DOCUMENT RESUME

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ABSTRACT

This document defines "photonics" as the generation, manipulation, transport, detection, and use of light information and energy whose quantum unit is the photon. The range of applications of photonics extends from energy generation to detection to communication and information processing. Photonics is at the heart of today's communication systems, from lasers that generate digital information transported along a fiber-optic cable to the detector that decodes the information. This booklet contains the skills standard that is intended to define the knowledge and the skills that workers in the photonics industry need. The focus of the standard is on the skills necessary for employment as a photonics technician. The seven parts of this skills standards document include the following: (1) the evolution of the occupation of photonics technicians; (2) the development process for the skills standard; (3) curriculum concerns; (4) photonics skills standard task list; (5) photonics technician curriculum outlining the knowledge components, tools, equipment, and relevant tasks for 17 courses; (6) supporting knowledge components in applied mathematics, physics, and biology/chemistry; and (7) teacher standards. (KC)

National Photonics Skills Standard For Technicians

1995

Photonics is the generation, manipulation, transport, detection, and use of light information and energy whose quantum unit is the photon.

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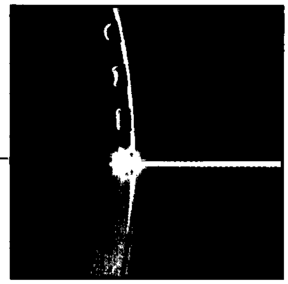
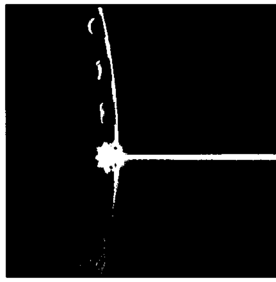


INTRODUCTION

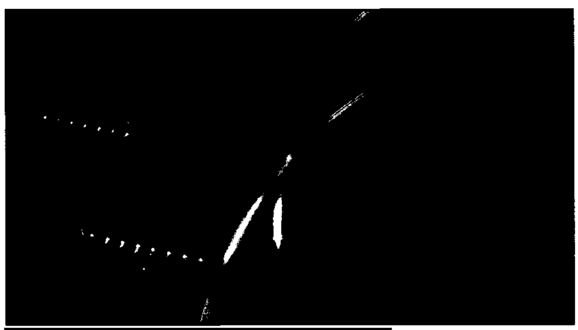


Photonics is defined as the generation, manipulation, transport, detection, and use of light information and energy whose quantum unit is the photon. The range of applications of photonics extends from energy generation to detection to communication and information processing.

Photonics is at the heart of today's communication systems, from the laser that generates the digital information transported along a fiber-optic cable to the detector that decodes the information. Whether the transmitted information is a phone call from across the street or across the globe, photonics brings it to you.

Where your health is concerned, photonics allows physicians to do minimally invasive surgery using fiber-optic endoscopes and lasers. Researchers using spectroscopy and microscopy are pushing the frontiers of biotechnology in activities as widespread as diagnosing disease and probing the mysteries of the genetic code.

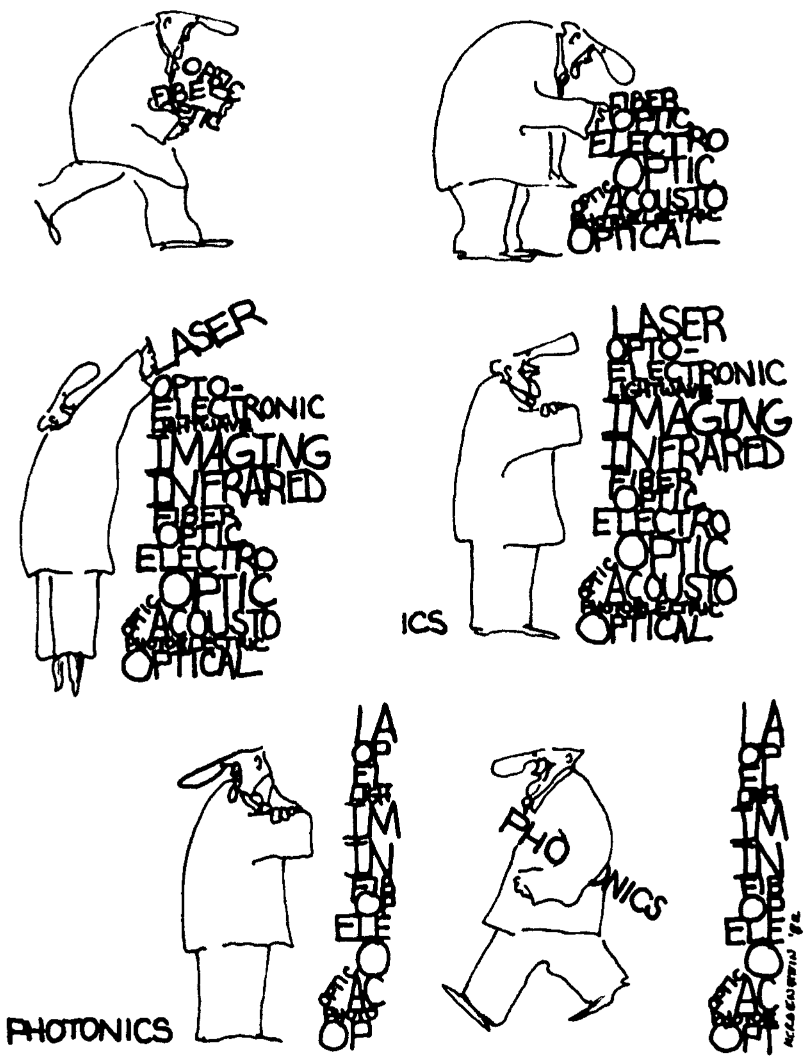
Advanced sensing and imaging techniques monitor the environment, gathering data on crops and forests, analyzing the ocean's currents and contents, and probing the atmosphere for pollutants. Transportation needs are being impacted by photonic sensors and laser rangefinders that will soon monitor and control the traffic on our nation's highways.



AT&T Lightwave transmitter and receiver.

In our factories, photonics provides machine vision systems that give a level of quality control human inspectors could never achieve. In manufacturing, lasers are replacing a variety of cutting, welding, and marking techniques, while imaging systems teamed with neural networks are producing intelligent robots. In short, photonics is paving our way into the new millennium.

This standard is intended to define the knowledge and capabilities — the skills — that workers in the photonics industry need. Photonics will be one of the primary battlefields of the world economic conflict, and it is imperative that U.S. photonics technicians be skilled enough to allow the United States to remain competitive in a global marketplace. The focus of this standard is on the skills necessary for employment as a photonics technician and is not intended to be an analysis of those skills that are important for workers in all occupational areas. A comprehensive treatment of the skills necessary for all workers has been the subject of a number of studies, most notably, the work of the SCANS (Secretary's Commission on the Achievement of Necessary Skills). It is our hope at CORD that the work presented in this document lends more detail and rationale for the accomplishment of the broader skills that should be obtained by all students.



Diane L. Morgenstein in *Photonics Spectra*

Photonics — the technology of generating and harnessing light and other forms of radiant energy whose quantum unit is the photon. The range of applications of photonics extends from energy generation to communications and information processing.

PHOTONICS SPECTRA

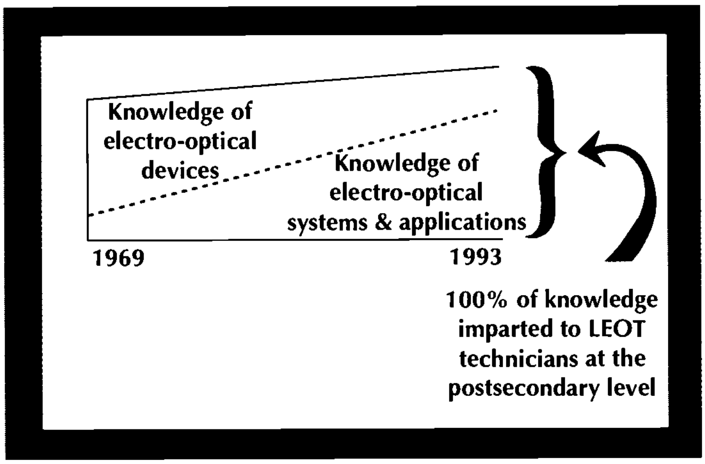
VOICE OF THE PHOTONICS TECHNOLOGY

Diane L. Morgenstein

ILLUSTRATION COURTESY OF **PHOTONICS SPECTRA**

If we trace a trend that started in the early 1970s, the evolution of the role of the photonics technician becomes clear. By 1972, Laser Electro-Optic Technicians (LEOTs) were appreciated if they possessed great troubleshooting skills. As more work was done to develop new processes and applications of lasers, technicians were valued for their ability to understand and use many different types of lasers, and optical and electronic equipment in the laboratory. Today, the applications of lasers and light continue to be developed at a high rate, and the applications and implementation of these developments have become a large part of what technicians should know, specifically how integrated systems operate. The empirical results of this trend are seen in the changes to LEOT curricula over the last 20 years, as shown in Figure 2.

Figure 2.



A changing workforce's need for a knowledge of optical and electrical components has evolved into a need for knowledge of whole systems and applications. This means that technicians must better understand the field or industry in which photonics is being used. This is a big change; while technicians have historically been good at assembly/disassembly, troubleshooting, and repair, they have had difficulty adapting, modifying, and interfacing lasers or optics in systems where knowledge of the application is critical.

How will the hardware of these emerging applications be constructed, tested, maintained, and repaired? How will photonics make it from the laboratory to the manufacturing floor to the home or office in a consistent and reliable manner? It will require a team effort. Engineers, physicists, and first-line managers cannot support the technology alone; they will need the assistance of certified technicians with a knowledge of photonics and a complement of broad technical skills related to the market.

The Center for Occupational Research and Development (CORD), a nonprofit, educational, public service organization, with the support of the U.S. Department of Education, has been given the task of organizing an effort to identify these skills.

ABOUT SKILL STANDARDS

At the issuance of this report, the United States remains the only major industrialized nation without standards to define the skills required for industrial occupations. With few exceptions, our schools have been preparing people for vocations with only vague job descriptions to guide them. Schools can only guess at the demands of a particular occupation. For the most part, schools have made this guess with the help of small numbers of local industrial representatives. This has limited the effectiveness of programs designed to meet the needs of industry. It is little wonder that schools are criticized for producing students who cannot function productively in an entry-level position without long periods of on-the-job training. Additionally, as industry's need for qualified, knowledgeable technicians has increased during the past decade, the opportunities for schools to develop such programs have also increased.

The current federal adminstration's educational initiative is designed to address this and other educational problems. A multifaceted Legislative Act called "Goals 2000: Educate America" has as one of its top prio development of voluntary skill standards in several pilot occupatio This document represents the initial version of one of these volu dards, and it is the hope of the administration as well as the proj this standard will continue to be developed and refined by volu pants long after the project ceases to exist.

DEVELOPMENT PROCESS FOR THE STANDARD

This standard, an evolving work,[1] began by defining the f and then progressed to creating occupational specialties f nicians. As these were determined, a survey was distribu resentatives asking them to identify the tools or equipmer nicians used and to associate a verb with each tool or piece These statements were then called tasks, because they say what a pho technician does. (Tasks were developed using tools or equipment because, in the photonics industry, technicians do not normally perform a work task unless they have one or more tools or pieces of equipment.)

Industry representatives from each of the following specialty or cluster areas were called together and met in separate groups to validate the task statements with respect to their own group's needs.

The specialty areas are:

- Defense/Public Safety/Aerospace
- Communications
- Medicine
- Environmental/Energy/Transportation
- Manufacturing with Photonics/Test and Analysis
- Computers (Entertainment, Consumer Devices, Hard Copy)

A description of each of the six specialty areas follows, and explains some of the applications of photonics in that area, pointing out the uniqueness of each group and its need for technicians.

MEDICINE

Perhaps more than in any other industry, the field of medicine has seen major strides in the commercialization of photonics technology. Laser surgery continues to be effective and has opened the door for photodynamic therapy and fluorescence technology. The desire for minimally invasive techniques makes fiber optics and other photonics components critical development factors for the integration of the technology in medicine.

A Coherent CO_2 laser

1. If you would like to have input into this standard, please contact CORD at (800) 972-2766, or on Internet at http://www.spie.org/photonics_ed.html

The need for biomedical photonics technicians is a reality, as the scope of knowledge required for this area continues to broaden. The repair and maintenance of machines used in applications like flow cytometry, DNA sequencing, confocal microscopy, and interferometry will eventually become the responsibility of technicians.

ENVIRONMENTAL/ENERGY/TRANSPORTATION

Spectrophotometry and laser spectroscopy have already found their way into the burgeoning environmental field. Closer monitoring of pollutants and use of natural energy sources are now a way of life for most power plants and electrical utilities, as well as many oil and gas refineries. Technicians who are comfortable with fieldwork and capable of understanding the effects of harsh environments on optical systems integrated with fluid, electrical, or mechanical stability systems will be important. This seems clear in applications such as solar detoxification of groundwater, laser altimeters for subglacial exploration, and ocean-surface spectroscopy, and in providing rural electrification with photovoltaics, which is enjoying renewed interest.

Photonics has an increasingly important role in transportation systems. Presently, photonics-based systems are used for land, air, and sea navigation. The developers and engineers of Intelligent Vehicle Highway Systems will also need photonics technicians who understand vehicle operation, heavy highway construction, or operations research principles for solving traffic-pattern problems.

DEFENSE/PUBLIC SAFETY/AEROSPACE

Photonics is critical to defense and aerospace, since, unlike devices using conventional electronics, photonic devices are resistant to electromagnetic interference. In addition, defense technology has many applications in the public safety industry. Problems such as drugs, terrorism, border security, urban crime, and natural disasters can in many cases be successfully battled or responded to with photonics-based technology. This requires that the photonics technician understand the operations of FLIRs, lidar, remote sensing, image processing, and so on, to be able to use these devices to enhance logistics, and command and control issues in a safe and reliable manner.

COMPUTERS (ENTERTAINMENT, CONSUMER DEVICES, HARD COPY)

The integration of photonics with computer and processing architecture is likely to provide the largest number of opportunities for commercial development. It involves applications like high-speed OCR, machine vision systems, virtual reality systems, laser light controllers for displays and shows, CD players, laser printers, molecular optical switches with photochromic materials, optical neural nets, and so on. High-resolution sensors like CCD devices will be widely used in the digitization of artwork, multimedia video, teleconferencing, telepresence, real-time gesture recognition, and digital cinema.

Matrix displays, including AMLCDs, EL devices, LEDs, plasma panels, and field emission displays will gradually supplant CRTs as the display of choice for direct-view applications. Advances in deformable mirror technology, solid-state lasers, and spatial light modulators will lead to electronic projection systems that rival conventional 35-mm film in both brightness and resolution. Technicians with an understanding of imaging and image processing will become highly valued in the workforce that supports these efforts.

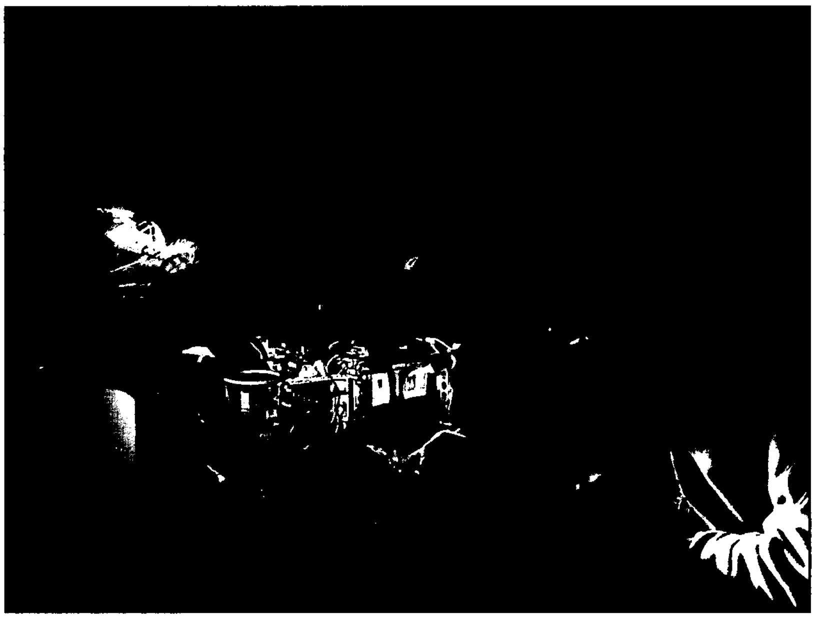
MANUFACTURING WITH PHOTONICS/TEST AND ANALYSIS

This area concerns those manufacturers who use photonics as part of the manufacturing process, for either fabrication, test, or analysis of their product. The group continues to grow, supported primarily by industrial lasers for cutting, welding, trimming, hole drilling, and heat treating. More and more frequently, the scientific instruments of the laboratory are finding their way onto the floor to perform spectroscopy, or holographic or interferometric testing, or as examination tools in photon microscopy.

COMMUNICATIONS

The "Information Superhighway" — which is actually a photonics superhighway — will create many new jobs for technicians and engineers with skills that relate to fiber optics, lasers, multigigabit processors, networking, and computer engineering. Telephone companies are not the only ones that will require this skilled workforce; TV/cable companies and electric power companies will also be involved in the information-highway revolution. At present, this industry offers the most economic promise for photonics technology, and as a result, it will require that the exit points for students be clearly defined. That way, students will understand the impact of their education upon employment as well as the various possibilities the industry offers.

Engineer aligns a demonstration prototype projector that uses advanced polarization-control technology for a brighter image.



STANDARDS TRANSLATED TO SUGGEST CURRICULUM DESIGN

The task listings generated by each specialty group were cross-referenced to find the tasks common to all specialty groups. This collection of validated task statements represents the common tasks all photonics technicians should be able to perform. (See list on pages 12-14.)

Finally, educators, primarily from two-year postsecondary institutions but also from secondary schools and four-year universities, participated in translating the task statements into knowledge components. These, then, represent the information a photonics technician must know and understand to be able to perform the tasks. The knowledge components and their related tasks are listed on pages 27-31. It is expected that these knowledge components will be taught at the postsecondary level.

Additional knowledge components that support these are also provided. These supporting knowledge components represent only a portion of those that should be taught throughout the secondary experience; they include the necessary elements typically taught in physics, mathematics, biology, and chemistry classes. See Figure 3.

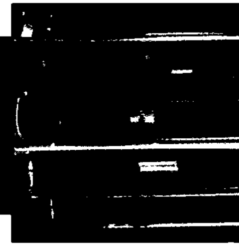


Figure 3.

A Suggested Program of Study for Associate's Degree

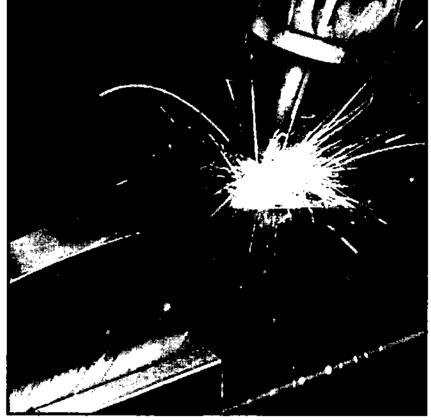
	9th Grade	10th Grade	11th Grade	12th Grade	Freshman Year		Sophomore Year	
Photonics			Electronics★ Machining Materials Processing★	Digital Circuits & Micropro-cessors★ Computer Applications Software★	Introduction to Photonics+ Support & Positioning Equipment+ Photonics Safety & Worksite Practices+ Computer Interfaces+	Vacuum Technology+ Electronics for Photonics Applications+ Optical Principles+ Fiber Optics+	Laser Sources+ Optical Principles+ Detection & Measurement+ Optical Communi-cation Systems+ Photonic Controllers+	Imaging & Display+ Spectroscopic Systems+ Material Processing Systems+ Holography & HNDT Systems+ Specialty Topics
Science	Applied Biology or Chemistry ▲+	Applied Physics I ▲+	Applied Physics II ★+					
Math	Applied Math I ▲+	Applied Math II ▲+	Applied Math III ▲	Algebra II ★	Statistics	Pre-calculus		
English and Social Science	English I, II, and III Geography, History, and Government Applied Communications ▲				Interpersonal Communi-cations	Composition	Economics for Technology	Technical Writing

•With selection of appropriate math and science courses, the associate degree graduate may articulate to a 4-year college program.

LEGEND

★ Electromechanical core that would feed several technician career pathways
▲ Basic core for all students
+ Knowledge components identified in this standard

The Lasercav laser, is shown here cutting pockets with varying geometry in a 3-D surface. The Lasercav is said to be the first machine tool for producing cavities with a laser.



CURRICULUM CONCERNS

In defining curricula for photonics technicians, it is important to note that students should decide prior to the 11th grade that they are interested in an electromechanical career pathway. In this, they will receive additional applied physics and mathematics, along with vocationally oriented courses in the 11th and 12th grades. These include electronic digital circuits and microprocessors, machining/materials processing, and computer application software. (See Figure 3.)

The students should also have experienced a basic core of applied academic, contextual courses — in mathematics, science, communications, computer literacy, socioeconomics, government/history, languages, arts, and the humanities — in grades 9 through 12. As they move into the freshman and sophomore years at community colleges and technical schools, students with the Tech Prep foundation outlined here will be prepared to understand the knowledge components necessary for the industry-specific tasks in the courses shown in Figures 3.

Photonics Technician Employment Opinion Survey

In a venture separate from the development of the National Skills Standard for photonics technicians, the Center for Occupational Research and Development conducted an opinion survey of the employment picture in the photonics industry in 1994. Voluntary respondents' survey results revealed:

At the present time, approximately 345,000[2] photonics technicians are employed in the United States.

By the year 2000, approximately 743,000[3] photonics technicians will be needed in the United States.

Respondents to the survey also indicated:

The most frequently desired education category necessary for employment as a technician was two years of postsecondary technical education (such as an associate's degree) or the equivalent.[4]

Half of the responding companies reported that a small percentage[5] of their technicians had attended a four-year school.

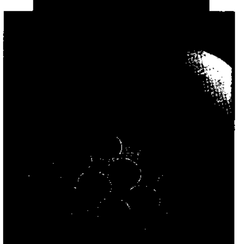
The most frequent starting salaries ranged from $20,000 to $25,000.

Given the tremendous growth in this field and the decreasing numbers of workers trained by the military and filtering into the commercial workforce, community colleges and technical schools will have to work very hard to meet the demand for training and education. These schools cannot meet the demand alone; they will need to work in coordination with secondary schools and four-year institutions to establish sound articulation agreements. It is expected that if they follow this standard in designing curricula and setting up programs, they will provide solid pathways for lifelong learning and good employment possibilities for thousands of our nation's youth.

2. A survey population of 23,640 was used. The survey population was established by selecting supervisors and managers from the mailing list of Photonics Spectra, a leading industry publication. The response rate was 7.2%, considered reasonable for a mail survey that did not offer a reward. Results showed that companies employed a wide range in number of photoics technicians — one reported 500 on staff; however, the mean number was just under 19 (18.85) for companies employing photonics technicians. Of the survey respondents, 77.5% reported that their company employed at least one photonics technician. Therefore the estimated total number employed is 77.5% of the 23,640 companies × 18.85, or approximately 345,000.
3. Using all of the responses (including those from companies not presently employing photonics technicians), the projected mean number of photonics technicians needed by the year 2000 was 31.426. Thus the survey projected number is approximately 743,000 (742,910.64 = 23,640 × 31.426).
4. 61 percent
5. 5 percent

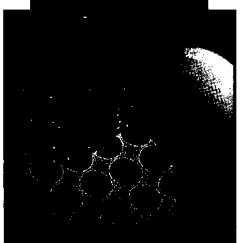
1	ACCESSORIES: E-O MODULATORS AND Q-SWITCHES	Clean, maintain, align, mount, install, operate and demonstrate E-O modulators and Q-switches.
2	ACCESSORIES: A-O MODULATORS AND Q-SWITCHES	Clean, maintain, align, mount and install A-O modulators and Q-switches.
3	ACCESSORIES: MECHANICAL DEFLECTORS AND SCANNERS	Clean, maintain, align, mount and install mechanical deflectors and scanners.
4	ANALYSIS, TEST AND MEASUREMENT: POWER AND ENERGY METERS	Clean, maintain, align, mount, install, operate, demonstrate, classify and identify power and energy meters.
5	ANALYSIS, TEST AND MEASUREMENT: MONOCHROMATORS	Align, mount, install, operate, demonstrate, classify and identify monochromators.
6	ANALYSIS, TEST AND MEASUREMENT: MICROSCOPES	Operate and demonstrate microscopes.
7	ANALYSIS, TEST AND MEASUREMENT: SPECTRUM ANALYZERS	Operate, demonstrate, classify and identify spectrum analyzers.
8	DETECTORS: SEMICONDUCTORS	Calibrate, test, clean, maintain, align, mount, install, operate and demonstrate semiconductor detectors.
9	DETECTORS: DETECTOR ARRAYS	Calibrate, test, align, mount, install, operate and demonstrate detector arrays.
10	DETECTORS: DETECTOR AMPLIFIERS	Calibrate, test, clean, maintain, align, mount, install, operate and demonstrate detector amplifiers.
11	DETECTORS: CCD/CIDs	Calibrate, test, align, mount, install, operate and demonstrate CCD/CIDs.
12	ELECTRONICS: POWER SUPPLIES	Operate, demonstrate, select, specify, purchase, classify and identify power supplies.
13	ELECTRONICS: PMT POWER SUPPLIES	Operate and demonstrate PMT power supplies.
14	ELECTRONICS: LASER POWER SUPPLIES	Clean, maintain, align, mount, install, operate, demonstrate, select, specify, purchase, classify and identify laser power supplies.
15	ELECTRONICS: DIGITAL CIRCUITS	Operate and demonstrate digital circuits.
16	ELECTRONICS: CAPACITORS	Operate, demonstrate, classify and identify capacitors.
17	ELECTRONICS: AMPLIFIERS	Operate and demonstrate amplifiers.
18	ELECTRONICS: OSCILLOSCOPES	Operate and demonstrate oscilloscopes.
19	ELECTRONICS: PULSE GENERATORS	Operate and demonstrate pulse generators.
20	FIBER OPTICS: NON-LASER LIGHT SOURCES	Align, mount, install, operate, demonstrate, classify and identify non-laser light sources.
21	FIBER OPTICS: FIBERS	Align, mount, install, operate, demonstrate, classify and identify fibers.
22	FIBER OPTICS: DETECTORS	Analyze, assess, evaluate, examine, operate and demonstrate detectors.
23	FIBER OPTICS: COUPLERS	Classify and identify couplers.
24	FIBER OPTICS: CONNECTORS	Analyze, assess, evaluate, examine, calibrate, test, align, mount, install, operate and demonstrate connectors.

Researcher with an optical communications test.



25	FIBER OPTICS: CABLES	Align, mount, install, operate, demonstrate, classify and identify cables.
26	FIBER OPTICS: FIBER OPTIC TRANSMITTERS	Operate and demonstrate transmitters.
27	FIBER OPTICS: TIME DOMAIN REFLECTOMETERS	Operate and demonstrate time domain reflectometers.
28	IMAGE AND DISPLAY: IR VIEWERS	Operate, demonstrate, select, specify, purchase IR viewers.
29	IMAGE AND DISPLAY: IMAGE PROCESSING EQUIPMENT	Operate and demonstrate image processing equipment.
30	IMAGE AND DISPLAY: CRTs	Operate and demonstrate CRTs.
31	LASERS: Nd:YAG	Operate, maintain, align, repair and demonstrate Nd:YAG lasers.
32	LASERS: DIODE	Analyze, assess, evaluate, examine, clean, maintain, align, mount, install, operate, demonstrate, select, specify and purchase diode lasers.
33	LASER SYSTEMS: COMMUNICATION SYSTEMS	Clean, maintain, align, mount, install, operate, demonstrate, classify and identify communication systems (laser).
34	LASER SYSTEMS: SPECTROSCOPIC SYSTEMS	Clean, maintain, align, mount, install, operate and demonstrate spectroscopic systems (laser).
35	OPTICAL AND COMPUTER DATA PROCESSING EQUIPMENT: ENGINEERING AND DESIGN SOFTWARE	Operate, demonstrate, select, specify and purchase engineering and design software.
36	OPTICAL AND COMPUTER DATA PROCESSING EQUIPMENT: PAGE LAYOUT AND GRAPHICS SOFTWARE	Operate and demonstrate page layout and graphics software.
37	OPTICAL AND COMPUTER DATA PROCESSING EQUIPMENT: SPREADSHEET SOFTWARE	Operate and demonstrate spreadsheet software.
38	OPTICAL AND COMPUTER DATA PROCESSING EQUIPMENT: WORD PROCESSING SOFTWARE	Operate and demonstrate word processing software.
39	OPTICAL AND COMPUTER DATA PROCESSING EQUIPMENT: IMAGE ANALYSIS SOFTWARE	Operate and demonstrate image analysis software.

40	OPTICAL COMPONENTS: MIRRORS AND REFLECTORS	Clean, maintain, align, mount, install, operate, demonstrate, select, specify and purchase mirrors and reflectors.
41	OPTICAL COMPONENTS: LENSES	Analyze, assess, evaluate, examine, clean, maintain, align, mount, install, operate, demonstrate, classify and identify lenses.
42	OPTICAL COMPONENTS: IR OPTICS	Clean, maintain, align, mount, install, operate, demonstrate, classify and identify infrared optics.
43	OPTICAL COMPONENTS: GRATINGS	Align, mount, install, select, specify and purchase gratings.
44	OPTICAL COMPONENTS: FILTERS	Analyze, assess, evaluate, examine, calibrate, test, clean, maintain, align, mount, install, operate, demonstrate, select, specify, purchase, classify and identify filters.
45	OPTICAL COMPONENTS: COLLIMATORS	Align, mount, install, operate, demonstrate, select, specify, purchase, classify and identify collimators.
46	OPTICAL COMPONENTS: COATINGS	Clean, maintain, select, specify and purchase coatings.
47	OPTICAL COMPONENTS: POLARIZING OPTICS	Analyze, assess, evaluate, examine, clean, maintain, align, mount, install, operate, demonstrate, select, specify, purchase, classify and identify polarizing optics.
48	OTHER EQUIPMENT: SAFETY EQUIPMENT	Operate and demonstrate safety equipment.
49	OTHER EQUIPMENT: CLEANROOM EQUIPMENT	Operate and demonstrate cleanroom equipment.
50	OTHER EQUIPMENT: SUPPORT AND POSITIONING EQUIPMENT	Alter, combine, integrate, align, mount, install, operate, demonstrate, select, specify and purchase positioning equipment.
51	SUPPORT AND POSITIONING EQUIPMENT: MICROPOSITIONERS	Align, mount, install, operate, demonstrate, select, specify and purchase micropositioners.
52	SUPPORT AND POSITIONING EQUIPMENT: BENCHES, RAILS AND TABLES	Align, mount, install, operate, demonstrate, select, specify and purchase benches, rails and tables.
53	LASERS: GAS LASERS	Operate, demonstrate, maintain, align and repair gas lasers.
54	LASERS: CO_2 LASERS	Operate, demonstrate, maintain, align and repair CO_2 lasers.
55	LASERS: DYE LASERS	Operate, demonstrate, maintain, align and repair dye lasers.
56	LASERS: EXCIMER LASERS	Operate, demonstrate, maintain, align and repair excimer lasers.
57	OTHER EQUIPMENT: VACUUM EQUIPMENT	Operate, demonstrate, maintain, clean and repair vacuum equipment.
58	LASER SYSTEMS: MATERIAL PROCESSING SYSTEMS	Operate, demonstrate, clean, maintain, align, install and repair material processing systems.
59	LASER SYSTEMS: HOLOGRAPHY AND HNDT SYSTEMS	Operate, demonstrate, clean, align, install and assemble holography and HNDT systems.
60	IMAGE AND DISPLAY: FLAT-PANEL DISPLAYS	Identify, operate, demonstrate, maintain, mount and test flat-panel displays.



COURSES

- Introduction to Photonics
- Optical Principles
- Support and Positioning Equipment
- Optical Components
- Electronics for Photonics Applications
- Photonic Controllers: Modulators, Deflectors and Q-switches
- Computer Interfaces
- Detection and Measurement
- Photonics Safety and Worksite Practices
- Laser Sources
- Fiber Optics
- Vacuum Technology
- Imaging and Display

SPECIALTY COURSES

- Optical Communications Systems
- Spectroscopic Systems
- Material Processing Systems*
- Holography and HNDT Systems*

*Not in Industry Group's core list

INTRODUCTION TO PHOTONICS

Knowledge Component	Tool or Piece of Equipment	Task#
Atoms, molecules, bonding		
Electronics supporting photonics		
Energy levels		
Principles of laser operation		
Survey of different light sources		
The electromagnetic spectrum		
The periodic table		
Stimulated emission	Gas, CO_2, Nd:YAG, dye and excimer lasers	53-56, 31
Laser threshold conditions	Gas, CO_2 Nd:YAG, dye and excimer lasers	53-56, 31
Feedback in lasers	Nd:YAG lasers	31
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Semiconductor band structure	Diode lasers, semiconductor detectors	32, 8
P-N junctions	Diode lasers, semiconductor detectors	32, 8
Semiconductor types	Diode lasers, semiconductor detectors	32, 8
Blackbody radiation	IR viewers	28
Wien's displacement law	IR viewers	28
Atmospheric transmission in IR	IR viewers	28
LEDs	Flat-panel displays, non-laser light sources	60, 20
Liquid crystal displays	Flat-panel displays	60
Principles of Q-switching	A-O modulators and Q-switches, E-O modulators and Q-switches	2, 1
Semiconductor operations (LED)	Non-laser light sources	20
Biasing of junctions (LED)	Non-laser light sources	20
Wavelength and spectral width (LED)	Non-laser light sources	20
Handling of LEDs	Non-laser light sources	20
Low-voltage measurements (LED)	Non-laser light sources	20
Incandescent light sources	Non-laser light sources	20
Arc and gas discharge sources	Non-laser light sources	20
Fluorescent light sources	Non-laser light sources	20

OPTICAL PRINCIPLES

Knowledge Component	Tool or Piece of Equipment	Task#
Geometrical optics	A-O modulators and Q-switches, E-O modulators and Q-switches, lenses, gratings, mirrors and reflectors, mechanical deflectors and scanners, image processing equipment, microscopes, engineering and design software	1, 2, 41, 43, 40, 3, 29, 6, 35
Physical optics	A-O modulators and Q-switches, E-O modulators and Q-switches, mirrors and reflectors, mechanical deflectors and scanners, holography and HNDT systems	1, 2, 40, 3, 59
Critical angle	Fibers	21
Snell's law	Lenses	41

Knowledge Component	Tool or Piece of Equipment	Task #
Total internal reflection	Polarizing optics	47
Laws of reflection	Filters, mirrors and reflectors, lenses, polarizing optics	44, 40, 41, 47
Reflection	Polarizing optics	47
Refraction	Polarizing optics, lenses	47, 41
Scattering	Filters	44
Interference	Coatings, holography and HNDT systems	46, 59
Diffraction	Gratings, monochromators, diode lasers	43, 5, 32
Diffraction-limited beam divergence	Diode lasers, Nd:YAG lasers	32, 31
The diffraction limit	Lenses, Nd:YAG lasers, material processing systems	41, 31, 58
Focusing of laser beams	Material processing systems, Nd:YAG lasers	58, 31
Birefringence	E-O modulators and Q-switches, polarizing optics	1, 47

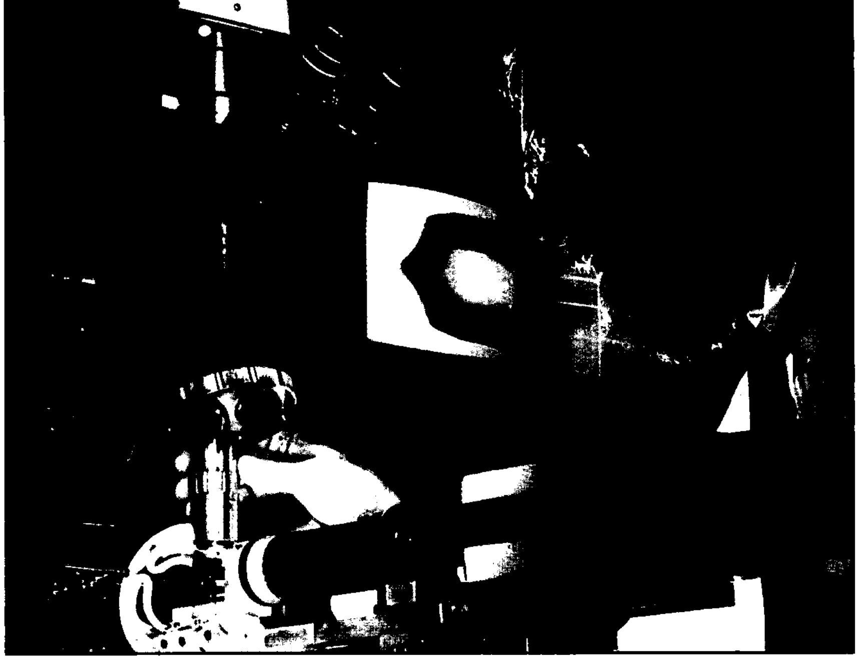
SUPPORT AND POSITIONING EQUIPMENT

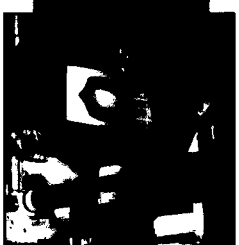
Knowledge Component	Tool or Piece of Equipment	Task #
Materials specifications for positioning equipment	Positioning equipment	50
Mechanisms by which movement is transferred through positioning equipment	Positioning equipment	50
Vibration stability	Positioning equipment	50
Selection criteria for positioning equipment	Positioning equipment	50
Ability to read scales	Positioning equipment	50
Alignment techniques for establishing a beam line	Benches, rails and tables	52
Choice of tables vs. benches vs. rails	Benches, rails and tables	52
Mounting techniques for rails	Benches, rails and tables	52
Mounting of components	Benches, rails and tables	52
Selection of benches, rails, tables	Benches, rails and tables	52
Measurement units: distance and speed	Micropositioners	51
Force	Micropositioners	51
Read a micrometer	Micropositioners	51
Mechanical stability	Micropositioners	51
Magnetic bases	Micropositioners	51
Strain and stress as related to optical properties	Mircopositioners	51
Positioning terminology	Micropositioners	51
Vibration isolation	Micropositioners	51
Electrical isolation	Micropositioners	51
Selection criteria for micropositioners	Micropositioners	51

OPTIONAL COMPONENTS

Knowledge Component	Tool or Piece of Equipment	Task #
Coating and substrate cleaning and materials	A-O modulators and Q-switches	2
Scratch and dig specifications	A-O modulators and Q-switches	2
IR transmitting materials	IR Viewers	28
Coating and substrate cleaning and materials	E-O modulators and Q-switches	1
Polarizers	Polarizing optics	47
Polarization characteristics of transmitters	Polarizing optics	47
Waveplates	Polarizing optics	47
Polarization-maintaining fibers	Polarizing optics	47
Types of polarizing prisms	Polarizing optics	47
Selection criteria for polarizers	Polarizing optics	47
Handling of IR optics	Infrared optics	42
Phosphors	Infrared optics	42
Storage: digital and analog	Infrared optics	42
IR transmitting materials	Infrared optics	42
Coating and substrate cleaning and materials	Infrared optics	42

Inspection using microscopes and an imaging system.





Knowledge Component	Tool or Piece of Equipment	Task #
Infrared optical components and applications	Infrared optics	42
Visible vs. infrared optical materials	Infrared optics	42
Use and application of IR	Infrared optics	42
Components: lenses, filters, gratings, prisms, windows, mirrors and viewers	Infrared optics	42
Identify the different types of lenses	Lenses	41
Ray trace: single and multiple lens systems	Lenses	41
Focal length	Lenses	41
Proper installation for given uses	Lenses	41
Installation to prevent distortion of lens	Lenses	41
Installation procedures in spectrometers	Gratings	43
Availability and characteristics	Gratings	43
Bragg's law	Gratings	43
Blazing of gratings	Gratings	43
Selection criteria for gratings	Gratings	43
Coating and substrate cleaning and materials	Coatings	46
Coating types	Coatings	46
Chemical and elements used in coatings	Coatings	46
Durability of coatings	Coatings	46
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Spectral characteristics of relevant coatings	Coatings	46
Elementary thin films	Coatings	46
Scratch and dig specifications	Coatings	46
Laser damage	Coatings	46
Multilayer dielectric coatings	Coatings	46
Antireflection coatings	Coatings	46
Selection criteria for coatings	Coatings	46
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Optical fibers		
Visible transmitting materials		
Ultraviolet transmitting materials		
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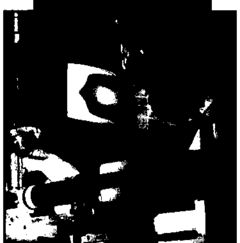
Lens alignment: retro reflection	Collimators	45
Wavelength absorption	Collimators	45
Wavelength reflection	Collimators	45
1 to 1 collimator	Collimators	45
Expand or collimator	Collimators	45
Down collimator	Collimators	45



Knowledge Component	Tool or Piece of Equipment	Task #
Cost constraints	Collimators	45
Selection criteria for collimators	Collimators	45
Coating and substrate cleaning and materials	Collimators	45
Polarization characteristics of transmitters	Filters	44
Absorption/emission characteristics	Filters	44
Transmission spectra	Filters	44
Materials: optical characteristics	Filters	44
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Cleaning techniques	Filters	44
Bandwidth of filters	Filters	44
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Types of reflection	Mirrors and Reflectors	40
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Cleaning mirrors	Mirrors and Reflectors	40
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How to identify and choose suppliers	Mirrors and Reflectors	40
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Metal mirrors	Mirrors and Reflectors	40
Selection criteria for mirrors	Mirrors and Reflectors	40
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ELECTRONICS FOR PHOTONIC APPLICATIONS

Knowledge Component	Tool or Piece of Equipment	Task #
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Characteristics of ideal amplifier	Amplifiers	17
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Adders	Amplifiers	17
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Multiplying circuits	Power supplies	12
Rectifiers: filtering	Power supplies	12
Fusing and grounding	Power supplies	12
Integrated circuit	Power supplies	12
Regulators	Power supplies	12
Switching supply principles	Power supplies	12
Testing: line regulation	Power supplies	12
Testing: load regulation	Power supplies	12
Testing: ripple and noise	Power supplies	12
Testing: isolation	Power supplies	12
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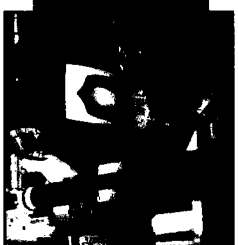

Knowledge Component	Tool or Piece of Equipment	Task #
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Electronic measurement techniques	Laser power supplies	14
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Operating procedures for pulse generators	Pulse generators	19
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Rise and fall times	Pulse generators	19
Waveform interpretation	Pulse generators	19
Coupling of pulse generators	Pulse generators	19
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Polarity, energy storage, voltage ratings, capacitance	Capacitors	16
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Pulse and waveform terminology	Digital circuits	15
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Multiplexing and demultiplexing	Digital circuits	15
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D-A and A-D converters	Digital circuits	15
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Inputs and outputs	Digital circuits	15

PHOTONIC CONTROLLERS: MODULATORS, DEFLECTORS AND Q-SWITCHES

Knowledge Component	Tool or Piece of Equipment	Task #
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A-O devices	A-O modulators and deflectors	2, 3
Acousto-optic effect	A-O modulators and deflectors	2, 3
Materials for A-O devices	A-O modulators and deflectors	2, 3
Operating procedures for A-O devices	A-O modulators and deflectors	2, 3
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Beam deflection with A-O devices	A-O modulators and deflectors	2, 3
Q-switching with A-O devices	A-O modulators and deflectors	2, 3
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Knowledge Component	Tool or Piece of Equipment	Task #
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Cleaning procedures	Mechanical deflectors and scanners	3
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Crystal types: KDP	Modulators and Q-switches	2, 1
Crystal types: $KNbO_3$	Modulators and Q-switches	2, 1
Crystal orientation electro-optic effect: classifying crystals with r-coefficients	Modulators and Q-switches	2, 1
Electro-optic effect: classifying with crystal orientation	Modulators and Q-switches	2, 1
Modulation schemes: phase modulation	Modulators and Q-switches	2, 1
Modulation schemes: polarization rotation <-> intensity modulation	Modulators and Q-switches	2, 1
Power supply systems: high voltage	Modulators and Q-switches	2, 1
Power supply systems: high power, high speed, high modulation rate	Modulators and Q-switches	2, 1
Q-switching with E-O devices	Modulators and Q-switches	2, 1
Beam deflection with E-O devices	Modulators and Q-switches	2, 1
Operating procedure for E-O devices	Modulators and Q-switches	2, 1
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Knowledge Component	Tool or Piece of Equipment	Task#
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Install and set up software	Page layout and graphics software	36
Computer software literacy	Page layout and graphics software	36
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Computer software literacy	Spreadsheet software	37
Specific application programs for spreadsheets	Spreadsheet software	37
Installation of software	Spreadsheet software	37
Computer software literacy	Engineering and design software	35
Ray tracing	Engineering and design software	35
Matrix optics	Engineering and design software	35
1st and 3rd order aberrations: qualitative and quantitative	Engineering and design software	35
PC types: operating systems	Engineering and design software	35
Testing methods	Engineering and design software	35
Installation of software	Engineering and design software	35
Specific application programs for engineering and design software	Engineering and design software	35

DETECTION AND MEASUREMENT

Knowledge Component	Tool or Piece of Equipment	Task#
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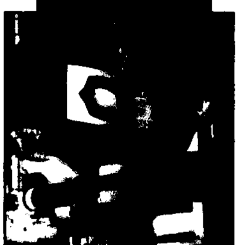
Available magnification	Microscopes	6
Available objectives	Microscopes	6
Numerical aperture/illumination required	Microscopes	6
Light sources	Microscopes	6
Types of microscopes: normal	Microscopes	6
Types of microscopes: phase contrast	Microscopes	6
Using cameras	Microscopes	6



Knowledge Component	Tool or Piece of Equipment	Task #
Electronic components	Detector amplifiers	10
Using signal generators	Detector amplifiers	10
Using VOMs	Detector amplifiers	10
Using oscilloscopes	Detector amplifiers	10
*Soldering	Detector amplifiers	10
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Detector types	Detector amplifiers	10
Amplifier types	Detector amplifiers	10
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Operating procedures	Semiconductor detectors	8
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Spectral characteristics	Semiconductor detectors	8
Photoconductive detectors	Semiconductor detectors	8
PIN detectors	Semiconductor detectors	8
Detector frequency response	Semiconductor detectors	8
Detector IV characteristics	Semiconductor detectors	8
APD detectors	Semiconductor detectors	8
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Single silicon photodetector: light detection characteristics saturation	CCD/CIDs	11
Single silicon photodetector: biasing, equivalent circuits	CCD/CIDs	11
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Addressing schemes	CCD/CIDs	11
Signal buffering to the outside world	CCD/CIDs	11
Video signal systems	CCD/CIDs	11
Practical sources of CCDs	CCD/CIDs	11
Practical sources of evaluation electronics	CCD/CIDs	11
Calibration procedures	CCD/CIDs	11
CCD: single cell: cooling	CCD/CIDs	11
CID operation	CCD/CIDs	11
CCD operation	CCD/CIDs	11
Types of monochromators	Monochromators	5
Selection of monochromators	Monochromators	5
Operation of monochromators	Monochromators	5
Installation of gratings	Monochromators	5
Understand manufacturers' manuals	Power and energy meters	4
Read calibration curves	Power and energy meters	4
Min/max power range	Power and energy meters	4
Accessing equipment	Power and energy meters	4
Types of power and energy meters	Power and energy meters	4
Operation of power and energy meters	Power and energy meters	4
Types of spectrum analyzers	Spectrum analyzers	7
Characteristics of spectrum analyzers	Spectrum analyzers	7

Knowledge Component	Tool or Piece of Equipment	Task #
Operating procedures for spectrum analyzers	Spectrum analyzers	7

PHOTONICS SAFETY AND WORKSITE PRACTICES

Knowledge Component	Tool or Piece of Equipment	Task #
Laser safety practices	Gas lasers, CO_2 lasers, dye lasers, Nd:YAG lasers, excimer lasers, diode lasers, safety equipment, material processing systems	53-56, 58-31, 32, 48
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Laser safety standards	Safety equipment	48
Safety with laser gases	Excimer lasers, safety equipment	56, 48
Laser protective eyewear	Safety equipment	48
Maximum permissible exposure; eyes and skin	Safety equipment	48
Classification scheme for lasers	Safety equipment	48
Electrical safety	Nd:YAG lasers, capacitors, CRTs, PMT power supplies, safety equipment, E-O modulators and Q-switches	31, 16, 30, 13, 48, 1
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Safety with cryogenic materials	Semiconductor detectors	8
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Classification of cleanroom equipment	Cleanroom equipment	49
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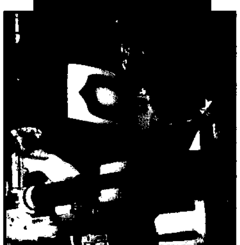
Cleanroom apparatus	Cleanroom equipment	49
*How the eye works		6
Chemical safety		

*Covered adequately in Biology/Chemistry, Principles of Technology or Applied Math



LASER SOURCES

Nd:YAG LASERS

Knowledge Component	Tool or Piece of Equipment	Task #
Nd lasing action	Nd:YAG lasers	31
Pumping	Nd:YAG lasers	31
Typical practical power supply circuit	Nd:YAG lasers	31
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Closed cycle systems	Nd:YAG lasers	31
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Cavity types: linear and folded	Nd:YAG lasers	31
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DIODE LASERS

Knowledge Component	Tool or Piece of Equipment	Task #
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Diode laser materials	Diode lasers	32
Wavelength availability	Diode lasers	32
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Damage mechanisms	Diode lasers	32
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Safe handling	Diode lasers	32
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GAS LASERS

Knowledge Component	Tool or Piece of Equipment	Task #
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Pumping HeNe lasers	Gas lasers	53
Operating procedures for argon lasers	Gas lasers	53
Operating procedures for HeNe lasers	Gas lasers	53

Using a laser to test for impurities in gallium arsenide.

Knowledge Component	Tool or Piece of Equipment	Task #
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Characteristics of HeNe lasers	Gas lasers	53
Maintenance of argon lasers	Gas lasers	53
Argon laser cooling	Gas lasers	53
HeNe laser power supplies	Gas lasers	53
Mirror requirements for gas lasers	Gas lasers	53

CO_2 LASERS

Knowledge Component	Tool or Piece of Equipment	Task #
Mirror requirements	CO_2 lasers	54
Gas mixtures	CO_2 lasers	54
Pumping	CO_2 lasers	54
Types of CO_2 laser structure	CO_2 lasers	54
Operating procedures	CO_2 lasers	54
Cooling	CO_2 lasers	54
CO_2 laser power supplies	CO_2 lasers	54
Maintenance	CO_2 lasers	54

DYE LASERS

Knowledge Component	Tool or Piece of Equipment	Task #
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Energy level structure of dyes	Dye lasers	55
Pumping	Dye lasers	55
Operating procedures	Dye lasers	55
Characteristics	Dye lasers	55
Jet streams	Dye lasers	55
Tuning	Dye lasers	55
Maintenance	Dye lasers	55
Mirror requirements	Dye lasers	55
Ring dye lasers	Dye lasers	55

EXCIMER LASERS

Knowledge Component	Tool or Piece of Equipment	Task #
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Excimer laser chemistry	Excimer lasers	56
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Excimer laser gas mix	Excimer lasers	56
Pumping	Excimer lasers	56
Operating procedures	Excimer lasers	56
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FIBER OPTICS

Knowledge Component	Tool or Piece of Equipment	Task #
Physical mechanisms for light transmission through fiber	Fibers	21

Knowledge Component	Tool or Piece of Equipment	Task #
Maximum acceptance angle and NA	Fibers	21
Core/cladding characteristics	Fibers	21
Single-mode/multimode operation	Fibers	21
GRIN and step index	Fibers	21
Power loss mechanisms and dB attenuation	Fibers	21
Signal distortion mechanisms -- analog and digital signals	Fibers	21
Information rate as related to pulse code modulation	Fibers	21
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Laser and LED source interfacing	Fibers	21
PIN detectors	Detectors for fiber optic systems	22
APD detectors	Detectors for fiber optic systems	22
Distance-bandwidth product	Detectors for fiber optic systems	22
Selection of detectors	Detectors for fiber optic systems	22
Operating characteristics of detectors for fiber optics	Detectors for fiber optic systems	22
Coupling of light into fibers	Non-laser light sources	20
Optical alignment techniques	Non-laser light sources	20
Connector types	Connectors	24
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Numerical aperture	Connectors	24
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Physical mechanisms for couplers	Couplers	23
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Single-mode fiber couplers, coupler losses	Couplers	23
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Cable types	Cables	25
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Macro- and microbends	Time domain reflectometers	27
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Drive circuiting for diode lasers	Transmitters	26
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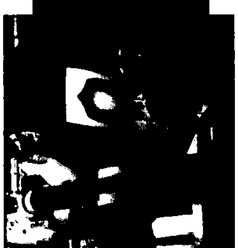
ENABLING TECHNOLOGIES

Knowledge component	Tool or Piece of Equipment	Task #
Principles of pumping	Vacuum equipment	57
Types of vacuum pumps	Vacuum equipment	57



Knowledge Component	Tool or Piece of Equipment	Task #
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Preparation of vacuum-deposited thin films	Vacuum equipment	57
Leak checking	Vacuum equipment	57
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IMAGING AND DISPLAY

Knowledge component	Tool or Piece of Equipment	Task #
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LED display	Flat-panel displays	60
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Color CRTs	CRTs	30
Horizontal and vertical drive circuits	CRTs	30
Storage: digital and analog	CRTs	30
Power supply load requirements	CRTs	30
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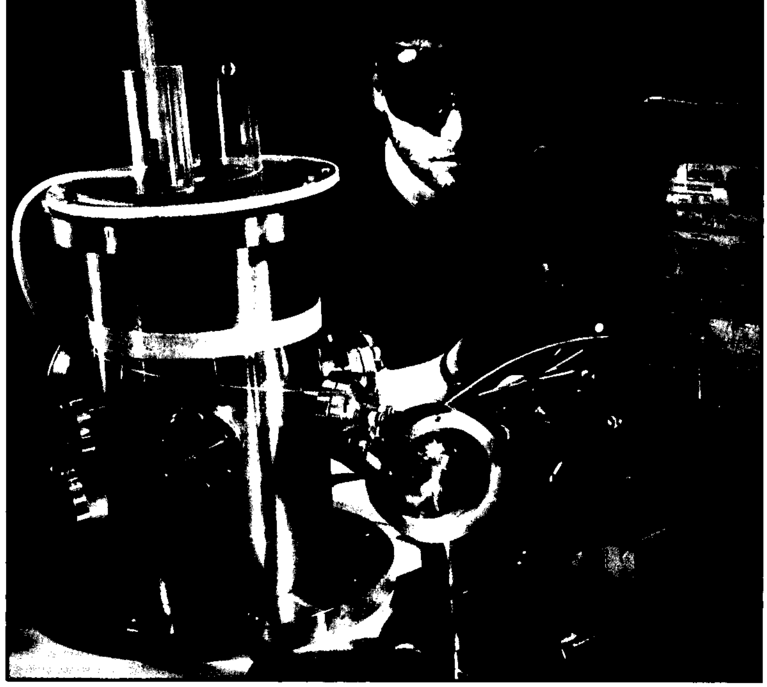
Frequency response of image processors	Image processing equipment	29
Interpret manufacturers' specifications	Image processing equipment	29
Bandwidth of image processors	Image processing equipment	29
Phosphors	IR Viewers	28
FLIR systems	IR Viewers	28
Optical configuration	IR Viewers	28
Scanning systems	IR Viewers	28
Nd:YAG laser viewing systems	IR Viewers	28
Operating procedures for IR Viewers	IR Viewers	28
Computer software literacy	Image analysis software	39
Specific application programs for image analysis	Image analysis software	39
Image processing algorithms	Image analysis software	39
Installation of software	Image analysis software	39
Image processing fundamentals	Image analysis software	39
Beam profiling principles	Image analysis software	39
Beam characteristics (divergence, irradiance, power distribution, TEM_{00} modes, spot size)	Image analysis software	39
Image digitization	Image analysis software	39

OPTICAL COMMUNICATIONS SYSTEMS

Knowledge Component	Tool or Piece of Equipment	Task #
Fiber optics	Communication systems	33
Light sources: multiplexers, demultiplexers, detectors	Communication systems	33
Connectors	Communication systems	33
Fiber types	Communication systems	33
EIA/TIA standards	Communication systems	33
Knowledge of common tools and equipment	Communication systems	33
Cable management	Communication systems	33
Power supplies	Communication systems	33
Copper systems	Communication systems	33

A laboratory set-up for developing fiber optic sensors for automotive use.



Knowledge Component	Tool or Piece of Equipment	Task #
Cable types	Communication systems	33
Switches	Communication systems	33
Systems integration	Communication systems	33
Optical repeaters	Communication systems	33
Performance characteristics (distance-bandwidth product, etc.)	Communication systems	33
Trade-offs to improve cost/performance	Communication systems	33

SPECTROSCOPIC SYSTEMS

Knowledge Component	Tool or Piece of Equipment	Task #
Emission and absorption spectra	Spectroscopic systems	34
Graphical interpretation	Spectroscopic systems	34
Calibration procedures	Spectroscopic systems	34
Tunable lasers	Spectroscopic systems	34
Maintenance	Spectroscopic systems	34
Operating procedures	Spectroscopic systems	34
Remote sensing	Spectroscopic systems	34
DIAL spectroscopy	Spectroscopic systems	34
FTIR spectroscopy	Spectroscopic systems	34
Grating spectroscopes	Spectroscopic systems	34
Display and manipulation of spectra	Spectroscopic systems	34

MATERIAL PROCESSING SYSTEMS

Knowledge Component	Tool or Piece of Equipment	Task #
Beam delivery optics	Material processing systems	58
Alignment of beam delivery optics	Material processing systems	58
Workpiece mounting effects of laser light on materials	Material processing systems	58
Procedures for laser welding	Material processing systems	58
Procedures for laser drilling	Material processing systems	58
Procedures for laser cutting	Material processing systems	58
Procedures for laser marking	Material processing systems	58
CNC programming principles	Material processing systems	58
ICON programming principles	Material processing systems	58

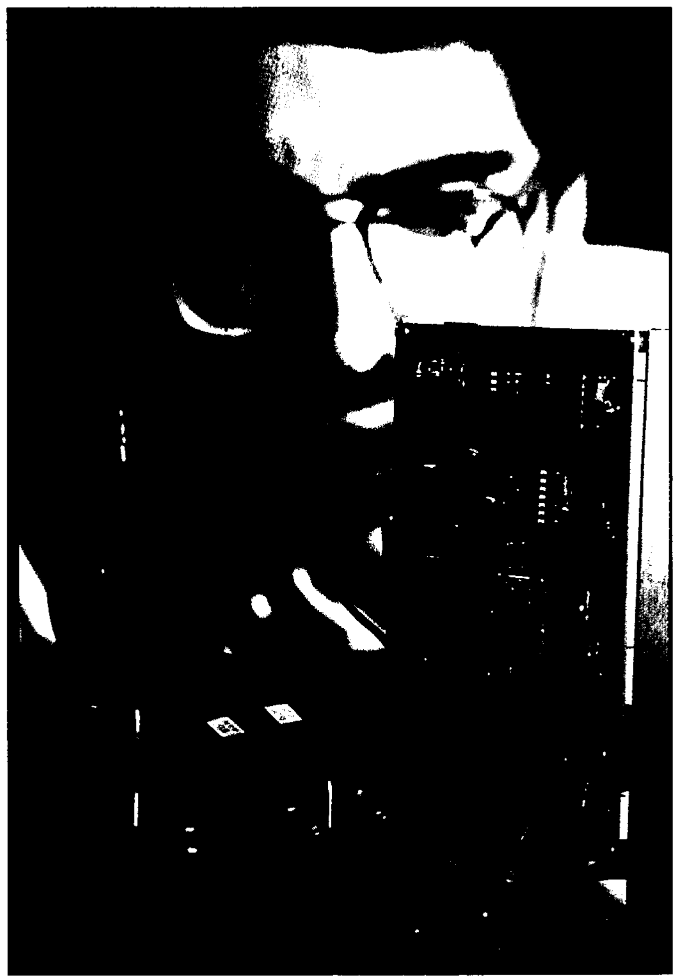
HOLOGRAPHY AND HNDT SYSTEMS

Knowledge Component	Tool or Piece of Equipment	Task #
Interference	Holography and HNDT Systems	59
Principles of holography	Holography and HNDT Systems	59
Setup and operation of holographic recording system	Holography and HNDT Systems	59
Demonstration of holographic reconstruction	Holography and HNDT Systems	59
Holographic recording materials	Holography and HNDT Systems	59
Setup of HNDT systems	Holography and HNDT Systems	59
Operation of HNDT system	Holography and HNDT Systems	59

APPLIED MATHEMATICS

- Work with fractions, decimals, percents.
- Collect data; draw and interpret graphs to include bar graphs, pie charts and line graphs.
- Learn how to apply general problem-solving techniques toward solution of any problem.
- Learn how to estimate answers and round off numbers.
- Learn English and metric units and how to convert from one to the other.
- Learn about lines and angles (parallel and perpendicular lines).
- Learn about perimeters and areas of rectangles, parallelograms, trapezoids, triangles and circles.
- Learn about surface areas and volumes of boxes, cones, cylinders and spheres.

Researcher John Daher with CCD chip.



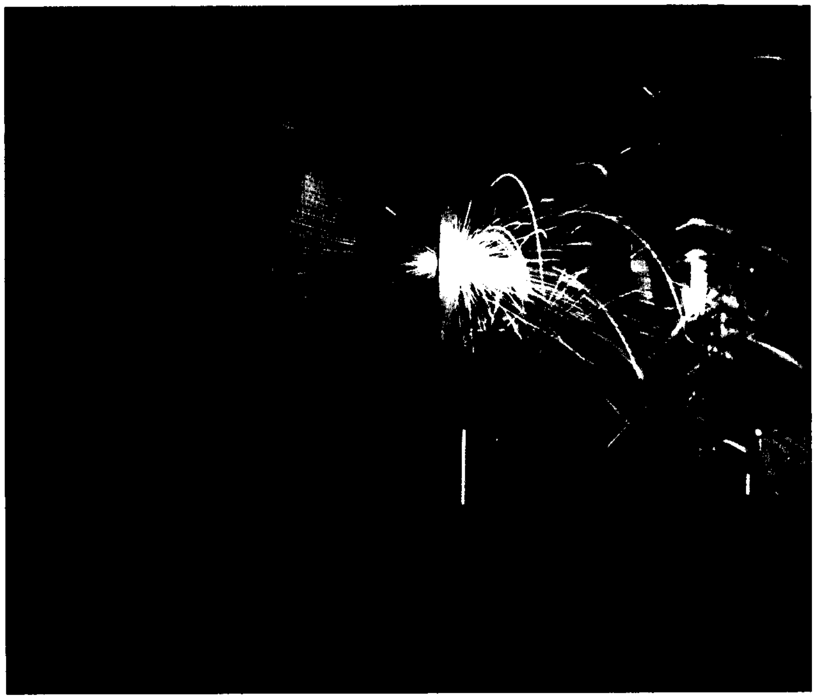
- Use ratio and proportion.
- Make and read scale drawings.
- Learn about powers, roots and scientific notation.
- Learn about precision, accuracy, and tolerance in measurement.
- Learn how to rearrange equations to solve for a specified unknown.
- Learn how to read and draw graphs for linear and nonlinear curves.
- Learn how to interpret and graph relationships that involve inequalities.
- Learn how to use probability to predict outcomes.
- Learn how to calculate mean, median, mode and standard deviation for a set of numerical data; apply statistics.
- Learn how to work with right triangles and use trig functions.
- Learn how to graph and solve quadratic equations.

- Learn how to solve systems of equations.
- Learn how to solve problems that involve combinations of geometry, trigonometry and algebra in real workplace applications.
- Use computers with spreadsheets and computer graphics.
- Learn how to measure and control quality for a manufacturing process in a real situation.

APPLIED PHYSICS

- Learn about forces in mechanical, fluid and electrical systems.
- Learn about movement of objects in linear and rotational motion; relate distance, speed, acceleration and time for each type of motion.
- Learn about pressure and flow rates in fluid systems.
- Learn about voltage, current and resistance in DC circuits.
- Learn about temperature and heat-flow rates in thermal systems.
- Learn about mechanical resistance, friction, fluid resistance, electrical resistance and thermal resistance (insulation).
- Learn about kinetic and potential energy in mechanical, fluid and electrical systems.
- Learn about power and efficiency of mechanical, fluid, electrical and thermal systems.
- Learn about ideal mechanical advantage and actual mechanical advantage for mechanical systems that involve levers, belts, pulleys, gears, and wheel/axle combinations.
- Learn about hydraulic jacks and pressure intensifiers.
- Learn about electrical transformers.
- Calculate efficiency of pressure intensifiers and electrical transformers.
- Learn about linear momentum, and angular momentum and their relation to linear and angular impulse.
- Relate momentum/impulse equation to design of 5-mph bumpers and air bags.
- Learn about transverse, longitudinal and harmonic waves.
- Calculate frequency, period, amplitude, displacement, wavelength and speed for harmonic waves.
- Describe what's meant by wave interference and wave superposition.
- Describe the characteristics of a standing wave and what it takes to produce one.
- Explain how to damp out unwanted vibrations in a system.
- Learn about energy convertors that convert energy between mechanical, fluid, electrical and thermal systems.
- Measure energy in, energy out and efficiency of different energy conversion systems.
- Describe characteristics of transducers that detect mechanical, fluid, electrical and thermal signals.
- Identify transducers that change mechanical signals into electrical signals.
- Identify transducers that change fluid signals into mechanical or electrical signals.
- Identify transducers that change electrical signals into mechanical or thermal signals.
- Identify transducers that change thermal signals into mechanical, fluid or electrical signals.
- Describe characteristics of the following transducers: strain gage, piezoelectric, bourdon gage, barometer, flowmeter, anemometer, moving-electrical coil, galvanometer, electrostrictive, photoconductive, bimetallic strip, thermocouple, and thermistor.
- Learn about electromagnetic and nuclear radiation.
- Describe the electromagnetic spectrum, from gamma rays to radio waves, and give representative wavelength and frequency ranges for major parts of the spectrum.
- Describe alpha, beta, X-ray and gamma radiation.
- Describe how Einstein's mass-energy relationship is used to make calculations for fission and fusion reactions.

The global market for industrial and scientific laser systems is expected to enjoy a healthy and remarkably consistent year-by-year growth between now and the 21st century.

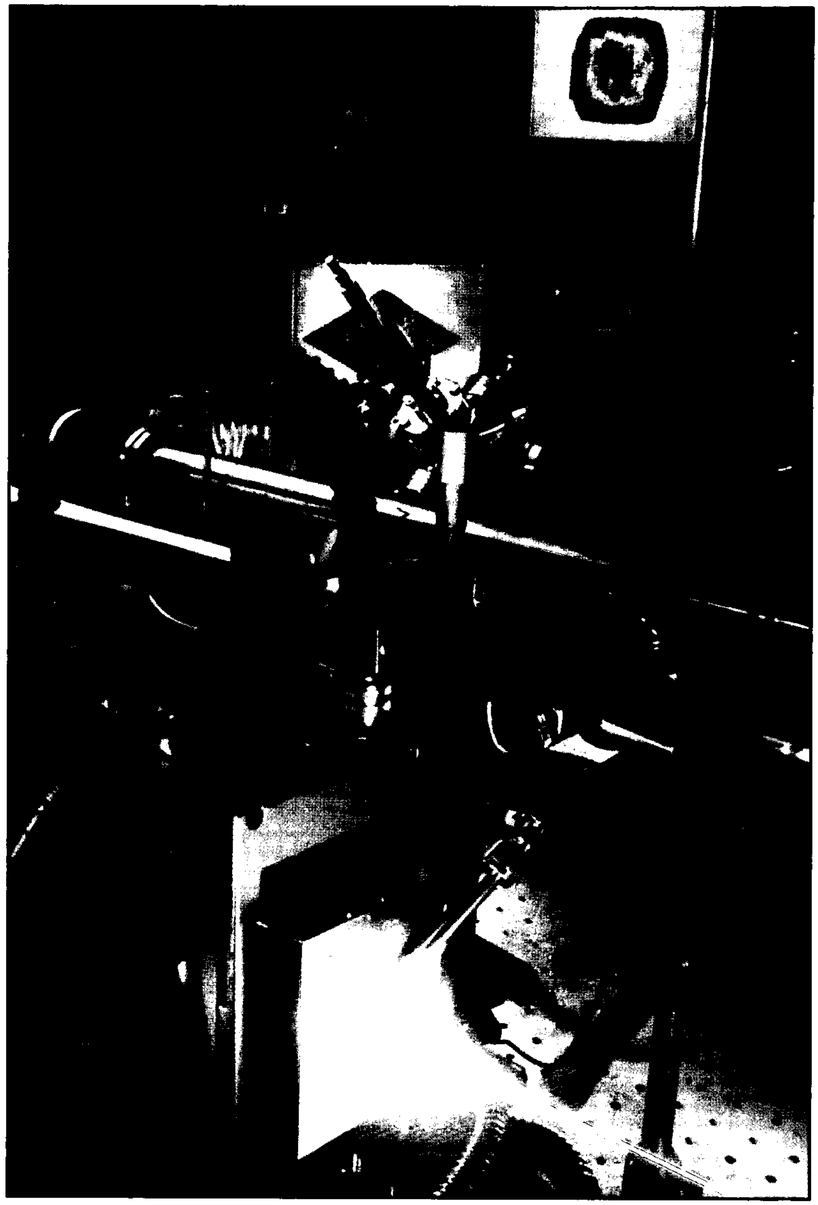


- Describe light in terms of rays and waves.
- Describe reflection and refraction of light.
- Describe the action of mirrors, lenses and prisms on laser beams.
- Describe interference and diffraction and how diffraction gratings and spectrometers disperse light.
- Describe the components of simple gas and solid-state lasers.
- Describe the characteristics of laser light.
- Describe how the eye, camera, beam-expanders, fiber optics and laser systems work as optical systems.
- Describe time constants for exponentially increasing or decreasing systems.
- Distinguish between 1/e and half-life time constants.
- Calculate mechanical, fluid, electrical and thermal time constants.

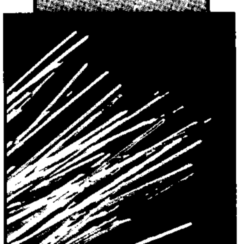
APPLIED BIOLOGY/CHEMISTRY

- Using appropriate resources, identify materials that have specific physical and chemical properties.
- Relate different types of chemical bonding to material properties.
- Relate the physical and chemical properties of metals and alloys to their uses.
- Explain the properties of metals and alloys in terms of atomic, crystalline, and grain structure.
- Distinguish ceramics from other materials such as metals and polymers on the basis of their chemical structure and properties.
- Model the chemical bonding involved in a polymerization reaction.
- Explain how the molecular structure of polymers affects their properties.
- Analyze the effect on a composite's performance of using different kinds of structural components.
- Develop a guideline for predicting what materials will float in water.
- Explain how the structure of a water molecule affects the way water behaves, especially the way that water dissolves materials.
- Explain how hydrogen bonding affects water's function as a solvent.
- Give examples of the "like dissolves like" rule in the everyday use of solutions.
- Determine the amounts of solute required for solutions of various concentrations, using three different types of units: molar, normal, and percent composition.

TRW technician drilling with a laser.



- Calculate dilution to a desired concentration.
- Make sketches of known crystals and compare them to a table of crystal systems.
- Identify five types of chemical reactions that play a role in the formation of materials.
- Predict the properties of steel based on the processes used to make it.
- Relate the differences in structure between crystalline and glass ceramics to the differences in their properties.
- Explain why high temperatures and atmospheric control are necessary for ceramic manufacturing processes.
- Model the chemical bonding involved in a polymerization reaction.
- Distinguish between structure of thermosetting and thermoplastic polymers and the properties and uses of each.
- Develop a guideline for predicting what materials will float in water.
- Explain how the structure of a water molecule affects the way water behaves, especially the way that water dissolves materials.
- Explain how hydrogen bonding affects water's function as a solvent.
- Give examples of the "like dissolves like" rule in the everyday use of solutions.



Testing optical fibers.

Solid-state lasers are being used for drilling and surface treatments during the manufacture of aircraft engine components, such as this one at GE Aircraft Engines in Cincinnati.

- Identify the types of stimuli that can be perceived by each of our senses.
- Draw a diagram to show the basic path of information through the human body as sensations are converted into the actions of muscles or glands.
- Explain how different types of stimuli — light, sound, pressure, etc. — are converted to impulses that can be carried by neurons.
- Analyze how each sense contributes to the body's ability to protect itself and maintain proper conditions for life.
- Evaluate different types of hearing and vision corrective/safety devices according to their appropriate use, risks, comfort, and durability.

Experience required is dependent upon the level of education achieved. These minimum requirements are for teachers at a two-year postsecondary institution.

POSTSECONDARY EDUCATION LEVEL ACHIEVED	RELEVANT PHOTONICS INDUSTRY EXPERIENCE
None	10 Years
A.S. or A.A.S.	2 Years
B.S., M.S. or Ph.D.	1 Year

This core model of a 4+2 curriculum identifies how the knowledge components connect with one another. The knowledge components identified for the first four years in the 9th, 10th, 11th and 12th grades come directly from applied physics, applied mathematics, and applied biology and chemistry curricula in the tech prep program of study. These are the supporting knowledge components for the 13th and 14th years.

In the 13th and 14th years, the core knowledge components for technicians specializing in one of the six cluster areas are the same and have been identified in this report. The tasks for technicians and the resulting knowledge components for approximately 20 percent of the knowledge required outside of the core have yet to be identified, and will be part of the activities in the second 18-month grant phase that began on November 1, 1994.

Rees Instruments engineer uses a transformer light guide and calibrated broadband source to optimize monochromator optics.

Purdue Professor Jerry M. Woodall and two graduate students growing III-IV compound semiconductor heterojunctions for use in photonic applications.

PROJECT STAFF

Director — Darrell Hull

Woody Baker
Piers Bateman
David Cash
Jim Cockerill
Kippy Cooper
Hope Cotner
William Halbert
Vickie Knapp
Judy Lawson
Margaret Leary
Judy McCarley
Chris Moore
Carolyn Prescott
Jack Ready
John Reiher
Teresa Rollins
Alan Sosbe
John Souders
Alice Thompson
Candy Todd
Peggy Tooker
Julie Vitale
April Watkins
Lisa Williams

PHOTONICS STEERING COMMITTEE

Arthur Guenther, Chairman	Sandia National Labs
Ken Edwards	International Brotherhood of Electrical Workers
Connie Giuliano	Alliance for Photonic Technology
Warren Grundfest	Cedars-Sinai Medical Center
David Hennage	OSA
Daniel M. Hull	CORD
William Latham	USAF Phillips Laboratory
Pete Lyons	Los Alamos National Laboratories
Ray Mataloni	Nichols Research Corporation
James Pearson	SPIE
Leno Pedrotti	CORD
Claude Phipps	Los Alamos National Laboratories
Bernard "Dino" Ponseggi	Consultant
Adrian Popa	GM Hughes Electronics/OIDA
Chandra Roychoudhuri	University of Connecticut
Fred Seeber	Camden County College
M.J. Soileau	University of Central Florida
John Wharton	ERIM

EDUCATION

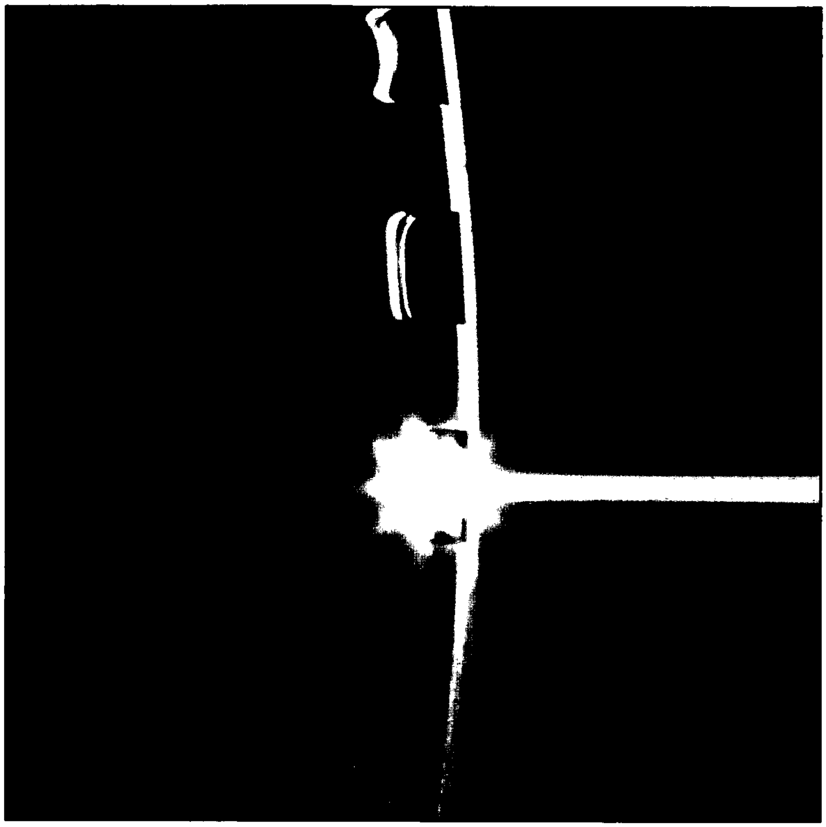
Ken Barat	Lawrence Berkeley Lab
Timothy Barko	Westmoreland Community College
Prem Batra	Cincinnati Technical College
Mark Berge	Hennepin Technical College
Patricia Berger	Indian Hills Community College
Dhrubes Biswas	Cornell University
Kathleen Blakely	Westmoreland Community College
Curt Bloomquist	Indian Hills Community College
Jim Bonner	Shoals Community College
Dan Brazelton	Sinclair Community College
Martin Buoncristiani	Christopher Newport University
Robert Carlson	San Diego City College
Francisco Carvajal	North Lake College
John Caulfield	Alabama A & M University
Cal Christiansen	Idaho State University
E. Dereniak	University of Arizona
Don Engelberg	Queensborough Community College of NY
Ralph Folger	Hudson Valley Community College
Karl Guenther	University of Central Florida
Tom Hammans	TSTC Harlingen
Clinton Harper	Moorpark College
Anna Hill	
Tommy Howard	Shoals Community College
David Iadevaiva	Pima College-East Campus
Surinder Jain	Sinclair Community College
Rollin Javens	Haywood Technical College
Carl Johnson	Edison Community College
Kristina Johnson	University of Colorado at Boulder
Charles Johnson-Bey	University of Delaware
Herbert Jones	Florida A & M University
John Jones	Northwest Community College
Mari Jones	Bucholz High School
Nancy Kinchelloe	Oregon Institute of Technology

Raman Kolluri	Camden County College
Gwe Fang Li	Rochester Institute of Technology
Wai-Min Liu	Pasadena City College
Steve Lympany	Central Carolina Technical College
Saied Mabrouk	Madisonville Community College
Tim Mathis	Southwestern College
Greg Mowry	
Agay Mukhopaday	Southeast Community College
Gary Mullett	Springfield Technical Community College
Thymothy Pearson	Maxine Waters EPC
Marek Osinki	University of New Mexico
Paul Penn	
Joaquin Perez	C & H Engineering
Mike Peterson	Texas State Technical College
Bob Pierce	Oregon Institute of Technology
Harvey Pollicove	University of Rochester
Barbara Ponzini	Massachusetts Bay Community College
Chon Quevedo	San Diego City College
Steve Quon	Ventura College
Jerry Reay	TSTC-Waco
Dean Richardson	SUNY Institute of Technology
Mohammad Rob II	University of Houston-Clearlake
Chandra Roychoudhuri	University of Connecticut
Jeff Ruckman	University of Rochester
William Schramm	Pasadena City College
Dan Sczygelski	Northcentral Technical College
Anthony Sena	Northern New Mexico Community College
Allen Shotwell	Indiana Vocational Technical College
Mark Smith	California State University-Long Beach
John Tenbrook	Camden County College
David Tyree	Vincennes University
Scott Walstein	SDLI
Neil Weintrowb	ITT Technical
Mary Wood	Lyman High School

INDUSTRY AND ARMED FORCES

Craig Aamodt	ITC
David Ackerman	AT&T Bell Labs
Frank Aranda	Golden Aspen
Benedict Archer	ACS
Jon Arenberg	TRW
Dennis Atkinson	
Stephen Bates	Thoughtventions Unlimited
Peter Baumgartner	Hughes Danbury Optical Systems
John Berthold	Babcock & Wilcox
Garland Best	OZ Optics Limited
Jerry Bowman	Lightguide Engineering Co.
Graham Brewis	Hughes JVC-Tech. Corporation
John Brock	TRW Inc.
Jo Bunkenburg	Melles Griot
David Caidan	Opticomm Corporation
Peter Cencik	Adept Technology
Ray Chen	Micro Electric Research Center
David Cheney	OIDA
William Cloake	Omnichrome Inc.
Tammy Cole	Teledyne Brown Engineering
Ron Collins	York Helicopter
David Cook	Accuwave
Angel De Le Torre	Unitek Equipment Inc.
Bimal Deka	Medical Optics
Brian Devall	Corning
Larry Dosser	Mound Applied Technologies
Pat Ferratella	Summers Laboratories
Phil Fostini	Evergreen Laser Corporation
Paul Goth	Chiron Vision
Roger Greenwell	SEA Inc.
Warren Grundfest	Cedars-Sinai Medical Center
Lincoln Gui	Hughes Aerospace and Electronics
Michael Hackman	Ball Aerospace Systems

David Hall	Litton Guidance and Control Systems
Bob Handren	Laser Institute of America
Bill Hara	NDC Systems
Rufugio Hernandez	
Robert Hill	Union Carbide Crystal Products
Gerald Holst	EO Technologies
Bob Hotes	Wilcox Electric Inc.
Grant Hudlow	Allied Science Inc.
Ronald Humphrey	Litton-Airtron Systems
Perry Hung	Vital Ind.
Mathias Ingold	Asea Brown Boveri Ltd.
Edwin Jamback	Ed Doc Jamback Inc
Robert Kawalec	Proformix
Jack Kelley	Cambridge Technology Inc.
Youssee Kohanzadeh	Rocketdyne
JoAnn LaCourse	GTE Labs
Patrick Lewis	UVP Inc.
Robert Lieberman	Physical Optics Corporation
John Lindsay	Polygon Industries
Wagih Makky	FAA Technical Center
Theresa Maldonado	University of Texas at Arlington
John Marez	
Ray Mataloni	Nichols Research Corporation
Jim Matheon	Education and Training Support Agency
B. Ethan Maxon	Opticomm Corporation
Bill Mitchell	Allied Signal
Joseph Monroe	GEOMAP
Joel Ng	Jenovation Opto-Electronics
Gary Noojin	TASC
Robert Nordstrom	Laser Science Inc.
William Owen	Wausau Medical Center
Preston Ozmar	CBN
Dennis Pape	Photonics Systems Inc.
Tony Pham	America Network
Bernard "Dino" Ponseggi	Consultant
Adrian Popa	GM Hughes Electronics
Rick Randall	Aerojet Electronic Systems Plant
Nina Richards	Melles Griot
Robin Risser	Picometrix Inc.
Thomas Roberts	Magnavox Electronic Systems
Bill Roden	General Dynamics
Mark E. Rogers	Armstrong Lab
Marshall Roragen	MM & R International
Richard Rowe	Cyberonics
William Schneider	Optronic Laboratories
K. Shaik	Jet Propulsion Lab
Raj Shori	Interserv Corp.
Donn Silbrman	IOLAB Corporation
David Snoke	The Aerospace Corp.
Spike Sojourner	Graseby Optronics
Robert Sparrow	Optovac
Thomas Stiko	Escantech
Stanley Sweeting	Pearson Technical Services
John Tamkin	Polyscan Inc.
Dean Tran	Pach & Co.
Lisa Tsufura	Melles Griot
Scott Tuber	Metrics Research
Kim Van Order	Prince Corporation
Linda Vandergriff	SAIC
Ravilla Venkat	Gentec Corporation
Tim Villeneuve	Granit Corp.
Bill Vivian	Laser Power Research
Truc Vu	Hughes Aircraft Co.
Hal Walker	Tech Plus
Mark Walker	ALS
Robin Wendell	Spectra Diagnostics
Steven Willing	RCS Technologies
Christine Wilson	
Darwyn Wolff	Aerovision Systems
Jim Wyant	WYKO
Bahram Zandi	Army Research Lab



ABOUT CORD

The Center for Occupational Research and Development (CORD) is a nonprofit public service organization. CORD helps educators in schools and industry address the technical education, training and retraining needs of workers — today and tomorrow. CORD's staff offers its extensive experience in engineering, science, technology, education and business through a wide range of educational services.

CORD's primary areas of operation include applied academics curriculum development, advanced technologies curriculum development, transformations adult training program implementation assistance, and tech prep program implementation assistance. CORD also administers the National Tech Prep Network and the National Coalition for Advanced Technology Centers.

In January 1993, CORD formed the CORD Foundation and CORD Communications to better serve the needs of an ever-changing educational community. The three organizations work side-by-side to fulfill their mission of providing quality educational materials and services for students, educators and employers.

This standard is a working document. If you would like to have input into the standard, please contact us at CORD. The tasks and knowledge components contained in this standard can be accessed without charge on-line at Internet address: **http://www.spie.org/photonics_ed.html**
A list server is available at this same address for comments and suggestions.

CORD

Center for Occupational Research and Development
P.O. Box 21689, 601 Lake Air Drive
Waco, Texas 76702-1689 1-800-972-2766

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