ECE 464
Laser Physics I

Overview

Course Catalog Description: Resonator optics. Rate equations; spontaneous and stimuated emission; gas, semiconductor and solid state lasers, pulsed and mode-locked laser techniques.
Prerequisites: N/A
Textbook: Joseph T. Verdeyen, *Laser Electronics* (*Third Edition*), Prentice Hall, 1995.
Class Goals: To understand the fundamentals of laser physics and have a reasonably solid feeling for issues related to laser engineering and laser safety.
Course Coordinator: Prof. R. K. Jain

Table I: Objectives, Implementation, and Assessment

Objectives		Implementation	Assessment	A	B	C	D	E	F	G	H	I	J	K
O_1	Understand the background of lasers	1 lecture in Week 1												
O_2	Understand E&M theory: Maxwell's equations, wave equation, wave propagation	2 lectures in Weeks 1 and 2	HW 1											
O_3	Understand ray-tracing (ABCD matrix): optical cavities, stability diagram, stable and unstable cavities	3 lectures in Weeks 2 and 3	HW 2 - 3											
O_4	Understand Gaussian beams: TEM_{00} and higher order modes, divergence of Gaussian beams	4 lectures in Weeks 4 and 5	HW 4 - 5											
O_5	Understand optical cavities: Gaussian beams in simple resonators, mode volume, Q-factor, photon lifetime, diffraction loss	2 lectures in Week 6	HW 6 Exam											
O_6	Understand gain medium (field-atom interaction): Einstein's A and B coefficients, optical amplification, line shapes and line broadening mechanisms	5 lectures in Weeks 7 – 10	HW 7 – 8											
O_7	Understand laser oscillation: threshold condition, gain saturation, multimode oscillation, amplified spontaneous emission	4 lectures in Weeks 10 – 12	HW 9 – 10											
O_8	Understand general laser characteristics: cw lasers, laser dynamics, q-switching and mode-locking	6 lectures in Weeks 12 – 15	HW 11 – 12											
O_9	Develop familiarity with various laser systems: 3- and 4- level lasers, rare-earth doped solid state and fiber lasers, gas lasers, semiconductor lasers	2 lectures in Week 16	HW 13											

Table II: Expectations and Outcomes Assessment

General expectations:
Homework:
All assignments involve the following 2 components

1. Sharpening/practicing/improving skills and understanding of laser physics,
2. Doing basic and critical computations related to laser physics and engineering

For component (1), we expect that 90% of the students will be able to answer at least 70% of the problems assigned.
For component (2), we expect 80% of the students to be able to complete this portion of the assignments.

Exams: Expect 75% of the students to score 70% or better on all exams.

Objectives		Outcome Assessment	Evaluation
O_1	Understand background of lasers		
O_2	Understand E&M theory	85% of students having completed HW 1 satisfactorily	Some students may lack some prerequisite knowledge in E&M
O_3	Understand ray-tracing (ABCD matrix)	90% of the students having completed HW 2 and 3 satisfactorily.	
O_4	Understand Gaussian beams	80% of the students having completed HW 4 and 5 satisfactorily.	
O_5	Understand optical cavities	85% of the students having completed HW 6 satisfactorily. Avg. on MT exam should be > 60%, with 85% scoring 70% or better	
O_6	Understand gain media (field-atom interaction)	75% of the students having completed HW 7 and 8 satisfactorily.	
O_7	Understand laser oscillation	80% of the students having completed HW 9 and 10 satisfactorily.	
O_8	Understand general laser characteristics	70% of the students having completed HW 11 and 12 satisfactorily.	
O_9	Familiarity with various laser systems	80% of the students having completed HW 13 satisfactorily. Avg. on final exam should be over 60%, with 85% scoring 70% or better	

Sample Course Schedule

Week	Lecture Topic	Assignment
1	Introduction	
	Review of E & M theory: Maxwell's equations, wave equation	Ch. 1
2	Review of E & M theory: wave equation, wave propagation	Ch. 1
	Ray tracing (ABCD matrix method): optical cavities	Ch. 2
3	Ray tracing (ABCD matrix method): stability diagram	Ch. 2
	Ray tracing (ABCD matrix method): stable and unstable cavities	Ch. 2
4	Gaussian beam: TEM_{00} and higher order modes	Ch. 3
	Gaussian beam: TEM_{00} and higher order modes	Ch. 3
5	Gaussian beam: divergence of Gaussian beams	Ch. 3
	Gaussian beam: divergence of Gaussian beams	Ch. 3
6	Optical cavities: Gaussian beams in simple resonators, mode volume	Ch. 5
	Optical cavities: Q-factor, photon lifetime, diffraction loss	Ch. 6
7	Exam	
	Gain Medium: Einstein's A and B coefficients	Ch. 7
8	Gain Medium	Ch. 7
	Fall Break	
9	Gain Medium: optical amplification	Ch. 7
	Gain Medium: line shapes and line broadening mechanisms	Ch. 7
10	Gain Medium: line shapes and line broadening mechanisms	Ch. 7
	Laser oscillation: threshold condition	Ch. 8
11	Laser oscillation: gain saturation	Ch. 8
	Laser oscillation: multimode oscillation	Ch. 8
12	Laser oscillation: amplified spontaneous emission	Ch. 8
	General laser characteristics: cw lasers	Ch. 9
13	General laser characteristics: cw lasers	Ch. 9
	General laser characteristics: laser dynamics	Ch. 9
14	General laser characteristics: laser dynamics	Ch. 9
	General laser characteristics: q-switching	Ch. 9
15	General laser characteristics: mode-locking	Ch. 9
	Thanksgiving Holiday	
16	Various laser systems:	
	3- and 4- level lasers, rare-earth doped solid state and fiber lasers	Ch. 10
	Various laser systems: gas lasers, semiconductor lasers	Ch. 10, 11