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 2021

Instructor: Orven Swenson
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Office hours: 1:00-1:50 MWF or by arrangement. You may meet with me in person during office hours (please remember to wear a face covering) or virtually using Blackboard Collaborate.

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*, 2nd or 3rd Ed., John Wiley & Sons, 2007/2019.

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 is a required/suggested course for the undergraduate Physics major, Optical Science and Engineering Option, and the undergraduate ECE major, Optical Engineering Option. Courses in the Optics Sequence are: 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.

GRADING

The final grade will be determined as follows:

PHYS/ECE 415		PHYS/ECE 615	
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 may be asked to 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.

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	10.1	Resonator modes
2	10.1	Losses and resonance spectra width
3	1.4	Matrix Optics
4	10.2	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	10.3	Two- and three-dimensional resonators
10	10.4	Microresonators
11	13.1	Energy levels
12	13.2	Occupation of energy levels
13		Exam 1
14	13.3-4	Interactions of photons with atoms, Thermal light
15	13.5	Luminescence and light scattering
16	14.1	Theory of laser amplification
17	14.2	Amplifier pumping
18	14.3	Common laser amplifiers
19	14.4	Amplifier nonlinearity
20	15.1	Theory of laser oscillation
21	15.2A	Characteristics of the laser output: Power
22	15.2B	Characteristics of the laser output: Spectral distribution
23	15.3	Common lasers
24	15.4AB	Pulsed lasers
25	15.4CD	Q-switching and mode locking
26		Exam 2
27	16.1AB	Semiconductor physics background
28	16.1C	Electron and hole concentrations
29	16.1D	Generation, recombination, injection
30	16.1E	Junctions
31	16.1FG	Heterojunctions and quantum-confined structures
32	16.2A	Photon interactions in bulk semiconductors
33	16.2B	Band-to-band transitions in bulk semiconductors
34	16.2C	Absorption, emission, and gain in bulk semiconductors
35	17.1A	Injection electroluminescence
36	17.1B	LED characteristics
37	17.2A	Semiconductor optical amplifiers gain and bandwidth
38	17.2BC	Pumping and heterostructures
39		Exam 3
40	17.3	Laser diodes
41		Laser safety
42		Graduate student presentations
		Final Exam – Monday, May 10, 1:00-3:00

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. 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 Zoom will be available if you wish to participate in lectures remotely; however, exams must be taken in person. Virtual participation in this course requires both video and audio capabilities.

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 615-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/admission/fall_2020_prelim_plan 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.
- If you fail to properly wear a face covering, you will not be admitted to the classroom. However, you may choose to participate in the class remotely. The following will be used as needed: referral to Dean of Students Office or administrative removal from 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/.
- Disinfecting supplies are provided for you to disinfect your learning space. You may also use your own disinfecting supplies.
- Students should observe social distancing guidelines whenever possible. Students should avoid congregating around instructional space entrances before or after class. Students should exit the instructional space immediately after the end of class to ensure social distancing and allow for the persons attending the next scheduled class to enter the classroom.
- 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.
- 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.
- Do not come to class if you are sick. Please protect your health and the health of others by staying home and participate in class remotely. For information on COVID-19, symptoms, testing, and steps to stay healthy see https://www.ndsu.edu/studenthealthservice/covid_19/.
- Do not come to class if you have been exposed to individuals who tested positive for COVID-19 and/or you have been notified to self-quarantine due to exposure.
- If you are absent from class as a result of a COVID-19 diagnosis or quarantine, the decision for approval of all absences and missed work is determined by the course instructor. As instructor, I will do the following to help you make progress in the course: You will be able to participate in class remotely. You will be able to makeup exams after your quarantine.
- 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.