OPTI 511R- Optical Physics and Lasers

Location: Meinel 422

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Course Description and Objectives

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. Fundamental concepts of quantum mechanics will be introduced and used to develop a fully quantum model of the hydrogen 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.

General 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

Expected Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Be conversant with the basic principles of quantum mechanics, the quantum model of the hydrogen atom, fundamentals of laser operation, and the descriptions of light-matter interaction.
2. Properly interpret the fundamental postulates of quantum mechanics.
3. Set up and solve basic time-independent problems in quantum mechanics
    a. Determine energy levels and eigenstates for simple 1-dimensional quantum well problems.
    b. Coulomb model for the hydrogen atom
4. Calculate basic properties of light-matter interaction. Examples include:
    a. Absorption cross-section
    b. Absorption coefficients
    c. Rabii frequency and pi-pulses
    d. Saturation intensity
5. Determine optical cavity properties. Examples include:
    a. Cavity stability.
    b. Resonant modes of an optical cavity.
    c. Cavity mode size.
    d. Gaussian beam propagation.
6. Calculate and categorize basic laser properties. Examples include:
    a. Determine the difference between 3 and 4 level laser
    b. Calculate small signal gain based on laser pumping conditions
    c. Threshold conditions for lasing.
    d. Calculate q-switched pulse parameters for a given system
    e. Determine mode-locked pulse properties such as minimum possible pulse duration.

Course Prerequisite's

Opti 501 and understanding of basic linear algebra

Course Format

Lecture only (Online course is available).

Grade Scale and Policy

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

Grades are typically dependent on the following policy:

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

Absence and Class Participation Policy

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious- accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See:

https://deanofstudents.arizona.edu/absences

Participating in the course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. Students who miss class due to illness or emergency are required to bring documentation from their health-care provider or other relevant, professional third parties. Failure to submit third- party documentation will result in unexcused absences.

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading- system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism, available at http://new.library.arizona.edu/research/citing/plagiarism.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy

The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies Student Assistance and Advocacy information is available at

http://deanofstudents.arizona.edu/student-assistance/students/student-assistance

Confidentiality of Student Records

http://www.registrar.arizona.edu/personal-information/family-educational-rights-and-privacy- act-1974-ferpa?topic=ferpa

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.