Instructor: Dr. Rolf Binder, College of Optical Sciences, room 632, phone 621–2892, e-mail: binder@optics.arizona.edu, homepage: fp.optics.arizona.edu/binder

Office Hours: Monday 4:00 PM - 4:45 PM

Class Homepage: fp.optics.arizona.edu/binder/opti561

Description: This course addresses basic properties of crystalline solids. The chief focus is on those properties which are relevant for the understanding of current topics in nonlinear semiconductor optics. However, the importance of these concepts, which include various kinds of elementary excitations, such as excitons and plasmons, is not restricted to semiconductor optics. Certain traditional aspects of solid state physics, like the theory of superconductivity, are not part of this course. A central topic of the course will be the linear and nonlinear optical response of semiconductors.

This course will mainly deal with theoretical physics and will include the application of advanced quantum mechanical concepts (second quantization and commutator algebra) to the physics of semiconductors. However, very advanced concepts such as the nonequilibrium Green’s function formalism are not part of this course.

Literature:

- **CLASS NOTES** (available at the UA Bookstore in the class notes section).
- N. Peyghambarian, S. W. Koch, and A. Mysyrowicz, *Introduction to Semiconductor Optics* (Prentice Hall, New Jersey, 1993). [Not required. This book is a very good introduction to semiconductor optics. As for the contents, it is similar to the Haug/Koch book but but contains more of an overview of physical effects rather than formal proofs and derivations.]
• C. Kittel, *Introduction to Solid State Physics* (Wiley and Sons, New York, 1986) [Not required. Similar to Ashcroft/Mermin.]
• C. Kittel, *Semiconductor Optics* (Springer, Berlin, 1995) [Not Required. Comprehensive text on semiconductor optics, mainly from an experimental point of view.]

**Homework:** Weekly homework assignments with a few problems, posted on class homepage. Some of the problems will be designed to complete intermediate steps of derivations presented in class.

**Exams:** Closed book one-hour in-class midterm exam. Closed-book two-hour in-class final exam.

In the midterm exam, one reference sheet is allowed, and in the final exam two reference sheets are allowed. A reference sheet is one letter-size ($8\frac{1}{2}'' \times 11''$) page of paper. The reference sheet must be turned in together with the exam (it will be returned to the student along with the graded exam). The words “Reference sheet” and the student’s name must appear clearly legible on that sheet of paper. Both
sides of each reference sheet may be used and all items on the sheet, i.e. figures, equations, etc. must have been produced by hand by the student him/herself.

**Grades:** The grades will be based 20% on homework, 35% on the midterm, and 45% on the final exam.

**Required extra curricular activities:** None.

**Special materials required:** Simple pocket calculator.

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**CONTENTS**

1. Basic concepts in solid state physics (crystal structure, electronic bandstructure, tight-binding approach, $\vec{k} \cdot \vec{p}$ theory and Luttinger Hamiltonian).

2. Introduction to many-particle theory (second quantization, commutator algebra, equations of motion in the Heisenberg picture).

3. Ideal quantum gases (Fermi distribution functions).

4. The interacting electron gas (jellium model, Hartree-Fock factorization, ground state properties, exchange interaction, pair-correlation functions).

5. Review of basic concepts of linear optical response (classical oscillator and two-level systems).

6. Linear and nonlinear optical response of semiconductors (linear optical bandedge spectra including excitonic effects, absorption and gain, Pauli blocking, semiconductor Bloch equations).

7. Semiconductor quantum wells (envelope function approach, $\vec{k} \cdot \vec{p}$ theory and Luttinger Hamiltonian for quantum wells).

8. Screening and plasmons.

9. Possible additional topics (time permitting): phenomenological treatment of scattering and relaxation, electron-electron scattering, phonons.