OPTI 557: Laser Engineering and Applications

Graduate Course Syllabus

Semester and Year this Document Covers

Spring 2021 and on

Course Number and Title

OPTI 557: Laser Engineering and Applications

Instructor Information

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Course Description

Laser engineering is a broad and interdisciplinary field that encompasses atomic and molecular physics, electromagnetism, nonlinear optics, mechanical design, thermodynamics, software, as well as economic and legal aspects. It is a very dynamic and rapidly evolving field that has been on the cutting edge of science and technology since the first operational laser was demonstrated in 1960 and continues to be such to this day. This one-semester, graduate-level course covers basic and applied aspects involved in the operation, design, characterization, and applications of lasers and laser systems. The course provides the students with practically applicable information essential for the educated use and design of various types of lasers in the laboratory and industrial settings. The course will self-consistently introduce the basic notation and principles involved in the operation of the laser and in the properties and characterization of radiation it generates. Different modes of laser operation will be covered, including continuous-wave, Q-switched, and mode-locked regimes. Various specific laser systems will be discussed including gas lasers, diode lasers, solid-state lasers, fiber lasers, as well as large-scale installation such as the National Ignition Facility in the US and the Extreme Light Infrastructure in Europe.

Course Prerequisites or Co-requisites

Previous completion of OPTI 345 (Introductory Quantum Mechanics) or OPTI 511R (Optical Physics and Lasers), or equivalent coursework, is recommended but not required.

Course Format and Teaching Methods

2 classroom lectures per week, weekly homework assignments, final exam. A group project in which groups of 3-4 students are tasked with the analysis of a particular commercial laser system, assigned to them by the instructor, and making a presentation to the class.

Course Objectives

The objective of this course is to provide students the necessary information and knowledge that is essential for the educated use, characterization, and design of various types of lasers. The course coverage will be broad, helping prepare the students for future careers in research or industrial environments where lasers are used.

Expected Learning Outcomes

After you complete this course:

- You will be able to apply the essential concepts involved in the operation, characterization, diagnostics, maintenance, and applications of lasers and laser systems.
- You will be prepared to measure the main parameters of laser radiation such as power, spectrum and linewidth, pulse duration, and beam quality.
- You will be able to recognize and describe the operation of key components of laser systems, including, laser resonators, gain media and pumping techniques, output couplers, modulators and switches, and so forth.
- You will be familiarized with the different common types of lasers, such as gas, diode, solid-state, and fiber, and be able to select a laser system based on a particular application.
- You will have the opportunity to work in small groups on the analysis of a particular commercial laser system and to present your findings to an audience of your peers.

400/500 Co-convened Course Information

N/A

Required Texts and Materials

Lecture summaries will be provided through the class website before each lecture. The following books are not required but are recommended and will be useful resources for the students in the future, should they pursue future education and/or careers involving laser engineering:

1. A. Siegman, *Lasers*, University Science Books, 1986. [available electronically through UA Library]
2. A. Yariv, P. Yeh, *Photonics: Optical Electronics in Modern Communications*, 6th edition, Oxford University Press, 2007.
3. W. Koechner, *Solid-State Laser Engineering*, 6th edition, Springer, 2006. [available electronically through UA Library]

Schedule of Topics and Activities

The following list of lecture topics is tentative. The order of topics may change, as the semester progresses. Each topic will be covered in one or two lectures.

Background:

1. Class overview, syllabus, the laser (definition, history)
2. Mathematical background: Complex notation, Gaussian integral, Gaussian beam optics, focusing, spectral density, units
3. Properties of laser radiation: Power, spectrum, linewidth, beam quality, continuous-wave (CW) vs. pulsed lasers
4. Overview of information resources and tools: Books, journals, web, computer-aided design (CAD) tools

Laser principles, characterization , and applications:

5. Generic laser system: Laser oscillator, laser amplifier, extracted power, optimization
6. CW lasers: single vs. multimode operation, linewidth, Schawlow-Townes limit
7. Nonlinear wavelength conversion: OPAs, OPOs, brief review of SNLO calculator
8. Characterization of laser radiation: Power meters, photodetectors, noise, spectrometers (scanning vs. single-shot), pulsed-laser characterization (autocorrelation, frequency-resolved optical gating, time-bandwidth product)
9. Laser applications: Communications, information storage (CDs and DVDs), sensing, material processing, medical, 3D printing, directed energy, basic science (laboratory astrophysics, fusion, laser cooling and trapping)
10. Practical issues: size, weight, and power (SWAP), cost, commercial off-the-shelf (COTS) components, cooling, eye safety
11. Landscape of laser research and industry: Major research centers and manufacturers of laser systems, components, and tools

Specific laser systems:

12. Gas lasers: He-Ne, Argon-ion, CO_2, excimer lasers
13. Diode lasers: Semiconductor bands, pumping, Fabry-Perot lasers, VCSELs, VECSELs
14. Solid-state lasers 1: Ruby
15. Solid-state lasers 2: Nd:YAG, 2nd, 3rd, 4th harmonic conversion
16. Solid-state lasers 3: Modelocking, carrier-envelope phase (CEP), CEP stabilization
17. Solid-state lasers 4: Ti:Sapphire laser, chirped-pulse amplification (CPA)
18. Ultrafast laser systems: Optical parametric amplifiers (OPAs), optical chirped parametric amplifiers (OPCPAs), examples
19. Fiber lasers, master oscillator – power amplifier (MOPA) systems, laser beam combination (coherent vs. spectral)
20. Exotics: High-harmonic generation (HHG), large-scale laser facilities (NIF, ELI)

Assessments

Grades for this course will be calculated based on the following assessments:

Assessment Categories	**Percentage of final grade**
Attendance of lectures and participation in class activities (asking and answering questions, participating in in-class discussions)	20%
Homework assignments	30%
Group project	25%
Final exam	25%
Total	100%

Group Project

For group projects, students will be divided into groups of three or four. Topics for group projects will be assigned by the instructor at the end of the 4th week of the semester. The groups will make their 30-min project presentations during the last four weeks of the semester. Grades for the presentation by a particular group will be the same for all members of the group.

Final Examination or Project

The final exam will be in an open-book, written format and will involve answering 4 or 5 short quiz-type questions and solving 4 problems based on the material covered in lectures throughout the semester. The difficulty of the questions and problems in the exam will be adjusted based on the overall progress of the students throughout the semester. The exam will not be curve-graded.

Grading Scale and Policies

Each student's final course grade will be based on the total points accumulated over the semester. A grade of "A" will be given for 90-100 total points, "B" for 80-89 points, "C" for 70-79 points, etc. For this course, A is interpreted as "Excellent – has demonstrated a more than acceptable understanding of the material; exceptional performance; exceeds expectations," B is interpreted as "Good – has demonstrated an acceptable understanding of the material; adequate performance; meets expectations," C is interpreted as "Average – has not demonstrated an acceptable understanding of the material; inadequate performance; does not meet expectations," D is interpreted as "Poor – little to no demonstrated understanding of the material; exceptionally weak performance.", and E is interpreted as "Failure – usually reserved for non-attendance."

Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

University Policies

All university policies related to a syllabus are available at: https://academicaffairs.arizona.edu/syllabus-policies.

Subject to Change Notice

Information contained in the course syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor of this course.

Graduate Student Resources

Link to the University of Arizona's Basic Needs Resources page: http://basicneeds.arizona.edu/index.html