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Development of a curriculum for a course in photonics and fiber-optic technologies for telecommunications

Edward Joseph Szumski

DEVELOPMENT OF A CURRICULUM FOR A COURSE IN PHOTONICS AND FIBER-OPTIC TECHNOLOGIES FOR TELECOMMUNICATIONS

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Education: Vocational Education

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by

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ABSTRACT

This project examined the degree to which the Communications Engineering Technology portion of the electronics program at San Bernardino Valley College meets the need of the area telecommunications industry. The electronics advisory committee, made up of full-time and part-time electronics instructors and industry representatives met and discussed the criteria required for the present and future needs of area telecommunications employers. Findings suggested that the programs in telecommunications at San Bernardino Valley College were lacking in fiber optic technologies. Area industry representatives suggested that this was because the local telephone companies took care of all transmissions over twisted-pair copper wire and fiber optic cables until the breakup of the telephone company into seven Regional Bell Operating Companies (RBOCs) and other long distance carriers. The telephone company is no longer training personnel to do the repair, maintenance and modification of fiber optic links and cabling and hasn't for the past thirteen years since deregulation. It was recommended that the electronics department develop a curriculum in photonic and fiber optic technologies. An instructional budget and an equipment budget were put together to purchase the eqipment necessary for laboratory demonstration purposes. Lastly, a recommendation was made to establish ties to local industry that rely on the graduates and/or certificate recipients of the communications engineering technology program.

ACKNOWLEDGMENTS

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I wish to express my heartfelt thanks to my colleague at San Bernardino Valley College, Mr. Carlos M. Busselle III for his continued support throughout my academic endeavor. His experience working with the curriculum committee at San Bernardino Valley College helped me to format this proposal for submission and eventual acceptance of course changes. Also to Mr. John Moore, Associated Technical College for his help in defining the curriculum used for fiber optics coursework at that San Bernardino campus. I am deeply grateful to my faculty advisor, Dr. Allen Truell for his comments, corrections, and suggestions throughout the process. His guidance provided the direction needed to work through this process. This manuscript was significantly strengthened by the detailed feedback and ideas he provided. I am grateful to my former advisors Dr. Joseph English and Dr. Theodore Zimmerman for their keen guidance and insightful comments. A special thanks goes to the members of the San Bernardino Valley College electronics advisory committee for their input and the suggestions concerning the curriculum changes. Their reviews of this manuscript at various points in the preparation provided me with thoughtful and insightful comments that were helpful in its development.

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CHAPTER ONE

Background

Introduction

The contents of Chapter One present an overview of the project. The context of the problem is discussed followed by the purpose and significance of the project. Next, the limitations and delimitations that apply to this project are reviewed. Finally, a definition of terms is presented.

Context of the Problem

Since 1960, the availability of laser sources has stimulated research into optical communication. However, optical communication was not considered to be practical until 1970, when optical fiber technology had advanced to the point where relatively low-loss fiber could be drawn routinely. Fiber optics has gained prominence in telecommunications, instrumentation, cable TV network, data transmission, and data distribution. Within this decade, there will be a significant changeover from wires and coaxial cables to optical fibers for telecommunication and information systems (Cheo, 1985).

The United States faces a shortfall of skilled technicians in key optics, photonics, and advanced electrical fields, and must take steps to create training programs by national standards to meet critical industry needs, according to the National Photonics Skills Standards Project. The National Photonics Skills Standards Project have described photonics as fundamentally important to the nation's economic future and a key technology to the Information Superhighway. According to a recent survey cited by the

National Photonics Skills Standards Project, approximately 340,000 photonics technicians are working in the United States today. By the year 2000, more than twice that number -- 743,000 -- will be needed. Furthermore, demand may be greater than estimated because military downsizing has led to a decrease in the number of trained photonics technicians entering the commercial workforce upon leaving the armed services.

The curriculum for the telecommunications portion of the electronics program at San Bernardino Valley College is not sufficient to prepare the students for this high technology world of work. When the existing curriculum was developed, wire and fiber optic systems came under the purview of the regional telephone companies. Since 1985, after the breakup of these Regional Bell Operating Companies (RBOCs), many smaller companies offering telephone and data communications services have appeared on the scene. This situation has increased the need for a well defined photonic and fiber optic technologies course.

Purpose of the Project

The purpose of this project was to design a one-semester course curriculum in photonics and fiber optic technologies for telecommunications for community college students. Specifically, the curriculum will serve the third and fourth semester students in the Communications Engineering Technology program portion of the Electronics program at San Bernardino Valley College in San Bernardino, California. The content of the curriculum consists of the fundamentals of fiber optic and laser technologies.

Significance of the Project

The current telecommunications curriculum is not sufficient to prepare students for the high technology world of work. This curriculum will provide students with the skills necessary to gain meaningful employment after graduation from San Bernardino Valley College or attaining a certificate of completion in Communications Engineering Technology. Further, the content will be the most current possible.

Limitations and Delimitations

A number of limitations and delimitations surfaced during the development of this project. These limitations and delimitations are presented in the next section.

Limitations. The following limitations apply to this project.

1. The photonics and fiber optics course was developed based on the budgeted monies available in the department.
2. The photonics and fiber optics course was developed based on the laboratory fiber optic and laser technology equipment available in the electronics department.
3. The photonics and fiber optics course was developed based on the laboratory space available to safely train the students enrolled in this course.

Delimitations. The following delimitations apply to this project.

1. The photonics and fiber optics course was developed specifically for the oscilloscopes, digital and analog volt-ohm-milliammeters, and function generators available in the electronics laboratories.
2. The curriculum is designed to use computer modeling on available computers running an Intel 386 processor or higher.

Definition of Terms

The following terms are defined as they apply to this project.

Bandwidth--The maximum range of decodable frequencies that can travel through an optical fiber of a given length. The difference is expressed in Hertz.

Cladding--Material, usually of a low reflectivity index, that surrounds the central core of an optical fiber to minimize surface scattering losses.

CRT--Cathode Ray Tube. The video display normally used in television sets and computer monitors.

Gbps--A rate of data transmission equivalent to one billion (10^9) bits per second.

Gigabit--Equivalent to one billion ($10^{9)}$ bits.

Laser--Acronym for Light Amplification by Stimulated Emission of Radiation. An active electron device that converts input power into a very narrow beam of coherent visible or infrared light.

LED--Light Emitting Diode. A semiconductor PN junction that emits incoherent monochromatic light by electron-hole recombination. It is used as a display and as an optical emitter in basic optics communications systems.

OCR--Optical Character Recognition. A technique in which a device reads printed characters by using a light-sensitive scanning process and converts them to digital signals.

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

Photon--The quantum of electromagnetic energy, generally regarded as a discrete particle having zero mass, no electric charge, and indefinitely long lifetime.

Quantum--An indivisible unit of energy. The smallest unit of measure used in a system.

RBOC--Regional Bell Operating Company. Can be considered part of the regional bell holding companies, one of the seven companies formed by AT&T's divestiture.

SONET--Synchronous Optical Network. A very high bit rate transmission optical network.

Organization of the Project

This project is divided into five chapters. Chapter One provides an introduction to the context of the problem, purpose of the project, significance of the project, limitations and delimitations, and definition of terms. Chapter Two consists of a review of the literature. Chapter Three outlines the population to be served and the project design. Chapter Four reviews the budget required for implementing the project. Chapter Five presents the conclusions and recommendations gleaned from the project. The project and references follow Chapter Five.

CHAPTER TWO

Review of the Literature

Introduction

Chapter Two consists of a discussion of the relevant literature. Specifically, the history of light as a communications medium, components and devices, and applications are presented.

History of Using Light as a Communications Medium

The history of using light as a communication medium goes way back in time to the island of Konos where a large 20-foot diameter dish reflector was used to reflect the sunshine to signal ships. Lanterns in Boston's Old North Church sent Paul Revere on his famous ride. Claude Chappe built an optical telegraph in France during the 1790s. Signalmen in a series of towers stretching from Paris to Lille, a distance of 230 km, relayed signals to one another through movable signal arms. Messages could travel end to end in about 15 minutes (Sterling, 1993).

John Tyndall, in 1870, demonstrated the principle of guiding light through internal reflections. In a demonstration before the Royal Society, Tyndall showed that light could be bent around a corner as it traveled in a jet of pouring water (Seippel, 1981). Water flowed through a horizontal spout near the bottom of a container into another container through a parabolic path through the air. When Tyndall aimed a beam of light out through the spout along with the water, the audience saw the light follow a zigzag path inside the curved path of the water. A similar zigzagging occurs in optical fibers (Sterling, 1993).

A decade later, Alexander Graham Bell patented the photophone, a series of lenses mirrors threw light onto a flat mirror attached to the mouth piece. The voice vibrated the mirror thereby modulating the light striking it. The receiver used a selenium detector whose resistance varied with the intensity of light striking it. Bell managed to transmit over 200 meters (Sterling, 1993).

In the 1950s, image-transmitting fibers were developed by Brian O'Brien at the American Optical Company and by Narinder S. Kapany and colleagues at the Imperial College of Science and Technology in London. Kapany invented the glass-coated glass rod and coined the term fiber optics in 1956 (Sterling, 1993).

In 1966, Charles Kao, and Charles Hockham, of Standard Telecommunications Laboratory in England, published a paper proposing that optical fibers could be used as a transmission medium if their losses caused by impurities in the fiber could be reduced to 20dB/km. Reducing these impurities could produce low-loss fiber suited for communications. This challenge was taken seriously in the United States both at Corning and Bell Laboratories. The AT&T process, known as the modified chemical vapor deposition process was similar to Corning's vapor deposition process (Sterling, 1993).

In 1970, Maurer, Schultz and Keck had reached the magical level of 20 dB/km in their optical experiments (Chaffee, 1988). Today, the fiber optic cable is made of glass or plastic so smooth and pure that if you looked through a wall of it 70 miles thick, you'd be able to see a candle burning on the other side (Gates, 1995). This increase in orders of magnitude of purity gave rise to a new definition of fiber optic technologies. The new term is photonics. Photonics is defined as the generation, manipulation, transport, detection, and use of light information and energy whose quantum unit is the photon.

Components and Devices

The range of applications of photonics extends from energy generation to detection to communication and information processing. Similar advances in semiconductor sources and detectors, connectors, transmission technology, communication theory, and other areas, as well as intense interest in exploiting the possible benefits of fiber optics, led to investigation of improvement of other components for telecommunications. At the end of each end of a fiber optic link is a transducer, which is simply a device for converting energy from one form to another. The electro-optic transducer converts electrical signals to an optical signal. The detector at the other end is the optoelectronic transducer which converts optical energy to electrical energy. The source of the light required for the electro-optic transducer is either the light emitting diode (LED) or a laser. The laser, an acronym for *l*ight *a*mplification by the *s*timulated *e*mission of *r*adiation, provides stimulated emission of radiation rather than the simpler spontaneous emission of LEDs. When operated above the threshold, the laser provides more power than the LED (Sterling, 1993).

The detector performs the opposite function from the source. The most common detector is the photodiode. The two types of photodiodes currently in use are the pin photodiode and the avalanche photodiode. The PIN photodiode is one that is constructed of both p-type semiconductor material and n-type semiconductor material separated by a layer of intrinsic semiconductor material. Avalanche photodiodes (APD) operate using a process called photomultiplication (Cheo, 1985). Generally, higher power supply voltages are necessary, but the overall effect and operation is the same as the pin photodiodes.

A connector is a disconnectable device used to connect a fiber to a source detector, or other fiber. It is designed to be easily connected and disconnected many times. A splice is a device used to connect one fiber to another permanently.
Some perspective is necessary to understand the importance of these improvements in telecommunications (Sterling, 1993).

In 1990, there were an estimated 5 million miles of fiber optic cable in the U.S. telephone system. The first fiber optic system installed in 1977, operated at 44.7 Mbps and was capable of carrying 672 voices simultaneously. Today, SONET, which is a standardized system for optical telephony, offers a top speed of 10 Gbps, over 200 times faster (Snyder, 1996). Fiber optics is a highly secure transmission medium. It does not radiate energy that can be received by a nearby antenna, and it is extremely difficult to tap a fiber for espionage purposes (Sterling, 1993).

Applications

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 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 (Uehling, 1996).

Advanced sensing and imaging techniques monitor the environment, gathering data on crops and forests, analyzing the ocean's currents and contents (Fitzgerald, 1996) 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 the United States highways (Mendonsa, 1997).

In factories, photonics provides machine vision systems that give a level of quality control human inspectors could never achieve (Kaplan, 1996). 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. 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 (Center for Occupational Research & Development, 1995).

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, optical and electronic equipment in the laboratory. Today, the applications of lasers and light continue to be developed at much the same 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.

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 (Hull, 1993).

The number of applications of photonics is so great that no one could be expected to learn all of the skills for each application in just two years of postsecondary education. Thus schools must reorganize their curricula to begin preparing technicians early for many career paths that require an electro-mechanical background. Completion of a two-year associate's degree in the photonics field must involve learning not only about the generation, manipulation, transport, and detection of light, but also about systems with integrated technologies. Applications will also have to be studied and/or hands-on skills specific to the field of application must be developed (Pedrotti, Massa, Soulsby, Enderle, & Roychoudhuri, 1995).

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.

This standard, an evolving work, began by defining the field of photonics and then progressed to creating occupational specialties for photonics technicians. As these were determined, a survey was distributed to industry representatives asking them to identify the tools or equipment they or their technicians used and to associate a verb with each tool or piece of equipment. These statements were then called tasks, because they say what a photonics 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 (Center for Occupational Research & Development, 1995).

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 Medical Environmental/Energy/Transportation Manufacturing with Photonics/Test and Analysis Computers (Entertainment, Consumer Devices, Hard Copy). 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.

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. 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. Descriptions of each of the six specialty areas follow, and explain some of the applications of photonics in that area, pointing out the uniqueness of each group and its need for technicians (Center for Occupational Research & Development, 1995).

Medicine Cluster

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 technology in medicine.

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.

Environment/Energy/Transportation

Spectrophotometry and laser spectroscopy have already found their way into the burgeoning environmental field (Hardin, 1997). 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 (Tatterson, 1997). 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, 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 (Mendonsa, 1997).

Defense/Public Safety/Aerospace

Photonics is critical to defense and aerospace (Chaffee, 1988), since devices using photonics are not susceptible to electromagnetic interference like conventional electronics. 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 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 (Rausch, 1996).

Computers

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 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 (Weiss, 1996).

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 (Foldvari, Kluft, & Börger, 1996).

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 (Miller, 1979) 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.

Curriculum Concerns

According to the Center for Occupational Research and Development (CORD), 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.

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.

Photonics Technician Employment Opinion Survey

In a venture separate from the development of National Skills Standards 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 photonics technicians are employed in the United States.
- By the year 2000, approximately 743,000 photonics technicians will be needed in the United States.

Respondents to the survey also indicated:

- The most frequently desired education category (61%) necessary for employment as a technician was two years of postsecondary technical education (such as an associate degree) or the equivalent.
- Half of the responding companies reported that 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 (Center for Occupational Research & Development, 1995).

Summary

The content of Chapter Two reviewed the relevant literature. Discussed were the history of light as a communications medium, components and devices, and applications.

CHAPTER THREE

Methodology

Introduction

Chapter Three details the steps used in developing the project. Specifically, the populations served is discussed. Next, the curriculum development process including the curriculum structure and content validation is presented. Lastly, the existing programs are delineated. The Chapter concludes with a summary.

Population Served

The curriculum was developed specifically for students in the electronics program at San Bernardino Valley College in San Bernardino, California. The curriculum is appropriate for use in the San Bernardino Community College District, since it was developed in accordance with the curriculum committee guidelines. The curriculum guidelines were developed by a committee headed by Dr. Eva E. Conrad, Vice President of Instruction and Carlos M. Busselle III, Department Head of the Electronics\Electricity Department.

Curriculum Development

The next section of the project provides an overview of the curriculum development process. Specifically, the curriculum structure and content validation process were reviewed.

Curriculum Structure. This curriculum was developed in accordance with the outline put forward by the San Bernardino Valley College Curriculum Committee. The outline consists of the following: (1) course identification, (2) entrance skills, (3) required course materials, (4) course objectives, (5) course content, (6) methods of instruction, and (7) methods of evaluation. The content for this curriculum was extracted from existing programs. Specific content revolves around introduction to fiber optic background (history), fiber optic components, and fiber optic systems. The prerequisite for this course is Electronics 115 and Electronics 116, Alternating Current Circuits Lecture and Alternating Current Circuits Laboratory.

Content Validation. The content for this curriculum was validated in using two methods. One, an extensive literature review was conducted. The competencies identified as essential to obtaining and maintaining meaningful employment were included in the curriculum. Two, a panel of experts working in the telecommunications industry was assembled. The suggestions for improvement made by the panel were incorporated into the curriculum. Mr. Carlos M. Busselle III, Department Head, Electronics\Electricity Department, reviewed and approved the final draft of the curriculum and the sample student projects.

Existing Programs. The curricula for two existing fiber optic programs were reviewed. One, the existing program at Riverside Community College, City Campus was reviewed (Appendix A). This existing program discusses basic fiber optic theory, transmission theory, system components and test equipment, and cable. Additional topics in this program include fiber multiplexing techniques and current technology trends. Two, the existing program used at the Associated Technical College, San Bernardino Campus was examined (Appendix B). This program revolves around the introduction to fiber optic history and equipment, the different types and installation of light guide cables, the splicing and connecturization of these cables, and the applicable test equipment.

Summary

Chapter Three detailed the steps used in developing the project. Specifically, the populations served is discussed. Next, the curriculum development process including the curriculum structure and content validation is presented. Lastly, the existing programs are delineated.

CHAPTER FOUR

Budget

Introduction

Chapter Four outlines the budget required for the curriculum. Specifically, the costs associated with instruction and equipment are outlined. The costs indicated for the existing programs are 1995 estimates based on information gathered relative to the cost of the presentations of the courses in 1994-1995 educational year.

Instruction

Photonics and Fiber-optic Course			Cost
I.	Course instructor (lecture)	51 hours	$1,824.00
II.	Course instructor (laboratory)	51 hours	$1,677.00
III.	Laboratory assistant	51 hours	$255.00
IV.	Total instructional costs		$3756.00

Equipment

I.	Fiber-optic trainers	5@$100.00/ea	$500.00
II.	Fiber-optic filament(E2545)	50 feet@$1.75/ft	$87.50
III.	LASER trainers	2@$235.00/ea	$470.00
IV.	Total equipment costs		$1057.50

Total budget costs $4813.50

Summary

The costs associated with this course were presented.

CHAPTER FIVE

Conclusions and Recommendations

Introduction

Included in Chapter Five is a presentation of the conclusions gleamed as a result of completing this project. Further, the recommendations extracted from this project are presented. Lastly, the Chapter concludes with a summary.

Conclusions

The conclusion extracted from this project follow.

1. Based on the literature and discussion with experts, the current curriculum must to be updated to reflect the needs of the telecommunications industry.
2. Students receiving certificates and/or graduating from San Bernardino Valley College are not adequately prepared in the area of photonics and fibre optic technologies required in the workplace.

Recommendations

The recommendations resulting from this project follow.

1. The curriculum be reviewed and updated annually to ensure that the students are receiving the most current instruction possible.
2. Funds set aside on an annual basis so that when the existing hardware and software needs to be updated, the money will be available. This strategy will ensure that the students are working with the most up-to-date equipment possible.
3. This curriculum will complete the communications engineering technology course offerings to establish a comprehensive program in telecommunications. The need for

technicians skilled in fiber optic technologies will continue to increase into the next century.

Summary

Chapter Five reviewed the conclusions derived from the project. Lastly, the recommendations culminating from this project were presented.

APPENDIXES: Fiber Optic Curricula

APPENDIX A:

Riverside Community College--Existing Course

Riverside Community College, City Campus

Course outline, Electronics 40

Course description

Fiber Optic Basics

Basic fiber optic theory, transmission theory, system components, and cable; communication transmission systems, fiber multiplexing techniques and terminals, tests and test sets, and current technology trends are also presented. Total of 54 hours lecture.

Course objectives

Upon successful completion of this course, the student will be able to:

1. Explain the basic concepts of fiber optic transmission theory.
2. Explain the basic concepts of fiber optic transmission components.
3. Demonstrate critical thinking skills by analyzing typical fiber optic transmission and multiplexing problems.
4. Demonstrate team work and communication skills during analysis of typical fiber optic transmission and multiplexing problems.
5. Present strategies for remaining technically current in the field of fiber optics.

Class topics

Communications transmission systems	3 hours
T1 overview	8 hours
Multiplexing techniques	4 hours
Fiber optic history and components	4 hours
Fiber optic transmission theory	4 hours

Fiber optic cable	4 hours
Fiber optic multiplexing terminals	4 hours
Fiber optic tests and test sets	4 hours
Fiber optic technology trends	16 hours
Final examination	3 hours
Total hours	54 hours

In addition to the indicated hours, students are assigned the following reading, writing and other assignments equivalent to two hours per one hour lecture, prorated for short term, lab and activity courses; reading, written and/or observation assignments as required by the instructor.

Methods of Instruction

Lectures

Demonstrations

Multi-media presentations

Class discussions

Field trip(s) based on availability and appropriateness

Homework

Methods of Evaluation

Grades are based on:

1. Demonstrated proficiency in subject matter,
2. Frequent quizzes and exams,
3. At least one written paper that will require library research that provides the student an

opportunity to focus upon a specific area concerning fiber optics technology,

4. Individual and team work skills demonstrated during analysis of typical fiber optic transmission and multiplexing problems,
5. Attendance and class participation, and
6. Comprehensive final exam.

Course Materials

All materials used this course will be periodically reviewed to insure to insure that they are appropriate for college level instruction.

Updated 4/95

APPENDIX B:

Associated Technical College--Existing Course

Associated Technical College, San Bernardino Campus

Course Outline, Fiber Optics

Course description

Fiber Optic Basics

Introduction to fiber optics; DS carrier; types of equipment; cable installation; AT&T STII connector, 3M ST connector; AT&T CSL splice; 3M reuseable splice; fusing splice; test equipment. Total of 25 hours.

Course objective

To introduce fiber optic equipment, cable, connecturization and splicing.

Class topics

Day 1 - Introduction to fiber optic history and equipment. 5 hours

A. Fiber optic transmission advantages
   1. A new system concept
   2. System formats
   3. Fiber optic format
   4. Early theories about light
B. Fiber optic transmission system
   1. Light source
      a. Injection laser diode (ILD)
      b. Light emitting diode (LED)
   2. Optical waveguide
      a. Fiber
      b. Cables
      c. Splices
      d. Connectors
   3. Detector
      a. Avalanche
      b. Photodiode or PIN diode
C. Digital made easy
   1. Analog transmission
   2. Digital conversion
   3. Digital transmission

D. Generic communications link
   1. Transducers
   2. The wave nature of light
E. The electromagnetic spectrum
   1. Bandwidth
   2. Connector loss
   3. Splice loss
   4. Component selection
F. Lightwave communications link
   1. Basic lightwave system
   2. Input/output communications link
G. Engineering consderations
   1. Lightwave system architecture
   2. Multiplex equipment

Day 2 - Introduction to different types and installation of light guide cables; also light guide distribution shelf. — 5 hours

A. System block diagram
   1. Lightwave regenerator
   2. The lightguide, or optical fiber
   3. The lightguide cable
   4. PDS fiber optic distribution elements - transmission
      a. Fiber designs
      b. 62.5/125-µm fiber
      c. 50/125-µm fiber
      d. Cable descriptions
         (1) Coated fiber, ribbon
         (2) Coated fiber, lightpack cable
         (3) Buffered fiber, building and jumper cables
   5. PDS fiber optic distribution elements - applications
      a. Filled lightguide cable
      b. 8.3/125-µm fiber
      c. Fiber interconnection cables
      d. 12 fiber ribbon cable
      e. Flame retardant lightguide cable
      f. B oversheath lightguide cable
   6. Splice and termination shelf installation

Day 3 - Introduction to ST connecturization and CSL splicing. — 5 hours

A. Rotary mechanical splice (RMS)
   1. Rotary splice description

2. Splicing procedures

B. AT&T splice instructions
   1. Using the 1048A tool kit or the 1041A work station
   2. Splicing procedures

C. AT&T CSL lightsplice system
   1. The training
   2. The trial splices
   3. Results
   4. Technology illustrated

D. Assembly instructions for ST lightguide cable connectors - single mode and multimode version
   1. General
   2. Precautions
   3. Assembly instructions for ST cable connections with LGBC
   4. Assembly instructions for ST lightguide cable connections with bare fiber

Day 4 - Continuation of ST connecturization and CSL splicing; also test equipment.	5 hours

A. Continuation of ST connecturization and CSL splicing
   1. Assembly instructions for ST lightguide cable connectors with single-fiber cable
   2. Interconnecting with ST lightguide cable connectors
   3. Ordering information
   4. Fiber optic tests cautions and procedures

Day 5 - Review and test	5 hours
Total hours	25 hours

Methods of Instruction

Lectures

Demonstrations

Class discussions

Methods of Evaluation

Grades are based on a comprehensive final exam.

Course Materials

All materials used this course will be periodically reviewed to insure to insure that they are appropriate for instruction.

Updated 6/90

APPENDIX C:

San Bernardino Valley College--New Course

Photonics & Fiber Optic Technologies

Fall 1997

Instructor....................................Ed Szumski

Office...T-108

Office hour............................9:30 to 10:00 am M-W-F
Noon to 1:00 pm Tues
4:00 to 4:30 pm Tues

Telephone..............................(909) 888-6511 ext 1330

Mail..............................San Bernardino Valley College
Technical Division
701 S. Mt. Vernon Avenue
San Bernardino, CA 92410-2798

Photonics & Fiber Optic Technologies

The grades earned for this course will be determined by the number of points each student accumulates. Students should use this form to keep track of the number of points they have earned. Specific information is provided about everything in this course for which points may be earned. In order to earn the maximum number of points possible, the students are encouraged to read all of the information provided in this syllabus and comply with the criteria indicated for each assignment. The number of points required to earn each of the grades possible for this course are:

A.........90 TO 100

B.........80 TO 89.9

C.........70 TO 79.9

D.........60 TO 69.9

F.........59.9 AND BELOW

Any conscientious student who listens and reads with comprehension and who speaks and writes clearly can earn the maximum number of points possible. Each student is directly responsible for determining his/her own grade by the amount of time and effort that he/she expends. It is expected that the students in this course will work hard and earn high grades.

TEST # (Chapters in the text book)	MAX SCORE	YOUR SCORE
TEST #1 Chapters 1 & 2	100	______
TEST #3 Chapters 3 & 4	100	______
TEST #4 Chapters 5 & 6	100	______
TEST #5 Chapters 7 & 8	100	______
TEST #6 Chapters 9 & 10	100	______
TEST #7 Chapters 11 & 12	100	______
TEST #8 Chapters 13 & 14	100	______
TEST #9 Chapters 15 & 16	100	______
The final exam is a comprehensive test covering all the material that was covered this semester.	200	______
TOTAL	1000	______

To determine your grade, add all the test scores and the final exam score. Divide the total by 10 and this is your numerical score. Determine the letter grade from the list on the prior page.

SCANTRON FORMS

Each student must purchase the SCANTRON forms prior to taking the tests. The SCANTRON form we will be using is the form number 882 or 882-E. The SBVC Bookstore has these forms available for purchase.

TEXT BOOK

The text book for this course is "Technician's Guide to Fiber Optics, Second Edition" by Donald J. Sterling Jr.

TOPICAL QUIZZES

There will be many quizzes given during this semester. These are diagnostic in nature and are meant only as an aid to your studying applicable material. These quizzes will be checked for completion by your instructor prior to the discussion of the quiz.

COURSE REPEAT POLICY

A grade, once entered on the student's permanent records, remains permanent unless changed by the instructor of record pursuant to the education code, section 76224. Courses in which "D", "F", or "NC" were received, may be repeated. The units for which credit is given will only count once toward an associate degree or a certificate. A course may be repeated only once and when a second grade is earned, the first grade can be lined-out on the permanent record upon request and will not be used to compute the grade point average. Students that repeat a course under this policy should contact the records office, room A-109, to request that the first grade be lined-out. I'm told that the form name is "REPEAT DELETE".

MAKE-UP TESTS

Here is the electronics department policy on make-up tests. All tests will be given when scheduled by your instructor. If you cannot attend class, call (909) 888-6511, extension 1330, and leave a message on my answering machine or (909) 888-6511, extension 1334, and leave a message concerning your absence with the secretary. **There will be no make-up test if you do not notify your instructor prior to the test!**

ATTENDANCE REGULATIONS

Students are required to attend all lecture and lab sessions unless absence is unavoidable. If your absence is unavoidable, please call (909) 888-6511, extension 1330, or extension 1334, and leave a message concerning your absence. Each student is allowed the maximum number of two unexcused absences for this course. Absences exceeding this limit or whenever a student's attendance becomes so irregular that it is unwise for him/her to continue, the instructor will drop the student from the roll sheet. It is the student's responsibility to officially drop the class.

CALCULATOR

The Electronics program here at San Bernardino Valley College covers simple addition to complex equations. You should purchase a calculator that will perform the following functions: addition, subtraction, multiplication, division, sine, cosine, tangent, logarithm and inverse (1/X) functions, and number system conversion ability: binary, octal, decimal & hexadecimal.

CREDIT/NO CREDIT OPTIONS

A student may take up to fifteen (15) units of credit "CR" courses to apply to his/her graduation requirements. No course in a student's major or required by his/her major may be taken for credit "CR"; that is, subjects in the student's major must be taken on a letter grade basis.

ADDITIONAL INFORMATION

The Technical Learning Center (TLC), room T-100, has many helpful programs loaded into the computers (IBM clone and Apple IIGS). There are also some computer-interactive disks (AppleIIGS) and filmstrips by Bergwall that will help your understanding of the material we'll be covering this semester. Mrs. Trost will be glad to help you with any questions you may have concerning the operation of the computers.

PERFORMANCE OBJECTIVES

By the conclusion of this course, it is expected that the students will be able to:

1. Define the terms *optical* and *light*.
2. Name the three main bands of the optical spectrum.
3. State the wavelength ranges of the optical spectrum.
4. State eight benefits of fiber optic cables over electrical cables for communications.
5. Name six typical applications for fiber optic cables.
6. Explain how light is propagated through a fiber optic cable.
7. Name the basic types of fiber optic cables, and state the two materials from which they are made.
8. Calculate the transmission loss in decibels of fiber optic cable and connectors over a distance.
9. Name the two types of optical transmitter components and their main operating range.
10. Explain the operation of an optical detector and receiver.
11. State the nature and frequency range of the infrared band.
12. Name natural and artificial sources of infrared light.

INFORMATION SHEET

FALL 1997

1. GRADUATION PETITION FILING PERIOD FOR SPRING 1998 BEGINS .... AUG 17
2. LABOR DAY HOLIDAY - NO SCHOOL .... SEPT 1
3. LAST DAY TO ADD CLASSES (3:00 PM DEADLINE) .... SEPT 12
4. LAST DAY TO DROP FULL TERM CLASSES AND RECEIVE FEE REFUND SEPT 12
5. VETERAN'S DAY HOLIDAY - NO SCHOOL .... NOV 11
6. LAST DAY TO DROP CLASSES WITH NO RECORD ON YOUR TRANSCRIPTNOV 14
7. LAST DAY TO OPT FOR CREDIT/NO CREDIT .... NOV 14
8. LAST DAY TO PETITION FOR SPRING 1998 GRADUATION .... NOV 21
9. LAST DAY TO WITHDRAW FROM CLASSES WITH A "W" ON RECORD .. NOV 26
10. THANKSGIVING HOLIDAY - NO SCHOOL .... NOV 27 - 28
11. LAST DAY OF INSTRUCTION FALL 1997 SEMESTER .... DEC 18
12. FINAL EXAMINATION SCHEDULE:

PHOTONICS & FIBER OPTICS	FRIDAY, DEC 12, FROM 11:00 AM TO 1:30 PM
F.C.C RULES & REGULATIONS	MONDAY, DEC 15, FROM 4:30 TO 6:00 PM
SOLID STATE DEVICES	TUESDAY, DEC 16, FROM 8:00 AM TO 10:30 AM

13. GRADES MAILED TO STUDENTS .... JAN 22
14. GRADUATION REQUIREMENTS: See the SBVC catalog for graduation requirements or make an appointment to see a counselor for information on a course curriculum for your major subject.

San Bernardino Valley College
Photonics and Fiber Optic Technologies

Course Content

I. Background

A. The communications revolution
1. The history of fiber optics
2. The information age
3. The wiring of America
4. Telecommunications and the computer
5. The fiber optic alternative

B. Information transmission
1. Communication
2. Analog and digital
    a. Digital basics: bits and bytes
    b. Why digital?
3. Information-carrying capacity
4. PCM and multiplexing
5. The decibel

C. Fiber optics as a communications medium: its advantages
1. Wide bandwidth
2. Low loss
3. Electromagnetic immunity
4. Light weight
5. Small size
6. Safety
7. Security

D. Light
1. The electromagnetic spectrum
2. Waves and particles
3. Light rays and geometric optics
4. Reflection and refraction
5. Fresnel reflections
6. Snell's law
7. Practical examples

II. Fiber optic components

A. The optical fiber

1. Basic fiber construction
2. Fiber classification
3. Modes
4. Refractive index profile
5. Step-index fiber
6. Graded-index fiber
7. Single-mode fiber
8. Dispersion-shifted fibers
9. Short-wavelength single-mode fibers

B. Fiber characteristics
   1. Dispersion
   2. Modal dispersion
   3. Material dispersion
   4. Waveguide dispersion
   5. Bandwidth and dispersion
   6. Attenuation
   7. Scattering
   8. Absorption
   9. Microbend loss

C. More fiber characteristics
   1. Equilibrium mode distribution
   2. Numerical aperture
   3. Fiber strength
   4. Bend radius
   5. Nuclear hardness

D. Fiber optic cables
   1. Main parts of a fiber optic cable
   2. Buffers
   3. Strength members
   4. Jacket
   5. Indoor cables
   6. Simplex cables
   7. Duplex cables
   8. Multifiber cables
   9. Duty specifications

E. Cable types
   1. Breakout cables
   2. Outdoor cables
   3. Additional cable characteristics
      a. Lengths

b. Color coding
c. Loads
4. Hybrid cables
5. Understanding cable specifications

F. Sources
1. Some atomic matters
2. Semiconductor PN junction
3. LEDs
4. LASERs
5. Safety
6. Source characteristics
7. Output power
8. Output pattern
9. Spectral width
a. Speed
b. Lifetime
c. Ease of use
d. Packaging

G. Detectors
1. Photodiode basics
2. PN photodiode
3. PIN photodiode
4. Avalanche photodiode (APD)
5. Noise
a. Shot noise
b. Thermal noise
c. Signal-to-noise ratio
6. Bit-error rate
7. Detector characteristics
a. Responsivity
b. Quantum efficiency
c. Dark current
d. Minimum detectable power
e. Response time
f. Bias voltage
8. Integrated detector/preamplifier
9. Packaging

H. Transmitters and receivers
1. Basic transmitter concepts
2. Modulation codes

a. NRZ code
b. Rz code
c. NRZI code
d. Manchester code
e. Miller code
f. Biphase-M code
g. 4B/5B and 4B/8B Encoding

3. Data rate and signal rate
4. Duty cycle
5. Transmitter output power
6. Basic receiver concepts
   a. Receiver sensitivity
   b. Dynamic range
7. Amplifier
8. Duty cycle in the receiver
9. Transceivers and repeaters
10. Transmitter and receiver packaging
11. Transmitter and receiver specifications

I. Connectors and splices
   1. The need for connectors and splices
   2. Connector requirements
   3. Causes of loss in an interconnection
   4. Intrinsic factors
   5. Extrinsic factors
      a. Lateral displacement
      b. End separation
      c. Angular misalignment
      d. Surface finish
   6. System-related factors
   7. Insertion loss
   8. Additional losses in an interconnection

J. Loss in single-mode fibers
   1. Return reflection loss
   2. Fiber termination
      a. Ferrules
      b. Epoxy and polish
      c. Epoxyless termination
   3. Compatibility
   4. Connector examples
      a. FC-style connector
      b. D4-style connector
      c. ST-style connector

d. SC connectors
e. FDDI MIC connector
f. ESCON connector
g. SMA connectors
h. Plastic-fiber connectors
5. Splices
a. Fusion splices
b. Mechanical splices
6. Fiber preparation
7. Connector assembly example

K. Couplers
1. Coupler basics
2. TEE coupler
3. STAR coupler
4. Reflective STAR couplers
5. Coupler mechanisms
a. Fused couplers
b. Centro-symmetrical reflective couplers
6. Wavelength-division multiplexer
7. Optical switch

III. Fiber optic systems

A. The fiber optic link
1. Preliminary considerations
2. System specifications
3. Power budget
4. A more complex example
a. Transmitter losses
b. Fiber 1 loss
c. Fiber-to-fiber connection
d. Receiver losses
e. Fiber 2 loss
5. Added complexities
6. Rise-time budget

B. Fiber optic installation and hardware
1. Bend radius and tensile rating
2. Direct burial installation
3. Aerial installation
4. Indoor installation
5. Tray and duct installations

6. Conduit installations
7. Pulling fiber optic cables
8. Splice closures/organizations

C. Distribution hardware
   1. Patch panels
   2. Wall outlets

D. Fiber optic systems and applications
   1. Local area networks
      a. LAN topologies
   2. Network layers
      a. Physical layer
      b. Data-link layer
      c. Network layer
      d. Transport layer
      e. Session layer
      f. Presentation layer
      g. Application
   3. Access method
   4. Frames
   5. Ethernet and token ring
      a. IEEE 802.5 token ring
      b. IEEE 802.3 ethernet
      c. FOIRL
      d. 10BASE-F
   6. Fiber distributed data interface (FDDI)
      a. FDDI topology
      b. FDDI stations
      c. FDDI applications
      d. FDDI on copper
   7. IBM ESCON system
   8. Fiber channel
   9. Telecommunications
      a. SONET
      b. Erbium-doped fiber amplifier
      c. Solitons

E. Introduction to test and other equipment
   1. Fiber optic testing
   2. Optical power meter
   3. Mode control
   4. Fiber loss measurements

5. Insertion loss tests
6. Time and frequency domains
7. Optical time-domain reflectometer
    a. Uses of OTDR
    b. Loss per unit length
    c. Splice and connector evaluation
    d. Fault location
8. Fusion splicer
9. Polishing machine
    a. Inspection microscope
    b. Installation kits

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