南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

# 课程详述

## COURSE SPECIFICATION

以下课程信息可能根据实际授课需要或在课程检讨之后产生变动。如对课程有任何疑问，请联系授课教师。

The course information as follows may be subject to change, either during the session because of unforeseen circumstances, or following review of the course at the end of the session. Queries about the course should be directed to the course instructor.

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| 1. | **课程名称 Course Title** | **半导体光学导论 INTRODUCTION TO SEMICONDUCTOR OPTICS** |
| 2. | **授课院系 Originating Department** | 电子与电气工程系<br>Department of Electrical and Electronic Engineering |
| 3. | **课程编号 Course Code** | EE309 |
| 4. | **课程学分 Credit Value** | 3 |
| 5. | **课程类别 Course Type** | 专业核心课 Major Core Courses |
| 6. | **授课学期 Semester** | 秋季 Fall |
| 7. | **授课语言 Teaching Language** | 中英双语 English & Chinese<br>（English with Detailed Explanations in Chinese） |
| 8. | **授课教师、所属学系、联系方式（如属团队授课，请列明其他授课教师）<br>Instructor(s), Affiliation& Contact<br>（For team teaching, please list all instructors）** | 张新海教授，电子与电气工程系<br>第二科研楼 511 室<br>zhang.xh@sustc.edu.cn<br>0755-8801-8566<br>Professor Zhang Xinhai, Department of Electrical and Electronic Engineering<br>Rm.511, Research Bldg. No. 2<br>zhang.xh@sustc.edu.cn<br>0755-8801-8566 |
| 9. | **实验员/助教、所属学系、联系方式<br>Tutor/TA(s), Contact** | 李鸿，电子与电气工程系<br>11553015@mail.sustc.edu.cn<br>13538041126<br>Li Hong, Department of Electrical and Electronic Engineering<br>11553015@mail.sustc.edu.cn<br>13538041126 |
| 10. | **选课人数限额(可不填)<br>Maximum Enrolment（Optional）** | |

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| 11. | 授课方式<br>Delivery Method | 讲授<br>Lectures | 习题/辅导/讨论<br>Tutorials | 实验/实习<br>Lab/Practical | 其它(请具体注明)<br>Other（Please specify） | 总学时<br>Total |
| | 学时数<br>Credit Hours | 48 | | | | 48 |

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| 12. | 先修课程、其它学习要求<br>Pre-requisites or Other Academic Requirements | 无 None |
| 13. | 后续课程、其它学习规划<br>Courses for which this course is a pre-requisite | 许多光电器件基于半导体的光学性质，学习本课程有利于透彻理解这些光电器件的工作原理。本课程为光电信息科学与工程专业核心课，是光电子技术基础、显示与照明技术课程先修课程；本课程不仅适用于光电专业的学生，也适用于学习物理、材料科学与工程的学生。<br>Many optoelectronic devices such as light emitting diodes, laser diodes, and solar cells are based on optical properties of semiconductors. Learning this course helps to improve the understanding of the operation mechanism of these devices. This course is one of the core courses for students with a major in Optoelectronic Information Science and Technology. it is a prerequisite for Optoelectronic Technology, Display and Lighting Technology. This course is also suitable for students of physics and material science. |
| 14. | 其它要求修读本课程的学系<br>Cross-listing Dept. | 无 None |

## 教学大纲及教学日历 SYLLABUS

15. **教学目标 Course Objectives**

本课程介绍半导体的光学性质，比如：透射光谱、反射光谱、荧光光谱以及在红外、可见、近紫外波段的复介电函数等，使学生对半导体光学的基本概念和基本物理基础有一个清晰透彻的理解。

The aim of this course is to introduce the optical properties of semiconductors, e.g., the spectra of transmission, reflection and luminescence, or of the complex dielectric function in the infrared, visible and near-ultraviolet part of the electromagnetic spectrum. We want to evoke in the reader a clear and intuitive understanding of the physical concepts and foundations of semiconductor optics and of some of their numerous applications. To this end, we try to keep the mathematical apparatus as simple and as limited as possible in order not to conceal the physics behind mathematics.

16. **预达学习成果 Learning Outcomes**

通过本课程的学习，预期达到如下的学习效果:

- 学生将对半导体光学的基本概念和基本物理过程有一个清晰透彻的理解；
- 透彻了解各种光电器件的基本工作原理及物理过程；
- 掌握一些研究测量半导体光学性质的基本方法和技术，比如透射光谱、反射光谱、荧光光谱等。

After completing this course, students should have

- a clear and intuitive understanding of the physical concepts and foundations of semiconductor optics
- mechanism of some optoelectronic devices such as LEDs, LDs, and Photodiodes
- a thorough understanding of a variety of methods and techniques of studying optical properties of semiconductors, such as Transmission spectroscopy, Reflection Spectroscopy, Photoluminescence spectroscopy

17. **课程内容及教学日历 （如授课语言以英文为主，则课程内容介绍可以用英文；如团队教学或模块教学，教学日历须注明主讲人）**
**Course Contents (in Parts/Chapters/Sections/Weeks. Please notify name of instructor for course section(s), if this is a team teaching or module course.)**

**Chapter 1. Introduction**: This introductory chapter consists of an outline of the fundamental concepts and ideas on which the text is based, including the rather limited prerequisites so that the reader can follow it and, finally, some hints about its contents.

**Chapter 2. Maxwell's Equations, Photons and the Density of States:** In this chapter we consider Maxwell's equations and what they reveal about the propagation of light in vacuum and in matter. We introduce the concept of photons and present their density of states. Since the density of states is
a rather important property in general and not only for photons, we approach this quantity in a rather general way. We will use the density of states later also for other (quasi-) particles including systems of reduced dimensionality. In addition, we introduce the occupation probability of these states for various groups of particles.

**Chapter 3: Interaction of Light with Matter:** In this chapter we present some basic interaction processes of light with matter from two different points of view. First we consider matter as a homogeneous medium described by the complex dielectric function ε(ω) or by the complex index of refraction ˜n(ω) (Sect. 3.1). We concentrate especially on the reflection and transmission of light at the plane interface between two media. As an especially simple case we investigate the boundary of matter and vacuum. In the later Sect. 3.2 we will discuss the interaction of the radiation field with individual atoms. In this case quantum mechanics must be used.

**Chapter 4: Ensemble of Uncoupled Oscillators:** The optical properties of matter are determined by the coupling of various types of oscillators in matter to the electromagnetic radiation field. In other words, an incident electromagnetic field will cause these oscillators to perform driven or forced oscillations. In this chapter, we will consider the optical properties of an ensemble of oscillators. We begin with the simplest case of uncoupled oscillators and refine the concept in various steps in next chapters.

**Chapter 5: The Concept of Polaritons:** In this chapter we want to discuss in more detail what is actually propagating when"light" travels through matter. In vacuum the situation was quite clear. Light in vacuum is a transverse electromagnetic wave, the quanta of which are known as photons. The concept of polariton is introduced when "light" travels through matter.

**Chapter 6: Kramers–Kronig Relations:** In this chapter we want to investigate some general relations between the real and imaginary parts of ˜n or ε.

**Chapter 7: Crystals, Lattices, Lattice Vibrations and Phonons**: In this chapter we start to discuss topics that are specific to crystalline solids. We discuss the lattice vibrations of crystal solids and introduce the concept of phonons.

**Chapter 8: Electrons in a Periodic Crystal:** In this chapter we want to discuss the behaviors of electrons in topics that are specific to crystalline solids. We introduce the concepts of polaron, effective mass, electronic band structure, etc. We discuss the electronic state of semiconductor quantum structures as quantum wells and quantum dots. We also discuss the carrier localization due to disorder.

**Chapter 9: Excitons, Biexcitons and Trions:** In this chapter we introduce the concepts of Exciton, Biexciton and Trion. We discuss their behaviors in bulk semiconductors and solids with reduced dimensionality.

**Chapter 10: Plasmons, Magnons and some Further Elementary Excitations:** In this chapter we will briefly address some other collective excitations in semiconductors and the quasi-particles which result from the quantization of these excitations like plasmons or magnons.

**Chapter 11: Optical Properties of Phonons:** In this chapter we will discuss the optical properties of phonons. We start with the properties of bulk materials, then the properties of materials with reduced dimensionality.

**Chapter 12: Optical Properties of Plasmons, Plasmon-Phonon Mixed States and of Magnons:** In this chapter we discuss the optical properties of Plasmons, Plasmon-Phonon Mixed States and of Magnons.

**Chapter 13: Optical Properties of Intrinsic Excitons in Bulk Semiconductors:** In this chapter we discuss the essence of semiconductor optics, namely the optical properties of excitons.

**Chapter 14: Optical Properties of Bound and Localized Excitons and of Defect States:** In this chapter we discuss the optical properties of defect and localized states in bulk materials, but mention that many of these aspects are also relevant for the structures of reduced dimensionality presented in the next chapter.

**Chapter 15: Optical Properties of Excitons in Structures of Reduced Dimensionality:** In this chapter we discuss the optical properties of excitons in systems of reduced dimensionality such as quantum wells and quantum dots.

**Chapter 16: Excitons Under the Influence of External Fields:** In this chapter we discuss the behaviors of excitons under the influence of external fields such as magnetic field and electric field.

**Chapter 17: From Cavity Polaritons to Photonic Crystals:** In this chapter we discuss briefly the concept of a Fabry–Perot resonator in the form of a (micro) cavity and then proceed to the cavity polaritons as a mixed state between a resonance in a solid (these are generally exciton resonances in quantum wells, wires or dots) and a cavity resonance. From there we reach, via different paths, the presently very active and potentially application-relevant field of photonic crystals with a subspecies known as photonic band gap materials.

**Chapter 18: Review of the Linear Optical Properties:** In this chapter, we shall review and summarize some of the aspects of the linear optical properties of semiconductors that were presented in the preceding chapters in some detail.

**Chapter 19: High Excitation Effects and Nonlinear Optics:** In this and in some of the following chapters we shall leave the regime of linear optics and proceed to the field of nonlinear optics. Nonlinear optics including high excitation phenomena, laser emission and electro-optics, forms together with the investigation of semiconductors of reduced dimensionality, presently the most active fields in semiconductor science.

**Chapter 20: The Intermediate Density Regime:** In this chapter we present selected examples from the intermediate density regime where excitons, biexcitons and trions are still good quasiparticles.

**Chapter 21: The Electron–Hole Plasma:** In this chapter, we will discuss details of some of the properties of electron-hole plasma.

**Chapter 22: Stimulated Emission and Laser Processes:** In this chapter, we will discuss stimulated emission and laser processes in semiconductors.

**Chapter 23: Optical Bistability, Optical Computing, Spintronics and Quantum Computing:** In this chapter, we present some of the properties of optical bistability, an effect that is not limited to semiconductors, and some of the concepts of digital optical computing.

**Chapter 24: Experimental Methods:** In this chapter, we will introduce experimental techniques, which have been or can be used for the optical spectroscopy of semiconductors.

**18. 教材及其它参考资料 Textbook and Supplementary Readings**

指定教材: Claus Klingshirn, Semiconductor Optics, 半导体光学（第三版）（影印版）科学出版社 2007.

推荐参考资料: Nasser Peyghambarian, Stephan W. Koch, Andre Mysyrowicz, Introduction to Semiconductor Optics, Prentice Hall, 1993

Required: Claus Klingshirn, Semiconductor Optics, 半导体光学（第三版）（影印版）科学出版社 2007.

Recommended: Nasser Peyghambarian, Stephan W. Koch, Andre Mysyrowicz, Introduction to Semiconductor Optics, Prentice Hall, 1993



## 课程评估 ASSESSMENT

**19.**

| 评估形式 Type of Assessment | 评估时间 Time | 占考试总成绩百分比 % of final score | 违纪处罚 Penalty | 备注 Notes |
|---|---|---|---|---|
| 出勤 Attendance | 每次课 Every class | 10% | 缺课一次扣一分 Each absence will be penalized 1 score | |
| 课堂表现 Class Performance | 每次课 Every class | 10% | | |
| 小测验 Quiz | | | | |
| 课程项目 Projects | | | | |
| 平时作业 Assignments | Every week | 20% | | |
| 期中考试 | | | | |

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| **Mid-Term Test** | | | | |
| **期末考试 Final Exam** | At the end of the semester | 60% | 迟到超过 30 分钟不允许参加考试 Late more than 30 Mins will not be allowed to sit for the exam | |
| **期末报告 Final Presentation** | | | | |
| **其它（可根据需要改写以上评估方式） Others (The above may be modified as necessary)** | | | | |

20. 记分方式 **GRADING SYSTEM**

☑ A. 十三级等级制 **Letter Grading**
☐ B. 二级记分制（通过/不通过） **Pass/Fail Grading**

## 课程审批 REVIEW AND APPROVAL

21. **本课程设置已经过以下责任人/委员会审议通过**
**This Course has been approved by the following person or committee of authority**