AC 2007-653: NSF-FUNDED PHOTON-2 PROJECT AND COURSE DEVELOPMENT IN PHOTONICS

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Abstract: In recent years, optical electronics and lasers have been widely employed in various realms of the electronics industry such as bioengineering, communication, CNC and routing in cheap designs. While optics has become a vital part of electronics, it has unfortunately been absent in most four-year college/university engineering technology programs. The Electronic and Computer Engineering Technology (ECET) program at California State Polytechnic University - Pomona (CalPoly-Pomona) has recognized this deficiency and in order to help alleviate this problem joined the NSF funded PHOTON2 project (1). The PHOTON2 project is a New England Board of Higher Education (NEBHE) sponsored program (2). By working closely with NEBHE, ECET program developed a senior level photonic course using modified PHOTON2 materials and laboratory experiments. This course uses optical and laser components and equipment supplied by PHOTON2 project. This paper will show how the NSF funded PHOTON2 project, helped the ECET program at CalPoly – Pomona, to develop its photonic course.

Introduction: In order to stay current with the industry, produce a knowledgeable workforce, and respond to industry needs and expectations, Electronic Engineering and Engineering Technology departments need to continuously update their curriculum. Optics is one of the areas to which engineering schools need to pay more attention. In the last decade, optics and its applications have become an integral part of almost every facet of the electronics industry such as medical, communication, heavy industry, lighting, manufacturing, and routing in cheap design.

Optical Company in the Southern California: Many optics related companies, that produce a wide range of optical systems and accessories, are located in southern California (3). These companies produce everything from Lasers, tunable lasers, diode lasers, to spectroscopy, sensors, motion control, telescopes, High Speed Cameras, visible, and UV, IR optics. Table (1) shows the Southern California optics industry. The optics industry consists of many companies ranging from large to small including many well-established companies. Most of these companies employ tens to hundreds of technical people and it can be assumed that their future employees will be graduates of southern California Engineering and Engineering Technology schools.

Table 1: Optics industry in the Southern California

Company	Products
Spectra Asahi USA, Inc.	Optical filters, optical instruments, Xenon light sources, measuring systems
Lambda Research Optics, Inc.	Ultra-Violet optics, visible optics, near infra-red optics, infra-red optics
Meade Instruments, Corp.	Telescopes, images, sport optics & microscopes and accessories
Melles Griot	Lasers, shutters, optical filters, apertures, isolators, fluorescence filters
Microlaser Syatems, Inc.	Free space and fiber optic lasers
Mindrum Precision, Inc.	Optical windows, motion control dampers, laser module, and Fresnel lenses
Newport Corp.	Fiber optic sources, crystals, diffraction gratings, light sources, motion control, vibration control, opto-mechanics, photonics instrumentation, spectroscopy, and optical filters
Optek, Inc.	Spectral Imaging instruments based on tunable laser systems
Photron, Inc.	Femto and pico second fiber lasers, high power fiber lasers/amplifier, broadband ASE sources
Elforlight Ltd.	Diode pumped solid-state lasers
Unitek-Myachi Laser	Laser welding and soldering, hot bar bonding,

Engineering Schools in Southern California and Optic related courses: A majority of Engineering and Engineering Technology students attend California State Universities. In Southern California, Cal-State Los Angeles, Long Beach, Fullerton, Northridge, San Diego, and CalPoly-Pomona offer Engineering programs. CalPoly Pomona is the only California State University that offers an Engineering Technology program in Electronics and Computer. The remaining California State Universities either do not offer optics or optical related course or they offer these courses as an option from 15-20 technical elective courses; this results in the optics or optical related course not being offered on a regular basis (4). Table (2) shows the optical related courses available in the engineering programs at several southern California State Universities.

Table 2: Optical related course offering at Southern California State Universities

Institution	**Optics and related courses**
Cal-State L.A.	One course (Fiber Optics), Elective
Cal-State Fullerton	Two courses (Eng. Optics and Electro-Optics Systems), both elective
Cal-State Northridge	None
Ca-State San Diego	Two courses (Electro-Optics and Optical Fiber Communications) both elective
Cal-State Long Beach	None
CalPoly-Pomona	Two courses (Laser and Optical Fiber Communications) both elective

Research and Findings: The research the ECET program conducted showed that the ratio of course offering in optics by Southern California State universities is insufficient while the demand from the optical industry in the area is continuously rising. To respond to this deficiency, the ECET program at CalPoly-Pomona developed a plan to add a four units (three unit lecture and one unit laboratory) optics course to its curriculum. This course would cover geometric optics, fiber optics, and optical communication. The inception plan for this course had two stages: 1) Search for funding/donation of laboratory equipment, develop an elective course, and offer the elective course once year. 2) Establish relationships with the local optics industry, get their feedback, revise course based on feedback and change the optics course from an elective to a core course. The end result of the first stage of our research and study was joining the NEBHE's NSF funded PHOTON2 as a Southern California Alliance.

NSF Funded PHOTON2: PHOTON2 is a New England Board of Higher Education (NEBHE) project. The "NEBHE was founded in 1955, when six visionary New England governors – realizing that the future prosperity of New England rested on higher education – committed their states to the shared pursuit of academic excellence. Soon thereafter, NEBHE was approved by New England's six state legislatures and authorized by the U.S. Congress. The mission of NEBHE is to promote greater educational opportunities and services for the residents of New England. In 2003, NEBHE received a three-year grant from the Advanced Technological Education (ATE) program of the National Science Foundation (NSF) for their PHOTON2 project. In the PHOTON2 project, educators from several geographic locations (four to six regions nationally) brought together to facilitate photonics technology education at their institutions that is intelligently developed and seamlessly articulated. The 'Alliances' consisted of four to six participants per region, including high school and two- and four-year college science, technology, engineering, and math instructors, as well as their institution's career and admissions counselors.

In August 2004, the ECET program at CalPoly-Pomona organized an alliance with high school science teachers as well as a community college electronics professor and applied to the NEBHE for participation in the PHOTON2 project as a Southern California Alliance and received its approval. In November 2004, the Senior Director of Program and Principal Investigator, Ms. Fenna Hanes and Co-Principal Investigator, Ms. Judith Donnelly, presented a two day PHOTON2 hands-on seminar/workshop at CalPoly

to members of the Southern California Alliance as well as to members of other alliances.

For each institution of the alliance, the PHOTON2 project provided a complete set of curriculum material in addition to an optics laboratory kit of which half of the total price was paid for by the PHOTON2 grant. The laboratory kit consists of various types of lenses, optical filters, lasers, light sources, light detectors, as well as a variety of other accessories. To supplement the one lab kit received from the grant, ECET purchased four additional lab kits to use in the new optics course serving 24 students.

The alliance with the PHOTON2 project helped the ECET department accomplish the first stage of plans to have enough optical equipment to offer a course in optics.

The Photonics course outline of the PHOTON2 project: The PHOTON2 curriculum materials consist of the following topics:

- Laser safety overview
- The nature of light
- Geometric optics
- Lenses and mirrors
- Waves: interference, diffraction, and polarization
- Optical instruments
- Introduction to laser physics and characteristics
- Lasers and materials processing
- Introduction to fiber optics
- Holography

In order to adopt the above topics into the ECET new optics course, the two topics of Laser safety overview and holography were removed and two topics of optical sensors and optical communications were added to above topics.

Laboratory Experiments: Out of the twenty laboratory experiments created by the PHOTON2 project, we adopted the following six experiments:

- Snell's law, lens-makers formula,
- Systems of two lenses
- Gaussian beam profile of a laser beam
- Laser bar code scanner
- Numerical aperture

To complete the ECET plan for laboratory experiments, three more experiments of: power losses due to the optical fiber mismatch, optical sensors, and optical communication were added to the above experiments. In order to satisfy TAC-ABET criteria "g" which states students must have the "ability to communicate effectively," the course plans also included a group project where students are asked to create a team of three, write a term paper on the recent developments in optics and its applications, and present it to the entire class.

Optics course and TAC-ABET's A-K criteria: The new optic course in the ECET program satisfies the following TAC-ABET criteria: a, b, c, d, e, f, g, h, and k.

The Photonics course description and course outline of the ECET program at CalPoly-Pomona University.

CALIFORNIA STATE POLYTECHNIC UNIVERSITY, POMONA

Course Information	ABET Unit Classification (4 Quarter Units)
Department: Engineering Technology Course Number: ETE 455/455L Course Title: Photonics Revision Date: 6/16/06 Revised by: Massoud Moussavi Compliant: Catalog 2006/07	Math: Basic Science: Engineering Topics: 4 Contains significant design content: No Other: Curriculum Designation: Elective

I. Catalog Description: Introduction to geometric optics and components (reflection, refraction, Snell's law, lenses, mirrors, beam splitter), wave and particle optics (polarization, interferences, and diffraction), fiber optics (optical fiber types, signal distortion and attenuation),

optical communication systems including light sources, detectors, receivers, amplifiers, and modulation.
3 lectures/problem-solving and 1 three-hour laboratory
Prerequisite: ETE 335
II. Prerequisites and Co-requisites: ETE 335/335L; Students are expected to have a good theoretical, analytical, and practical knowledge of communication system including modulation, demodulation, transmission, receivers, transmission line, and signal amplification
III. Textbook and/or other Required Material: PHOTON2 project course materials Louis Desmarais, Applied Electro-Optics, Prentice Hall Publication Co. ISBN 0-13-802711-0
IV. Course Objectives: Upon successful completion of this course, each student should be able to:

1. Understanding of geometric optics: reflections, refraction, and Snell's law
2. Understanding of optical components such as thin and thick lenses, mirrors, beam splitters
3. Understanding of wave and particle optics: polarization, interferences, diffraction, quanta and energy of photons.
4. Understanding of single and multimode optical fibers and their characteristics such as absorption, scattering, internal and modal dispersions.
5. Understanding the semiconductor light sources such as LED, laser diodes, and tunable laser diodes, their characteristics and applications.
6. Understanding light detectors such as PIN photodiodes, Avalanche photodiodes phototransistors, and photo-couplers, their characteristics and applications.
7. Analysis of LED and laser-diode modulations and circuits (both analog and digital formats)

V. Expanded Course Description: A. Expanded Description of the Course

1. Geometric optics and optical components: Characteristics of geometric optics: incident, reflection, and refraction rays. Snell's law, converging and diverging lenses, thin and thick lenses, real and virtual focal points, forming images, magnification, plane and spherical mirrors, beam splitters. (2 weeks)

2. Wave and particle optics: Study of wave and particle optics including: superposition of wanes, temporal and spatial coherences, Young's experiment, diffraction, interferences, and polarization, Planck' law and energy of photons (2 weeks)
3. Optical Fibers:. Characteristics of optical fibers, optical fibers types: multimode step-index, multimode graded-index, and single mode, numerical aperture, absorption and scattering in the optical fibers and losses, modal and interamodal dispersions, pulse distortion and information rate in optical fibers, losses due to: source coupling and connectors. (2 weeks)
4. Light sources and optical amplifiers: Study of the characteristics and applications of semiconductor light sources such as: Light-Emitting-Diodes (LEDs), laser principles, laser-diodes, tunable laser-diodes, fiber laser, VCSE laser-diodes, and optical amplifiers. (2 weeks)
5. Light detectors and modulation: Study of physical characteristics of photo-detection, photo-multipliers, semiconductor photodiodes such as PIN and Avalanche, phototransistors, opt-couplers, LED and laser-diode modulation circuits, analog and digital modulation formats. (2 weeks)

B. Typical Laboratory Experiments

Lab 1. Snell's Law.

Lab 2. Systems of two lenses.

. Lab 3. Gaussian beam profile of a laser beam.

Lab 4. Laser bar code scanner

Lab 5. Numerical aperture of an optical fiber.

Lab 6. Losses in an optical fiber system

Lab 7. Optical communication I. Optical transmitters

Lab 8. Optical communication I. Optical receivers

Lab 9 and 10: Mini project and oral presentation

VI. Class/Laboratory Schedule: Lecture: Two 75 minutes sessions per week.
Lab: One 3 hours session per week.
VII. Contribution of Course to Professional Component: Lecture: Students learn about principles of optics and optical communications, the characteristics and applications of optical components and electro-optical devices. Lab: Students learn how to build, test, and troubleshoot the variety of optical systems and electro-optical circuits. They also build and test a mini project, write a paper on a specific application of optical communication and present it to the entire class.
VIII. Evaluation of Students: The instructor evaluates outcomes using the following methods: homework assignment submittals, midterm and final exams, one-on-one discussions during office hours, laboratory experiments, and laboratory reports.

The student grades are typically based on the following factors: quizzes, homework, midterm exam and final Exam.

IX. Relationship of Course Objectives to Program Outcomes

Course Obj	**Program Outcomes**										
	(a) **Use of modern tools of discipl**	***(b)*** **Use of math, science, Engg & Tech**	***(c)*** **Do experi-ments**	***(d)*** **Dsn of sys & components**	***(e)*** **Work on teams**	***(f)*** **Do Tech probs**	***(g)*** **Eff Com**	***(h)*** **Life-long learn**	***(i)*** **Prof, ethics, social resps**	***(j)*** **Prof, soc, globl, diversity**	***(k)*** **Qual, Cont impr, timeliness**
1		X	X		X	X					
2		X	X		X	X					
3		X	X	X	X	X					
4	X	X	X	X	X	X	X				
5	X	X	X	X	X	X	X	X			

Students' response**:** Both junior and senior students showed their interest for this new course. In summer 2005, when the Photonics course offered for the first time, 56 students signed up for course, way behind the limit (24 students) for a course with laboratory session. The majority of students showed their interest mostly on applications of optical devices and equipment rather than their physical behavior specifically on laser and photo- detectors. They also showed their interest in the fiber optics related experiments and optical communications rather than experiments on geometric optics. Seven students in the first Photonics class found employment in optical companies.

Conclusion: The year and a half plan of the ECET program at CalPoly-Pomona to develop a new course in optics and optical communications was successfully accomplished with the help of the PHOTON2 project. ECET has been able to offer this course in summer quarter of 2005 and spring quarter of 2006. One of the ECET goals was to create a course that would help to provide knowledgeable technical workforce for local optical companies. Many optical companies in southern California are looking for graduates who have some knowledge in optics and laser and those ECET graduates who took this photonic course have since found gainful employment. This effort was deemed a success when it reached its goal of helping match its graduates with local optical companies.

References:

1. PHOTON2 website: www.nebhe.org/photon2
2. NEBHE website: www.nebhe.org
3. Websites of the Optical companies in the Southern California
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4. Websites of the California State Universities in the Southern California
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