OPTI 511R: OPTICAL PHYSICS AND LASERS

Class Location: 307
Class Times: Tues/Thur 2:00-3:15
Instructor:
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Please see class D2L page for up to date information and assignments.

Course description
OPTI 511R is an *introduction* to basic concepts of optical physics and the interaction between light and matter. This course is designed to give optics students a broad understanding of the generation and absorption of light by matter, and how light can be used to manipulate properties of matter and be manipulated by matter. In this course, basic ideas from quantum mechanics will be introduced and used to develop a fully quantum model of the atom that will enable a deeper understanding of light-matter interactions beyond the classical Lorentz model (or more specifically, the interaction between a classical light field and an ensemble of atoms in a dilute gas). After developing a perspective on both classical and semi-classical pictures of light-matter interactions, the basic properties of laser operation will be explored. The course is not designed as a broad survey of laser systems, but rather a careful look at the classical and quantum perspectives of light-matter interaction and the properties of this interaction that make laser operation possible. A few examples of different laser systems that exemplify specific properties will be given, however the course is not intended as a laser engineering course. A brief introduction to a fully quantum model of light-matter interactions and the field of quantum optics will be given towards the end of the course. While previous courses in physics would indeed be helpful, **this course is designed to be accessible to students who have a general science or engineering background and basic familiarity with using complex numbers, matrices, and differential equations.   Previous courses in quantum mechanics are NOT required.**

Course emphasis
Because this is an introductory course covering many topics, this course will not develop detailed exploration of all subjects that will be covered. If you have further interest in any of the course topics, other specialized classes cover the subjects in detail. In this respect, OPTI 511R covers material that is fundamental to many other Optics courses in quantum optics and photonics. In OPTI 511R, an emphasis will be placed on the learning of new concepts, rather than detailed mathematical derivation of all of the subjects. Many of the concepts of quantum mechanics and quantum optics may seem strange and non-intuitive. For some of these concepts, an initial (perhaps tentative) acceptance will be needed until they become more familiar. The math used in this course is generally not difficult. However, learning the mathematical formalism and the application of the mathematical tools can be tricky and

confusing. Many simple tricks and approximations exist to solve problems, some of which we will explore.

The language of optical physics and quantum mechanics can also be confusing at times. Previously familiar words take on new meanings or new mathematical formalism, and a single concept can have various mathematical representations or notations on paper. As in most scientific disciplines, different authors and instructors use different symbols to represent identical concepts. In this course, it is the concept that is of primary importance; given a symbol or a problem, you must interpret the expression or method to solve the problem, and extract the relevant concepts.

General Course syllabus and topics list

Quantum Mechanics
1. Introduction to quantum mechanics, wave/particle duality, uncertainty principle
2. Quantum mechanics of free and bound particles, wave packets
3. Schrödinger equation, wave functions, eigenvalue equations
4. Postulates of quantum mechanics
5. Measurements in quantum mechanics, expectation values
6. Quantum harmonic oscillator
7. Dirac notation, matrix formulation of quantum mechanics
8. Hydrogen atom, quantum mechanics of the real hydrogen atom
9. Spin angular momentum, Pauli exclusion principle

Optical Physics
10. Hamiltonian for light/matter interaction, time-dependent probability amplitudes
11. Electric dipole approximation, Rotating wave approximation
12. Two-level atom approximation, Rabi oscillations
13. Collisional decay and spontaneous emission, rate equations
14. Blackbody radiation, Einstein A and B coefficients
15. Steady-state absorption coefficient, saturation
16. Inhomogeneous line broadening, absorption lineshapes
17. Quantization of the electromagnetic field, vacuum field fluctuations, photon statistics

Lasers
18. Optical resonators, resonator stability
19. Population inversion
20. Threshold gain and steady-state laser operation
21. Laser output characteristics and output control
22. Pulsed lasers, Q-switching, mode locking
23. Survey of lasers and output characteristics

Prereqs: OPTI 501 and basic linear algebra

Particularly, it is assumed that the following concepts will be familiar:
1. Wave equation and complex representation of EM waves
2. Lorentz oscillator model, absorption, and refractive index
3. Basic operations with vectors and complex variables
4. Manipulation of matrices

5. Eigenvalues and eigenvectors/eigenfunctions in algebraic and matrix forms.
6. Basic properties of Fourier transforms
7. Separation of variables method of solving partial differential equations

If you are weak in any of these areas, you may need to do some extra work during the course of OPTI 511. Some key ideas will be reviewed, but these topics will not be taught from scratch. **Again, previous courses in physics will be helpful, but are not required.** This course is designed to be accessible to students without a physics background.

Grading Scale
90-100 A
75-89   B
60-74   C
50-59   D
<50 fail

Grading
Midterm Exam #1 (15%)
Midterm Exam #2 (30%)
Final Exam   (40%)
Homework   (15%)

Academic Integrity
According to the **Arizona Code of Academic Integrity**, "Integrity is expected of every student in all academic work. The guiding principle of academic integrity is that a student's submitted work must be the student's own." Unless otherwise noted by the instructor, work for all assignments in this course must be conducted independently by each student. Co-authored work of any kind is unacceptable. Misappropriation of exams before or after they are given will be considered academics misconduct.
Misconduct of any kind will be prosecuted and may result in any or all of the following:
- Reduction of grade
- Failing grade
- Referral to the Dean of Students for consideration of additional penalty, i.e., notation on a student's transcript re: academic integrity violation, etc.

ACCESSIBILITY AND ACCOMMODATIONS
If a student is registered with the **Disability Resource Center**, he/she must submit appropriate documentation to the instructor if he/she is requesting reasonable accommodations.
At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, **https://drc.arizona.edu/**) to establish reasonable accommodations**.**