This paper is freely available as a resource for the optics and photonics education community.

From Optics to Optical Engineering: 20 Years of Optics Education at Rose-Hulman Institute of Technology

Robert M. Bunch, Charles Joenathan, Azad Siahmakoun
Rose-Hulman Institute of Technology, 5500 Wabash Avenue, Terre Haute, Indiana 47803

Abstract: The optics educational programs at Rose-Hulman Institute of Technology have progressed and evolved over the past twenty years. Beginning with a modest undergraduate area minor in applied optics we now offer bachelors and masters degree programs in optical engineering. Distinctive elements of the current optical engineering programs including courses and curricula will be discussed.
©2003 Optical Society of America
OCIS codes: (000.2060) Education, (350.4600) Optical engineering

1. Introduction

Rose-Hulman Institute of Technology is a small, primarily undergraduate science and engineering institution although we have an active masters level graduate program in many areas. The institution has been ranked number one in the category of undergraduate engineering schools without a Ph.D. program by U.S. News & World Report magazine for the past four years from 2000 to 2003[1]. RHIT has an outstanding student body. The median SAT scores for the first-year class are 1300. The Department of Physics and Optical Engineering offers B.S. degrees in Optical Engineering and in Physics and an M.S. degree in Optical Engineering. Other areas of study leading to bachelor degrees are: Applied Biology, Biomedical Engineering, Chemistry, Chemical Engineering. Civil Engineering, Computer Science, Electrical Engineering, Mechanical Engineering, Mathematics, Optical Engineering and Physics.

2. History and Evolution of Rose-Hulman's Applied Optics Educational Programs

Optics educational programs at Rose-Hulman began around 1980[2]. Although an introductory optics had been taught before there was a growing interest by students and faculty to broaden the set of courses offered and introduce modern topics in optics such as lasers and fiber optics. Advice from industrial representatives and other optics educators was critical in establishing criteria for course and curriculum development. These criteria are still used today. First and foremost is an emphasis on hands-on experience for the students through the lab-intensive nature of a majority of the optics courses[3]. Second, we wanted to enhance the student's technical communication by having them write lab reports, produce project reports and give presentations that were evaluated on the written communication skills as well as the technical content. Other criteria include: integration of computer skills, data acquisition, modeling and simulation.

In the fall of 1983 we initiated what is called at Rose-Hulman an Area Minor in Applied Optics program. An area minor is simply a set of five courses indicating a concentration of elective courses in a specific area of study. The first required courses were: geometrical optics, physical optics, laser physics, optical instrumentation and fiber optics. [4] This program met with enthusiastic response by the students. In fact, the first time that we offered the physical optics course over sixty students enrolled in the course.

The title of Applied Optics was chosen at that time to describe the program content because of the combination of basic optical science courses with courses that included material on optical science and applications of optics. As an example, the laser physics and applications course provided students with a physical foundation in laser science but also covered a number of topics such as laser cutting, laser welding, and applications to biomedicine.

The next step in the development of the applied optics educational programs at Rose-Hulman was undertaken in 1985 when we began offering a masters degree in applied optics. In the masters program the intention was to provide a degree for those students who require additional knowledge of optics beyond the undergraduate level for students entering from a physics background or an engineering background. The program was designed from its inception to be a terminal degree program that prepares students for working in the industry consistent with Rose-

Eighth International Topical Meeting on Education and Training in Optics and Photonics,
edited by Barry L. Shoop, Grover Swartzlander Jr., Proc. of SPIE Vol. 9663, 966307
© 2003 SPIE, OSA, ICO · doi: 10.1117/12.2207316

Hulman's educational philosophy and vision. The students in the program are required to do an optics-related thesis project, and whenever possible, the thesis topic would be a project of interest to an industrial sponsor. By offering a masters degree we complement the undergraduate program with more advanced courses and topics and provide professional development activities for faculty members. To date 69 masters degrees in applied optics have been awarded by Rose-Hulman averaging about four students per year.

Further development of the applied optics program, courses and lab experiments accelerated when the Department of Physics received a grant from Lilly Endowment, Inc. to develop the courses and curricula for the M. S. (Applied Optics) program. One of the unique elements of this grant allowed us to begin a visiting Lilly Fellows program. The visiting Lilly Fellows were leaders in the optics community with educational and industrial backgrounds and included, Brian J. Thompson, Robert E. Fischer, James C. Wyant, and Jean M. Bennett. The visiting Lilly Fellows visited our campus, met with faculty and students and provided input on how we could improve and strengthen our courses and programs.

Encouraged by student interest and feedback from industrial representatives a B. S. (Applied Optics) degree program began at Rose-Hulman in 1988. This program was built upon the experiences and development of the undergraduate Applied Optics Area Minor and the M. S. (Applied Optics) programs. We used the same criteria in developing the courses and curricula for the B. S. (Applied Optics) program as we used previously. Optics courses include laser physics, electro-optics, fiber optics, optical metrology, physical optics, paraxial optics, lens design and aberrations, wave optics and coherence, optical instrumentation, semiconductor devices and materials, applied optics projects laboratory. To date 86 bachelors applied optics degrees have been awarded.

3. Transition to an Optical Engineering

Rose-Hulman has a history of meeting the need for optical engineers via the Applied Optics Programs described above. In fact, many of our program graduates at both the bachelor and masters level have been employed with job titles such as optical engineer and optical design engineer. Feedback from potential employers and former students indicated that the title of applied optics does not carry the same connotations in industry as optical engineering. Some of our students indicated that they believed the title applied optics hindered their obtaining employment with companies that were not aware of our program. Last year, the departmental advisory board that consists of top professionals from the optical industry and education strongly endorsed the name change to optical engineering. Offering B.S (Optical Engineering) and M.S. (Optical Engineering) degrees will hopefully reinforce the idea that we are educating our students in applications of optics that deal with real world problems and practice the profession optical engineering.

An undergraduate optical engineering curriculum is by nature multidisciplinary and must involve a mix of engineering, physics, engineering science and optics fundamentals. In the transition to an optical engineering degree program we are also faced with the task of designing a curriculum to meet not only the growing needs of the industrial market but also to provide our students with a foundation in optical science and engineering.

The current B.S (Optical Engineering) program was built upon the lessons learned in the development of the undergraduate applied optics area minor and bachelors degree programs. Throughout the curriculum laboratory experiments have been developed that reinforce concepts for students to understand basic scientific ideas of a particular subject and gain necessary experimental skills. In addition, we have introduced a sequence of two project-based courses [4] that are intended to awaken the scientific curiosity as well as the engineering creativity of our students.

A list of the optics-related courses in the current B.S. (Optical Engineering) program is given in Table 1. During the freshman year we introduce students to optics topics through a course devoted to holography and photography. Each student makes their own hologram during a workshop session associated with the course. A survey course entitled Optics in Technology provides students with the idea that optics plays a pervasive and enabling role in many familiar consumer products and devices. The curriculum in the sophomore year provides a foundation in optical science and engineering with courses in physical optics, paraxial optics, optical systems and electrical and mechanical systems. During the junior and senior year students take courses that provide depth and breadth in optics that include lasers, electro-optics, fiber optics, optical metrology, lens design and aberrations, semiconductor

devices and materials. Students also take a two course sequence called Optical Engineering Project Lab[4]. In this course the students use their optics background to design, test, and construct a prototype optical part, component, or a system. From an educational perspective this course requires the students to use their optics fundamentals and apply them to a practical problem.

Table 1. **UNDERGRADUATE OPTICS-RELATED COURSES AT ROSE-HULMAN**

OE 171	Holography & Photography
OE172	Optics in Technology
OE 280	Paraxial Optics
PH 292	Physical Optics
OE 295	Optical Systems
PH 405	Semiconductor Materials and Devices I
PH 406	Semiconductor Materials and Devices II
OE 415	Optical Engineering Design I
OE 416	Optical Engineering Design II
OE 450	Laser Systems and Applications
OE 480	Lens Design and Aberrations
OE 485	Electro-Optics and Applications
OE 493	Fiber Optics and Applications
OE 495	Optical Metrology

Like the B.S. (Optical Engineering) program, Rose-Hulman has also made a transition to offer the M.S. (Optical Engineering) degree. In addition to the thesis project, a total of 36 credit hours of coursework is required. Currently the core course requirements include topics in principles of optics, lens design and aberrations, optical metrology, electro-optics, guided wave optics and Fourier optics. Special topics courses are also offered regularly. Elective courses such as Advanced Image Processing and Biomedical Optics are available to the students.

4. Industrial Outreach Programs

4.1 Center for Applied Optics Studies

At about the same time that the masters degree program was established Rose-Hulman created the Center for Applied Optics Studies (CAOS) through financial support of Indiana's Corporation for Science and Technology, later renamed the Indiana Business Modernization and Technology Corporation. CAOS has four major functions: 1) Education, 2) Research & Development, 3) Technology transfer, and 4) Service to the industry. Thus, in addition to coordinating the applied optics educational programs, CAOS became an industrial outreach for the institute and a resource to businesses needing optics assistance and expertise.

Over one hundred projects have been completed and titles of many of the technical reports accessed can be online (http://www.rose-hulman.edu/PHAO/). Some of the topics involved in industrial related projects include: fiber optic connectors, fiber optic sensors, image processing, machine vision, photorefractive applications, non-linear optics, speckle pattern interferometry. Examples of a few of the projects completed by faculty members, undergraduate students and graduate students are: vibration analysis using fiber optic electronic speckle pattern interferometer[5], fiber optic core and cladding diameter measurement [6], investigations of the aging of biological specimen using laser speckles [7], and investigations of photorefractive material properties [8].

4.2 Rose-Hulman Ventures

In 2000 Rose-Hulman started Rose-Hulman Ventures which is a technology-based business incubator collocated with a new product development laboratory. Rose-Hulman Ventures is unique because it is engineering oriented vs. tech transfer oriented, provides on-site product development staff and has direct access to venture capital through its own resources. The facility provides excellent educational opportunities for nearly students and faculty members through their direct participation in the development of the new technology-based products and services of client companies. Optical technology is one of the key supporting and enabling technologies available to client companies. A fellowship for an entrepreneurial M.S (Optical Engineering) student has just been funded that will allow them to pursue their new business and use their ideas for a new optics-related product or service as part of their masters degree thesis topic.

5. Summary

New applications of optics appear everyday. It is imperative that optical science and engineering education continues to evolve to keep pace with these advances. It is also important to provide a balance between scientific fundamentals and discussions about the applications of optics. Laboratory experiments and activities are necessary to optics education and get the students involved and excited about studying optics.

One of the major challenges for the optics community is to increase the source of promising students entering optics at the undergraduate level. Everyone in our field must become involved in encouraging prospective students to study optics and to see that optical science and engineering is an exciting and rewarding career.

6. References

1. Best Undergraduate Engineering Programs: Schools without engineering doctorate programs , http://www.usnews.com/usnews/edu/college/rankings/brief/engineering/nophd/topprogs_nophd_brief.php
2. B. M. Khorana, “Birth and evolution of a new optics degree program,” in 1988 International Conference on Education in Optics, Brij M. Khorana, Editor, Proc. SPIE 978, 21-22 (1988).
3. R. M. Bunch, “Development of instructional optics laboratory,” in 1988 International Conference on Education in Optics, Brij M. Khorana, Editor, Proc. SPIE 978, 52-55 (1988).
4. C. Joenathan, R. M. Bunch, and A. Siahmakoun, “Project oriented laboratory courses in optics education” in 1995 International Conference on Education in Optics, M.J. Soileau, Editor, Proc. SPIE 2525, 266-271 (1995).
5. C. Orcutt, C. Joenathan , and B. M. Khorana "Fiber Optic Electronic Speckle Pattern Interferometric system with a 1550 nm laser diode," Optik (Germany), 100, 57-60 (1995)
6. C. Joenathan and R.M. Bunch, "Diameter measurement of single-mode fibers using interferometric and imaging techniques," Applied Optics, 32, 5989-5996 (1993)
7. X. Zijjie, C. Joenathan and B. M. Khorana "Some investigations of the temporal and spatial properties of the time-varying speckles of botanic specimen," Optical Engineering, 34, 1487-1502 (1995)
8. D. Jeurgens, A. Siahmakoun, and W. Wood, "Temperature tuning of two-wave coupling in InP:Fe at 1.32," Trend in Optics and Photonics, 27, 90-95 (1999)