An Accredited B.S. Program in Optical Sciences and Engineering

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1. Introduction and Background

Responding to pleas from industry in Arizona, an Optical Engineering B.S. program was initiated at the University of Arizona (UA) in the middle to late 1980's. This effort was led by the Optical Sciences Center (OSC) which is a freestanding academic and research unit, but not a traditional department within a college. While OSC has offered M.S. and Ph.D. programs, handled through the UA Graduate College, for many years, it had not previously offered undergraduate courses. As such, the UA Provost at that time directed OSC to offer the proposed B.S. in Optical Engineering (BSOE) jointly with an engineering department which would assume administrative control of the program. The Electrical and Computer Engineering (ECE) Department was selected as the academic partner for the new program initiative based on long standing joint collaborations and an existing B.S. in Electrical Engineering (BSEE) program which, with significant but not overwhelming modification, could be restructured to create the new BSOE program. While ECE would handle the administration of the program, the contents of the curriculum and other curricular matters would be handled by a joint curriculum committee staffed by faculty from ECE and OSC.

The BSOE program was formed by replacing about eight courses in the BSEE with new required optical engineering courses which, after some initial shakedown, evolved into the following set of courses (3-credit semester courses, except 210L and 226L which are each 1-credit):

OPTI 210	Geometrical Optics
OPTI 210L	Geometrical Optics Laboratory
OPTI 226	Physical Optics
OPTI 226L	Physical Optics Laboratory
OPTI 342	Fourier Optics
OPTI 350	Radiometry, Sources, and Detectors
OPTI 370	Lasers and Electro-Optical Devices
OPTI 412	Optical Instrumentation
OPTI 416	Optical Design, Fabrication, and Testing
OPTI 470a	Optics Laboratory
OPTI 470b	Optics Laboratory

In addition, because this was a joint program with ECE, students were required to take seven electrical engineering courses, four semesters of calculus, three semesters of chemistry, and three semesters of physics. The optics curriculum itself actually started in the sophomore year, as all freshman engineering students take a common set of courses in english, humanities, calculus, chemistry and physics. The 200-level courses were intended to be taken in the student's sophomore year, the 300-level the junior year and the 400-level in the senior year.

The BSOE officially began in 1988, had its first seven students graduate in 1992, and operated as a small (~100 students maximum) but successful program throughout the 1990's. Accreditation by the Accreditation Board for Engineering and Technology (ABET) was not sought at either of the regular-cycle ABET accreditation visits that occurred during this period for a number of reasons (e.g., waiting to gain program experience, program didn't fit traditional ABET categories, not sure accreditation was necessary/that meaningful for such a specialty program, etc.). Toward the latter part of the 1990's it also became clear that the existing BSOE, with its tight coupling to the BSEE and strong photonics emphasis, was too narrowly focused to adequately meet the needs of the growing optics industry in Arizona. This precipitated program transformation activities. The first was an initiative by OSC to create a Bachelor of Science in Optics, without the full compliment of engineering courses typically required in ABET accredited programs, which was to be offered through the UA University College. Before this new program began to take effect, the College of Engineering and Mines (CoEM) successfully argued to the UA Provost that an optical engineering program, broader than the old BSOE, should continue for which ABET accreditation would be sought. This led to the second and final transformation of the program into the present B.S. in Optical Sciences and Engineering (BSOSE), a collaboration between OSC and CoEM with college-level CoEM program administration. In this transformed program, students have the option of pursuing different tracks, presently including Opto-Electronics (most like the old BSOE program), Opto-Mechanics, Optical Materials, and Optics.

2. The Initiative for ABET Accreditation

As a part of the program transformation to the new BSOSE program, a commitment was made to pursue ABET accreditation at the earliest possible opportunity, namely, in fall 2001 when an ABET team would be making an interim visit to UA. This was motivated by the fact that one must have graduated at least one student under a program to seek accreditation, and this would have to be from the old BSOE program which was rapidly winding down in the transformation to the new BSOSE (a situation accelerated by the fact that students in the old BSOE program could elect to transfer at any time into the new BSOSE program). The dilemma posed with this approach was the recognition that the old BSOE program fell short of strong compliance with ABET Criteria 2000 ([1]see the ABET Web site for information on Criteria 2000), whereas the new BSOSE program had been formulated with these criteria in mind. The strategy that was pursued in preparing the Self-Study Report for the requested Criteria 2000 ABET visit was to address the old BSOE as the past/existing program (having graduated over 100 students), but present the new BSOSE as the replacement program, incorporating changes and processes evolving from assessment/feedback activities expected under Criteria 2000. An effort was made to enhance pre-visit communications as much as feasible concerning this somewhat hybrid program because past experience had demonstrated the value of pre-visit communications in addressing in advance simple omissions/errors, clarifying misunderstandings, and expanding time for more productive interactions during the actual visit ([2]Gerhard et al., 1999).

The curriculum for the new BSOSE program is given in Table 1. Concerning the specialized courses from selected Tracks, the Tracks and Track requirements are as follows:

Table 1 The 2002-2003 Optical Sciences and Engineering Curriculum

All engineering majors undertake a common freshman curriculum.
The Optical Sciences and Engineering program begins in the sophomore year.

16 Credits: Freshman Year, First Semester
3 Math 124/125 Calculus I
3 Chem 103A Fundamentals of Chemistry
1 Chem 103A Fundamentals of Chemistry Lab
3 Engl 101 First-Year Composition I
3 Engr 102 Introduction to Engineering
3 Tier 1 Individuals and Societies

17 Credits: Freshman Year, Second Semester
3 Math 129 Calculus II
4 MSE 110 Solid-State Chemistry
4 Phys 141 Introductory Mechanics
3 Engl 102 First-Year Composition II
3 Tier 1 Individuals and Societies

15 Credits: Sophomore Year, First Semester
4 Math 223 Vector Calculus
4 Phys 241 Introduction to Electricity and Magnetism
3 Opti 201R Geometrical and Instrumental Optics I
1 Opti 201L Geometrical and Instrumental Optics Lab I
3 Tier 1 Traditions and Cultures
or Specialized Course from Selected Track

17-18 Credits: Sophomore Year, Second Semester
3 Math 254 Introduction to Differential Equations
3 Phys 242 Intro to Relativity and Quantum Physics
3 Opti 202R Geometrical and Instrumental Optics II
1 Opti 202L Geometrical and Instrumental Optics Lab II
3 Tier 1 Traditions and Cultures
4-5 Specialized Course(s) from Selected Track

16 Credits: Junior Year, First Semester
3 Math 322 Analysis for Engineer
3 Opti 310 Physical Optics I
3 Opti 370 Lasers and Photonics
1 Opti 380A Intermediate Optics Lab I
3 Tier 2 Humanities or Arts
3 Specialized Course from Selected Track

16 Credits: Junior Year, Second Semester
3 Opti 330 Physical Optics II
3 Opti 340 Optical Design
3 Opti/ECE 360 Electronics for Optical Engineers/Scientists
1 Opti 380B Intermediate Optics Lab II
3 Tier 2 Individuals and Societies
3 Specialized Course from Selected Track

16-17 Credits: Senior Year, First Semester
3 Opti 400 Radiometry, Sources, and Detectors
3 Opti 410 Optical Fabrication and Testing
3 Opti 430 Optical Communications
2 Opti 471 A Optics Lab I
3 Engr 498A Senior Capstone Project
2-3 Specialized Course from Selected Track

14 Credits: Senior Year, Second Semester
3 Opti 420 Introductory Opto-Mechanical Design
2 Opti 471 B Optics Lab II
3 Engr 498B Senior Capstone Project
3 Specialized Course from Selected Track
3 Specialized Course from Selected Track
or Tier 1 Traditions and Cultures

The Tracks

Optics Track - The optics core is supplemented with courses chosen from one or more science or engineering departments. Students take Opti 280, Computer Programming Workshop and 18 units of technical electives as approved by their advisor. The technical electives may consist of optics, ECE, MSE, AME, or basic science courses. At least six units of the technical electives must include engineering design content.

Optical Materials Track - The optics core is supplemented with materials science courses dealing with the structure, processing, and properties of metals, semiconductors, ceramics, polymers, and composite materials. Students take Opt 280, Computer Programming Workshop: MSE 240, Thermodynamics; MSE 260. Structure and Properties of Materials; MSE 434, Electrical and Optical Properties of Materials, MSE 480, Experimental Methods for Microstructural Analysis and six units of Materials Science and Engineering technical electives as approved by their advisor.

Opto-Electronics Track - The optics core is supplemented with electrical engineering courses dealing with the design and analysis of electronic circuits and electromagnetic theory. Students take ECE 220, Basic Circuits, ECE 275, Computer Programming for Engineering Applications: ECE 381, Introductory Electromagnetics and eight units of Electrical and Computer Engineering technical electives at the 400 level as approved by their advisor.

Opto-Mechanics Track - The optics core s supplemented with mechanics engineering courses dealing with the design, analysis. and control of mechanical systems. Students take Opti 280, Computer Programming Workshop and 18 units of Aerospace and Mechanical Engineering courses as approved by their advisor. At least six units of the technical electives must include engineering design content.

An essential feature of the new program that better addresses ABET 2000 Criterion 4: Professional Component, is the addition of the two semester senior capstone sequence (Engr. 498A/498B). Students under the old BSOE program had for the most part participated in one or more notable design experiences in their required courses (as discussed in the Self-Study Report), but their experiences were admittedly varied, ranging from marginally acceptable to exceptional examples of a major design experience.

In preparing for the ABET accreditation evaluation visit, attention was also focused on formalizing/quantifying program objectives and outcomes, and on processes for assessment and improvement of same. Efforts in this regard had been somewhat informal and ad hoc under the old BSOE program, handled mainly through the program joint curriculum committee. The program objectives established for the new BSOSE program are listed in Table 2. They are now published on the OSC web site <www.optics.arizona.edu>, but were not at the time of the ABET visit, a point of weakness noted in the evaluation report. The outcomes specified for the new BSOSE program are identical with the ABET required outcomes (i.e., the **a** through **k** outcomes).

Table 2. Objectives of the Optical Sciences and Engineering Degree Program

The objectives of the undergraduate B.S. program are that its graduates will have:

1.	An understanding of fundamental mathematics, including calculus and differential equations.
2.	An understanding of the basic principles of physics, including electromagnetism.
3.	An understanding of the basic principles of geometrical optics, physical optics, and radiometry, and experience in applying these principles to optical engineering problems.
4.	An understanding of the basic principles of electrical and electronic circuits.
5.	Experience in developing basic laboratory skills, including experimental setup and troubleshooting, and in making electrical and optical measurements.
6.	Familiarity with the operation and use of a wide variety of optical components, including optical sources and detectors.
7.	Experience in computer programming, and in the use of specialized, technical computer programs.
8.	Experience in developing written and oral communication skills.
9.	An understanding of design processes, and participation in open-ended design projects.
10.	Additional in-depth knowledge in a technical area relevant to optical engineering, such as opto-mechanics, optical materials, opto-electronics, or some other specialized area of optics.
11.	Appreciation of engineering as a profession, including the need for life-long learning and an appreciation of ethical, legal, societal, environmental, political, and economic issues.

These objectives are fully consistent with the mission of the Land Grant University of Arizona, which reflects the need to educate students for an increasingly diverse and technological world. It also is in keeping with the dynamic growth of technologically-based industry in the state of Arizona and the simultaneous growth of the optical industry locally in Tucson.

3. Accreditation Visit Results and Continuing Activities

The Engineering Accreditation Commission (EAC) of ABET conducted a visit October 7-9, 2001 to evaluate the optical engineering program at UA for initial accreditation. Following due process responses/considerations and actions at the annual ABET meeting, accreditation was granted in July 2002, making the UA program, to the best of our knowledge, only the second optical engineering program to be accredited in the USA. Not surprisingly, the evaluators identified some points of weakness and concern that need to be addressed on or before the next scheduled ABET evaluation visit to UA in fall 2004 in order to keep the program on track for continued accreditation. These identified weaknesses and concerns centered primarily around the observed need to better define/document processes, and demonstrate implementation of these processes, for satisfying ABET 2000 Criterion 2: Program Educational Objectives and Criterion 3: Program Outcomes and Assessment.

Actions being pursued at UA in a continuing effort to strengthen compliance of the BSOE/BSOSE program with ABET 2000 criteria include the following:

- Implementation of a new design course, OPTI 422X Optical System Engineering, to provide a major design experience for students still completing their degrees under the old BSOE program. Students in the new BSOSE program will obtain a major design experience under the required senior capstone sequence Engr 498A/498B.

- BSOSE Curriculum Committee charged to more fully document/formalize processes for setting, modifying in response to constituent inputs, and demonstrating achievement of program objectives.

- Creation of an Outcomes Assessment Committee, as a sub-committee of the BSOSE Curriculum Committee, charged with three tasks:

    - Based on assessment data and input from the undergraduate teaching faculty, evaluate the program's student outcomes and recommend curricular or other changes that will improve those outcomes.
    - Evaluate existing assessment tools and recommend changes that will improve student assessment.
    - Produce an annual report documenting the outcomes assessment activities and program changes resulting from assessment.

Course objectives/syllabi and assessment measures are also being reviewed and updated, guided by recent suggestions for designing and teaching courses to satisfy ABET criteria given by [3]Felder and Brent, 2003.

The above described efforts will also be facilitated by BSOSE program participation in CoEM college-wide coordinated activities designed to assist programs in sustaining compliance with ABET criteria. These include a College Assessment Committee for steering/advising program assessment activities and the implementation/posting of program web-based matrices addressing educational objectives, ABET criteria, curriculum, and outcomes assessment. Examples of

updated course syllabi and these program web-based matrices will be included in the oral presentation of this paper. We are confident that these collective efforts and coordinated activities will insure that the BSOSE program will be well prepared for the next ABET evaluation visit and will lead to continued accreditation.

4. Conclusions

A non-accredited B.S. in Optical Engineering program in existence at the University of Arizona for over a dozen years has been transformed into a new B.S. in Optical Sciences and Engineering program designed to be in compliance with ABET 2000 criteria. ABET accreditation has been successfully sought for this transforming program (approved July 2002), making it one of two optical engineering programs now ABET accredited in the USA. Efforts continue to strengthen program activities concerned with processes for defining/modifying/assessing program objectives and outcomes with the goal of being well prepared for the next ABET evaluation visit and maintaining program accreditation.

5. References

1. ABET (Accreditation Board for Engineering and Technology). Criteria for accrediting engineering programs: Effective for evaluations during the 2002-2003 accreditation cycle. <http://www.abet.org/images/Criteria/2002-03EACCriteria.pdf>.

2. J. Orr, G. Gerhard, J. Reagan and H. Tharp, "Enhanced Pre-Visit Communication under Criteria 2000," *ASEE/IEEE Proc. Frontiers in Education Conference*, paper 13b8, pp. 1-3, San Juan, Puerto Rico, November 10-13, 1999.

3. R.M. Felder and R. Brent, "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria," *Journal of Engineering Education,* Vol. 92, No. 1, pp. 7-25, January 2003.

6. Author Biographies

JOHN REAGAN received the B.S. degree in Physics in 1963 and the M.S. degree in Electrical Engineering in 1964, both from the University of Missouri, Rolla. He received his Ph.D. in Electrical Engineering in 1967 from the University of Wisconsin. Dr. Reagan has worked in teaching and research at the University of Arizona for over thirty years, and is a Professor of both Electrical and Computer Engineering and Optical Sciences.

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