Session 2648

A Two Course Sequence In Optical Communications

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Abstract
The growth of the Internet traffic has made optical communications an essential technology which meets the communications demand of higher bandwidth and transmission of high speed data at a longer distance. The paper discusses the development of a two-course sequence in optical communications at the electrical engineering technology department of the State University of New York Institute of Technology (SUNYIT), Utica, New York. The first course deals with the basics of fiber optics and contains a structured lab of eight experiments while the second courses includes advance topics and experiments in optical communications, and a project. The paper also discusses the development of experimental facilities used in support of these courses. The implementation of these courses has made our curriculum current, and helped the students to enhance their career options in the current technological environment.

Introduction
Optical communication is a technology of transmitting information in the form of light by way of optical fibers or free space as a medium. Over the last two decades the low cost of optical fibers, enormous capacity and accuracy has revolutionized long range communication making possible the Internet as we know it. The rapid transition of wavelength division multiplexing (WDM) techniques from laboratories to the field is adding even more capacity, and fiber is increasingly becoming the media of choice in metropolitan area networks, local area networks, campuses, hospitals, factories and soon even in homes. However, there is an acute need for a network to provide huge bandwidth far beyond the capacity of current networks and it is suggested that optical Internet based on dense wavelength division multiplexing (DWDM) is a viable solution to fulfill the ever-increasing bandwidth demand in the Internet [1]. The purpose of introducing a two- course sequence in optical communication in the department of electrical engineering technology at the State University of New York Institute of Technology (SUNYIT[2]) was to meet the demand for skilled workers with hands-on experience to maintain and design new optical communication networks or systems. Currently, it is the only sequence of optical courses offered in the communication option of electrical engineering technology program. SUNYIT, historically an upper-division institution, will for the first time accept freshman into eleven bachelor's degree programs. SUNYIT offers twenty bachelor's degree programs to transfer students, and 11 master's degree programs.

Development of Course Sequence

An introductory course on " Fiber Optics (ETC 391)" was first introduced in the 1980s when the telecommunication companies started to use single mode optical fiber in the long haul communications links because of its low loss. This course was first offered with two credits and a lab was later added to make it a four credits course. A second course on "Optical Communications (ETC 483)", was introduced in the 1990s when optical fiber was increasingly used in optical networks and undersea communication due to the development of fiber doped amplifiers and progress in optical switching. This course provided advanced material and was targeted toward students who already had a basic knowledge of fiber optics.

Experimental Facilities

Two laboratories were developed to provide hands-on experience to the students in these two courses. The fiber optics and optical communications laboratories are equipped with optical time domain reflectometers, fusion splicers, optoscope, power meters, optical spectral analyzers, waveform analyzers, Newport project kits in fiber optics, light sources in addition to infrared viewers, cameras and coherent fiber optics, fiber optic telecommunication links, and plastic and glass fibers. The fiber optic lab is also equipped with various splicing, connectorizing, cleaving and polishing kits and tool accessories necessary to provide students with hands-on experience. An optical networking lab based on FDDI was also developed with support from NSF under the Instrumentation and Laboratory (ILI) program [3]. The course on optical communication also makes use of the college photonics labs.

Implementation of Course on Fiber Optics (ETC 391)

This course deals with the principles and analysis of fiber optic components and systems, fiber optic sensors, and applications of fiber optics in telecommunications and instrumentation. It is a four- credit course with three hours of lecture and two hours of laboratory per week. The prerequisite is one physics course with optics. The text book, currently used, is " Elements of Fiber Optics" by S.L. Wymer Meardon, published by Regents/Prentice Hall, New Jersey. The course is supplemented with additional handouts on fiber optic sensors and fiber doped amplifiers. The course objective and outcomes are given below:

- To review the fundamentals of optics as applied to the field of fiber optics
- To study the functions of components used in fiber optic telecommunication systems
- To study the use of relevant techniques (theory and practice) required in the analysis and evaluation of fiber optic systems

On the successful completion of the course, the students have:

- Understanding of the fundamentals of optics as applied to the field of fiber optics

- Theoretical and practical knowledge of fiber optic components and its usage in fiber optic communication systems
- The ability to implement, analyze and maintain basic fiber optic communication systems

The course schedule and lab assignments are given below:

Course Schedule

Week 1 Review and introduction to the field of fiber optics, applications and advantages, fiber optic link, new trends

Week 2 Principle of light, wave nature and particle nature of light, Snell's law, total internal reflection, Fresnel reflection, diffraction, polarization and interference

Week 3 Optical fiber as a waveguide, parameters of optical fiber, types of glass and plastic fibers, single mode and multi-mode fibers

Week 4 Transmission characteristics of optical fibers, losses and dispersion of fibers, absorption, scattering and radiative effects in fibers, modal, material and waveguide dispersions

Week 5 Method of fabrication of fibers, low loss fibers, chemical vapor deposition techniques, outside vapor and vapor-axial deposition techniques

Week 6. Fiber drawing process, cable design

Week 7 Connectors, splices and couplers, fiber alignment and joint losses, types of fiber splices and connectors, preparation of fiber for splicing and connectorization

Week 8 Types of couplers, coupler design and networks

Week 9 Optical sources, spontaneous and stimulated emission, types and requirement of light sources, light emitting diodes, semiconductor and distributed feedback lasers

Week 10 Photodetectors, requirement and types of photodetectors for fiber optic communications, PIN diode, avalanche photodiode (APD) and phototransistor

Week 11 Modulation of light, direct intensity modulation, indirect modulation of light

Week 12 Analog and digital modulation, multiplexing, frequency division, multiplexing, time division multiplexing and wavelength division multiplexing

Week 13 Fiber optic transmitters and receivers, Long haul and short haul communication systems, transceivers and repeaters

Week 14 System architecture, point to point links, local area network, standards, SONET, FDDI, system design, power throughput analysis, loss and bandwidth budget

Week 15 Fiber optic sensors, types of sensors, amplification of light, Principle of erbium doped amplifier

Laboratory Assignments:
Eight lab assignments were developed to incorporate in the course on fiber optics. Each lab was designed to supplement and apply to the course material covered in the class. The first lab is web-based experiment of fiber optics principles and systems and uses fibersim.Zip[4] and Corning's [5] Fiber Optic Software. The remaining seven experiments use optical and electrical equipment to study, measure and characterize optical fibers, light sources, fiber optic couplers and fiber optic communication system. The objectives, methodology and list of equipment needed to setup the experiment is provided to the student. The students, however, are required to develop the introduction and background theory of each experiment by consulting the text- book and other related resources. The students work in a group but each student has to submit his/her report written in their own words in a recommended format. Following are some of the experiments, which are implemented:

1. Web -based experiment of fiber optic principles and system
2. Measurement of optical power and characterization of optical fibers using optical time domain reflectometer
3. Splicing of optical fibers using fusion and mechanical splicing
4. Coupling of light into optical fibers and measurement of numerical aperture
5. Spectral analysis of light sources (LED and Laser)
6. Implementation and study of fiber optic communication systems
7. Bit error rate of simulated fiber optic link
8. Characterization and application of fiber optic coupler

Implementation of Course on Optical Communications (ETC 483)
This is a senior level course usually taken by the electrical engineering technology students concentrating in the area of communications. Students are required to have taken the basic course in fiber optics as a prerequisite. The objective of the course is to establish the place of optical technology within the field of communications. This involves the study of those aspects of the field of optics which appear to offer the greatest advancement in meeting system requirements as well as those which at present are preventing full adoption of all optical communication systems. The text book currently used is " Optical Fiber Communication" by Gerd Keiser, third Edition, McGraw Hill Publications. The course outcomes are given below:

- Understand the basis of optics required in the implementation of optical communication systems.
- Understand the principle of components used in optical communication systems
- Be able to understand the use of formula used in the design and performance analysis of the system.

Course Schedule

Week 1 Review of optical communication systems, guided and free space communication
Week 2 Ray optics, wave optics, electromagnetic optics, quantum optics, guided wave optics
Week 3 Light emission and optical sources, semiconductor physics, direct and indirect band
gaps, LED and laser diodes
Week 4 Single mode lasers, quantum well and vertical cavity surface emitting laser, fiber lasers
Week 5 Optical amplification, semiconductor optical amplifiers
Week 6 Fiber doped amplifiers, Raman amplifier, praseodymium doped amplifier
Week 7 Amplifier noise, wavelength converters, tunable light sources
Week 8 Direct and coherent modulations, integrated modulators, optical switching
Week 9 Optical fibers and waveguides, mode theory for circular and cylindrical waveguides,
Maxwell's equations, fiber couplers and fiber grating
Week 10 Photodetectors and optical receivers, avalanche photodiode, photodetector noise,
structure of InGaAs APD
Week 11 Digital signal transmission, digital receiver
Week 12 Optical networks and WDM concepts

Week 13 Implementation of DWDM, network topologies
Week 14 SONET/SDH, waveguide routed networks, Solitons
Week 15 Optical CDMA, optical MEMS

Laboratory Assignments or Projects

The laboratory assignments/projects are based on experimental work involving the design, experimental study or implementation of a system relating to optical communications. Topics include characterization of laser diode, accusto-optic modulator (indirect modulation), free space laser communications, optical power budgeting and FDDI based optical networks. In addition simulation software and web- based educational material was used for the design and
study of optical system and optical communication links. This helped the students to create and
experiment with certain concepts which would otherwise require expensive and time consuming setup. Web-based educational material developed by Alexander N. Cartwright and others [6] for photonics engineering education at the University of Buffalo was used in this course. It is a Java based Applet project sponsored by NSF for online teaching, experimentation and research. The Applets developed so far covered include topics in Ray tracing, Gaussian beams, polarization, gain medium, cavities, modulators, light sources, quantum electronics, photonic devices and others.

LinkSIM of RSoft, Inc.[7] is used to define optical communication links and simulate them to determine their performance given various component parameters. It is used for the simulation of single channel , time division multiplexed (TDM), wavelength division multiplexed (WDM), and parallel optical bus architectures.

Following are some of the experiments which were implemented:

10 Gbps externally modulated single channel link
10 Gbps 2 channel WDM link
10 Gbps 4 channel DWDM link
Optical Soliton
Erbium doped fiber amplifier
Raman Amplifier
Mach Zehnder modulator

Conclusion

The two- course sequence in optical communications provides a solid background for designing and maintaining optical communication systems. The first course on fiber optics has been very popular since it was first introduced. It is usually taken by students from the programs in electrical engineering technology, computer science, mechanical engineering technology, photonics and telecommunications. Photonics and telecommunication programs used this course as one of the core courses for their programs. The second course is taken mainly by the students in the electrical engineering technology and photonics programs. The introduction of web-based learning and simulation software made students more interested to investigate the concepts and implement the systems, which are difficult and may require an expensive

setup. The feedback from our graduates showed that they found these courses useful in industry. These courses also helped them enhance their career options and enabled them to enter the work-force of the optical communication industry. Future plans include updating the labs and introduce equipment in the area of optical amplifiers, optical networking and switching.

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Biography

SALAHUDDIN QAZI holds a Ph.D. degree in electrical engineering from the University of Technology, Loughborough, England, U.K. and is a Professor in the School of Information Systems and Engineering Technology at the State University of New York Institute of Technology, Utica, New York. He teaches and conducts research in the area of fiber optics, optical communications and wireless communications. He has helped develop and coordinate an undergraduate program in Photonics and a graduate program in Advanced Technology. He is a senior member of IEEE. and a member of American Society of Engineering Education.