University of California, Riverside
Department of Physics and Astronomy

PHYS209A - Quantum Electronics

Course Information, Fall 2017

Instructor

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Catalog brief description

4 Units, Lecture 4.5, Prerequisite(s): PHYS 135B, PHYS 156A; or consent of instructor. Quantum theory of light and interaction of light with atoms. Density matrix formulation of atomic susceptibility. Propagation of light in matter and optical waveguides. Optical resonators. Theory and operation of common lasers.

Course description

This course is part of a lecture series (209A, B, C) which aims to address graduate students from all disciplines that work with lasers, built optical setups or run laser spectroscopy experiments.

The course is divided into two parts. The first part discusses applied photonics, covering Gaussian beam optics, optical resonators, high-finesse cavities, an introduction to commonly used laser systems (cw and pulsed), electro- and acousto-optics, laser frequency locking schemes and fiber optics. The first part of the course will provide you with the principles of typical tools used in optical spectroscopy and optical systems engineering. The second part reviews the basics of quantum mechanics, including the density matrix formulation and the interaction of light and matter. After taking this course, you will be able to grasp the general ideas of papers published in the area of optical science and engineering.

Prerequisites

- Physics 135B, Minimum Grade of D-. May not be taken concurrently.
- Physics 156A, Minimum Grade of D-. May not be taken concurrently.

Schedule and location

	Day	Time	Building	Room
Lecture	Monday	9.10am - 10.00am	Physics	2111
Lecture	Wednesday	9.10am - 10.00am	Physics	2111
Lecture	Friday	9.10am - 10.00am	Physics	2111
Tutorial	Monday	2.10pm - 3.00pm	Physics	2111

Homework and final exam

There will be weekly problem sets and a final exam. Each student has to hand in a separate homework. Working with other on problems is permitted, however, all solutions must be your own. The homework will include usage of software tools and smaller programming assignments - previous knowledge of programming should not be necessary. The final exam will be in the form of a 30 min presentation about a publication on recent research closely related to the topics of the second part of this course. The presentation can be done using slides or the whiteboard.

Textbooks

- Yariv, Quantum Electronics, ISBN: 978-0471609971
- Saleh and Teich, Fundamentals of Photonics, ISBN: 978-0-471-35832-9
- Hobbs, Building electro-optical systems, ISBN: 978-0-470-40229-0

Access

If you need disability-related accommodations, please meet with the instructor early in the semester, so that accommodations can be arranged.

Topics covered in this course

Part I: Lasers, optical resonators and electro-optics

- Week 1: Ray and Gaussian beam optics
  - Ray optics and optical systems
  - Gaussian beam propagation and ABCD matrices
  - Software tools for optics beam simulation

- Week 2: Optical resonators
  - Stable, unstable resonators
  - High-finesse cavities
- Week 3: Principle of Lasers
  - Laser oscillation
  - Threshold inversion
  - Rate equations
- Week 4: Specific laser systems
  - General overview of wavelength vs laser availability
  - CW lasers: Solid-state, dye, diode, fiber lasers
  - Pulsed lasers: Q-switching, mode-locking, frequency combs
- Week 5: Acousto, electro-optics and laser-locking techniques
  - Electro-optic modulators
  - Acousto-optic modulators
  - Stabilization of lasers: Doppler-free absorption spectroscopy, Pound-Drever-Hall lock, Haensch-Couillaud lock
- Week 6: Guided wave optics and polarization optics
  - Optical fibers
  - Waveplates, birefringence
  - Polarizers

Part II: Review of quantum mechanics and treatment of light-matter interaction

- Week 7: Basic quantum mechanics
  - Schroedinger equation and interpretation of the wavefunction
  - Operators and measurements
  - Expectation values and Ehrenfest theorem
  - Time-independent potentials
  - Dirac notation
- Week 8: Methods to solve Schroedinger's equation
  - Harmonic oscillator using creation and annihilation operators
  - Matrix representation of operators
  - Perturbation theory
  - Time-independent and time-dependent perturbation theory

- Week 9: Matrix formulation of quantum mechanics
  - Unitary matrices, eigenvalues, time propagation operator
  - Density matrix formulation, mixed and pure states
  - Time evolution of density matrix
  - Dyson series, multi-photon processes
- Week 10: Interaction of light and matter
  - Semi-classical bloch equations
  - Coherent radiation-atom interaction
  - Steady state solutions, susceptibility