Thirty-five years of optics education at Rose-Hulman: from optical sciences to optical engineering – 3 cycles of ABET accreditation

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ABSTRACT

Rose-Hulman Institute of Technology has 35 years of graduating optical scientists and engineers. The change from the Applied Optics degree program to the Optical Engineering degree program occurred in 2003, which paved the way for ABET accreditation. The past and present program reinforces the idea that we are educating our students in optics applications to deal with real-world problems and practice the profession of optical engineers. The RHIT program has been at the forefront of developing project-based learning since its inception in 1983. Since the name changed, the optical engineering program (OE) has completed three cycles of ABET accreditation. We are continuously improving our OE curriculum to meet the current and future needs of the industry and cutting-edge research. To lead the ABET review, Rose-Hulman initiated the dialogue with SPIE to be the lead society for optical engineering in 2004. This paper will discuss several steps taken to develop a world-class OE program with state-of-the-art laboratory facilities for undergraduate optical engineering education.

Keywords: Optical Engineering, Education, ABET accreditation

1. INTRODUCTION

Rose-Hulman Institute of Technology (RHIT) is a small, primarily undergraduate science and engineering institution, although we have an active master's level graduate program. The institution has been ranked number one in undergraduate engineering schools without a Ph.D. program by U.S. News & World Report magazine for the past 23 years since 2000. The campus is housed on a 300-acre land in Terre-Haute, even though the entire campus is over 1800 acres. Rose-Hulman has a 2000-member student body with a median SAT score for the incoming first-year class of 1370. RHIT has a long history of graduating optical engineers at the undergraduate and graduate levels.

The optics educational programs at RHIT have evolved over the past forty years from a science-based degree to an engineering degree by creating SPIE as the affiliated society for accreditation. First and foremost is an emphasis on hands-on experience for the students through the lab-intensive nature of most optics courses [1]. 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 their written communication skills and the technical content. Other criteria include integrating computer skills, data acquisition, modeling, and simulation.

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2. OPTICS EDUCATION SINCE 1983

The program began with a modest undergraduate area minor in applied optics in 1983 and then quickly progressed to offer bachelor's and master's degree programs in Applied Optics. The title 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 optics applications. An area minor is a set of five courses indicating a concentration of elective courses in a specific study area. The first required courses were: geometrical optics, physical optics, laser physics, optical instrumentation, and fiber optics. [2]. For example, the laser physics and applications course provided students with a physical foundation in laser science but also covered several topics such as laser cutting, laser welding, and applications to biomedicine. The next step in developing the applied optics educational programs at RHIT was undertaken in 1985 when we began offering a master's degree in applied optics.

In the master's 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 or engineering background. The students in the program must do an optics-related thesis; whenever possible, the thesis topic would be a project of interest to an industrial sponsor. 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, including 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 improving and strengthening our courses and programs. Encouraged by student interest and feedback from industrial representatives, a B. S. (Applied Optics) degree program was initiated at RHIT in 1988. This undergraduate program was rooted in implementing courses that allowed students to get a broad knowledge of optics which included courses like 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. In the later years, culminating project courses were introduced that brought in industrial projects for students to complete as part of the course.

3. OPTICAL ENGINEERING AND ABET

In 2000 a decision was made to transform the applied optics program to optical engineering using the ABET 2000 criterion. Motivation for such changes stemmed from the need for graduated students in applied optics to be working as engineers and to allow the department to streamline its program to revamp the project-based learning that was already introduced. At the time, the need for optical engineers grew rapidly, and companies were searching for optical engineers. In search of an accrediting society, we initiated SPIE as the lead society for optical engineering accreditation with ABET. It took over four years for this to happen, and the optical engineering program was accredited in 2006, with SPIE and IEEE being the lead societies.

An undergraduate optical engineering curriculum is 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 tasked with designing a curriculum to meet the growing needs of the industrial market and 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 developing the undergraduate applied optics area minor and bachelor's degree programs.

Throughout the curriculum, laboratory experiments have been designed to 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 [2] 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 first year, we introduce students to optics topics through a practice devoted to holography and photography. Each student makes their 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 years, students take courses that provide depth and breadth in optics, including lasers, electro-optics, fiber optics, optical metrology, lens design and aberrations, and semiconductor devices and materials. Students also take a two-course sequence called Optical Engineering Design [3]. In this course, the students use their optics background to design, test, and construct a prototype optical part, component, or 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 RHIT (2010)

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
OE 415 Optical Engineering Design I	PH 406 Semiconductor Materials and Devices II
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

Table 1 shows that the courses were modified once the decision was made to alter the applied optics program to optical engineering. RHIT also transitioned to offer the M.S. (Optical Engineering) degree simultaneously. In addition to the thesis project, thirty-six credit hours of coursework are required. 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. At the same time the master's degree program was established, RHIT created the Center for Applied Optics Studies (CAOS) through the financial support of Indiana's Corporation for Science and Technology, later renamed the Indiana Business Modernization and Technology Corporation. CAOS has four primary 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 the titles of many of the technical reports accessed can be found online.

4. CONTINUOUS IMPROVEMENT CYCLE

Since making the changes, the optical engineering program has undergone two ABET accreditation cycles. The continuous improvement process has allowed several modifications to meet the ABET accreditation criteria for Optical, Photonics, and similarly named engineering programs in addressing the need to meet specific criteria through assessing the data collected in the data on course content and the overall assessment of the curricula.

The Optical Engineering program's continuous improvement involves identifying program stakeholders (constituents) who are polled to capture their needs. These needs, along with ABET's requirements and the institute's mission, are captured and evaluated, which helps in the necessary revision of the PEOs. These then determine the changes needed for the SLOs and, thus, the program curriculum. The assessment results and feedback from program stakeholders are evaluated, and necessary modifications to the program are drafted to improve student attainment of SLOs. Constant feedback from students who graduate and enter the field provides input to the ongoing process of PEO and SLO reviews and revisions. This forms a close loop, as shown in Figure 1.

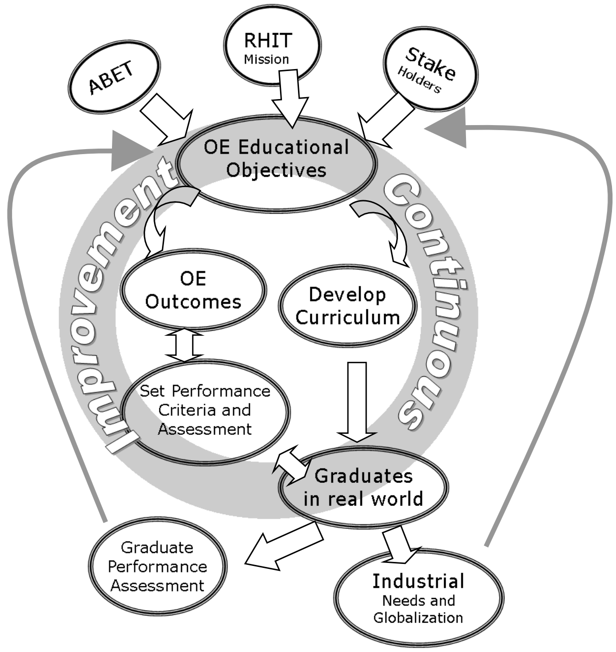

Fig. 1 The flow chart of the process for continuous improvement

A complete review was performed, and several changes were introduced in 2014; thus, the program's new program educational objectives (PEOs) were established, and the student learning objectives were reviewed and modified [4,5]. The department curriculum committee discovered that areas such as linear system theory and non-imaging optical design (lighting and illumination) needed to be covered. Overcoming several constraints, a curriculum revision was performed, and new courses and sets of student learning objectives (SLOs) were generated for continuous improvement. Since the program is laboratory intensive with three capstone design courses, a modified curriculum was developed, and several new courses were introduced. Four overarching tracks within the optics curriculum were identified: physical optics, geometrical optics, photonic systems, and materials. In addition to this, there was a set of courses that were predominantly experimentally intensive, and these courses fell under a separate track.

Table 2: The modified Optical Engineering program

Track 1: Physical Optics	**Track 2: Geometrical Optics**
PH292 Physical Optics	OE280 Geometrical Optics
OE392 Linear Optical Systems	OE480 Optical System Design
OE494 Optical Metrology	OE434 Non-Imaging Optics
	OE437 Introduction to image processing
Track 3: Photonic Systems	**Track 4: Materials**
OE295 Photonics Devices and Systems	OE360 Optical Materials
OE393 Fiber Optics and Applications	OE435 Biomedical Optics
OE493 Optical Communications	OE450 Laser Systems and Applications
Laboratory courses	**Laboratory courses**
OE395 Opto-mech and Opt. Eng. Lab	OE 416 Optical Eng. Design II
OE 415 Optical Eng. Design I	OE 417 Optical Eng. Design III

All capstone design projects are industry sponsored to closely match the industry's needs and provide the students with mirroring the workforce [4,6]. Presently, changes are being made to the curriculum as part of the continuous improvement process. The curriculum will have slight tweaking to ensure all stakeholders' needs include ABET, alums, and industrial and education leaders. The Center for Applied Optics Studies is part of the department and still is the industrial arm of the optics program. The three capstone design courses are projects provided by industry, and students work with industrial sponsors for all the projects.

5. MASTERS IN OPTICAL ENGINEERING:

The department also offers a powerful master's level program with several options for students to complete. Students not only enroll in the program after their bachelor's degree, but also there is an option for students within the curriculum at RHIT to finish a bachelor's and master's in 4 years called the R^2 program and another R+1 program for students to finish bachelor's and master's in 5 years. To complete a master's degree student must have thirty-six course-based credits and twelve thesis credits. Table 3 lists courses to be taken in the master's program. The MS in optical engineering underwent a north central accreditation two years ago with a full review of the program, its PEOs and SLOs, and the assessment process set to do the continuous improvement process.

Table 3: Courses for the master's program

Master's level courses for MS in Optical Engineering
OE 570 Special Topics
OE580 Lens Design and Aberrations
OE592 Fourier Optics and Applications
OE594 Guided Wave Optics
OE520 Principles of Optics
OE585 Electro-Optics and Applications
OE595 Optical Metrology
Three Elective courses to be taken from a list of courses
OE 590 Thesis research – max of twelve credits

6. SUMMARY

The optics education at RHIT has shined for the last 35 years, where new curriculum development and continuous improvement assessment innovations were introduced. The bachelor's program has undergone three ABET assessment cycles and the master's through one process. The faculty continually make thoughtful and needful changes to the curriculum at the undergraduate and graduate levels. All the courses, along with their electives, have been modified and are well-established. The department continues to be part of making SPIE one of the lead societies for ABET accreditation. The faculty continues to work closely with colleagues from other universities by actively inviting them to be part of the department advisory board.

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