OPTI 370. Lasers and Photonics (3). Principles of lasers; properties and manipulation of laser light; physical effects and operating principles of photonic components and devices including light modulators and optical fibers; elements of photonic telecommunications. Enrollment Requirements: Major: OSE. Adv Stdg: Engineering. OPTI 210.

Announcements and assignments are posted on D2L. No paper copies of the announcements and homework assignments will be distributed. Potential updates to the syllabus due to the coronavirus situation will be announced in class, via email, or posted on D2L.

Course Objectives:

- Understanding of the basic principles of lasers (not including semiconductor lasers)
- Understanding of the basic principles of photonic devices, including various components used in optical and optoelectronic communication systems

Learning Outcomes:

The students will be able to analyze optical wave interference of monochromatic and bichromatic waves.

The students will be able to perform a Fourier analysis of optical light pulses.

The students will be able to predict the finesse of planar-mirror resonators.

The students will be able to predict the stability of spherical-mirror resonators.

The students will be able to predict the beam divergence angle of Gaussian beams in spherical-mirror resonators.

The students will be able to relate coherence length and coherence time of optical fields to the underlying random nature of light.

The students will be able de-code term symbols of atoms and molecules and to extract information such as spin, orbital, and total angular momentum.

The students will be able to relate atomic cross sections to absorption and stimulated emission.

The students will be able to derive rate equations for two, three and four-level systems.

The students will be able to utilize the gain-saturation principle in order to predict laser performance characteristics such as input-output relations.

The students will be able to predict pulse repetition rates and pulse durations of passively mode-locked lasers.

The students will be able to predict polarization states of light traversing through uniaxial crystals, including half-wave and quarter-wave retarders.

The students will be able to distinguish the operating principles of Wollaston and Glan-Thompson polarizing beam splitters.

The students will be able to derive the rotatory power of optically active media.

The students will be able to derive the rotatory power resulting from the magneto-optic Faraday effect.

The students will be able to design 3-port interconnects, elementary bi-directional duplex communication systems, and circulators using polarizing beam splitters, Faraday rotators and wave retardation plates.

The students will be able to design advanced polarization-insensitive optical isolators using Faraday rotators and wave retardation plates.

The students will understand the relation between general attribute-based routing and the specific examples of multiplexers and demultiplexers.

The students will be able to design add-drop multiplexers using circulators, optical fibers and fiber-Bragg gratings.

The students will be able to apply the Pockels effect to design integrated waveguide modulators operating similar to Mach-Zehnder interferometers.

Course requirements and grading policy

Grades: There will be weekly homework assignments, two written in-class closed-book closed-notes midterm exams (date and time to be announced), and one in-class closed-book closed-notes final exam (see UA Catalog for time and date). ***The grades will be based 30% on the homework and in-class quizzes, 15% on the first midterm exam, 20% on the second midterm exam, and 35% on the final exam.***

Students who take the exam at DRC must schedule the exam for the same day as the in-class exam, and ensure that the time slot of the DRC exam overlaps with the time of the in-class exam.

Homework: Late homework will not be accepted. You may not be given credit for problems that are not legible. Submitted pages must be (i) Letter-size (8.5" x 11"), (ii) stapled (if more than one page), and (iii) your name, course number and homework assignment number must appear on the first page. A well-prepared assignment will include: all intermediate steps, formulas written neatly (use a ruler for long fractions if necessary), symbols and lines not overlapping, high contrast between ink or pencil and the background paper color. Points will be deducted for sloppy preparation and homework assignments which exhibit an overall sloppy appearance may be returned without a grade and the student receiving zero credit for that assignment. **Further remarks on homework preparation are on D2L.**

Attendance: You are responsible for obtaining any information given in class, posted on D2L, or sent by email from your instructor. Notify the instructor in advance if you must miss class, arrive late to class, or leave early from class.

Electronic devices: Any audio or video recordings must have advanced approval by the instructor.

Textbook (required):

B.E.A. Saleh and M.C. Teich, *Fundamentals of Photonics*, Second Edition 2007 (Third Printing, January 2009) or Third Edition 2019 (Wiley-Interscience)

Recommended texts (not required):

Books on electrodynamics, quantum mechanics and mathematics:

- J.D. Jackson, *Classical Electrodynamics*, 1975 (Wiley)
- D.J. Griffiths, *Introduction to Electrodynamics*, 1999 (Prentice Hall)
- D.J. Griffiths, *Introduction to Quantum Mechanics*, 1995 (Prentice Hall)
- D. Hughes-Hallet et al., *Calculus*, 2005 (Wiley)

<u>Other books on optoelectronics and lasers:</u>

- S.O. Kasap, *Optoelectronics and Photonics – Principles and Practices*, 2001 (Prentice Hall)
- Wilson and Hawkes, *Optoelectronics: An Introduction*, 3rd edition 1998 (Prentice Hall)
- W.T. Silfvast, *Laser Fundamentals*, 2004 (Cambridge University Press)

Topics Covered:

The following list is meant to serve as a guideline. Changes to the list may be made without prior notification. Some topics will be discussed in detail, while others are only covered briefly. The numbers in (parenthesis) [brackets] refer to the chapters in the (second edition) [third edition] of the text book by Saleh/Teich.

Brief review of wave optics (2.1) [2.1]
Brief review of monochromatic waves, Helmholtz equation (2.2 A) [2.2 A]
Brief review of planes wave and dispersion relation (2.2 B) [2.2 B]
Brief review of interference of two waves (2.5 A) [2.5 A]

Fourier Transform (Appendix A) [Appendix A]
Pulsed light, quasi-monochromatic pulses (2.6 A) [2.6 A]

Brief review of Maxwell's equations and wave equation (5.1, 5.2) [5.1,5.2]
Irradiance (intensity) of monochromatic plane waves (5.4) [5.4]
Susceptibility, absorption coefficient and refractive index (5.2) [5.2]

Planar-mirror resonators (10.1 A) [11.1]
Brief review of Gaussian beams (2.2 C and 3.1) [2.2 C and 3.1]
Spherical-mirror resonators (10.2) [11.2]

Coherent vs. random light, temporal coherence function, coherence length, spectral width (11.1 A,B) [12.1 A,B]

Brief summary: Schrödinger equation, energy levels (13.10 [14.1], excluding semiconductors
Thermal equilibrium distribution (13.2 A) [14.2 A]

Interaction of photons with atoms, transition cross section, stimulated emission rate, photon flux, lineshape function, spontaneous emission rate (13.3) [14.3]

Laser amplification, gain coefficient (14.1) [15.1]

Rate equations, steady-state inversion, four-level pumping, three-level pumping (14.2) [15.2]

Laser oscillation, small signal gain coefficient, saturated gain coefficient, threshold gain condition (15.1) [16.1]
Laser output, number of modes, mode selection, Brewster window (15.2) [16.2]

Examples of lasers and laser media: He-Ne, Nd^{3+}:YAG, Nd^{3+}:Glass, Ti:Sapphire, Er^{3+}:Silica fiber (13.1, 14.3, 15.3) [14.1, 15.3, 16.3]

Mode locking (15.4) [16.4]

Polarization optics, linearly and circularly polarized light, propagation along principal axes in uniaxial crystals (6.1) [6.1]

Phase retardation, half-wave retarder, quarter-wave retarder, light intensity control, polarizers, polarizing beam splitters (6.6) [6.6.]

Optical activity, rotatory power, Faraday effect, optical isolator (6.4) [6.5]

Optical interconnects, wavelength-division multiplexers (23.2) [24.2], circulator, add-drop multiplexer (20.3) [21.3]

Electro-optics, Pockels effect, anisotropic nonlinear refractive indices, phase retardation, retardation half-wave voltage, Pockels cell intensity modulator, waveguide Mach-Zehnder interferometer (20.1) [21.1]

Brief overview: optical fiber, step-index multi-mode fiber, step-index single-mode fiber (9.1) [10.1]
Brief overview: dispersion-shifted fiber, dispersion-flattened fiber, dispersion-compensating fiber (9.3) [10.3]

Group velocity and group velocity dispersion (5.6) [5.7]

Brief overview: optical fiber attenuation and dispersion, WDM channels, channel separation (24.1, 24.3) [25.1, 25.3]

Academic Integrity

According to the **Arizona Code of Academic Integrity,**
https://deanofstudents.arizona.edu/policies/code-academic-integrity ,
integrity is expected of every student in all academic work. The guiding principle of academic integrity is that a student's submitted work must be the student's own." Unless otherwise noted by the instructor, work for all assignments in this course must be conducted independently by each student. Co-authored work of any kind is unacceptable. Misappropriation of exams before or after they are given will be considered academics misconduct.

Misconduct of any kind will be prosecuted and may result in any or all of the following:

- Reduction of grade
- Failing grade
- Referral to the Dean of Students for consideration of additional penalty, i.e., notation on a student's transcript re: academic integrity violation, etc.

Students with Learning Disabilities

If a student is registered with the **Disability Resource Center**, he/she must submit appropriate documentation to the instructor if he/she is requesting reasonable accommodations.

The information contained in this syllabus may be subject to change with reasonable advance notice, as deemed appropriate by the instructor.