OPTI 507

Announcements and assignments are posted on D2L.
Potential updates to the syllabus due to the coronavirus situation will be announced in class, via email, or posted on D2L.

Solid-State Optics (3 units). Basic concepts in crystals and in optical response; optical properties of metals, insulators and semiconductors; quantum wells; glass and polymers; optical nonlinearities; solid-state devices and laser diodes. P, PHYS 371 or OPTI 511R. Knowledge of quantum mechanics is necessary.

Meeting Times:

Lectures: Tu/Th 11:00 a.m. to 12:15 p.m. | Room 305

Description:

This is an introductory-level course in the field of solid-state optoelectronics. It includes an introduction to the microscopic properties of solids such as bulk metals, insulators, semiconductors, polymers, glass and semiconductor heterostructures, as well as their linear and nonlinear optical response. It also contains a discussion of basic operation of principles of opto-electronic devices such as lasers, light modulators and detectors
.
A necessary prerequisite is a good understanding of electromagnetic theory (including Maxwell's equations and the mathematics of Fourier transformations) and a solid understanding of quantum mechanics (including the mathematical framework of quantum mechanics, the physics of the hydrogen atom and perturbation theory).

Some of the topics of this course will be covered in detail (for example, the linear optical response of solids, simple optical properties of phonons and the physics of quantum wells), whereas other topics will only be covered in the form of general overviews (for example electro-optical properties of semiconductors).

No advanced mathematical techniques, such as second quantization, will be used.

There are two major goals of this course. First, the course should present basic facts about optical properties of solids based on their microscopic structure. Second, the student should be enabled to understand various optical and opto-electronic phenomena used in devices on the basis of the basic microscopic aspects presented in this course.

Learning Outcomes:

The students will be able to analyze optical absorption spectra of semiconductors in terms of fundamental models such as the Lorentz and Drude models.

The students will become familiar with the concepts of electronic band structure and the Bloch theorem for electrons in periodic potential..

The students will be able to derive phonon dispersion relations.

The students will be able to use time-dependent perturbation theory to derive an analytical expression for the semiconductor absorption coefficient.

The students will be able to differentiate between optical response with and without exciton effect.

The students will be able to derive and calculate quantum confinement effects.

The students will be able to relate operating principles of lasers, LEDs and photodetectors to the underlying microscopic physics of semiconductors.

Homework:

- Weekly homework assignments with a few problems will be handed out each week.

  Homework assignments are due one week after distribution. The written homework assignments are for credit.

Exams:

- Closed book in-class midterm exam.
- Closed book in-class final exam.

Students who take the exam at DRC must schedule the exam for the same day as the in-class exam, and ensure that the time slot of the DRC exam has some overlap with the time of the in-class exam.

Grades:

- The grades will be based 30% on the homework, 25% on the midterm and 45% on the final exam.

Instructor:

Dr. Rolf Binder
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Meinel Building, Room 632

Office Hours: see D2L

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

Teaching Assistant: See D2L

Course Outline:

- Basic concepts of crystals (Bravais lattice, symmetry operations, lattices with basis, reciprocal lattice, Brillouin zone, Bloch wave functions, electronic energy bands, effective mass, Fermi distribution functions, classification of solids, electrons and holes, density-of-states, examples of important semiconductors).
- Basic concepts of optical response (Dielectric optical response, refractive index and absorption, dispersion relations, Kramers-Kronig relation, optical properties of metals, polaritons, plasmons, surface plasmon polaritons, SPP biosensors).
- Optical properties of phonons (optical and acoustic phonons, dispersion relations, diatomic lattice, 3-dimensional crystals, effective charges, Bose functions, optical excitation of phonons, infrared absorption, microbolometers, phonon polaritons, light scattering, Raman and Brillouin scattering, coherent Raman spectroscopy, Raman microscopy).
- Linear optical properties of semiconductors (direct and indirect gap semiconductors, energy and momentum conservation in band-to-band transitions, optical absorption derived from quantum mechanical time-dependent perturbation theory, dipole allowed transitions in the parabolic band approximation, indirect optical transitions, excitons, two-particle Schrödinger equation, selection rules, excitonic absorption in semiconductors).
- Quasi-two-dimensional semiconductors (quantum confinement, ternary and quaternary compounds, lattice mismatch, quantum wells, subbands, superlattices, optical transitions and selection rules in 2D, excitons in quantum wells).
- Overview of electro-optical properties of semiconductors and quantum wells (Franz-Keldysh effect, DC Stark effect, exciton ionization, quantum-confined dc-Stark effect, electro-absorption modulators, QWIPs, quantum cascade lasers).
- Concepts of semiconductor lasers and detectors (lasing conditions, doping, p-n heterojunctions, biased p-n junctions and I-V curve, edge-emitting lasers, VCSELs, photovoltaic cells).
- Brief introduction to the optics of non-crystalline solids (glass optics, concepts in organics and polymer optics). THE MATERIAL IN THIS SECTION WILL NOT BE PART OF THE MIDTERM OR FINAL EXAM.

Textbook and Class Notes (Required):

- N. Peyghambarian, S.W. Koch, and A. Mysyrowicz: Introduction to Semiconductor Optics (Prentice-Hall, New Jersey, 1993).
- Class Notes

  Both are available in the Class Notes section of the UofA Bookstore. They are titled "*Solid State Optics - The Book*" and "*Solid State Optics - Class Notes*", respectively.

  Most of the material presented in this course will be taken from the book Introduction to Semiconductor Optics. However, not all chapters of the book will be covered in this course, and some topics are not covered in the book.

Other Textbooks for Reference (Not Required):

- C. Klingshirn, Semiconductor Optics (Springer, Berlin, 1995)
- P. Yu and M. Cardona, Fundamentals of Semiconductors: Physics and Material Properties, (Springer, Berlin, 1999)
- J.D. Jackson, Classical Electrodynamics Wiley, New York, 1975)
- B.E.A. Saleh and M.C. Teich, Fundamentals of Photonics (Wiley, New York, 1991).
- S.L. Chuang, Physics of Optoelectronic Devices (Wiley, New York, 1995).
- P. Bhattacharya, Semiconductor Optoelectronic Devices (Prentice Hall, Englewood Cliffs, 1994)
- H.M. Gibbs, Optical Bistability: Controlling Light with Light (Academic Press, New York, 1985).
- H. Haug and S.W. Koch, Quantum Theory of the Optical and Electronic Properties of Semiconductors, 4th ed. (World Scientific, Singapore, 2003). Contains many more rigorous derivations of the introductory required text book by Peyghambarian *et al.*
- A. Yariv, Optical Electronics (Saunders College Publishing, Philadelphia, 1991)
- F. Wooten, Optical Properties of Solids (Academic Press, New York, 1972)
- C.R. Dillard and D.E. Goldberg, Chemistry; Reactions, Structures and Properties (Macmillan, New York, 1971)
- J.B. Pierce, The Chemistry of Matter (Houghton Mifflin, Boston, 1970)
- D.W. Snoke, Solid State physics: essential concepts (Addison-Wesley, San Francisco, 2009
- N.W. Ashcroft and N.D.Mermin, Solid State Physics (Rinehart and Winston, New York, 1976)
- C. Kittel, Introduction to Solid State Physics (Wiley and Sons, New York, 1986)
- W. Schäfer and M. Wegener, Semiconductor Optics and Transport Phenomena (Springer, Berlin, 2002)

Academic Integrity

According to the **Arizona Code of Academic Integrity,**
https://deanofstudents.arizona.edu/policies/code-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.

Students with Learning Disabilities
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.

The information contained in this syllabus may be subject to change with reasonable advance notice, as deemed appropriate by the instructor.

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