Providing Photonics Education for Technicians

Dan Hull and John Souders

APRIL 2010

This material is based on work supported by the National Science Foundation under Grant No. NSF/DUE 0603275. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

ABSTRACT: Photonics is a cutting-edge technology that offers rewarding career opportunities to graduates of AAS programs. Photonics devices and applications play an essential role in many high-tech commercial enterprises. Because of the breadth and depth of photonics applications, virtually every technical AAS program should contain elements of photonics instruction. This monograph provides the background and first steps necessary to initiate programs and revitalize existing programs. The authors represent OP-TEC: The National Center for Optics and Photonics Education, and NSF ATE National Center of Excellence. OP-TEC is able to provide services and materials designed to assist two-year colleges in providing photonics instruction for technicians.

PROVIDING PHOTONICS EDUCATION FOR TECHNICIANS

Dan Hull and John Souders

I. Background and Purpose

Photonics, a technology that combines optics and electronics, is a rapidly expanding field that provides rewarding jobs for technicians and excellent opportunities for economic growth. A 2009 survey of U. S. employers estimated that nearly 2200 new photonics technicians were needed that year. "Photonics-related companies number more than 5000, and their net financial impact amounts to more than $50 billion annually." (*Harnessing Light,* National Research Council)

Photonics devices and applications include lasers, fiber-optics, telescopes, interferometers, spectrometers, infrared sensors, and laser/light-emitting diodes—all of which play essential roles in larger systems such as laser welders, laser surgical devices, LIDARS, electronic/digital displays, information technology, solar voltaic panels, lighting systems, and target designators. Lasers and other photonics devices are also used as tools and diagnostic equipment in genetic engineering, controlled thermonuclear fusion, environmental probes, and nanotechnology.

Photonics is not only a technology field in and of itself but is an *enabler* of nearly every other technology field*,* including renewable energy, telecommunication, micro- and nanotechnology, information technology, biotechnology, medical equipment, robotics, measurement and materials processing for manufacturing, remote sensing, solid-state lighting, electro-optics displays/imaging, and defense and homeland security.

Because of the breadth and depth of photonics applications, certain elements of photonics education should be included in virtually all two-year AAS technician education programs.

The purpose of this monograph is to provide preliminary information that will enable two-year colleges to begin the process of developing photonics programs and/or adding photonics elements to their existing technical programs. Specifically, the monograph will identify:

1. Three levels of technicians needed by U.S. employers,
2. The educational requirements for each level, and
3. Strategies for creating new programs, adapting existing ones, infusing photonics into core knowledge and skills, and transitioning over time from one level of photonics education to another. (Details pertaining to curriculum structures and course content to support these strategies are described in a companion monograph titled "A General Curriculum Framework for Infusing 'Enabling' Technologies into Two-Year Postsecondary Technical Programs.")

II. Photonics Knowledge and Skills Required in the Workplace

Today's high-technology workplaces require three levels of technicians: (A) Photonics Technician Specialists; (B) Photonics Application and Systems Integration Technicians; and (C) Technicians in Other Fields. The levels differ in the knowledge and skills required, and thus differ in the course content of the programs that prepare technicians for the workplace.

A. *Photonics Technician Specialists*—These technicians work as (a) R&D laboratory technicians, (b) field service technicians for laser/optical equipment, and (c) development and test technicians for laser original equipment manufacturers (OEM). They require a high level of knowledge and skills in laser fundamentals and components, geometrical and wave optics and components, specific laser systems, electro-optics measurement equipment and techniques, and electro-optic instruments such as spectrophotometers and interferometers. A typical AAS curriculum for preparing Photonics Technician Specialists contains 5–8 photonics specialty courses and a strong electronics or electro-mechanical core.

B. *Photonics Applications Technicians*—These technicians typically have educational backgrounds and experience in specialty fields in which photonics devices and applications are evident, such as manufacturing and materials processing, information technology, biomedical equipment, and defense and homeland security. A typical AAS curriculum for preparing Photonics Applications and Systems Integration Technicians contains two photonics courses infused into the curriculum for the specialty field.

C. *Technicians in Other Fields*—Technicians at this level work in fields such as consumer electronics, microelectromechanical systems (MEMS), semiconductors, and biotechnology. Specific equipment and/or applications of photonics in these and related fields have been identified; others are emerging. A typical AAS curriculum for preparing technicians at this level would include at least one course in photonics fundamentals.

The 2009 survey of photonics technician employers revealed that 2190 new photonics technicians are currently needed. It is estimated that less than one-fourth (500) of these jobs require *Photonics Technician Specialists* (Level A); over three-fourths (1500–1600) require *Photonics Applications Technicians* (Level B).

III. Curriculum Strategies for Developing and Updating AAS Programs

Curriculum for Photonics Systems Specialists (Level A)—In the 1970s, 1980s, and early 1990s, lasers and laser applications were still in the developmental stage; thus nearly all technician jobs in this field required *Photonics (or Laser) Systems Specialists.* During that same period, 20–30 colleges initiated laser/electro-optics technology (LEOT) AAS programs. Graduates of those programs were in high demand and continue to support critical skill needs in the areas of photonics R&D, OEM, and field service. But LEOT programs are expensive to maintain because of the equipment and faculty expertise they require. Today, fewer than ten of the original LEOT programs remain; many are undergoing significant redesign and streamlining to remain fiscally viable and to serve an ever-changing labor demand. Curriculum materials for the first generation

of LEOT programs, which were developed and maintained by CORD, have recently been extensively revised and updated by OP-TEC to meet the requirements of the third edition of *The National Photonics Skill Standards for Technicians* (NPSST).

Curriculum for Photonics Applications Technicians (Level B)—The development of curriculum for *Photonics Applications Technicians* was initiated in 2003 by CORD under the NSF/ATE STEP II grant. CORD developed two photonics courses—*Course 1: Fundamentals of Light and Lasers* and *Course 2: Elements of Photonics*—designed to support the infusion of photonics education into application areas such as manufacturing, medical equipment, and telecommunications. Beginning in 2006, OP-TEC revised and developed technical assistance for the use of those courses and developed nineteen teaching modules in *photonics-enabled technologies* (PET) such as nanotechnology, alternative energy, defense and homeland security, and environmental monitoring. The purpose of the PET modules is to enable instructors to *infuse* elements of photonics instruction into their existing programs. Using this infusion strategy, new photonics programs have been initiated at six colleges, and existing LEOT programs have been redesigned or updated at eight colleges. OP-TEC will continue to develop PET modules as new applications emerge.

Course 1: Fundamentals of Light and Lasers provides the foundational knowledge and skills necessary to understand and begin *using* photonics technology. It also serves as the foundation for most of the PET modules. It is recommended that *Course 1: Fundamentals of Light and Lasers* be included in the technical core of all electronics-based systems technologies.

IV. A General Curriculum Infusion Framework for the Three Levels of Photonics Technicians

Figure 1 depicts a general curriculum infusion framework for the three levels of photonics technicians. (For more detailed information on how the framework is applied, see the companion monograph, "A General Curriculum Framework for Infusing 'Enabling' Technologies into Two-Year Postsecondary Technical Programs.") As Figure 1 shows, the framework involves an overall progression from general to more specific, depending on the technical specialty that the student is pursuing.

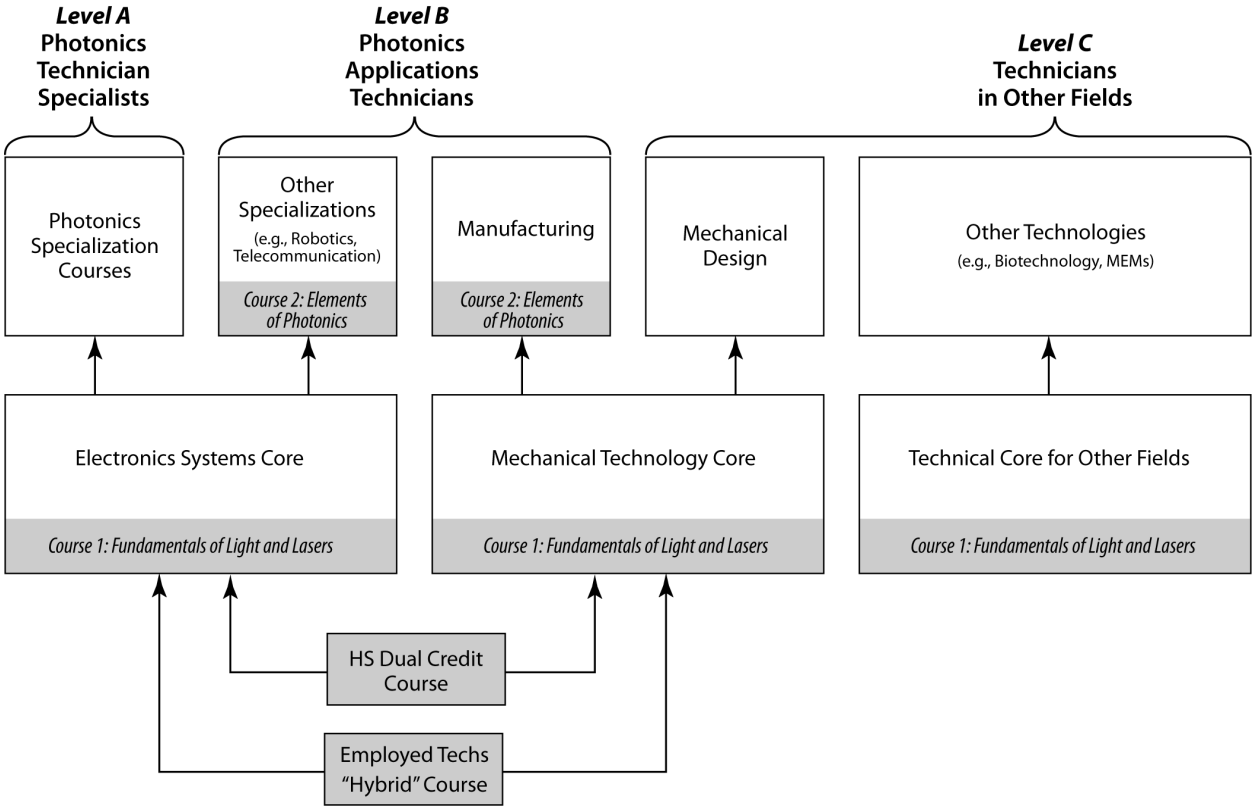

Figure 1. General Curriculum Infusion Framework

All the technical specialties represented use *Course 1: Fundamentals of Light and Lasers* in the first year (technical core). Several aspects of this course make it a good choice:

- *It's interesting and fast-moving and can be completed by first-year technology students*—Many first-term technology students are still looking for interesting, achievable majors. Lasers are attractive to young people because of their futuristic, high-tech applications. For this reason, courses in areas such as lasers, robotics, automated systems, and computer/Internet should be included in the first year of the technical core. Photonics is math-intensive, but the math in the first photonics course can be limited to algebra, geometry, and some trigonometry. OP-TEC provides a supplementary text titled *Mathematics for Photonics Technicians* that correlates the required math to specific problem-solving assignments in *Course 1: Fundamentals of Light and Lasers*.
- *It provides knowledge and skills needed by electronics systems technicians*—*Course 1: Fundamentals of Light and Lasers* is being used to educate employed technicians who do not have prior photonics knowledge and skills. Employers say that this course gives their technicians *cross-training abilities* so that they can function effectively in photonics-related systems work.
- *It can serve as the first, foundational course in curricula for all three of the technician levels described in Section II*—Details on how the general curriculum infusion framework is applied to different technical specialties are provided in the companion monograph, "A

General Curriculum Framework for Infusing 'Enabling' Technologies into Two-Year Postsecondary Technical Programs." Having a common photonics course that can be used in the technical core(s) for multiple technical specialties will minimize the number of classes, labs, and faculty needed, thus maximizing institutional efficiency and economy.

- *It can be used as a dual-credit course to link AAS programs with high school STEM programs*—All the colleges that currently offer photonics education are seeking ways to increase their enrollments by creating a "high school pipeline." *Course 1: Fundamentals of Lights and Lasers* has been shown by several of OP-TEC's partner colleges to be an effective way to attract high school students to STEM fields and to help them earn postsecondary credits and gain confidence. OP-TEC has identified and validated a low-cost equipment package that enables high schools to create their own photonics laboratories for the course.
- *It can be used as the first photonics course in programs designed to enhance the skills of working technicians*—Using a combination ("hybrid") of online and face-to-face delivery, the course has been effectively offered to working technicians. In addition to providing valuable knowledge and skills, the course provides postsecondary credits that can be applied toward postsecondary certificates or AAS degrees.

V. Where to Begin

Finding and Using Available Resources

If your college has not previously offered instruction in lasers, optics, or photonics, you should probably consider strategies that require an initial offering of only one or two photonics courses. Your initial investigation should rely on three resources: (1) resources already available at your institution, (2) resources available from OP-TEC, and (3) employers in your institution's service area. The following points are designed to help you identify gaps and begin planning a course of action.

1. *Resources already available at your institution*

   Do you already have an electronics core curriculum? If so . . .

   - Is it "systems-oriented" and up to date?
   - What program majors does the core support?
   - Are student enrollments for these programs strong?
   - Is employer support for these programs high?
   - Would adding a photonics course to the "core" strengthen the program in terms of student interest and employer support?

What other technology majors, which may require photonics applications, are offered at the institution?

- Look for areas where there are known photonics applications. Many of these applications are identified in Sections I of this monograph. For more in-depth explanations of these applications, review the PET modules listed on the OP-TEC website (www.op-tec.org/laser.php).
- Are the faculty and employer advisory committees of these programs open to considering the infusion of photonics applications as a way of updating these programs?

2. *Resources available from OP-TEC*
   - *The National Photonics Skill Standards for Technicians* (www.op-tec.org/skill.php)
   - OP-TEC program planning guides (5) for infusing photonics into AAS programs in manufacturing, telecommunication, opto-electronics, defense/homeland security, and biomedical equipment (www.op-tec.org/programplanning.php)
   - Monographs on model programs at OP-TEC's partner colleges
   - Monograph titled "A General Curriculum Framework for Infusing 'Enabling' Technologies into Two-Year Postsecondary Technical Programs"
3. *Employers in your institution's service area*
   - Employer advisory committees at your institution
   - Employers in photonics and related technologies in your service areas (OP-TEC can provide this information.)

Initial Planning Decisions

In almost every situation, increasing student access to photonics instruction will involve choosing one of three options:

- Adding a photonics course to the electronics core
- Infusing two photonics courses into a photonics-enabled technical specialty that is presently being taught at the institution
- Beginning the process of developing and growing an AAS program for technicians at Level A (*Photonics Technician Specialists*) or Level B (*Photonics Applications Technicians*)

Follow-up Support Available from OP-TEC

OP-TEC is able to provide the following support services:

- Identification of photonics employers
- Assistance in conducting job needs studies

- Advisement on decisions pertaining to curriculum, planning, labs, and equipment
- Mentoring (provided by faculty members from OP-TEC's eight partner college)
- Online faculty training

VI. Where and How to Make Changes

Colleges that offer or previously offered laser, optics, or photonics education may want to consider curriculum and program changes designed to improve:

- Student enrollment and/or sustainability.
- Program costs.
- Program revitalization/updates.
- Photonics support for existing photonics-enabled technologies.

If you offer or previously offered an AAS program in lasers, optics, or photonics, it is possible to streamline the program and increase student enrollment by aligning the initial laser/photonics course with the topics covered by *Course 1: Fundamentals of Light and Lasers.* Graduates of AAS programs in lasers, optics, and photonics are still badly needed; OP-TEC encourages you to continue your program but consider changes that would reduce costs and improve enrollment. These changes could make your program more appealing and achievable to incoming students. It would also provide a pipeline for:

- Dual-credit students from high school STEM programs.
- Employed technicians who have recently received photonics-related job assignments.
- Students in photonics-enabled technology programs.

Some colleges that offer or previously offered laser, optics, or photonics programs have opted (with the advice of their employer advisory committees) to rebuild their programs by using a leaner curriculum supported by an electronics or electromechanics core. This change has allowed them to achieve substantial cost savings by reducing the number of photonics courses and eliminating expensive, difficult-to-maintain and out-of-date laboratory equipment.

Other colleges have opted to engage in a more severe change that involves teaching photonics as an enabling technology in a manufacturing or telecommunication core curriculum.

All the changes described above have recently been made by colleges affiliated with OP-TEC. All those colleges are well positioned to see improvement in student enrollment and retention and in their programs' appeal to employers. Some of the colleges have documented their changes and results in OP-TEC monographs; representatives of other colleges are available to discuss with you their recent experiences.

OP-TEC will help you to make the changes that you and your employer advisory committee choose.

VII. Where Will the Additional Photonics Courses Fit?

It seems that there is never enough room to fit all the necessary course content into a two-year curriculum. Adding one or two photonics courses to an existing curriculum will pose challenges. Although updating and/or restructuring a curriculum is always difficult and sometimes painful, it is often a necessary step in keeping the program up-to-date and sustainable.

It will probably be necessary for faculty (with the advice of employers) to remove or reduce some existing content, or to combine courses to make room for the courses recommended in this monograph. Technical curriculum content does not necessarily become subject to removal just because the underlying technology has changed. Sometimes changes are necessary to accommodate changing student interests and needs or to provide a broader technical base that will give graduates more mobility in a rapidly changing job market.

VIII. How to Grow a Program from One Level to Another

Every college has resources that are unique to its situation. Some colleges may be able to address this opportunity quickly and aggressively; others may have to move at a more cautious pace. The key to success is not which approach you are able to take, but whether your faculty, administrators, and employer partners have the vision and enthusiasm to plan and build a successful initiative.

The key is to begin at whatever level you choose with a photonics foundation that will allow you to grow as opportunities arise. If you choose to begin at the level of adding a photonics course to your electronics core, OP-TEC recommends that you choose a course such as *Course 1: Fundamentals of Light and Lasers.* This course is sufficient to enhance your core, provide a dual-credit partnership with local high schools, and offer education and training for employed technicians.

If, at a later time, you choose to infuse photonics applications into programs in photonics-enabled technologies, adding a second course such as *Course 2: Elements of Photonics* will allow you to tailor the programs' content to the requirements of the technologies being taught.

And if you eventually determine that your institution should offer a full AAS degree in photonics, you will have the foundation and core to build on.

If you have questions or require additional information, refer to the OP-TEC website www.op-tec.org or contact us. We are available and eager to assist you in planning and enhancing educational opportunities for photonics technicians.

Dan Hull
PI, Director, OP-TEC
P.O. Box 21689
Waco, TX 76702-1689
(245) 741-8338
(254) 399-6581 fax
hull@cord.org

Dr. John Souders
Director of Curriculum, OP-TEC
P.O. Box 21689
Waco, TX 76702-1689
(254) 772-8756 ext 393
(254) 772-8972 fax
souders@cord.org