**ENMA 443 “Photonic Materials, Devices and Reliability”**

**Co-listed with ENMA 643**

**Course Meeting Times**

Lectures: 2 sessions / week, 1.10 hours / session.

**Instructor: Professor Aris Christou, Office: 2309 Chem/Nuc Building, christou@umd.edu**

**Prerequisites**

ENMA 300, Phys 161, Chem 131

**Requirements**

The course will have 5 Problem Sets, 2 Midterms and Final Exam. One class project will be assigned on an advanced topic in Photonics. The class project has a final report and class presentation requirement. The students must select their topic from a list of projects proposed by Prof Christou

**Recommended Course Text Book (only for the purpose of explaining lecture material, additional reading materials will be posted on Canvas). This is not a required text book.**

**Vittorio Degiorgio and Ilaria Cristiani, “Photonics” second edition, published by Springer. ISBN 978-30319-20626-4.**

**Aris Christou, “Photonic Materials, Devices and Reliability,” (pdf). Will be available on CANVAS.**

**Grading Policy**

The grade will be decided based on the results of two exams, the final exam, and the course project. The homework will count towards the final grade. The table below gives the emphasis that will be given to homework, quizzes, and the final exam in determining the final grade.

| **activities** | **percentages** |
| --- | --- |
|  |  |
| Homework | 15%, hw will be collected, and graded. |
| Class Tests (two) | 30% |
| Final Exam  Final Class Project | 30%  35% |

**Homework Policies**

The class will have 5 problem sets which will be posted on CANVAS. Normally the solutions are due in the following week. If for some reason you cannot submit the solution on time, please contact me before the solution is due. Solutions to the problems will be posted on Canvas.

Collaboration on problem sets is encouraged. However, you must write your own solutions to the problems rather than copying solutions from somebody else. Please cite all people with whom you have collaborated.

The problem set on which you get the lowest grade will not be counted towards the final grade. Only the top 5 graded problem sets out of the 6 problem sets you have to submit will count towards your final grade.

The grades for homework will depend not only on the correctness of the final result, but also on the ideas used for the solution. If the idea is correct but there was some mathematical error made, you still will have a good chance of getting a good grade. It is a good idea to check the final result for physical consistency. The solution must have adequate explanations which demonstrate your approach towards the solution. This does not mean that you need to explain each equation you are writing. Doing so will provide me with valuable feedback on your understanding of the concepts. Solutions without adequate explanations will be graded lower. Solutions without units are always incorrect.

**Quizzes and Final Exam**

The class will have two class tests and the final exam. The tests will be 1.25 hours long, the final exam will be 2 hours long. The problems in the tests and final exam are of the similar type as your homework, but with greater emphasis on concepts.

The tests and final exam will be closed book, i.e. no books, class notes, or other materials are allowed. However, you may take one double-sided page of notes to the first test, two pages to the second, and three to the final exam. Using calculators is allowed. Cooperation of any kind is not permitted. I do reserve the option of giving a “take-home” final instead of an in-class final.

**Calendar**

| **lec #** | **TOPICS** | **KEY DATES** |
| --- | --- | --- |
| 1, 2 | Introduction to Photonics: New advances, photonic crystals, plasmonics, photonic integrated circuits, single photon detection. |  |
| 3 | [Energy in a Magnetic Field](#_Toc110155692)  [Poynting's Theorem, Conservation of Energy](#_Toc110155694)  [Electromagnetic Waves](#_Toc110155695)  [Linear and Circular Polarization](#_Toc110155696) | Problem set 1 out |
| 4 | Electromagnetic Waves and Interfaces I (Review)  [Reflection and Refraction of EM Plane Waves at Interfaces](#_Toc110155697)  [Frequency Dispersion Characteristics of Dielectrics, Conductors and Plasmas](#_Toc110155698)  [Waveguides and Resonant Cavities](#_Toc110155699)  [Cylindrical Cavities and Waveguides](#_Toc110155700) |  |
| 5 | Electromagnetic Waves and Interfaces II  [Waveguides](#_Toc110155701)  [Resonant Cavities](#_Toc110155702)  [Maxwell's Equations In A Medium](#_Toc110155704)  [Non-Linear, Dispersive, and Inhomogeneous Media](#_Toc110155705)  [Wave Optics and Electromagnetic Waves](#_Toc110155706)  [Wave Equation, Helmholtz Equation](#_Toc110155707)  [Interference of Two Waves](#_Toc110155708) | Problem set 1 due |
| 6 | Mirrors, Interferometers and Thin-Film Structures  [Review of Mirrors and Lenses](#_Toc110155712)  [Lenses](#_Toc110155713)  [Lens Waveguide](#_Toc110155714)  [Biperiodic Lens Sequence Equal Lens Waveguide](#_Toc110155715)  [Rays in Lens Like Media](#_Toc110155717) | Problem set 2 out |
| 7 | Gaussian Beams and the Wave Equation  [Rays in a Planar Dielectric Core Cladding Interface](#_Toc110155718)  [Transverse Modes](#_Toc110155719)  [Wavelength Dispersion](#_Toc110155720) |  |
| 8 | Optical Fibers and Resonators  [Optical Beams in Fibers](#_Toc110155732)  [Transverse Modes](#_Toc110155733)  [Circular (Cylindrical) Fibers](#_Toc110155734)  [Optical Waveguide Theory](#_Toc110155735)  [Cutoff Condition](#_Toc110155736)  [Modal Dispersion](#_Toc110155737)  [Light Insertion](#_Toc110155738) | Problem Set 2 due. |
| 9, 10 | Optical Fibers (More Stuff)  [Mathematical Treatment of Optical Beams in Fibers](#_Toc110155739)  [Wave Equation](#_Toc110155740)  [Mode Characteristics](#_Toc110155741)  [Linearly Polarized Modes](#_Toc110155742)  [Graded Index Fibers](#_Toc110155743)  [Power Flow and Power Density in a Silica Fiber](#_Toc110155744)  [Light Insertion Calculations Into Fibers](#_Toc110155745)  [Losses - Scattering](#_Toc110155746)  [Mechanical Losses](#_Toc110155747) | Exam 1  Problem set 3 out |
| 11 | Lasers and Coupled Mode Theory, rate equations |  |
| 12 | Optical Resonators  [Fabry-Perot Etalon (Interferometer)](#_Toc110155749)  [Fabry-Perot Etalons - Optical Spectrum Analyzers](#_Toc110155750)  [Fabry-Perot Laser](#_Toc110155751)  [Resonance Frequencies](#_Toc110155752)  [Longitudinal Modes](#_Toc110155753)  [Losses in Optical Resonators](#_Toc110155754) | Problem set 3 due |
| 12 | Anisotropic Media: Crystal Optics and Polarization  [Introduction](#_Toc110155758)  [Transitions Due to Electron-Photon Interactions](#_Toc110155759)  [Optical Cavities](#_Toc110155760)  [Energy Considerations](#_Toc110155761)  [Steady State](#_Toc110155762)  [Optical Resonance and Average Energy](#_Toc110155763) |  |
| 13 | Quantum Nature of Light and Matter  Schrödinger Equation and Stationary States  Harmonic Oscillator and Hydrogen Atom | Problem set 4 out |
| 14 | Laser Transition Theory, optical resonance |  |
| 15 | [Lasers](#_Toc110155766)  [Three Level System Transition Rates](#_Toc110155767)  [Laser Fundamentals Review](#_Toc110155768)  [Laser Oscillations](#_Toc110155769)  [Multi-mode Laser Oscillation](#_Toc110155770)  [Specific Laser Systems](#_Toc110155771) |  |
| 16 | [Semiconductor Lasers and Light Emitting Diodes](#_Toc110155818)  [Compound Semiconductors](#_Toc110155819)  [Light Emitting Diodes (LED)](#_Toc110155820)  [Infrared LEDs](#_Toc110155821)  [Physics of LEDs](#_Toc110155822)  [Homojunctions and Heterojunctions](#_Toc110155823)  [Calculation of Threshold Current Density](#_Toc110155824) | Problem Set  4 due |
| 17 | Optical Amplifiers and Lasers  [Quantum Well Lasers (QW, MQW)](#_Toc110155825)  [Laser Physics](#_Toc110155826)  [Threshold Current Density in Double Heterostructure Lasers](#_Toc110155827)  [Power Output](#_Toc110155828)  [Start Oscillation Condition for Semiconductor Lasers](#_Toc110155829)  [Distributed Feedback Laser](#_Toc110155830) |  |
| 18 | [Physical Processes For Optical Detection](#_Toc110155785)  [Detection of Optical Signals](#_Toc110155786)  [Photomultiplier Detector](#_Toc110155787)  [Noise Mechanisms in Photomultipliers](#_Toc110155788)  [Minimum Detectable Power in Photomultipliers](#_Toc110155789)  [Heterodyne Detection with Photomultipliers](#_Toc110155790)  [Photoconductive Detectors](#_Toc110155791)  [Time Response](#_Toc110155792)  [Generation Recombination Noise in Photoconductive Detectors](#_Toc110155793) | Problem set 5 out |
| 19, 20 | More on Optical Detection  [Heterodyne Detection](#_Toc110155794)  [PN Junctions as Photodetectors](#_Toc110155795)  [Photodiodes as Light Detectors](#_Toc110155796)  [PIN Structures as Photodetectors](#_Toc110155797)  [Avalanche Photodiodes](#_Toc110155798)  [Real Detector Characteristics](#_Toc110155799) | Exam 2 |
| 21 | [Characteristics Of Photodetectors](#_Toc110155801)  [Response Time and Frequency Response](#_Toc110155803)  [Spectral Response](#_Toc110155804)  [Detector Noise Sources](#_Toc110155805)  [Graded Bandgap Detectors](#_Toc110155806)  [Optical Fiber Link](#_Toc110155807) | Problem set 5 due |
| 22 | [Modulation of Laser Beams and Non Linear Optical Materials](#_Toc110155809)  [Electro-Optic Amplitude Modulation](#_Toc110155811)  [Phase Modulation of Light](#_Toc110155812)  [High Frequency Effects](#_Toc110155813)  [Transverse Mode of Modulation](#_Toc110155814)  [Modulation of Light by Means of the Quadratic Electro-Optic Effect](#_Toc110155815)  [Internal Modulation](#_Toc110155816) |  |
| 23 | |  | | --- | | [Failure Mechanisms of Optoelectronic Devices and Components](#_Toc110155847) and Plasmonics  [Introduction to Reliability](#_Toc110155848)  [Analysis of Bond Related Failures in Optoelectronics](#_Toc110155849)  [Failure Mechanism Related to Contamination in Optical Devices](#_Toc110155850)  Packaging Considerations  [The Failure Modes in Devices](#_Toc110155851)  [Electromigration in Opto-Circuit Metallizations](#_Toc110155852) | |  |
| 24 | Project Presentations |  |
| 25 | Project Presentations |  |