ECE325/425
Semiconductor Lasers I

Fall 2017

Last revised on: Oct 17, 2017

Course Description

The fundamentals of semiconductor lasers with an engineering prospective. Students will learn the basics of semiconductor lasers, and gain an understanding of the physical details of their operation. Topics include —basic phenomenological equations to solve problems on real laser diodes; mirrors and resonators for edge-emitting and vertical-cavity surface-emitting lasers; optical gain and spontaneous emission; dynamic effects; and dielectric waveguides. (**Prerequisite:** ECE 203 Introduction to Electromagnetic Waves and ECE 126 Fundamentals of Semiconductor Devices)

Class Course Site:

https://coursesite.lehigh.edu/course/view.php?id=94154

Instructor

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Lectures (Details in course schedule)

Maginnes Hall, Room 105
Mon/Wed/Fri 9:10 am to 10:00 am

Office Hour Schedule

Prof. Wierer
Sinclair Laboratory, Room 205D
Monday 11:10 am - 12:10 pm
Thursday 3:10 pm - 4:10 pm

Required Textbook

1. Larry Coldern, Scott Corzine, and Milan Masanovic, *Diode Lasers and Photonic Integrated Circuits,* Second Edition, (2012).
   - We will cover parts of Chapters 1-5, and *8*, and also Appendices 1 and 2 (details in course schedule).

- I may supplement other reading material, if I feel the book is lacking in particular subjects. (See additional references).

Non-required Additional References

1. Shun Lien Chuang, *Physics of Photonic Devices*, Second Edition (2009).
2. Peter Blood, *Quantum Confined Laser Devices*, First Edition (2015).
3. Prasanta Basu, et al., *Semiconductor Laser Theory* (2016).

Course Grading

The course will consist of weekly homework assignments, possible quizzes (20 min in class), a midterm exam, and a final exam with the following proportions toward the final grade:

1. Homework assignments and quizzes – 30 % (~12 homework sets, 0-2 quizzes)
2. Midterm Exam – 30 % (~2 hr, scheduled in the evening on 10/20)
3. Final Exam – 40 % (~3 hr, scheduled by the Registrar Office)

Homework Policy

1. Homework is given on *almost* every Friday, and due on the following Friday before class. See exceptions in the course schedule near holidays and breaks.
2. No late homework is accepted unless permission is given in advance.
3. Some of the homework problems will require more complicated calculations and plotting of results. Using a software package such as Matlab or Excel will be required.
4. Working together on homework is encouraged, but please do not copy each other!
5. Academic Dishonesty will be subject to disciplinary action by Lehigh University. http://studentaffairs.lehigh.edu/content/student-handbook-section-3-lehigh-university-student-conduct-system

Exam/Final Policy

1. One midterm exam will be given in the evening and the date is listed in the full schedule.
2. The final is scheduled by the registrar and will be held during finals week.
3. One and two pages of notes are allowed for the exams and final, respectively.
4. A calculator is required.

Electronic Devices

1. Please silence cell phones and refrain from using them unless it is an emergency.
2. Please use laptops only for note taking, and sit away from classmates to avoid distracting them.

Accommodations for Students with Disabilities

If you have a disability for which you are or may be requesting accommodations, please contact both your instructor and the Office of Academic Support Services, Williams Hall, Suite 301 (610-758-4152) as early as possible in the semester. You must have documentation from the Academic Support Services office before accommodations can be granted.

The Principles of Our Equitable Community

Lehigh University endorses The Principles of Our Equitable Community [http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf]. We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.

Student Senate Statement on Academic Integrity

We, the Lehigh University Student Senate, as the standing representative body of all undergraduates/graduates, reaffirm the duty and obligation of students to meet and uphold the highest principles and values of personal, moral and ethical conduct. As partners in our educational community, both students and faculty share the responsibility for promoting and helping to ensure an environment of academic integrity. As such, each student is expected to complete all academic course work in accordance to the standards set forth by the faculty and in compliance with the University's Code of Conduct.

Course Schedule (The schedule is subject to change and will be updated in syllabus.)

Class	Date	Chapters from Coldren's book	Homework
1	M 08/28	**Chapter 1 Ingredients (in semiconductor lasers)** 1.1 Introduction 1.2 Energy levels and bands in solids	
2	W 08/30	1.3 Spontaneous and stimulated emission 1.4 Crystal growth 1.5 Transverse confinement of carriers and photons	
3	F 09/01	1.6 Semiconductor materials for laser diodes 1.7 Lateral confinement of current, carriers and photons	HW1 Assigned
4	M/09/04	**Chapter 2 A Phenomenological Approach to Diode Lasers** 2.1 Introduction 2.2 Carrier Generation and Recombination in Active Regions	
5	W 09/06	2.3 Spontaneous Photon Generation and LEDs 2.4 Photon Generation and Loss in Laser Cavities (part 1)	
6	F 09/08	2.4 Photon Generation and Loss in Laser Cavities (part 2) 2.5 Threshold or Steady-State Gain in Lasers (part 1)	HW1 Due HW2 Assigned
7	M 09/11	2.5 Threshold or Steady-State Gain in Lasers (part 2) 2.6 Threshold Current and Power Out Versus Current (part 1)	

8	W 09/13	2.6 Threshold Current and Power Out Versus Current (part 2)	
9	F 09/15	2.7 Relaxation Resonance and Frequency Response	HW2 Due HW3 Assigned
10	M 09/18	2.8 Characterizing Real Diode Lasers **Appendix 1 Review of Elementary Solid-State Physics** A1.1.1 Introduction	
11	W 09/20	A1.1.2,3 Potential Wells, Bound Electrons, and Density of states	
12	F 09/22	**Chapter 4: Gain and Current Relations** 4.1 Introduction 4.2 Radiative Transitions (4.2.1)	HW3 Due HW4 Assigned
13	M 09/25	**Appendix 2 Relationships between Fermi Energy and Carrier Density** A2.1 General Relationships *Extra*: Fermi Energy and carrier density at threshold.	
14	W 09/27	4.2 Radiative Transitions (4.2.2, Radiative rate) 4.2. Radiative Transitions (4.2.3, Trans matrix element)	
15	F 09/29	4.2. Radiative Transitions (4.2.3, Cont, Trans matrix element)	HW4 Due HW5 Assigned
	M 10/02	4.2. Radiative Transitions (4.2.4 reduced DOS) 4.3 Optical Gain (4.3.1)	
16	W 10/04	No Class	
17	F 10/06	4.3 Optical Gain (4.3.1)	HW5 Due HW6 Assigned
18	M 10/09	4.3 Lineshape broadening (4.3.2)	
19	W 10/11	4.4 Spontaneous emission	
	F 10/13	No class	HW6 Due
	M 10/16	Pacing Break	
	W 10/18	**Review, discussion and problem solving**	
	F 10/20	**Midterm (lectures 1-17, HW 1-5)**	
20 & 21	M 10/23	4.5 Nonradiative Transitions	
22	W 10/25	**Chapter 5 Dynamic Effects** 5.1 Introduction 5.2 Review of Chapter 2 (5.2.1)	
23	F 10/27	5.2 Review of Chapter 2 (5.2.2, 5.2.3)	HW7 Assigned
24	M 10/30	5.3 Differential Analysis of Rate Equations	
25	W 11/01	5.3 Differential Analysis of Rate Equations (5.3.1 Small signal frequency response)	

26	F 11/03	5.3 Differential Analysis of Rate Equations (5.3.2 Small signal transient response)	HW7 Due HW8 Assigned
27	M 11/06	**Chapter 3 Mirrors and Resonators for Diode Lasers** 3.1 Introduction 3.2 Scattering Theory	
28	W 11/08	3.2 Scattering Theory 3.3 S and T Matrices for Some Common Elements (3.3.1, 3.3.2)	
29	F 11/10	3.3 S and T Matrices for Some Common Elements (3.3.3)	HW 8 Due HW 9 Assigned
30	M 11/13	3.3 S and T Matrices for Some Common Elements (3.3.5 Fabry Perot laser cavity) 3.4 Three and Four-Mirror Laser Cavities (3.4.1 3-mirror laser)	
31	W 11/15	3.4 Three and Four-Mirror Laser Cavities (3.4.2, 4-mirror laser) 3.5 Gratings (3.5.1 Intro)	
32	F 11/17	3.5 Gratings (3.5.2 T-matrix for gratings)	HW9 Due HW10 Assigned
33	M 11/20	3.5 Gratings (3.5.2 T-matrix for gratings) 3.6 Lasers based on DBR mirrors (3.6.2, threshold gain and power out)	
	W 11/22	Thanksgiving break	
	F 11/24	Thanksgiving break	
34	W 11/27	3.6 Lasers based on DBR mirrors (3.6.3, mode selection in DBR-based lasers. 3.6.4 VCSEL design)	
35	F 11/29	3.6 Lasers based on DBR mirrors (3.6.5, In-plane lasers and tunability)	
36	F 12/01	Extra: Dielectric waveguides	HW10 Due HW11 Assigned
37	W 12/04	**Chapter 8 Photonic Integrated Circuits** 8.2.1, 8.2.2	
38	F 12/06	8.2.3, 8.2.4	
	F 12/08	**Review, discussion and problem solving**	HW 11 Due
	S 12/16	**Final Exam** **Covers whole class** **12p-3p, Sat. Dec 16, Maginnes Hall Rm. 105**	