MS in Photonics – Recrafting a Curriculum

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Abstract

The Master of Science in Photonics has been created as a new graduate offering in the Department of Electrical & Computer Engineering. This degree program has evolved slowly; a core of courses in the late 1980's initially presented advanced electrical engineering topics like fiber optic communications and lasers. A university commitment to building a Photonics Center, and NSF Combined Research and Curriculum Development support allowed creation of a modern teaching laboratory, curriculum design, and growth in faculty and students.

The new MS program follows the structure of our existing MSEE and MSCE degrees, and requires little additional university investment. Specific course offerings will be described, along with their laboratory components and the set-up of the Photonics Instructional Laboratory. Curricular overlap with senior electives and with graduate students from other disciplines will also be presented. Connections for research and entrepreneurship in photonics have been created, allowing students to undertake MS thesis work, MS projects, or prepare for Ph.D. level study. Recent connections to distance learning will be described.

This paper also will describe the administrative issues that arose within the department, as a new degree grew from existing offerings, and within the wider university, as our new degree proposal was assessed and reviewed. Some of these lessons should help readers considering new specialized degree programs in their own colleges.

Introduction

A typical engineering curriculum is continually evolving. Specific course content may change from semester to semester while laboratories evolve more slowly as equipment and facilities are upgraded. Degree program requirements change even more slowly, in response to changes in engineering practice, accreditation guidelines, student interest, and engineering market demands. Slowest of all are changes in actual degree concentrations, which must respond to long-term development of new areas of engineering specialty.

At Boston University, the College of Engineering's four departments (Aerospace & Mechanical, Biomedical, Electrical & Computer, and Manufacturing) offer Bachelors, Masters, and Ph.D. degrees in Aerospace Engineering, Biomedical Engineering, Computer Systems Engineering, Electrical Engineering, Manufacturing Engineering, and Mechanical Engineering. This degree mix has changed little over the last 20 years. New MS programs in Cognitive and Neural Systems

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and in Bioinformatics arose in the 1990s, but these were established within campus-wide interdisciplinary centers, with Engineering as one of many participants.

Photonics, the science and technology of light, has been evolving as a distinct engineering area over the last two decades. Photonics is a global industry with estimated annual volume exceeding $100B. Its companies usually provide enabling technology for other products and services, supporting the transmission of information, the processing of materials, the manufacturing of microelectronics and nanotechnology, sensing, display, and scientific measurement. The industry has a wide demand for technical graduates, from established large corporations like Corning (optical fibers), to agile start-ups like Cierra Photonics (optical coatings). Median technical staff salary for 0-5 years experience is $68,000[1].

Photonics specialists have traditionally studied electrical engineering, materials science, physics, or optics. Nearly 150 institutions list graduate programs in optics or photonics[2] but a few large centers grant most related graduate degrees (e.g., University of Rochester, University of Arizona, and University of Central Florida). New degree programs in photonics (also, electro-optics, optoelectronics, and imaging) have been developed with external funds (NSF-IGERT[3]) and through institutional support[4].

Photonics is the subject of a new Master of Science engineering degree program at Boston University, under the Department of Electrical and Computer Engineering. This paper describes the gestation of this new program, including the evolution of photonics courses, photonics research, faculty development and finally the formal degree proposal for the MS in Photonics.

University Context – The Boston University Photonics Center

In the early 1990's, Boston University developed a series of white papers addressing the importance of the photonics industry to industry and national security, and proposing a regional center for the study of photonics. At the time, over 200 photonics-related firms were identified in the New England region. These white papers led to the establishment of the Boston University Photonics Center in 1994 with a seed grant from the federal government. In 1997 the Photonics Center moved into a new nine-story research building that houses the laboratories, meeting rooms, offices and company incubator space. The photonics building includes a photonics instructional laboratory, maintained by ECE for course labs and student projects in photonics. ECE offices, laboratories, and instructional laboratories also occupy the lower floors of the photonics building, and the second floor has university classrooms and lecture halls. It is a world-class facility of over 250,000 ft^2.

Construction of the Photonics Center provided two important elements: modern interdisciplinary ***research facilities*** for students and faculty, and a ***commitment by the University*** toward supporting new faculty lines and student recruiting. The scale of the investment made it easier to compete for external funds, and ECE received a fellowship grant for photonics students from the Department of Education (Graduate Research Applied to National Needs), and a curriculum development grant from NSF (Combined Research and Curriculum Development) as the building was being constructed.

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Course Development

ECE had offered a few graduate technical electives in photonics since the mid-1980s, including Fiber Optics and Lasers and Applications. A favorable interdisciplinary environment had developed among physics, chemistry and electrical engineering that encouraged sharing of students and elective courses, and keeping enrollments steady. Once the Photonics Center opened and an expanded faculty was hired, more courses began to appear. The NSF CRCD support allowed the new courses to be coordinated with the new instructional lab facilities, and to influence undergraduate coursework through photonics modules[5]. Experiments with web-based education and lab work began at this time.[6,7]

Over the last five years course offerings have expanded to reflect the research of new faculty and evolving industry needs (Table 1). This energetic ***environment fostering curriculum development*** , driven by CRCD funding and new faculty enthusiasm, provided another element for creating a new degree program. These courses remain acceptable to the MSEE and MSCE programs, so enrollments are not diminished by their affiliation with the photonics degree.

Table 1 Photonics Courses in ECE Department	
Introduction to Photonics	Image Reconstruction and Restoration
Fiber-Optic Communication Systems	Advanced Topics in Photonics
Lasers	Quantum Optics
Quantum Mechanics and Its Application to Semiconductor Devices	Nonlinear and Ultrafast Optics
Semiconductor Devices	Optical Measurements
Solid-state Devices	Guided-wave Optoelectronics
Image Processing	Integrated Optoelectronics
Biophotonics	Fiber Sensors
Project in Photonics	LEDs

Laboratory Facilities

Dedicated photonics ***laboratory instructional space*** was integral to the design of the Photonics Center, and is critical to a strong degree program in this area. Approximately 1100 ft^2 of laboratory space was fitted with six 4 ft x 6 ft optical tables, power, networking, and cooling water. The instructional lab is comparable to most faculty research labs. Four tables are in the main teaching lab, and two

Fig. 1 Photonics Teaching Laboratory (partial view)

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are in a more secure project space to support graduate projects and also BS capstone design projects in photonics. Equipment was donated by industry or purchased using CRCD and University funds. The four tables are also equipped with a suite of test equipment and a networked PC controlling the instruments.

In a typical semester, as many as three classes and several projects will use the laboratory. The reuse of the tables puts more demands on the teaching assistants, but allows one facility to serve a large number of students.

Links across Campus and within ECE

As the photonics courses, research and faculty grew, stronger campus ties developed. Photonics courses and short courses were offered using distance learning, including NTU broadcasts. Interdepartmental collaborations were strengthened through joint proposals in photonics, and some new ECE photonics faculty received joint appointments Biomedical Engineering, Manufacturing Engineering, Physics, and Astronomy. The Photonics Center, as an interdisciplinary center, fostered stronger ties among departments and the sharing of students and facilities. Its incubator space provided industry contacts for students and faculty. Finally, interdisciplinary photonics-based senior capstone design projects made connections with other undergraduate faculty within Engineering.

Particularly within ECE, the new photonics faculty and courses, and the department's re location to the Photonics Center, were seen as positive events that strengthened all programs. Both internally and across the University, the growing photonics program earned the ***support of interested faculty, departments and Centers***.

The Degree Proposal

Formal university procedures for review of proposals for degree programs take about a year at Boston University. They require review and approval from all levels of faculty, departments and Centers with interest in the proposed degree area, from the University administration, and eventually, the Board of Trustees. A team of ECE photonics faculty prepared several drafts of the formal proposal, addressing:

1. Program Objectives and Need
2. Academic Program
3. Program Administration
4. Academic Resources
5. Financial and Physical Resources
6. Relations with Other B.U. Programs
7. Letters of Support; Budget Details

The proposal also required extensive review and revision of ECE Department and Engineering brochures, admission materials, bulletins and web sites. As the proposal was reviewed, the faculty also had to explain and support the proposal when concerns were identified. The degree program is expected to be in place for students matriculating in September 2002.

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Conclusions

Developing a new engineering degree program is a major undertaking for a department and college, and requires substantial preliminary work to ensure that critical elements are in place. These include adequate research facilities, a commitment by the University for faculty recruitment, creating an environment fostering curriculum development, establishing laboratory instructional facilities, and cultivating the support of interested parties in the University. Over ten years of expanding activities and curricula in photonics have led to a proposal for a new MS in Photonics offered through the Department of Electrical and Computer Engineering.

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Biography

MICHAEL RUANE is Associate Professor of Electrical & Computer Engineering at Boston University. He received the B.E.E. from Villanova University in 1969, his S.M.E.E. from MIT in 1973, and the Ph.D. in Systems Engineering from MIT in 1980. He spent two years as a Peace Corps volunteer in Sierra Leone, was a staff member of the MIT Energy Laboratory from 1973 until 1977 and is a registered professional engineer (electrical). He joined Boston University in 1980 and is a member of the Boston University Photonics Center and of the Center for Subsurface Sensing and Imaging Systems.

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