Challenges of introducing optoelectronics into an entrenched electrical engineering curriculum

Harbans S. Dhadwal

State University of New York, Department of Electrical Engineering
Stony Brook, New York 11794

ABSTRACT

Practical difficulties of introducing an optoelectronics course into an entrenched electrical engineering curriculum are discussed. Detailed descriptions of a lecture course, designed to meet the needs of engineers, and an accompanying laboratory course in optoelectronics are given.

1. INTRODUCTION

Recognition of the emergence of a strong optoelectronics industry in the next decade has caused universities with entrenched electrical engineering programs to look into innovative ways of preparing their undergraduate students to meet these new challenges. This awareness was driven, initially, by the revolutionary changes brought about by the proliferating use of fiber optics in communications, and is now being fed by the expansion of new areas such as optical storage, display and sensors. Most electrical systems incorporate some type of optical sensor to provide feedback and control. In response to these technological changes universities with adequate resources, or traditionally strong in optics, have introduced new degree programs in optoelectronics, however, there is still no unified consensus on the syllabus, and certainly the programs are not accredited by any governing agency. Most universities, due to inadequate resources, have opted either to ignore this technological impact or have introduced a token optoelectronics course at the senior technical elective level. Our goal in this paper is paper is to address some of the challenges facing electrical engineering faculty who have, in most cases, voluntarily and single-handed taken on the task of incorporating optics/fiber optics into an existing degree program at institutes with inadequate resources.

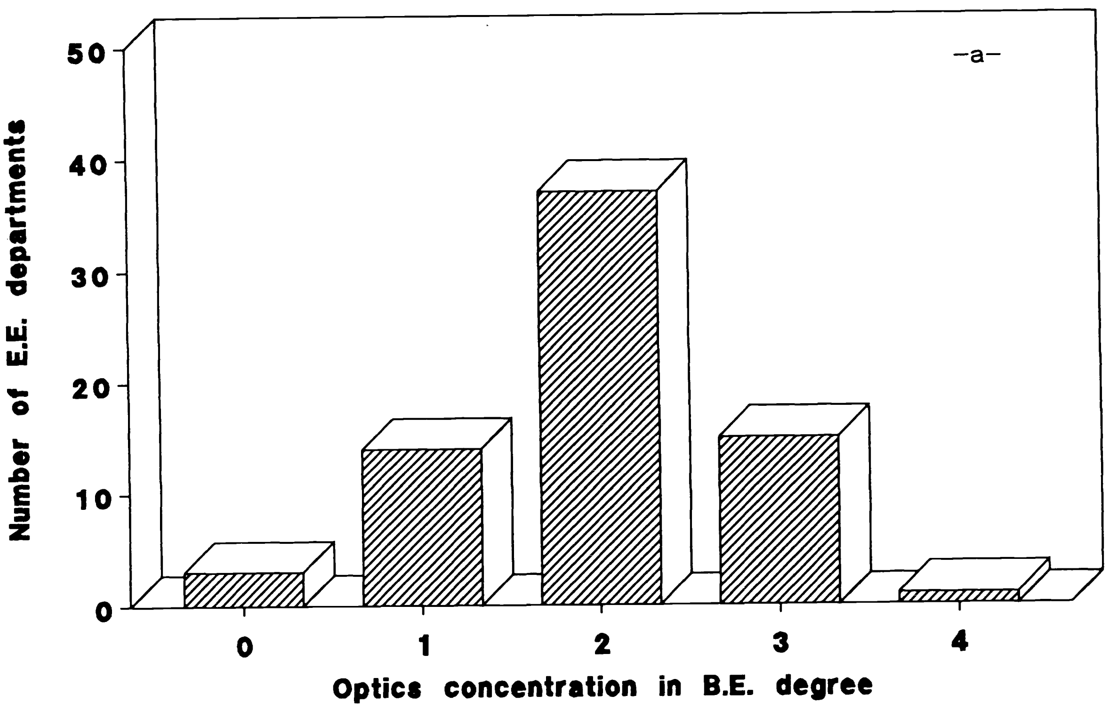
In the last five years there has been continued growth in the educational opportunities in optoelectronics. The *1985 Optics in Education [1]* survey published by SPIE lists 30 schools with courses/program in optics. According the *1990 Guide to Optics Courses and Programs in North American Colleges and Universities* published by the Optical Society of America [2] this number stands at 496. The growth in the importance of education in photonics [3], which encompasses optoelectronics, is driven by an expected 400 billion dollar per year industry. Photonics includes three major areas of telecommunications, optical information processing and optical displays, storage and sensors.

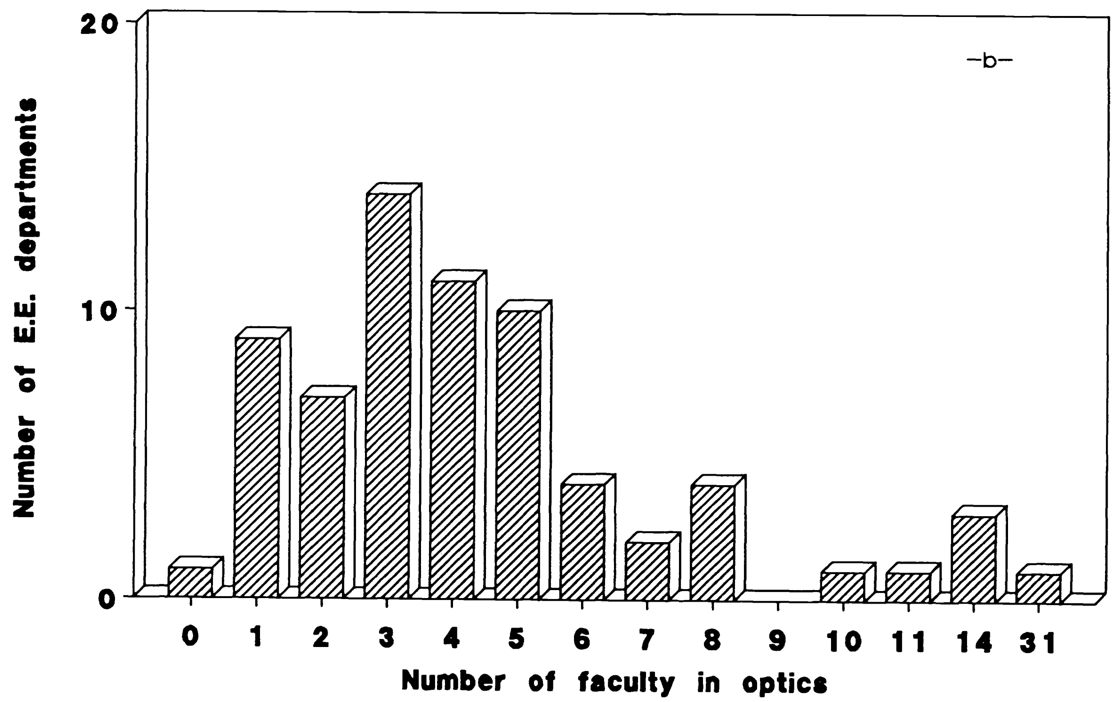
2. AN ACCREDITED ELECTRICAL ENGINEERING DEGREE PROGRAM

A four year accredited electrical engineering degree program follows a precisely defined curriculum, which is controlled by an accreditation board [4], the university and the department. Table 1 shows the basic requirements for a general Bachelor of Engineering Degree in Electrical Engineering . Introduction of new courses has to be very carefully planned without increasing the total credit hours required for graduation while satisfying the minimum ABET [4] requirements for each of the categories listed in Table 1. The only way to achieve our goal of introducing a new specialty into the program is to offer relevant courses as senior technical electives. The number of technical electives that a department can offer at any given time is determined by its faculty strength and faculty workload. For a moderate sized department this process requires considerable motivation and creativity in its execution. The electrical engineering department at Stony Brook has a faculty strength of 22 with 400 undergraduate and 120 graduate students. In order to place proper perspective to the task at hand, we have collated the data published by the OSA guide. Out of the 496 universities and colleges with optics related courses/program 70 are within the electrical engineering department. The optics concentration ranges from a single course to a formal degree with optics as a major. Figures 1a and 1b shows the optics concentration and faculty strength, respectively. Our department is

 0-8194-0732-1/92/$4.00

Figure 1: Summary of data from OSA survey [4] for optics program within the electrical engineering department. a) number of optics related courses: 0 - none ; 1 - one; 2 - several ; 3 - concentration; 4 - formal degree. b) faculty strength in optics.





typical of the 70 electrical engineering departments surveyed by OSA, and therefore are experiences should be typical of those faced by our sister institutions. In the following sections we will focus on the development of optoelectronics at Stony Brook, this project is still in its infancy and we are hopeful of continued growth.

Table 1: Requirements for a four year accredited electrical engineering degree

Category	Credits (minimum)
College core distribution (humanities, fine arts, social and behavioral sciences)	23
Mathematics	18
Natural Sciences	17
Computer Science	3
Engineering Sciences	22
Engineering Synthesis and Design	11
Engineering Specialization Technical Electives	27
Upper-Division Writing Requirements	1
Open Electives	X
Total (minimum)	130

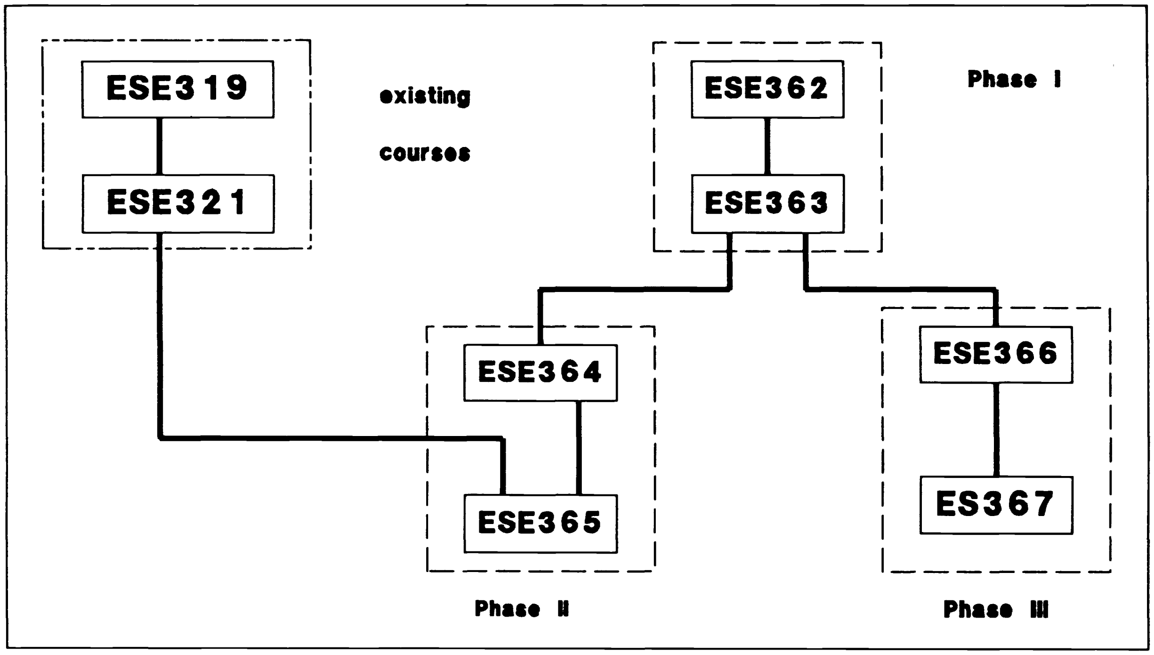
3.0 DEVELOPMENT OF A TECHNICAL ELECTIVE

3.1 Long term planning:

The process of upgrading the electrical engineering program at Stony Brook began with a firm belief that optoelectronics would be a strong discipline in the next decade, and that our undergraduate students needed to be exposed to this material if they were going to keep U.S. industry competitive in the information processing era. We knew from the outset that in order to avoid confrontation within the department the new material should not encroach or replace existing sub-specialties in the electrical engineering degree program. It was clear that the new material had to be introduced at the technical elective level, in this way the core ABET requirements remain in tact. The disadvantage of being able to teach only the senior level undergraduate student is that most of the material has to be covered in say 2 courses. In order to avoid the inevitable dilution to the course material if such a path was taken, we opted to concentrate on a particular topic within optoelectronics.

After careful review of the status of the electrical engineering program it was a natural choice to add a single technical elective course into the course offerings in the electro-magnetics specialization. A long term plan, as shown in Fig. 2, was developed, with clearly marked milestones. Identification of distinct phases in the evolution of the electro-magnetic and optics specialization was necessary in order to split the project into manageable bites, the success of each bite being easily measured. Each phase of the long term plan was determined by the sub-specialty. For example, Phase II deals with fiber optics and Phase II with optical system design. Phase I was more general and would be used as a pre-requisite for the Phase II and III. We are currently in the concluding stages of Phase I. The lecture course, *Optoelectronic devices and optical imaging techniques (ESE362)*, has been taught for last 5 years and the complementary laboratory course, ESE363 has been established.

Figure 2: Proposed long term structure of the technical elective sequence in the electro-magnetic and optics specialization.



ESE319	Introduction to electromagnetic waves and fields
ESE321	Electromagnetic waves and fiber optics
ESE362	Optoelectronic devices and optical imaging techniques
ESE363	Optoelectronics laboratory
ESE364	Optical fiber communications
ESE365	Fiber optics laboratory
ESE366	Optical systems design
ESE367	Optical systems design laboratory

3.2 Detailed description of ESE362

Once the goals and overall structure of the optoelectronics specialization had been established, we began the most rewarding task of designing a single course to meet the needs and background of students expected to take the course. The objective of the course was to expose senior level students to the fundamental processess governing the generation and detection of photons, and to emphasize quantitative approaches to the design of optoelectronic systems. Wave propagation through optical waveguides was intentionally omitted as we had planned a separate sequence of course on fiber optics. The other major omission was the detailed analysis of fabrication processes, teaching of which would not be appropriate without access to fabricating facilities. As a consequence of the broad set of technical electives and specializations within the electrical engineering curriculum ESE362 would have a minimum pre-requisite of a course in modern physics and a second circuit analysis course, both of which are required for graduation. In this way all seniors would have the option of taking the optoelectronics course, in fact, 20% of the seniors have taken ESE362.

Due to the nature of the course we have not found any single text to be suitable for the entire course. The policy has been to encourage students to use several books as well as to search current technical literature. Course material is supplemented with notes from the instructor. Table 2 lists the description of the material we cover in ESE362. Laboratory demonstrations were included in lieu of hands on laboratory experience - this was a temporary addition until a laboratory could be established. We have used innovative ways of presenting some of the difficult material. Appreciation of the discrete nature of light, in fact matter, is fundamental to the understanding of semiconductor sources and detectors. This material is presented using the Feynman approach [5], together with a photon counting system for the purpose demonstrations. The students quickly grasp the concept of photons and their unique properties.

Table 3: Optoelectronic devices and optical imaging techniques: ESE362 course outline

Introduction to light
- Wave nature
- Quantum electrodynamics
- Optical radiation units
- Measurement of optical quantities

Elements of solid state physics
- Review of band structure in semiconductors

Display devices
- luminescence
- photoluminescene
- injection electroluminescence
- recombination processes

* Light emitting diodes
  - fabrication
  - modulation
  - applications

Lasers
* Principles of operation
  - Einstein's rate coefficients
  - Threshold conditions
  - Properties
  - coherence
  - mode structure
  - mode locking
* Semiconductor lasers
  - homojunction
  - heterojunction
  - double heterojunction
  - buried double heterojunction
  - distributed feedback
  - distributed Bragg reflector
  - quantum well
  - laser diode arrays

Optical radiation detectors
- Characterization
- quantum efficiency and responsivity
- frequency response
- noise considerations

- equivalent circuits

* Particular detectors
    - photoconductor
    - photodiode
    - pin photodiode
    - avalanche photodiode
    - photomultiplier
    - charge coupled diode array
    - position sensitive

* Receiver design considerations

System applications

Laboratory demonstrations

Demo 1	Visualization of photons
Demo 2	Interference and diffraction
Demo 3	Photoluminescence in semiconductors
Demo 4	Measurement of far field radiation distribution
Demo 5	Scanning of laser beams

---

4. A LABORATORY COURSE IN OPTOELECTRONICS

In choosing our approach to the structure of the optoelectronics laboratory we have considered such issues as the number of work stations, cost effectiveness of the laboratory, the flexibility for expansion, and the sharing of equipment. Firstly, in an undergraduate laboratory it has been our experience that sharing of equipment among different work stations is fraught with problems. Equipping the laboratory with identical workstations, similar to the situation encountered in an electrical measurement laboratory, is at first glance very attractive, however, in the optoelectronics area very few experiments require the same set of equipment and secondly most of the instrumentation is extremely expensive. For these reasons, we have decided that our laboratory equipment will be dictated by a set of ten experiments which cover the material taught in the optoelectronics course described above. The equipment request should directly reflect the requirements of a particular experiment, with enough flexibility for some changes to be incorporated at a later date. However, this approach requires that the student groups be rotated among the different experiments, and for this reason the lecture course must be offered in the preceding semester. Table 3 lists a set of ten experiments which have been designed to complement the optoelectronics course.

Securing sufficient funding for a new laboratory is a difficult task requiring persistence, particularly, in department with inadequate resources. In such situation, it is essential to seek out external funding agencies. For example the National Science Foundation has an instrumentation and laboratory improvement program which has been operating annually. Spectra Physics also provide help in preparing proposals and seeking out potential sponsors.

5. SUMMARY

We have discussed some of the difficulties encountered in the uprading of an electrical engineering curriculum in order include optoelectronics. Detailed descriptions for a technical elective lecture and a laboratory course have been given.

Table 3: Optoelectronic Laboratory I - list of experiments

Experiment	Title (comments)
1	Nature of light
2	Continuous wave measurements of near far field radiation patterns
3	Characteristics of laser cavities
4	Laser beam characteristics and spatial filtering
5	Measurement of mutual coherence function of several optical sources
6	Characteristics of optical radiation detectors
7	Polarization and birefringence
8	Light modulation and beam deflection by the acousto-optic effect
9	Optical design I
10	Optical design II

6. REFERENCES

1. *Optics Education (1991)*, published by the SPIE - The International Society for Optical Engineering, Bellingham, WA 98225

2. *Guide to Optics Courses and Programs in North American Colleges and Universities 1990*, published by the Optical Society of America, Washington, DC 20036

3. *Photonics: Maintaining Competitiveness in the Information Era*, published by the National Academy of Sciences, Washington, DC (1988)

4. Accreditation Board For Engineering and Technology (ABET), Angola, IN 46703

5. Richard P. Feynman, *The Strange Theory of Light and Matter*, Princeton Science Library, Princeton, New Jersey 08540 (1988)