16 Feb 18 HW3 posted
17 Feb 22 End Density, begin Rate	17 Feb 21 End Density
18 Feb 24	18 Feb 23 Begin Rate
19 Feb 26 HW 4 posted	19 Feb 25 HW3 due
20 Mar 1 End Rate, Begin OBE	20 Feb 28 End Rate
21 Mar 3	21 Mar 2 Begin OBE
22 Mar 5 End OBE	Mar 4 1st Midterm
23 Mar 8 Begin MBE, HW 4 Due	Mar 7 Spring Break
Mar 10 Reading Day HW 5 posted	Mar 9 Spring Break
Mar 12 Midterm	Mar 11 Spring Break
24 Mar 15 End MBE	22 Mar 14
25 Mar 17 Begin Lasers	23 Mar 16 End OBE
26 Mar 19	24 Mar 18 Begin MBE HW 5 Posted
27 Mar 22 HW 5 due HW 6 posted	25 Mar 21 End MBE HW 4 Due
28 Mar 24 End Lasers	26 Mar 23 Begin Lasers
29 Mar 26 Begin Intro FT	27 Mar 25 End Lasers HW5 due
30 Mar 29 End Intro Field Theory	28 Mar 28 Begin Intro to FT, HW6 posted
31 Mar 31 Begin QED HW6 due	29 Mar 30
Apr 2 Reading Day	30 Apr 1 End intro to FT/Begin QED

32 Apr 5 End QED
33 Apr 7 Beamsplitter
34 Apr 9 Begin SOTF, HW7 due

35 Apr 12
Apr 14 2nd Midterm
36 Apr 16 No lecture, HW8 Posted

37 Apr 19 End SOTF, Begin QLM
Apr 21 Reading Day
38 Apr 23

39 Apr 26 End QLM, HW8 Due, HW9 posted
40 Apr 28 Begin WW
41 Apr 30

42 May 3 End WW, HW9 Due
43 May 5 Extra day

May 7 Final Exam 10:30-12:30

31 Apr 4 HW6 due HW7 posted
32 Apr 6 End QED
33 Apr 8 Begin BS, End BS

34 Apr 11 Begin SOTF, HW8 posted
35 Apr 13 HW7 due Apr 14
36 Apr 15 HW7 due End SOTF, HW8 posted

37 Apr 18 Begin QLM
38 Apr 20
39 Apr 22 2nd Midterm,

40 Apr 25 End QLM,
41 Apr 27 Begin WW, HW8 due, HW9 posted
42 Apr 29

43 May 2 End WW
44 May 4 Extra day

May 6 Final Exam 10:30-12:30

2020: Total: 43 lectures, after losing 4 to travel/Covid/ midterms and gaining 2 from makeups.

2021: Total: 43 lectures, after losing 2 to midterms. 2 makeups?

2022: Total: 43 lectures, after losing 2 to midterms. Makeups? Midterm on April 22