PHYS/ECE 413/613 Lasers for Scientists and Engineers

Course info

Course prefix, number(s), and title: PHYS/ECE 413/613 Lasers for Scientists and Engineers
Number of credits: 3 (*Undergraduate/Graduate*)
Prereq: PHYS 252 or graduate standing
Term and year: Spring 2023

Instructor: Orven Swenson
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Bulletin Description

Lecture introduction to lasers. Spontaneous and stimulated transitions, line-broadening, gain, gain saturation, optical resonators, Fabry-Perot interferometers, theory of laser oscillation, rate equations, transverse modes, coherence, and Gaussian beams. Prereq: PHYS 252 or graduate standing.

Required Textbook

B. E. A. Saleh and M. C. Teich, *Fundamentals of Photonics*, 3rd Ed., John Wiley & Sons, 2019. Inclusive Access eBook link available in Blackboard Course Materials. Hard copy 2nd or 3rd Ed. also acceptable.

Course Objectives

The goal of this course is to provide students with the fundamentals necessary to enable them to successfully apply lasers in their respective disciplines. This will be accomplished through classroom discussions and group homework to experience and understand the basic principles of laser operation and the properties of laser radiation.

Additional graduate student objective: graduate students will demonstrate the ability to research a laser topic and present it to the class using terminology and concepts learned in the course.

This is a 3 semester-credit-hour senior undergraduate/first year graduate level course with minimum course prerequisites (PHYS 252: University Physics II or graduate standing). Lectures will be based on the text Fundamentals of Photonics by Saleh and Teich. The topics covered will include optical resonators, Fabry-Perot interferometers, Gaussian beams, spontaneous and stimulated transitions (Einstein coefficients), line-broadening, gain of an optical frequency amplifier, gain saturation, theory of laser oscillation, rate equations, transverse modes, and characteristics of common lasers.

This course is part of the Optics Sequence: ECE/PHYS 411/611, Optics for Scientists and Engineers; ECE/PHYS 413/613, Lasers for Scientists and Engineers; ECE/PHYS 415/615, Elements of Photonics; and ECE/PHYS 417/617, Optical Signal Transmission. Each course is stand alone and they do not need to be taken in order.

Grading

The final grade will be determined as follows:

PHYS/ECE 413		PHYS/ECE 613	
Exam 1	20%	Exam 1	20%
Exam 2	20%	Exam 2	20%
Exam 3	20%	Exam 3	20%
Final Exam	20%	Final Exam	20%
Homework	20%	Homework	10%
		Project	10%

A total average of 89**.**5% of the possible points or more ensures an A**,** 75**.**5 to 89**.**4% ensures a B**,** 59**.**5 to 75**.**4% ensures a C, 49.5 to 59.4 ensures a D and below 49.5 will be an F. Depending on the class average**,** curving may be applied to grades; however, the **lowest** passing final grade (C or higher) in the course will always be 50% or higher.

The exams will include conceptual questions requiring short answers and quantitative problems similar to the assigned homework problems. The final exam will consist of problems requiring the application of principles learned throughout the course. The Final Exam is **mandatory**. Exams must be taken in person.

Homework Assignments

Problem solving is the primary learning method for this course. Homework will be emphasized and assigned in groups. You will be assigned to a homework group, optimally 4 members, for the semester. One legible problem solution set per group will be turned in on 8 1/2" x 11" paper ONE SIDE ONLY. SHOW all work. The students in the group will present and/or discuss their solutions in class. Each group needs to decide on their group rules such as when you will meet, what the consequences are for members that don't show up/contribute, rotation for preparing the solutions to hand in, rotation for presenting solutions in class, etc. Students will receive one point added to their homework total score for each non-exam classroom attendance.

Additional Requirement for Graduate Students

Graduate student exams and homework will be graded separately. In addition, graduate students will research a laser topic of their choice (that is not covered in class) such as quantum-confined lasers, microcavity lasers, ultrafast lasers, etc. They will present their topic to the class during the last week of the course and will provide notes to be posted on BlackBoard for distribution to the other students. Their presentation and notes will be graded using the attached rubric. Satisfactory completion of this task is mandatory.

Tentative Course Outline

Lesson	Saleh/Teich	
1	11.1	Resonator modes
2	11.1	Losses and resonance spectra width
3	1.4	Matrix Optics
4	11.2	Spherical-mirror resonators
5	3.1	The Gaussian beam
6	3.1B	Properties of the Gaussian beam
7	3.2	Transmission through a thin lens
8	3.3	Hermite-Gaussian beams
9	11.3	Two- and three-dimensional resonators
10	11.4	Microresonators
11	14.1	Energy levels
12	14.2	Occupation of energy levels
13		Exam 1
14	14.3-4	Interactions of photons with atoms, Thermal light
15	14.5	Luminescence and light scattering
16	15.1	Theory of laser amplification
17	15.2	Amplifier pumping
18	15.3	Common laser amplifiers
19	15.4	Amplifier nonlinearity
20	16.1	Theory of laser oscillation
21	16.2A	Characteristics of the laser output: Power
22	16.2B	Characteristics of the laser output: Spectral distribution
23	16.3	Common lasers
24	16.4AB	Pulsed lasers
25	16.4CD	Q-switching and mode locking
26		Exam 2
27	17.1AB	Semiconductor physics background
28	17.1C	Electron and hole concentrations
29	17.1D	Generation, recombination, injection
30	17.1E	Junctions
31	17.1FG	Heterojunctions and quantum-confined structures
32	17.2A	Photon interactions in bulk semiconductors
33	17.2B	Band-to-band transitions in bulk semiconductors
34	17.2C	Absorption, emission, and gain in bulk semiconductors
35	18.1A	Injection electroluminescence
36	18.1B	LED characteristics
37	18.2A	Semiconductor optical amplifiers gain and bandwidth
38	18.2BC	Pumping and heterostructures
39	18.3	Laser diodes
40		Exam 3
41		Laser safety
42		Graduate student presentations
43		Graduate student presentations
		Final Exam – Wednesday, May 10, 10:30-12:30

Attendance Statement

According to NDSU Policy 333 (www.ndsu.edu/fileadmin/policy/333.pdf), attendance in classes is expected.

Veterans and student service members with special circumstances or who are activated are encouraged to notify the instructor as soon as possible and are encouraged to provide Activation Orders.

Students are expected to attend all class sessions except for valid excuses such as medical situations, and attendance will be part of the homework grade. Active participation in lectures is essential. Students are expected to read the lesson prior to coming to class and to be prepared to discuss it in class. Material may be presented that is not in the text or it may be presented in a different way. Students are responsible for all material presented in class including that missed during excused absences. Attendance at exams is mandatory unless excused for a valid University approved reason.

Blackboard

Course assignments, lesson notes, information, and messages will be posted to Blackboard: https://blackboard.ndus.edu. Your NDSU email address is the official route for information.

Graduate School Statement

The 613-level version of this class is a graduate level course and is subject to the General Policies of the Graduate School: https://bulletin.ndsu.edu/graduate/graduate-school-policies/#supervisorycommitteeplanofstudytext.

Accreditation Criteria

Per department requirements, accreditation descriptions may be included as they relate to this course.

Americans with Disabilities Act for Students with Special Needs

Any students with disabilities or other special needs, who need special accommodations in this course, are invited to share these concerns or requests with the instructor and contact the Disability Services Office (www.ndsu.edu/disabilityservices) as soon as possible.

Academic Honesty Statement

The academic community is operated on the basis of honesty, integrity, and fair play. NDSU Policy 335: Code of Academic Responsibility and Conduct applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context. Students found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Student academic misconduct records are maintained by the Office of Registration and Records. Informational resources about academic honesty for students and instructional staff members can be found at www.ndsu.edu/academichonesty.

Health and Safety Expectations

See https://www.ndsu.edu/police_safety/news/detail/63323/ for information on COVID-19 and NDSU's response.

- NDSU requires students to wear face coverings in classrooms. Wearing face coverings helps reduce the risk to others in case you are infected but do not have symptoms.
- You must properly wear a face covering (covering both the mouth and nose) for the entirety of the class.
- Students who cannot wear a face covering due to a medical condition or disability may seek accommodation through Disability Services

(701-231-8463; https://www.ndsu.edu/disabilityservices/).

- In accordance with NDSU Policy 601, failure to comply with instructions, including this syllabus, may be handled according to the Code of Student Conduct resolution process and may result in disciplinary sanctions.
- Food and drink are not allowed in the class unless a student has a documented accommodation through Disability Services. Students will have to remove their masks to eat or drink.
- Do not come to class if you are sick. Please protect your health and the health of others by staying home. For information on COVID-19, symptoms, testing, and steps to stay healthy see COVID-19 Information | Student Health Service | NDSU
- If you are unable to attend class at the regularly scheduled time due to illness, contact the instructor for alternate arrangements, including recordings of class sessions and assignments as well as accommodations and extensions as needed.
- In this course recording the lectures for anything other than personal use is prohibited.

Physics/ECE 613 Graduate Student Presentation Rubric

Criteria	A	B	C	D
Content	**18 to 20 points** Content appropriate for the course. Detailed content reflecting significant research. Well-integrated citations. May be from course textbook.	**16 to 17 points** Content was mostly appropriate for the course. Content reflecting adequate research. Used appropriate citations. May be from course textbook.	**14 to 15 points** Content was somewhat appropriate for the course. A few significant content errors but general ideas are correct. No appropriate citations. May be from course textbook.	**12 to 13 points** Content had little correlation with the course.
Planning & Preparation	**18 to 20 points** Manages time well, presentation lasts 20-40 min. Smooth transitions, ideas flow effectively, topic presented in a logical order. Appropriate topic and level for class. Little or no use of technical jargon, all technical words appropriately defined.	**16 to 17 points** Manages time fairly well, presentation slightly outside of 20-40 min. Fair transitions, ideas flow reasonably effectively, fairly easy to follow. Somewhat appropriate topic and level for class. Some use of technical jargon, all technical words defined.	**14 to 15 points** Presentation well outside of 20-40 min. Choppy transitions, somewhat difficult to follow. Topic too simple or complex for class. Use of technical jargon, technical words not defined.	**12 to 13 points** Hard to understand presentation. Preparation was incomplete or hastily done.
Subject Knowledge	**18 to 20 points** Clear, complete and accurate explanation of physics concepts.	**16 to 17 points** Parts of explanations had gaps in clarity, completeness or accuracy.	**14 to 15 points** Much of explanations had gaps in clarity, completeness or accuracy.	**12 to 13 points** Did not understand topic.
Lesson Notes	**9 to 10 points** Comprehensible to average 413/613 student. Sufficient information for students to follow presentation.	**8 to 8 points** Somewhat disorganized but contains necessary details for students to follow presentation.	**7 to 7 points** Descriptive but too much or too little information is presented.	**6 to 6 points** Notes delivered too late to post on BlackBoard before presentation.
Use of Visual Aids	**9 to 10 points** All visual aids (PowerPoint and blackboard) are relevant to the topic or support the presentation. Easy to read and understand.	**8 to 8 points** Most visual aids (PowerPoint and blackboard) are relevant to the topic or support the presentation. Most are easy to read and understand.	**7 to 7 points** Visual aids (PowerPoint and blackboard) are not very relevant to the topic.	**6 to 6 points** Missing or difficult to read and understand.
Delivery	**9 to 10 points** Clear and engaging. Nearly continual use of direct eye contact with audience, seldom used notes. Easy to hear.	**8 to 8 points** Relied heavily on notes. Some direct eye contact.	**7 to 7 points** Parts of the presentation were difficult to hear or understand. Occasional eye contact with audience.	**6 to 6 points** Entire presentation was difficult to hear or understand. Not much eye contact with the audience.
Answering Questions	**9 to 10 points** Answered all questions clearly and completely.	**8 to 8 points** Answered nearly all questions clearly and completely.	**7 to 7 points** Had trouble answering questions.	**6 to 6 points** Did not answer questions.