A General Curriculum Framework for Infusing "Enabling" Technologies into Two-Year Postsecondary Technical Programs

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OP-TEC
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ABSTRACT—OP-TEC: The National Center for Optics and Photonics Education has published two monographs designed to show how two-year postsecondary technical programs can be developed or reconfigured to produce technicians who are qualified to meet workforce needs in photonics and technologies that are "enabled" by photonics.[1] The first monograph, titled "Providing Photonics Education for Technicians," identifies three levels of technicians needed in the workplace, presents a framework for infusing photonics instruction into two-year programs, provides reasons why the framework can positively affect recruitment and lead to higher program completion rates, and outlines initial steps for implementing the framework. This, the second monograph, elaborates on how the framework can be applied to programs for all three levels of technicians. Although photonics-based examples are provided, the framework is applicable to other technologies.

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[1] Photonics-enabled technologies include fields such as biomedicine, optoelectronics, robotics, hi-tech manufacturing, semiconductors, consumer electronics, microelectromechanical systems (MEMS), telecommunication, and defense and homeland security.

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Background

OP-TEC: The National Center for Optics and Photonics Education has examined a number of two-year postsecondary technical curricula to determine what education is necessary for technicians to meet workforce needs in photonics. The results of that examination have been published in an OP-TEC monograph titled "Providing Photonics Education for Technicians," which defines three levels of technicians and provides a general curriculum framework for supporting each level (Figure 1).

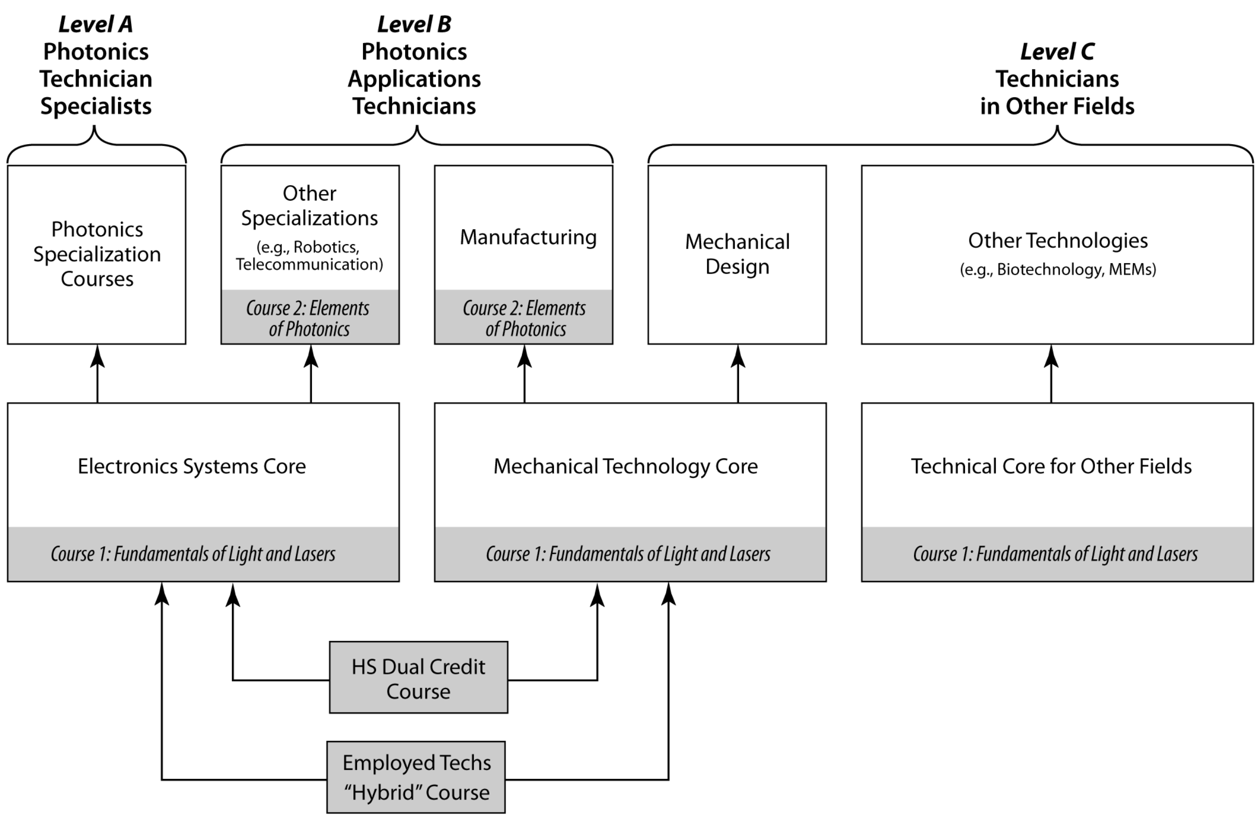

Figure 1. General Curriculum Infusion Framework from the Monograph Titled "Providing Photonics Education for Technicians"

The three levels identified along the top row of the figure differ in the knowledge and skills they require. Thus the educational requirements for the three levels also differ.

A. *Photonics Technician Specialists*—These technicians work as (a) R&D laboratory techs, (b) field service technicians for laser/optical equipment, and (c) development and test techs 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.

"Providing Photonics Education for Technicians" explains the rationale for infusing photonics instruction into courses and programs designed to produce technicians at each of the three levels and provides an example of the infusion process. The monograph supports implementation of the infusion process described by providing guidelines for finding and using available resources.

The purpose of this, the second, monograph is to extend this support by providing further details on implementation. This purpose will be accomplished by focusing on the three components of the general curriculum infusion framework—the academic core, the technical core, and the infusion component. Examples will be provided of how the framework is used in supporting the three levels of technicians defined in "Providing Photonics Education for Technicians" and the preceding paragraphs A, B, and C. We will also present the model's efficiencies, that is, its potential to reduce the number of courses required in AAS programs. Though photonics instruction is emphasized, the framework can be adapted to other technologies.

The Basic Building Block of the General Curriculum Infusion Framework

Every technical program based on the general curriculum infusion framework consists of three components:

1. Technical specialty courses
2. A technical core (Each core supports one or more technical specialties.)
3. A general education core

Figure 2 shows the relationships between the three components. The resulting configuration is the basic building block of the general infusion curriculum framework.

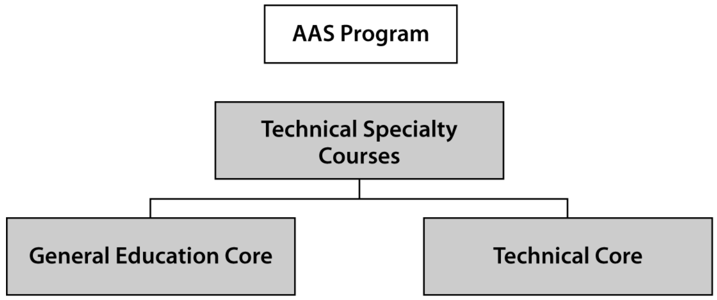

Figure 2. Basic Building Block of the General Infusion Curriculum Framework

General Education Core: This component provides mathematics and science prerequisites for a broad range of technical fields. It also gives the curriculum enough breadth to satisfy state and local higher education requirements in the humanities and social sciences. Because the purpose of Figure 1 is to show only the flow of *technical* concepts, it does not show this component. However, the general education component is fundamental to all technical program curricula. Table 1 lists courses that the general education core would typically include.

Table 1. Representative Courses in the General Education Core

Technical Courses	Nontechnical Courses
Technical Math	Business Fundamentals
Algebra	English/Communication
Trigonometry	Humanities
Applied Science (Physics, Chemistry, Biology etc.)	Social Science
Computer Applications (Software, Internet, Word Processing, Spreadsheets, Databases)	

Technical Core: This component includes courses that provide a technical foundation for learning the applications and concepts required in the supported specialty area(s). The course content of technical cores varies depending on the specialties they support. For example, Table 2 lists the courses typically taught in the electronics systems and mechanical technology cores shown in Figure 1.

Table 2. Courses Typically Taught the Electronics Systems and Mechanical Technology Cores

I. Electronics Systems Core
AC and DC Circuits
Logic Circuits
Intro to Electronics
Troubleshooting and Repair Techniques
Programmable Logic Controllers

II. Mechanical Technology Core
Mechanical/Fluid Components and Systems
Metrology
Basic Metallurgy
CAD
Machine Design I
Schematics/Blueprint Reading

As shown in Figure 1, the technical core is one of two optimum places to insert an infusion course. Infusion courses give students opportunities to broaden their understanding of the enabling technologies that apply within their specialty fields. For example, a student in manufacturing (a specialty field) would benefit from taking courses on laser safety and operations (an enabling technology, given that lasers are used in many aspects of manufacturing).

Technical Specialty: This component comprises the courses that prepare students to become technicians in specific technical fields. Several of these fields have the potential to enhance student recruiting because they involve high-growth, emerging technologies that are attractive to students and provide strong employment opportunities. Examples of such fields are robotics, high-tech manufacturing, biomedicine, optoelectronics, biotechnology, microelectromechanical systems (MEMS), and telecommunication.

A Generic Application of the General Curriculum Infusion Framework

Using the basic building block described in the last section, Figure 3 shows how the general curriculum infusion framework could be applied to three technical specialties (unspecified) supported by the same technical core. The number of technical specialties in the figure (three) is arbitrary. In reality, the number of technical specialties would be determined by the resources of the college implementing the framework and the number of technical specialties supported by the technical core.

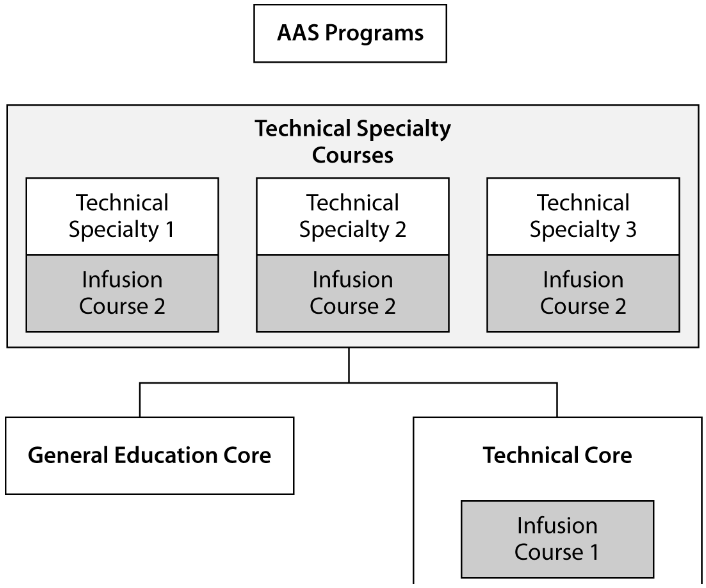

Figure 3. The General Curriculum Infusion Framework Applied to Three Technical Specialties Supported by the Same Technical Core

To simplify the framework as shown in the figure, we have not listed courses in the general education core or technical core. These are usually mandatory and will vary from state to state. (See Tables 1 and 2 for a sampling of the courses that would typically appear in these components.) What we have attempted to show in Figure 3 is that the infusion process can be accomplished using only two courses, one at the level of the technical core ("Infusion Course 1") and the other at the level of the technical specialty ("Infusion Course 2"). Both infusion courses would focus on a technology that is an enabler of the technical specialties referred to as "Technical Specialty 1," "Technical Specialty 2," and "Technical Specialty 3."

The courses that we refer to as "Infusion Course 1" and "Infusion Course 2" are the keys to the infusion process. Their purpose is not to provide in-depth treatment of the enabling technology but to present its foundational concepts and, more importantly, to provide instruction on how that technology enables other technical specialty areas.

Applying the General Curriculum Infusion Framework to Technical Specialties

In this section, we turn from a generic application of the framework to a photonics-specific application. The framework will be used to develop a curriculum for educating and training the *Photonics Technician Specialists* (Level A) and *Photonics Applications Technicians* (Level B) shown in Figure 1. Instead of the generic titles "Infusion Course 1" and "Infusion Course 2," we will now refer to two infusion courses developed by OP-TEC—*Course 1: Fundamentals of Light and Lasers* and *Course 2: Elements of Photonics* (also shown in Figure 1). We will also show how *Course 2: Elements of Photonics* can be customized. Our intention is that readers who work in technical areas other than photonics will get a sense of how to develop similar courses in their technical specialty areas to achieve the same infusion objectives.

Figure 4 presents an application of the general curriculum infusion framework in which the enabling technology is photonics. For the specialty areas shown in the figure (photonics, biomedicine, and optoelectronics), the technical core would be the electronics core presented in Table 2. We matched these particular specialty areas to the electronics core because they require a good grounding in electronics and are enabled by photonics. Telecommunication and environmental monitoring could also have been chosen as specialty areas for this application of the framework.

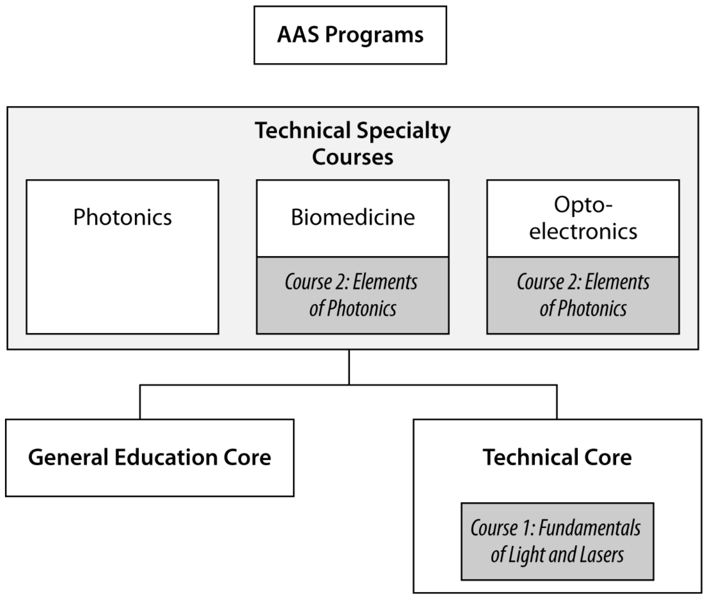

Figure 4. Photonics Application of the General Curriculum Infusion Framework

In this model, Infusion Courses 1 and 2 of Figure 3 have been replaced by the two photonics-specific courses cited above. *Course 1: Fundamentals of Light and Lasers* builds on foundational concepts learned in high school and in general education courses and provides a broad overview of the basic concepts that are fundamental to photonics. *Course 2: Elements of Photonics*, in the technical specialty area, builds on the concepts learned in *Course 1: Fundamentals of Light and Lasers* and further extends the student's understanding of the basic concepts that underlie photonics. In addition, *Course 2: Elements of Photonics* provides specific instruction on how photonics is applied and integrated into the processes and systems that technicians encounter in specialty areas such as biomedicine and optoelectronics.

The topics covered in *Course 1: Fundamentals of Light and Lasers* and *Course 2: Elements of Photonics* are shown in Tables 3 and 4. (The topics in Course 1 can be covered in one semester.)

Table 3. Topics in *Course 1: Fundamentals of Light and Lasers*

Nature and Properties of Light
Optical Handling and Positioning
Laser Safety
Basic Geometric Optics
Basic Physical Optics
Principles of Lasers

Table 4. Topics in the *Course 2: Elements of Photonics*

Operational Characteristics of Lasers
Specific Laser Types
Optical Detectors and Human Vision
Specialization Module 1
Specialization Module 2
Specialization Module 3

Course 2: Elements of Photonics builds on the concepts presented in *Course 1: Fundamentals of Light and Lasers* and gives students an understanding of the different types of lasers, their basic operational capabilities and applications, and methods for determining their output characteristics. Covering the first three topics in Course 2 requires about half a semester. With these basics in place, students preparing to become *Photonics Applications Technicians* (Level B) are now ready to spend the remainder of their semester learning how photonics enables systems and processes in the technical specialty areas in which they are earning their AAS degrees. This learning is supported by the modules referred to in Table 4 as Specialization Modules 1, 2, and 3.

These "specialization modules" are the capstone of the infusion aspect of the general curriculum infusion framework. They provide instruction on how photonics concepts presented earlier in the curriculum act as enablers in technical specialization areas.

OP-TEC has developed a series of specialized modules for customizing *Course 2: Elements of Photonics* for use in programs in technologies that are enabled by photonics. Collectively the modules are referred to as the Photonics-Enabled Technologies (PET) series. Table 5 lists the technical areas that are covered by the PET series and also provides the titles of the modules that are currently available (spring 2010).

Table 5. Specialization Modules in the PET Series

Manufacturing	Biomedicine	Forensic Science and Homeland Security
Laser Welding and Surface Treatment	Lasers in Medicine and Surgery	Lasers in Forensic Science and Homeland Security
Laser Material Removal: Drilling, Cutting, and Marking	Therapeutic Applications of Lasers	Infrared Systems for Homeland Security
Lasers in Testing and Measurements: Alignment Profiling and Position Sensing	Diagnostic Applications of Lasers	Imagining System Performance for Homeland Security
Lasers in Testing: Interferometric Methods and Nondestructive Testing	**Environmental Monitoring**	**Optoelectronics**
	Basics of Spectroscopy	Photonics in Nanotechnology
	Spectroscopy and Remote Sensing	Photonics Principles in Photovoltaic Cell Technology
	Spectroscopy and Pollution Monitoring	Photonics in Nanotechnology Measurements: A Study of Atomic Force Microscopy

Let's look at the curriculum presented in Figure 4 and customize the *Course 2: Elements of Photonics* text for each technical specialty. A biomedicine program would use the first three modules of *Course 2: Elements of Photonics* along with a combination of those listed in Table 5 under biomedicine. Likewise, an optoelectronics program would use the first three modules of *Course 2: Elements of Photonics* along with a combination of those listed in Table 5 under optoelectronics. If the technical core supports other technical specialties such as environmental monitoring or forensic science and homeland security, *Course 2: Elements of Photonics* would be similarly adapted for those specialties.

It should now be clear why what we refer to as "Infusion Course 1" in Figure 3 is part of the technical core and "Infusion Course 2" is grouped with the technical specialty courses. "Infusion Course 1" covers only the basics of whatever technology is being infused into the curriculum and is not specific to any one technical specialty. "Infusion Course 2," on the other hand, can be customized to include topics that are specific to any of several technical specialties.

The connection between a technical specialty and its technical core is not always obvious. Consider the case of manufacturing. Manufacturing uses lasers in a number of processes that are enabled by photonics—treating surfaces, welding, positioning and aligning specimens, and measuring, to name a few. Consequently, a manufacturing curriculum should definitely include the infusion of photonics instruction. However, because manufacturing programs emphasize mechanical systems rather than instrumentation, the appropriate technical core is mechanical technology (Table 2-II) rather than electronics systems (Table 2-I). *Course 1: Fundamentals of Light and Lasers* would serve as the infusion course for the technical core, and the first three modules of *Course 2: Elements of Photonics* would be used for the technical specialty courses—along with specialization modules selected from those listed under manufacturing in Table 5.

The resulting curriculum (represented in Figure 5) would prepare students to work as Manufacturing Technicians (a subset of *Photonics Applications Technicians*, Level B).[2]

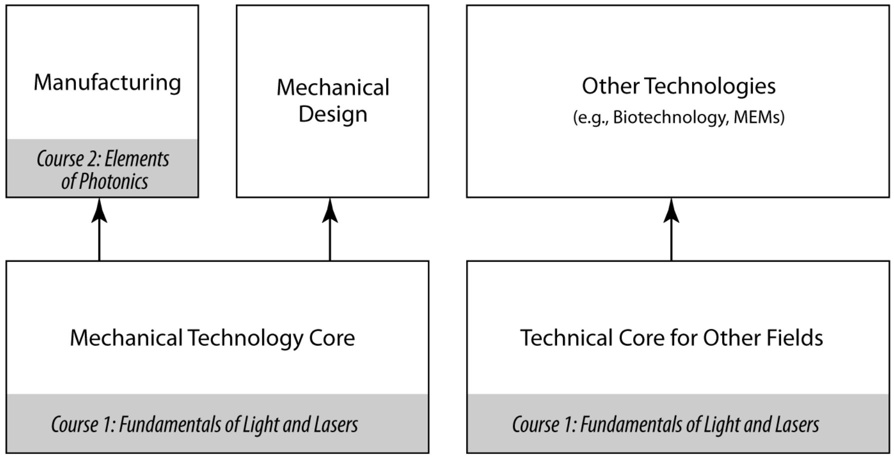

Figure 5. General Curriculum Infusion Framework Adapted for a Manufacturing Technology Program

Some technical programs call for only one infused photonics course (as part of the technical core). This is true, for example, of mechanical design, which is built on the same technical core as manufacturing but does not call for the infusion of the second photonics course (at least not yet). The reason for infusing only one course in some technical programs is that the full extent of the *enabling potential* of many technologies is still being discovered. As science and industry find more applications of enabling technologies, the need for higher-level infusion of those technologies into educational programs will grow. In the meantime, it is important that students are well grounded in the fundamentals of the technologies that enable their technical specialties. This is the purpose of *Course 1: Fundamentals of Light and Lasers*.

The one level of technician that we have not yet addressed is the *Photonics Technician Specialist* (Level A). In the next section we will discuss the specialty courses required for a technician at this level and provide examples of the courses that an AAS in photonics should include. We will also highlight efficiencies of the general curriculum infusion framework that provide accelerated paths for completion of AAS programs and eliminate the need to add courses.

The Efficiencies of the General Curriculum Infusion Framework

The general curriculum framework may appear to violate one of the most basic tenets of curriculum design: *You can't add courses to a program that's already full.* Typically, the curricula of technical programs contain the maximum number of courses allowed by the state. Does this mean that adopting the general curriculum infusion framework will require adding two more courses to an already full curriculum? Fortunately, the answer is no. The general curriculum infusion framework provides two efficiencies that make its adoption possible without adding to the total number of courses required.

[2] Refer to Figure 1 and the accompanying text for descriptions of the three levels of technicians.

Efficiency 1

Course 1: Fundamentals of Light and Lasers contains a number of important basic science concepts. Table 3 shows that students taking this course will learn about properties of light; concepts related to energy and heat transfer; and basic principles in optics, wave mechanics, and elementary atomic physics. Because of its strong science content, this course can be used as a substitute for the basic science course typically required in the general education component. This substitution has been successfully made at OP-TEC partner colleges.

Likewise, the PET modules that support manufacturing, optoelectronics, and other technical programs listed in Table 5 contain content that is probably already being taught in other technical specialty courses in those programs. For instance, if the four manufacturing modules in Table 5 are used as "specialization modules" along with the first three modules of *Course 2: Elements of Photonics,* students will receive a strong grounding in such basic manufacturing processes as welding, grinding, marking, polishing, measuring, aligning, and nondestructive testing—topics that can be eliminated from the other technical specialty courses in the manufacturing program. With careful planning, content can be removed from some of the courses already in place, making room for the infusion courses without adding to the total number of courses required. This process of replacing course content is common practice at colleges and is in fact the only way colleges can keep technical program curricula relevant and up to date.

Efficiency 2

The second efficiency pertains to technical programs in which the primary technologies are the same as the technologies that are being infused into the technical cores that support them. For example, in the photonics specialty shown in Figure 4, the infused technology and the primary technology are the same—photonics. The topics covered in *Course 2: Elements of Photonics* would be covered in this program in considerable depth, but the course itself would not be *infused into* a pre-existing curriculum and thus would not call for the elimination of content.

This efficiency does not affect the role of *Course 1: Fundamentals of Light and Lasers,* which should still be part of the technical core. There are two reasons for this. First, the concepts presented in the course expose students to applications of technology that naturally invite interest and would improve student recruitment and retention. Second, maintaining a photonics course in the technical core of a photonics program can reduce the number of specialty courses needed for program completion. This reduction in courses once again allows for the addition of an infusion course without increasing the total number of courses required for graduation. Here is how the reduction might occur. Table 6 shows the typical specialty courses a student might take if the general curriculum infusion framework ***is not used*** in offering an AAS in photonics. (To add specificity, we have used titles that appear in the recently updated OP-TEC LEOT series.)

Table 6. Specialty Courses Required for Offering an AAS in Photonics
(General infusion curriculum model not used)

1. Introduction to Lasers
2. Geometric Optics
3. Laser Technology
4. Light Sources and Wave Optics
5. Laser/ Electro-Optic Devices
6. Laser/Electro-Optic Components
7. Laser Electronics
8. Laser/Electro-Optic Measurements

If the infusion framework *is* used, *Course 1: Fundamentals of Light Lasers* would be taught before students take any specialty courses. As seen in Table 3, the concepts of wave optics and geometric optics are presented both in *Course 1: Fundamentals of Light Lasers* and two specialty courses listed in Table 6. Since *Course 1: Fundamentals of Light Lasers* presents only the basics of those topics and the OP-TEC LEOT courses cover the same basics, there is an obvious duplication of content. This duplication can be eliminated by combining the LEOT *Geometric Optics* and *Wave Optics* courses into a single course that would only present advanced content in those two topics. Eliminating the basic content from both specialty courses makes it possible to restructure and consolidate them into a single course.

Tables 7 and 8 show how this restructuring and consolidation might be accomplished. Table 7 presents the topics covered in the LEOT *Geometric Optics* and *Wave Optics* courses.

Table 7. Content of the LEOT *Geometric Optics* and *Wave Optics* Courses

Geometric Optics	Wave Optics
1. Reflection at Plane and Spherical Surfaces	1. Light Sources and Their Characteristics
2. Refraction at Plane Surfaces	2. Radiometry and Photometry
3. Refraction at Spherical Surfaces	3. Wave Nature and Light
4. Imaging with a Single Lens	4. Reflection and Refraction
5. Imaging with Multiple Lenses	5. Propagation
6. F-Stops and Apertures	6. Interference
7. Optical Systems	7. Diffraction
8. Matrix Optics	8. Polarization
9. Fundamentals of Fiber Optics	9. Holography

The first five topics in each LEOT course are very basic and effectively covered in *Course 1: Fundamentals of Light and Lasers*. Therefore, students in programs based on the general curriculum infusion framework would not need to repeat those topics, but merely to review them to ensure currency and mastery. Thus, the two courses could be combined by providing a review of fundamentals and then moving directly into advanced topics. Table 8 presents this combined course.

Table 8. Combined *Geometric and Wave Optics* Course

1. Review of Fundamentals
2. F-Stops and Apertures
3. Optical Systems
4. Matrix Optics
5. Fundamentals of Fiber Optics
6. Interference
7. Diffraction
8. Polarization
9. Holography

As shown in Table 8, photonics students would receive all their basic instruction in these topics via *Course 1: Fundamentals of Light and Lasers* and all advanced instruction via the new combined specialty course. Thus, the infusion of *Course 1: Fundamentals of Light and Lasers* eliminates one specialty course, thereby eliminating the need to increase the total number of courses required. Table 9 presents a revised sequence of specialty courses supporting an AAS photonics program based on the general curriculum infusion framework.

Table 9. Specialty Courses Required for Offering an AAS Photonics Program
(General curriculum infusion framework model used)

Introduction to Lasers
Geometric Optics and Wave Optics
Laser Technology
Laser/ Electro-Optic Devices
Laser/Electro-Optic Components
Laser/Electro-Optic Measurements

It should also be noted that if, as suggested earlier, *Course 1: Fundamentals of Light and Lasers* is substituted for a basic science course in the general education core, students pursuing an AAS in photonics would be able to take *two* fewer courses to meet graduation requirements. Thus, with the proper restructuring and substitutions, the general curriculum infusion framework can provide an accelerated path to graduation.

The two efficiencies presented also apply to other enabling technologies. The key is to develop two infusion courses—one for the technical core and one to be included among the technical specialty courses—that generate the same course reductions as *Course 1: Fundamentals of Light* *and Lasers* and *Course 2: Elements of Photonics.* If the technology being infused into this curriculum is truly an enabler for the other technologies being offered, then these two courses will provide an effective template for developing the required infusion courses.

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.

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