GUJARAT TECHNOLOGICAL UNIVERSITY

ELECTRONICS & COMMUNICATION (COMMUNICATION SYSTEMS ENGG) (05)

FIBER OPTIC COMMUNICATION

SUBJECT CODE: 2710503

SEMESTER: I

Type of course: Core - II

Prerequisite: Semiconductor Physics, Electromagnetic, Mode theory of waveguide

Rationale: To introduce the students to various optical fiber modes, configurations and various signal degradation factors associated with optical fiber and to study about various optical sources and optical detectors and their use in the optical communication system.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks		Practical Marks				
				ESE (E)	PA (M)	PA (V)		PA (I)		
						ESE	OEP	PA	RP	
4	2#	2	6	70	30	20	10	10	10	150

Content:

Sr. No.	Topics	Teaching Hrs.	Module Weightage
1	**Optical Wave Guides:** Light propagation in a linear dielectric media, Cylindrical wave guide, Boundary conditions, Cut-off frequencies, Modes, Linearly Polarized Modes, Single Mode & Multi Mode fibers, Step index Fiber, Index profiles, Graded Index Fiber. Comparison of Optical fibers with other interconnects Types and classification of optical fibers.	5	5
2	**Signal degradation in Optical Fibers:** Fiber Attenuation, Absorption losses, Scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in communication link, Nonlinearities, Importance of Nonlinear Effects, Self-Phase Modulation, Cross Phase Modulation	4	15
3	**Dispersion Management** Need for Dispersion Management , Pre-compensation Schemes , Post-compensation Schemes, Dispersion-Compensating Fibers , Fiber Bragg Gratings, Optical Phase Conjugation , Broadband Dispersion Compensation , Tunable Dispersion Compensation, PMD Compensation	5	10
4	**Fiber Optic Components:** Couplers , Conservation of Energy , Isolators and Circulators , Multiplexers and Filters , Bragg Gratings , Fabry-Perot Filters , Multilayer Dielectric Thin-Film Filters, Mach-Zehnder Interferometers, Arrayed Waveguide Grating, Optical Switches, Wavelength Converters .,Four waves mixing	4	10
5	**Optical Transmitters** LED & Laser Diodes, Direct Band gap materials, Population Inversion	4	10

	in Laser Diodes, Gain guided – index guided LDs,DFB/DBR lasers, Quantum lasers, , Tunable Semiconductor Lasers, Vertical-Cavity Surface-Emitting Lasers , Transmitter Design.		
6	**Optical Amplifiers** Basic Concepts ,Semi-conductor Optical Amplifiers ,Amplifier Design , Pulse Amplification, System Applications , Raman Amplifiers , Amplifier Characteristics , Amplifier Performance, Erbium-Doped Fiber Amplifiers , Gain Spectrum , Amplifier Noise, Multichannel Amplification, Distributed-Gain Amplifiers , System Applications	6	10
7	**Optical Receivers** Basic Concepts, PIN Photodiodes, Avalanche Photodiodes, Receiver Design , Noise Mechanisms , PIN Receivers ,APD Receivers , Receiver Sensitivity , Bit-Error Rate, Minimum Received Power, Sensitivity Degradation Coherent optical detection	5	10
8	**Optical Fiber Link:** Fiber-optic communication system requirements, Link Design, Link Loss Budget - Power budget and time budget. BER Optical Power Penalties, Link Budget Analysis	4	5
9	**Multichannel Systems** WDM Light wave Systems , High-Capacity Point-to-Point Links , WDM Transmitters and Receivers , System Performance Issues	2	5
10	**WDM Network Elements and network design** Optical Line Terminals, Optical Line Amplifiers, Optical Add/Drop Multiplexers, OADM Architectures, Reconfigurable OADMs, Optical Cross connects, All-Optical OXC Configurations,Cost Trade-Offs: A Detailed Ring Network Example, LTD and RWA Problems, Dimensioning Wavelength-Routing Networks, Statistical Dimensioning Models, Maximum Load Dimensioning Models	6	10
11	**OPTICAL NETWORKS:** Network Topologies - FDDI Networks: - Frame and Token formats - Network operation. SONET/SDH: - Optical specifications - SONET frame structure - SONET layers - SONET/SDH networks. – Optical Network Survivability -Basic Concepts, Protection in SO N E T / S D H, Protection schemes	5	10

Reference Books:

1. Senior J., Optical fiber communications, Principles and Practice, PHI.
2. Keiser G., Optical fiber communications, McGraw-Hill.
3. Fiber Optic Communication systems by Govind P. Agrawal, A John Wiley & Sons, Inc., Publication.
4. Optical Networks: A Practical Perspective by Rajiv Ramaswami and Kumar N. Sivarajan, Elsevier Publication.
5. Nonlinear fiber optics by Govind P. Agrawal, Academic Press.
6. D. K. Mynbaev, Fiber Optic Communications Technology, PEARSON

Course Outcome:

1. To comprehend the basic elements of optical fiber transmission link, fiber modes and structure configurations.
2. To visualize the significance of the different kind of losses, signal distortion in optical wave guides , signal degradation factors and dispersion management techniques in optical system performance.
3. To compare the various optical source materials, LED structures, quantum efficiency as well as structures and figure of merit of Laser diodes.

4. To analyze the fiber optical receivers such as PIN APD diodes with noise performance , receiver operation and configuration.
5. To analyze and integrate fiber optical network components in variety of networking schemes, FDDI, SONET/ SDH and operational principles WDM.
6. To analyze the system performance of optical transmitters,,receivers and optical amplifiers.
7. To analyze and deign optical fiber link with encapsulation of different system components

List of Experiments:

1. To study the basic structure and types of the optical fiber.
2. To measure the numerical aperture (NA) of the fiber optical cables.
3. To set up Analog/Digital Optical Communication Link.
4. To observe the attenuation & coupling loss in optical fiber.
5. To measure the optical power emitted by the LED.
6. Measurement of attenuation characteristics of an optical fiber.
7. To measure
   a) NA of a multimode fiber.
   b) Mode field diameter of a single mode fiber.
   c) Dispersion of optical fiber.
8. To observe and analyze the effect of
   a) PAM on fiber optic link
   b) PWM on fiber optic link
   c) PPM on fiber optic link
9. To measure attenuation with OTDR.
10. To study the Data quality with EYE PATTERN.
11. To perform TDM on fiber optic link.
12. To set up of voice link on Optical communication Link.
13. To check characteristics of E-O Converter using OPM.
14. To check characteristics of the optical detectors.
15. To simulate the performance of passive optical components and link budget.

Open Ended Problems:

Open ended Problem:

1) A graded index fiber with a core axis refractive index of 1.5 has a characteristic index profile of 1.90, a relative refractive index difference of 1.3 % and a core diameter of 40 μm and determines the cutoff value of the normalized frequency for single mode transmission in the fiber.
2) A single mode step index fiber has a core and cladding refractive indices of 1.498 & 1.495 respectively. Determine the core diameter required for the fiber to permit its operation over the wavelength range 1.48 to 1.60 μm. Calculate the new fiber core diameter to enable single mode transmission at a wavelength of 1.30 μm.
3) A 15 km optical fiber link used fiber with a loss of 1.5 dB/km. The fiber is joined every km with connectors which give an attenuation of 0.8 dB each. Determine the minimum mean optical power which must be launched in to the fiber in order to maintain mean optical power level of 0.3 μW at the detector.
4) An 11 km optical fiber link consisting of optimum near parabolic profile graded index fiber exhibits rms intermodal pulse broadening of 346 ps over its length. If the fiber has a relative refractive index difference of 1.5 %, estimate the core axis refractive index. Hence determine the numerical aperture for the fiber.
5) Given the following parameters for single mode step index fiber with a fusion splice, estimate a) the fiber core diameter b) numerical aperture for the fiber

Fiber normalized frequency = 1.9
Fiber core refractive index=1.46
Splice lateral offset=0.5 μm
Splice lateral offset loss=0.05 dB
Splice angular misalignment=0.3˚
Splice angular misalignment loss= 0.04 dB

6) A gallium arsenide injection LASER with a cavity of length of 500 μm has a loss coefficient of 20 cm^{-1}. The measured differential external quantum efficiency of the device is 45%. Calculate the internal quantum efficiency of the LASER. The refractive index of gallium arsenide is 3.6.
7) Estimate the external power efficiency of gallium arsenide planner LED when a transmission factor of gallium arsenide air interface is 0.68 and the internally generated optical power is 30% of the electrical power supply. The refractive index of gallium arsenide may be taken as 3.6.
8) APD with multiplication factor of 20 operates at a wavelength of 1.5 μm. Calculate the quantum efficiency and the output photo current from the device if its responsivity at this wavelength is 0.6 A/W and 10^{10} photons of wavelength of 1.5 μm are incident upon it per second.
9) An analog optical fiber system employs an LED which emits 3 dBm mean optical power in to air. However a coupling loss of 17.5 dB is encounter when launching in to a fiber cable the fiber cable which extends for 6 km without repeaters exhibits a loss of 5 dB/km. It is spliced every 1.5 km with an average loss of 1.1 dB per splice. In addition there is a connector loss at the receiver of 0.8 dB. The PIN FET receiver has a sensitivity of -54 dBm at the operating bandwidth of a system. Assuming there is no dispersion equalization penalty, perform an optical power budget for the system and establish a safety margin.
10) A 2 X 2 wave guide coupler has k= 0.4 mm-1, α= 0.06 mm-1 and Δβ=0. How long should it be to make a 3 dB power divider? If that length is double, what fraction of input power imerges from second channel?

Major Equipments: Fiber Optical Trainer Kit, Laser Source, Photo Detector, Optical Power Meter, OTDR,WDM trainer setup, splicing and connectorization kits.

List of Open Source Software/learning website:

- http://www.cdeep.iitb.ac.in/nptel/Electrical%20&%20Comm%20Engg/Optical%20Communication/Course%20Objective.htm
- http://www.journals.elsevier.com/optics-communications/
- http://www.redbooks.ibm.com/redbooks/pdfs/sg245230.pdf