NEW YORK CITY COLLEGE OF TECHNOLOGY
The City University of New York

DEPARTMENT: Electrical and Telecommunications Engineering Technology

SUBJECT CODE AND TITLE: TCET 4162/TC 760 Photonic Devices

COURSE DESCRIPTION: This course provides a broad overview of photonic devices, including the underlying principles and applications for communications. This course discusses planar waveguides, semiconductor photonic devices, including light emitting diodes (LEDs) and laser diodes, devices for polarization and modulation, photodetectors, and optical sensors. The course also considers system performance of photonic devices and their applications in practical modules.

PREREQUISITE: TCET 3202/TC 620

TEXTBOOK: Djafar K. Mynbaev and Lowell L. Scheiner, *Fiber-Optic Communications Technology*, Prentice Hall, 2001, ISBN 0-13-962069-9.
Course notes prepared by Professor Djafar Mynbaev, New York City College of Technology, Fall 2005.

COURSE OBJECTIVES/ COURSE OUTCOMES: Upon completion of this course students will posses the ability to:

1. Understand the general principles of light propagation and basic physical concepts of material responses to optical fields (ABET Criteria 2a, 2b, 2d, 2g).
2. Explain light propagation using Maxwell's wave equation, TE and TM modes, and planar optical waveguides (ABET Criteria 2a, 2b, 2d, 2f).
3. Describe the theoretical performance of optical fibers (ABET Criteria 2a, 2b, 2d, 2f).
4. Explain the principle of operation and applications of light emitting diodes (LEDs) (ABET Criteria 2a, 2b, 2d, 2g).
5. Understand the fundamentals of semiconductor laser and their applications in communications systems (ABET Criteria 2a, 2b, 2d, 2f, 2k).
6. Analyze the characteristics and evaluate the performance of photo detecting devices (ABET Criteria 2a, 2b, 2f, 2k).

7. Describe the technical and physical fundamentals of various optical sensors (ABET Criteria 2a, 2b, 2f, 2g).
8. Understand and use technical documentation of all the discussed devices (ABET Criteria 2a, 2b, 2c, 2d, 2f).
9. Understand the current status and future trends in development of photonic devices (ABET Criteria 2a, 2b, 2c, 2d, 2f, 2h).

TOPICS: Topics include light propagation, applications of planar waveguide devices, light emitting diodes (LEDs), laser fundamentals, semiconductor and other lasers, polarization and modulation of light, photo detecting devices, optical sensors, system performance of optoelectronic devices, and system applications of opto-electronic devices.

CLASS HOURS: 2

LAB HOURS: 3

CREDITS: 3

Prepared by: Professors D. Mynbaev, and Sunghoon Jang
October 2006

Course Coordinator: Professor D. Mynbaev
(718) 260-5304 E-mail: dmynbaev@citytech.cuny.edu

Descriptive details for laboratory coursework:

Laboratory exercises contain observation of basic principles and the concepts in waveguide, planar waveguide devices, LEDs circuit, and gas & semiconductor lasers. The students will also examine and analyze the concept and basic characteristics of photonic devices based on polarized light, photo detectors, optical sensors, noise in photonic devices, devices for light modulation.

GRADING POLICY: TCET 4162/TC 760

Laboratory part	30%
Quizzes	30%
Research paper	10%
Final Exam	30%

Letter Grade	Numerical Grade Ranges	Quality
A	93-100	4.0
A-	90-92.9	3.7
B+	87-89.9	3.3
B	83-86.9	3.0
B-	80.82.9	2.7
C+	77-79.9	2.3
C	70-76.9	2.0
D	60-69.9	1.0
F	59.9 and below	0.0

Class policy:

1. Students are required to attend all regularly scheduled class meetings.
2. Students are required to be on time for all class meetings.
3. Students are responsible for all material covered by the instructor in class whether they are present or not. If a student must be absent, it is their responsibility to find out what was missed from either the instructor or a fellow student.
4. Students are expected and encouraged to see the instructor for extra help outside of class as soon as difficulty in understanding the material is encountered. Students who do not grasp the material the material from a given day's class will not be able to understand the material in subsequent classes.
5. Students are expected and encouraged to use online options, such as Blackboard and e-mail, for additional help and advice
6. Students are expected to work all homework and test problems.
7. Students are expected to keep a class notebook.
8. Students require submitting a laboratory report next week after the experiment is conducted.
9. Research paper is due the week before the final examination.
10. No food or drink is allowed in the classroom at any time.

Assessment

The following assessment techniques are correlated to the course objectives as follows: In addition, each assessment technique incorporates one or more of the following ABET Criteria 2 outcomes (2a, 2b, 2c, 2d, 2f, 2k

COURSE OBJECTIVES	COURSE ASSESSMENT
For the successful completion of this course, the students should be able to:	Evaluation Methods and Criteria: Students will exhibit skills in class discussion, homework assignments, laboratory exercises, quizzes, exams, and course projects.
1. Understand the general principles of light propagation and basic physical concepts of material responses to optical fields.	1. Analyze fundamental principles and applications of photonic devices
2. Explain light propagation using Maxwell's wave equation, TE and TM modes, and planar optical waveguides.	2. Analyze the principles of light propagation in free space and within waveguides. Develop the skills to perform necessary calculations based on Maxwell's equations.
3. Describe the theoretical performance of optical fibers.	3. Analyze the principles of operation of optical fibers and calculate transmission parameters of optical fibers. Simulate operation of optical fibers.
4. Explain the principle of operation and applications of light emitting diodes (LEDs).	4. Analyze operation of light sources based on spontaneous emission, compute main characteristics of LEDs and present the results in tabulated and graphical formats.
5. Understand the fundamentals of semiconductor laser and their applications in communications systems.	5. Analyze laser operation, apply this analysis to semiconductor lasers and connect operational principles with technical characteristics of laser diodes.
6. Analyze the characteristics and evaluate the performance of photo detecting devices.	6. Analyze operation of p-i-n and avalanche photodiodes. Relate the principle of operation of photodiodes with their technical characteristics.
7. Describe the technical and physical fundamentals of various optical sensors.	7. Analyze the principle of operation and technical characteristics of optical sensors. Simulate their operation.
8. Understand and use technical documentation of all the discussed devices.	8. Analyze industry technical documentation and develop the skills to use these documents for design of photonic devices and analysis of their performance.
9. Understand the current status and future trends in development of photonic devices.	9. Analyze state-of-the-art photonic devices, including optical sensors and switches, and describe the future trends, including nanophotonics.

Week	Topic	Reading Assignments	Laboratory
1.	**Introduction to the course outline**. **Review of optics**: reflection and refraction, total internal reflection, plane waves, polarization, coherence, wave optics, quantum optics.	Chapter 1	**Introduction to course labs.**
2.	**Light propagation**: Light propagation, waveguiding properties, Maxwell's equations, TE and TM modes, mode profiles, Optical fiber waveguides, waveguide mode properties.	Chapter 1&2	**Waveguides**: Introduce students to the basic principles in wave-guiding and examine how an optical fiber guides light.
3.	**Applications of planar waveguide devices**: Theoretical performance of polymer optical fibers, planar waveguides, and amplifiers, WDM applications, etc.	Chapter 2	**Planar Waveguide Devices:** Examine the concept of planar waveguide and observe the modes of a planar waveguide
4.	Quiz #1 **Light emitting diodes**: The light emitting diodes (surface emitter LEDs, edge emitter LEDs, superluminesent LEDs, LED characteristics), modulation bandwidths (electrical and optical), laser amplifiers.	Chapter 3	**LEDs**: Build an LED circuit including DC power supply, resistors, transistor, etc and measure the voltage, current, and optical power curves for an LED (V-I and P-I curves).
5.	**Laser Fundamentals**: Emission and absorption of radiation, population inversion, optical feedback and gain, cavity modes, single mode operation, frequency stabilization, mode locking techniques, Q-switching, etc.	Chapter 4 Class Note	**Gas Lasers:** Observe the characteristics of a Helium-Neon laser. Use an optical table and mirrors to build a light path and measure the laser output power.
6.	**Semiconductor lasers**: Semiconductor concepts (energy bands, semiconductor statistics; bandgap and E-k diagrams), optical emission from semiconductors (the p-n junction; principle of laser diode), heterostructure laser diodes, elementary laser diode characteristics; quantum well devices, vertical cavity surface emitting lasers; optical laser amplifiers.	Chapter 4	**Semiconductor Lasers:** Measure the output light power versus the input current (P-I curve). Plot the data and determine the threshold current and calculate the efficiency.
7.	**Quiz #2** **Other Lasers**: Gas, solid, fiber, chemical, etc.	Chapter 4	**Semiconductor Lasers:** Use a random pulse generator to modulate the laser diode. Use an optical receiver and an oscilloscope for the time domain measurement.

8.	**Polarization and modulation of light:** State of polarization, Malus's law, birefringent optical devices, electro-optic effects, etc.	Chapter 7	**Photonic devices based on polarized light:** Examine the concept of light polarization in order to find light polarization changing with polarizers. Use a polarizer and analyzer pair to observe Malus's law.
9-10.	**Photo detecting devices**: Detector performance parameters, characteristics of noise, detection techniques (incoherent and coherent detections), thermal detectors, photo-detectors, p-n junction and p-i-n photodiodes, speed of response, detector array devices.	Chapter 5	**Photo Detectors:** Investigate the characteristics of a photodiode operating in the photovoltaic and photoconductive mode.
11-12.	**Quiz #3** **Optical sensors**: Technical and physical fundamentals, construction, function, applications and developments of the various types of sensors.	Class Note	**Optical Sensors:** Examine the characteristics of optical sensors and study various configurations. Design, build, and characterize an optical sensor configuration for the particular sensing problem.
13.	**System performance of optoelectronic devices**: Noise sources (photon, shot, photon-electron, gain, circuit noise, etc), Analog signal-to-noise ratio, Probability of error in digital systems, Distortion.	Class Note	**Noise in photonic Devices:** Use a laser and an optical receiver, from previous experiments. Build a transmission setup and measure the signal & noise. Calculate the signal to noise ratio.
14.	**System applications of opto-electronic devices**: Communications (telephone trunks, submarine systems, fiber-to-the-home), Video (CATV, broadcast TV), Data networks (LANs, MANs, WANs).	Class Note	**Devices for light modulation:** examine the characteristics of the $LiNbO_3$ Mach-Zehnder Interferometer (MZI) based modulators and electro-absorption modulators (EAM).
15.	**Final Examination.**		