Session 1526

An Interdisciplinary Combined Research-Curriculum in Biomedical Optics

Sohi Rastegar, Gerard L. Coté
Texas A&M University

ABSTRACT

The objective of this project sponsored by the NSF Combined Research-Curriculum Development program is to develop, implement, and evaluate an interdisciplinary curriculum in Biomedical Optics. The thrust of the new curriculum includes the development of four new courses based on research advances made within the Biomedical Engineering Program at Texas A&M University in collaboration with internal and external medical centers. The four Senior/First-year-Graduate level courses are broken down into two principles courses, a hands-on laboratory course, and a design course. One principles course is on therapeutic applications of lasers and the other on optical monitoring and biosensing applications. They both include outside lectures from faculty within other Engineering disciplines and from the Medical collaborators. In addition, the lectures are supplemented with critical reviews of the literature and group discussions. With this pedagogy in the classroom courses, the laboratory course, and in particular, the design course, the emphasis will be placed on real world problem solving. The curriculum is being developed with input from an industrial and faculty advisory board containing technical and medical experts, specialists from both small and large Biomedical Optics companies, and individuals experienced in curriculum development. Upon completion of this curriculum development, a broader impact on engineering fields other than Biomedical Engineering is anticipated due to the modular nature of the proposed course offerings. While the curriculum as a whole gives the student a premier background in Biomedical Optics, the individual courses offer many unique applications and fundamental principles of lasers and optics beneficial to other engineering disciplines.

INTRODUCTION

The introduction of photonic technology into medicine over the last decade has revolutionized many procedures, and because of low cost relative to many other technologies it has the potential to greatly impact health care in the nation and throughout the world. For example, coherent fiber optic bundles have been applied in laproscopy cholycystectomy to transform a once painful and expensive surgery into virtually an outpatient procedure. Our team of collaborators has been active in defining and demonstrating the engineering fundamentals of the interaction of light and heat with biological media with interest in several important clinical applications in dermatology, ophthalmology, cardiology, urology, and oncology. We perceive there to be an excellent match between a major need of society, from health care and from industrial perspectives, and the opportunity to apply a unique aggregate abilities and facilities to realize a significant contribution to engineering education.

As the industry gets poised for expanding in commercial exploitation of these advances in biomedical optics, there is a clear void in availability of engineers knowledgeable and properly trained in noninvasive and minimally invasive, cost effective, techniques using Biomedical Optics. Optical engineering is traditionally taught in the electrical engineering curriculum and has been primarily applied in defense technology. In biomedical optics applications, however, there are many issues related to the interaction of light with participating biological media that classical optics books and curricula do not cover. In addition, to mirror the need for information in this rapidly growing field, one of the traditional optics journals namely; Applied Optics: Optical Technology, is under going a change in focus and title to Optical Technology and Biomedical Optics. Finally, biomedical optics may serve as an avenue of international competitiveness for the U.S. in an area where we have international leadership, and high quality engineers properly trained in this critical area are the asset by which to maintain this competitiveness.

COURSE DEVELOPMENT

The objective of this project was to develop, implement, and evaluate a unique interdisciplinary curriculum in Biomedical Optics. The thrust of the new curriculum includes the development of four new courses based on research advances made within the Biomedical Engineering Program at Texas A&M University in collaboration with internal and external medical centers. The Senior/First year Graduate level courses were broken down into two principles courses, a hands-on laboratory course, and a design course. The interdisciplinary team includes faculty from two Colleges within Texas A&M University (TAMU), three external Medical Centers, and Industry personnel as depicted in Figure 1 below. The primary investigators responsible for the bulk of the course development and implementation are Drs. Rastegar and Coté from within the Texas A&M Bioengineering Program. An advisory board has been developed with a representative from each of the collaborating institutions listed below. The group has been selected to based on their expertise in either the technical aspects of Biomedical Optics, curriculum development, or industrial perspective. Many of the members have overlapping expertise in these three areas. The technical group's primary responsibility will be the transfer of the latest Biomedical Optics research to the curriculum, development of the curriculum, and dissemination of the results throughout the engineering academic community. The academic group will primarily guide and evaluate the curriculum as well as provide innovative approaches to curriculum development and suggest outside reviewers for final assessment. The industrial advisory members have not only indicated their interest in hiring students with this curriculum background, but also have agreed to provide input as to the needs of industry, evaluate the program, and give an outside perspective of the utility of the material covered by the curriculum.

Principles courses

The two principles course which were taught for the first time this year were entitled, "Optical Diagnostics and Monitoring Principles" and "Optical Therapeutic and

Interventional Principles". Both courses were listed as both undergraduate (489) and graduate (689) level courses and were cross listed among Bioengineering (BIEN), Electrical Engineering (ELEN), and Chemical Engineering (CHEN). The syllabus that was handed out to each student for each course is available on our home page described under the dissemination section of this paper and is attached to this article as appendices A and B. Dr. Coté focused on the "Optical Diagnostics and Monitoring Principles" course and Dr. Rastegar focused on the "Optical Therapeutic and Interventional Principles" course but each took an active and interested role in the other's course content and materials covered. Within the two principles courses about 1/3 of the students were enrolled in both the Optical Therapeutics and the Optical Diagnostics/Sensing courses.

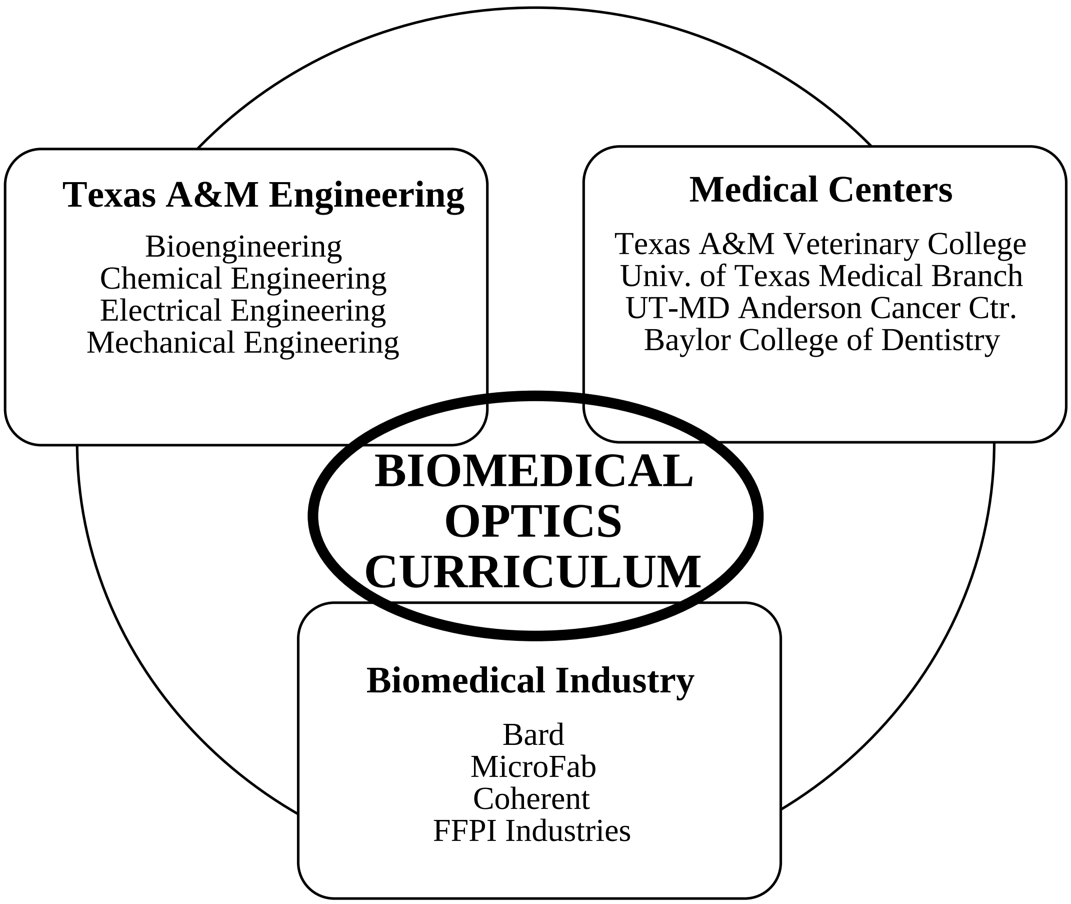

Figure 1: Members of the biomedical optics curriculum multidisciplinary team.

In the Optical Diagnostics and Monitoring Principles Course there was an enrollment of 29 students (5 from Electrical Engineering, 2 from Chemical Engineering, 1 from Civil Engineering, 1 from Toxicology, and 20 from Bioengineering). Four of the students were undergraduates and 25 were graduate students. The students were exposed to ours and others' research in the recent literature of optically-based biomedical sensing. The material outlined in the syllabus (attached appendix A) under I through V was covered during the semester. However, under number VI, "Optical Imaging Modalities", time only permitted a single lecture in this area by an outside expert (Dr. Lihong Wang from the Bioengineering Program at Texas A&M). An additional expert in the area of fiber optic interferometers (Dr. Henry Taylor from the Electrical Engineering Program at Texas A&M) gave one lecture for the course. In addition to the faculty lectures, the graduate students were afforded the opportunity to do written as well as oral presentations of specific optical biosensors based on a review of at least five recent refereed journal articles. This not only gave each student a more in depth knowledge in one optical biosensing modality, but also allowed the other students an opportunity to learn about the various optical biomedical sensors currently being researched.

In Optical Therapeutic and Interventional Principles Course a total of 31 students were enrolled. Of these, 19 were in the graduate section (16 Biomedical, 1 Electrical, 1 Chemical, and 1 Toxicology) and 12 were in the undergraduate section (7 Biomedical, 1 Electrical, and 4 Chemical). A total of 23 Biomedical Engineering students, 5 Chemical Engineering students, 2 Electrical Engineering students, and 1 Toxicology student took the course. Of the materials in the outline in the First Day Handout/Syllabus (attached as appendix B) most were covered. Item XI (Economics of Device Development) was not covered explicitly but rather was discussed in several lectures in conjunction with therapeutic modalities being described. Item VII (Optical Fibers and Catheter Design), and item X (Safety and Hazard Considerations) were not covered and will be covered in the Laboratory course in which they are more relevant. As in the Diagnostics course, the students enrolled in the graduate section gave an oral presentation of their library research materials. They did this once in the middle of the semester focusing on one journal article and again at the end of the semester giving an overview of recent literature on the state-of- the-art in the particular research topics they chose. This helped expose the whole class to this material. Invited lectures by our collaborators, Dr. Jacques from the University of Oregon and formally from the University of Texas-M.D. Anderson Cancer Center, Dr. Motamedi from the University of Texas Medical Branch, and Dr. Thomsen the University of Texas-M.D. Anderson Cancer Center, are planned for the Spring semester on various aspects of laser-tissue interaction related to our curriculum.

Lab and Design Courses

A 900 square foot laboratory has been acquired adjacent to the research laboratories of Drs. Rastegar and Coté, which is currently being re-structured with extra sinks, extra electrical outlets and chilled water for use as a Biomedical Optics teaching laboratory. Over $70,000 dollars have been spent purchasing various optical equipment, optical components, electronic equipment, electronic components, and computers for the lab.

Nine of the ten labs to be performed by students have been fully written as defined below and the tenth lab, on microscopy, is currently being completed. The laboratory course, along with the semester design projects, will be taught for the first time in year two. The ten labs are as follows:

1. Biomedical Optics Laboratory Fundamentals
2. Fundamental Opto-Electronic Signal Detection
3. Fiber Optics
4. Optical Interferometric Biosensing

5. Laser Coagulation and Therapy
6. Measurement of Tissue Optical Properties
7. Infrared Spectroscopy of Physiologic Chemicals
8. Fluorescence Spectroscopy of Physiologic Fluorophores
9. Polarimetric Quantification of Chiral Substances
10. Optical and Birefringent Microscopy

The Design of Biomedical Optic Systems course is structured to give the student an entire semester to devote to the design and development of an optical therapeutic, diagnostic, or monitoring system in our research labs based on their fundamental knowledge from the previous courses. Combined with real-world problems identified by our medical center and industrial collaborators, well defined research projects are being identified such as the design of a therapeutic fiber optic delivery system which is bio-compatible, small enough to be interfaced for instance with an ultrasound probe for monitoring the coagulation front, and flexible enough to allow delivery of the light energy without significantly effecting the thermal noise in the monitoring probe. Many of the students are given the opportunity to do the bulk of their project in the Biomedical Optics research laboratories at Texas A&M.

DISSEMINATION AND EVALUATION

Internet Dissemination

A homepage was developed describing the new laboratory and the new courses being taught. It is located at http://biomed.tamu.edu/bmol . The page describes the purpose of the lab, its facilities, and the equipment found within. There are links to the faculty and staff, as well as to the courses being taught. The courses page provides separate links to Optical Diagnostic and Monitoring Principles, Optical Therapeutic Principles, and the Biomedical Optics Laboratory. The linked pages summarize each course, provide links to the instructors' pages and e-mail, list guest lecturers, and provide a full syllabus for each course. The plans for updating the page in year two include providing links to complete class notes for the semester and to student surveys that can be filled out on-line.

Advisory Board Curriculum Evaluation and Student Survey

Based on a recommendation of the Chair of our Advisory Board it was decided to have a board meeting before beginning to teach the curriculum course. A preliminary plan was sent to all board members (listed in the table below). We had a meeting on 11 June, 1996, on the Texas A&M campus. All except those indicated by * below were able to attend the meeting. A summary of the meeting was e-mailed to the absent members.

The key recommendations of the board were:
1) to provide a review of physiology in the curriculum,
2) to include optical microscopy in the materials, and

3) to provide an overview of the potential medical applications of this research field that could lead to new industries or new products within existing companies.

Advisory Board Members

Team Member	Affiliation	Advisory Board Group		
		Technical	Academic	Industrial
Karan Watson	TAMU-College of Eng.		X	
John Weese*	TAMU-Eng. Technology		X	
Gerald Miller	TAMU-Bioengineering		X	
Henry Taylor	TAMU-Electrical Eng.	X	X	
	FFPI Industries			X
Chris Burger	TAMU-Mechanical Eng.	X	X	
Lyndon Archer	TAMU-Chemical Eng.	X	X	
Theresa Fossum	TAMU-Veterinary College	X	X	
Jon Hunter	TAMU-Veterinary College	X	X	
Massoud Motamedi	UT-Medical Branch	X	X	
Steve Jacques*	UT-MD Anderson Cancer Center	X	X	
Charles Arcoria*	Baylor College of Dentistry	X	X	
William Norton*	Bard	X		X
Chris Jaska	Coherent	X		X
Chris Frederickson	MicroFab	X		X

FUTURE PLANS

In year 2 of this Combined Research-Curriculum Development effort the Laboratory and Design courses will be taught based on the above descriptions. The lecture notes for the Principles Courses will be typed and an abridged version made available on the home page. Letters and summary will be written to all Biomedical Engineering Departments informing them of our curriculum development effort and requesting that any interested parties within their department be informed. Letters describing a summary of our effort will be written to other Universities/Institutions where there is activity in biomedical optics and their feedback requested. The results of student surveys and evaluations will be assessed by the Advisory Board. The Advisory Board will meet prior to Fall '97 to review the course notes, the results of student surveys and evaluations, and give their guidance before embarking on the second years' teaching effort.

BIOGRAPHICAL INFORMATION

SOHI RASTEGAR
Dr. Rastegar received the BS degree in 1980, the MS degree in 1982 in aerospace engineering, and the Ph.D. degree in 1987 in biomedical engineering from the U of Texas, Austin. He is currently an Associate Professor with the Bioengineering Program at Texas A&M University. His research interests are in laser interaction with biological tissues with an emphasis in modeling and optical therapeutic principles.

GERARD L. COTE
Dr. Coté received the BSEE in 1986 from Rochester Institute of Technology, the M.S. in 1987, and the Ph.D. in 1990, both in Bioengineering from the U of Connecticut. He is an Assistant Professor of Bioengineering at Texas A&M University (TAMU). His primary research focus is biomedical sensing and diagnostics using optics and fiber optics with an emphasis in noninvasive approaches.