MOHAMED SATHAK AJ COLLEGE OF ENGINEERING ENGINEERING COLLEGE

DEPARTMENT OF ELECTRONICS & COMMUNICAITON ENGINEERING

EC8751 – OPTICAL COMMUNICATION

IV YEAR, VII SEM

By

Dr.M.SIVAKUMAR

Associate Professor/ECE

MSAJCE

Syllabus

EC8751 OPTICAL COMMUNICATION L T P C 3 0 0 3

OBJECTIVES:

- To study about the various optical fiber modes, configuration and transmission characteristics of optical fibers.
- To learn about the various optical sources, detectors and transmission techniques.
- To explore various idea about optical fiber measurements and various coupling techniques.
- To enrich the knowledge about optical communication systems and networks.

UNITI INTRODUCTION TO OPTICAL FIBERS 9

Introduction-general optical fiber communication system- basic optical laws and definitionsoptical modes and configurations-mode analysis for optical propagation through fiber modes in planar wave guide-modes in cylindrical optical fiber-transverse electric and transverse magnetic modes- fiber materials-fiber fabrication techniques-fiber optic cables-classification of optical fiber-single mode fiber-graded index fiber.

UNITII TRANSMISSION CHARACTERISTIC OF OPTICAL FIBER 9

Attenuation-absorption-scattering losses-bending losses-core and cladding losses-signal dispersion –inter symbol interference and bandwidth-intra model dispersion-material dispersion-waveguide dispersion-polarization mode dispersion-intermodal dispersion, dispersion optimization of single mode fiber-characteristics of single mode fiber-R-I Profile- cutoff wave length-dispersion calculation-mode field diameter.

UNITIII OPTICAL SOURCES AND DETECTORS 9

Sources: Intrinsic and extrinsic material-direct and indirect band gaps-LED-LED structuressurface emitting LED-Edge emitting LED-quantum efficiency and LED power-light source materials-modulation of LED-LASER diodes-modes and threshold conditions-Rate equations-external quantum efficiency-resonant frequencies-structures and radiation patterns-single mode laser-external modulation-temperature effort.

Detectors: PIN photo detector-Avalanche photo diodes-Photo detector noise-noise sources-SNR-detector response time-Avalanche multiplication noise-temperature effects-comparisons of photo detectors.

UNITIV OPTICAL RECEIVER, MEASUREMENTS AND COUPLING 9

Fundamental receiver operation-preamplifiers-digital signal transmission-error sources-Front end amplifiers-digital receiver performance-probability of error-receiver sensitivity-quantum limit. Optical power measurement-attenuation measurement-dispersion measurement- Fiber Numerical Aperture Measurements- Fiber cut- off Wave length Measurements- Fiber diameter measurements-Source to Fiber Power Launching-Lensing Schemes for Coupling Management-Fiber to Fiber Joints-LED Coupling to Single Mode Fibers-Fiber Splicing-Optical Fiber connectors.

UNITV OPTICAL COMMUNICATION SYSTEMS AND NETWORKS 9

System design consideration Point – to –Point link design –Link power budget –rise time budget, WDM –Passive DWDM Components-Elements of optical networks-SONET/SDHOptical Interfaces-SONET/SDH Rings and Networks-High speed light wave Links-OADM configuration-Optical ETHERNET-Soliton.

TOTAL: 45 PERIODS

OUTCOMES:

At the end of the course, the student should be able to:

- Realize basic elements in optical fibers, different modes and configurations.
- Analyze the transmission characteristics associated with dispersion and polarization techniques.
- Design optical sources and detectors with their use in optical communication system.
- Construct fiber optic receiver systems, measurements and coupling techniques.
- Design optical communication systems and its networks.

TEXT BOOKS:

1. P Chakrabarti, "Optical Fiber Communication", McGraw Hill Education (India)Private Limited, 2016 (UNIT I, II, III)
2. Gred Keiser, "Optical Fiber Communication", McGraw Hill Education (India) Private Limited. Fifth Edition, Reprint 2013. (UNIT I, IV, V)

REFERENCES:

1. John M.Senior, Optical fiber communication, Pearson Education, second edition.2007.
2. Rajiv Ramaswami, Optical Networks, Second Edition, Elsevier, 2004.
3. J.Gower, Optical Communication System, Prentice Hall of India, 2001.
4. Govind P. Agrawal, Fiber- Optic communication systems, third edition, John Wiley & sons, 2004.

UNIT I - INTRODUCTION TO OPTICAL FIBERS			
Introduction-general optical fiber communication system- basic optical laws and definitions optical modes and configurations-mode analysis for optical propagation through fiber modes in planar wave guide-modes in cylindrical optical fiber-transverse electric and transverse magnetic modes- fiber materials-fiber fabrication techniques-fiber optic cables-classification of optical fiber-single mode fiber-graded index fiber.			
PART-A			
Q. No	**Questions**	**BT Level**	**Domain**
1.	State the reasons to opt for optical fiber communication.	BTL 1	Remembering
2.	Summarize the conditions for light to be propagation inside a fiber.	BTL 2	Understanding
3.	Express Snell's Law.	BTL 2	Understanding
4.	Detect why partial reflection does not suffice the propagation of light?	BTL 4	Analyzing
5.	Define modes.	BTL 1	Remembering
6.	Show the configuration of an optical fiber.	BTL 1	Remembering
7.	Write the transverse electromagnetic modes in a planar waveguide.	BTL 1	Remembering
8.	Infer Leaky Modes.	BTL 2	Understanding
9.	Draw the transverse field distributions of the lowest order transverse electric (TE_{01}) and lowest order transverse magnetic(TM_{01}).	BTL 1	Remembering
10.	List the raw materials used for glass fiber.	BTL 1	Remembering
11.	Examine the PCS fiber. Point out the advantages of this fiber over plastic fiber.	BTL 6	Creating
12.	Compose preform and invent the typical dimensions of a preform.	BTL 6	Creating
13.	Mention the reason of sintering is not needed in plasma chemical vapor deposition.	BTL 2	Understanding
14.	Evaluate the two basic fiber optic cable structures.	BTL 5	Evaluating
15.	Examine the cross sectional view of secondary coated fiber stranded around a central strength member.	BTL 4	Analyzing
16.	Classify the fibers based on index of refraction and modes.	BTL 3	Applying
17.	A single mode fiber operating at $1330 mm$ has a modal birefringence of 1.5×10^{-5}. Measure the fiber beat length.	BTL 4	Analyzing

18.	A manufacturing Engineer wants to make an optical fiber that has a core index of 1.480 and cladding index of 1.478. Identify the core size for single mode operation at 1550nm.	BTL 3	Applying
19.	Discover the characteristics of graded index fiber.	BTL 3	Applying
20.	Determine the Numerical aperture of graded-index fibers.	BTL 5	Evaluating
PART-B			
1.	Label a neat block diagram and explain the fundamental blocks of optical fiber communication.(13)	BTL 1	Remembering
2.	Show the ray theory transmission behind the optical fiber communication with a special mention about the reflection, refraction, total internal reflection, Snell's law, critical angle, phase-shift in total internal reflection and Goos-Hänchen shift. (13)	BTL 3	Applying
3.	(i) Examine the fiber configurations of Step-Index (SI) and Graded Index (GI) Fibers with appropriate diagrams.(9) (ii) Explore the bound or guided modes in cylindrical optical fibers. (4)	BTL 4	Analyzing
4.	(i) Give the main idea of a single mode and multimode fibers with neat diagrams.(10) (ii) Outline the cladding modes in cylindrical optical fibers. (3)	BTL 2	Understanding
5.	Describe the following (i) Meridional and skew rays. (4) (ii) Numerical aperture (NA) and acceptance angle for meridional rays with relevant expressions. (9)	BTL 1	Remembering
6.	(i) Propose the acceptance angle for skew rays and Numerical aperture of graded-index fibers. (7) (ii) A step-index silica fiber with a core radius much longer than the operating wavelength of light has a core refractive index of 1.50 and a cladding refractive index of 1.48. Estimate the values of a) Numerical aperture of the fiber. b) Maximum acceptance angle in air. c) Maximum acceptance angle in water having a refractive index of 1.33.(6)	BTL 6	Creating

7.	(i) Illustrate about the modes in a planar waveguide with well-ordered diagrams.(10) (ii) Summarize the concepts of leaky modes in cylindrical optical fibers. (3)	BTL 2	Understanding
8.	Analyze the wave equations for a step-index fiber and the normalized frequency or V-number for modes in cylindrical optical fibers. (13)	BTL 4	Analyzing
9.	Examine the following fiber materials in detail (i) Glass fibers.(6) (ii) Fluoride fibers.(7)	BTL 3	Applying
10.	Explain the following fiber materials. (i) Active glass fibers. (6) (ii) Chalcogenide glass fibers. (4) (iii) Plastic Clad Silica (PCS) fiber. (3)	BTL 1	Remembering
11.	(i) Interpret the fiber material of Plastic Optical Fiber (POF). (8) (ii)Discuss the Plasma Chemical Vapor Deposition (PCVD)of fiber fabrication techniques. (5)	BTL 2	Understanding
12.	Inspect the following fiber fabrication techniques with proper diagrams. (i) Outside Vapor Deposition (OVD). (8) (ii) Vapor Phase Axial Deposition (VAD). (5)	BTL 4	Analyzing
13.	List the optical fiber cables in brief with relevant figures. (13)	BTL 1	Remembering
14.	Conclude the importance of single mode fibers and birefringence in a single-mode fiber. (13)	BTL 5	Evaluating

PART-C			
1.	Evaluate the mode analysis for optical propagation through fibers with significant illustration and expressions. (15)	**BTL 5**	**Evaluating**
2.	Elaborate the following of modes in cylindrical optical fibers (i) Relationship between number of modes and V-number. (5)	**BTL 6**	**Creating**

	(ii) Linearly Polarized Modes. (10)		
3.	Demonstrate the Transverse Electric$(TE)$and Transverse Magnetic (TM)modes in cylindrical optical fibers with necessary diagram. (15)	**BTL 5**	**Evaluating**
4.	Discuss the following fiber fabrication techniques in detail with suitable figures. (i) Fiber pulling from a preform. (7) (ii) Fabrication of fiber preforms. (3) (iii) Modified Chemical Vapour Deposition (MCVD). (5)	**BTL 6**	**Creating**

UNIT II - TRANSMISSION CHARACTERISTIC OF OPTICAL FIBER			
Attenuation-absorption-scattering losses-bending losses-core and cladding losses-signal dispersion –inter symbol interference and bandwidth-intra model dispersion-material dispersion- waveguide dispersion-polarization mode dispersion-intermodal dispersion, dispersion optimization of single mode fiber-characteristics of single mode fiber-R-I Profile- cutoff wave length-dispersion calculation-mode field diameter.			
PART-A			
Q. No	**Questions**	**BT Level**	**Domain**
1.	Infer about attenuation.	**BTL 2**	**Understanding**
2.	A fiber has an attenuation of $0.5\, dB/Km$ at $1500nm$. If $1500nm$. If $0.5mW$ of optical power is initially launched into the fiber, estimate the power level after $25Km$?	**BTL 6**	**Creating**
3.	Inspect the three different mechanisms which cause absorption.	**BTL 4**	**Analyzing**
4.	How does the scattering loss occur?	**BTL 1**	**Remembering**
5.	Light is launched from an injection laser diode operating at $1.55\mu m$ to an$8\ /\ (125\mu m)$ single mode fiber. The bandwidth of the laser source is $500MHz$. The single mode fiber offers an average loss of $0.3\frac{dB}{km}$. Compute the values of threshold optical power for the cases of stimulated Brillouin scattering.	**BTL 5**	**Evaluating**

6.	Give note about bending losses. Mention the types of bending losses.	**BTL 1**	**Remembering**
7.	Draw and label the significance of microscopic bending.	**BTL 1**	**Remembering**
8.	State the causes of dispersion.	**BTL 1**	**Remembering**
9.	Rephrase the bandwidth of RZ and NRZ in a fiber.	**BTL 2**	**Understanding**
10.	Explain chromatic dispersion.	**BTL 2**	**Understanding**
11.	Outline the Zero-material dispersion	**BTL 2**	**Understanding**
12.	Interpret waveguide dispersion.	**BTL 3**	**Applying**
13.	Define polarization mode dispersion and write the expression for it.	**BTL 3**	**Applying**
14.	Explore the expression for the delay difference responsible for intermodal dispersion.	**BTL 3**	**Applying**
15.	Analyze the parameters used in the design optimization of single mode fiber.	**BTL 4**	**Analyzing**
16.	Justify the attributes of single mode fibers.	**BTL 4**	**Analyzing**
17.	Brief about depressed cladding fibers.	**BTL 1**	**Remembering**
18.	Recall the effective cut off wavelength in a fiber.	**BTL 1**	**Remembering**
19.	Explain dispersion shifted fiber.	**BTL 5**	**Evaluating**
20.	Compose mode field diameter.	**BTL 6**	**Creating**
PART-B			
1.	Define the following: (i) Absorption by atomic defects in the glass composition. (4) (ii) Intrinsic Absorption. (9)	**BTL 1**	**Remembering**
2.	(i) Identify the two major extrinsic absorption mechanisms and develop it. (10) (ii) Select the values of peak wavelength and loss present in glass fiber for the metal impurities Fe^{2+}, Cu^{2+} and Ni^{2+}. (3)	**BTL 3**	**Applying**
3.	List in detail about the linear scattering losses that occur in an optical fiber with relevant diagrams and expressions. (13)	**BTL 1**	**Remembering**
4.	Inspect the non-linear scattering losses in a fiber and examine the Stimulated Brillouin Scattering and Stimulated Raman Scattering. (13)	**BTL 4**	**Analyzing**
5.	(i) Explain the bending losses of an optical fiber with appropriate diagrams. (8)	**BTL 4**	**Analyzing**

	(ii) With suitable expressions point out the Core-Cladding Loss. (5)		
6.	Conclude the Inter symbol Interference and Bandwidth in an optical fiber. (13)	**BTL 5**	**Evaluating**
7.	(i) Discuss about Intramodal Dispersion. (4) (ii) A $20\ km$ long optical fiber exhibits anrms pulse broadening of $20\ ns$ due to material dispersion alone, when the power is launched from an LED operating at $850\ nm$ with a spectral width of $30nm$. Estimate the material dispersion parameter of the fiber. (4) (iii) A silica fiber operating at $650\ nm$ has a core refractive index of 1.46. The photo elastic coefficient and isothermal compressibility of the silica glass are 0.3 and $7 \times 10^{-11} m^2/N$ respectively. Estimate the loss due to Rayleigh scattering in the fiber assuming the fictive temperature of glass to be $1400\ k$. (5)	**BTL 6**	**Creating**
8.	Illustrate the material and waveguide dispersion mechanisms with necessary mathematical expressions. (13)	**BTL 2**	**Understanding**
9.	Summarize the Waveguide Dispersion in a Single Mode Fiber. (13)	**BTL 2**	**Understanding**
10.	Infer the single mode fibers suffer from other two forms of dispersion and explain it. (13)	**BTL 2**	**Understanding**
11.	Show the Intermodal Dispersion and Pulse broadening in a Multimode Step-Index Fiber. (13)	**BTL 1**	**Remembering**
12.	Explore the following (i) RMS Pulse Broadening. (10) (ii) Intermodal Dispersion in a Multimode Graded-Index Fiber. (3)	**BTL 3**	**Applying**
13.	Analyze the Optimum Refractive-Index Profile of a Graded-Index Fiber. (13)	**BTL 4**	**Analyzing**
14.	Examine the following characteristics of single mode fibers (i) Refractive-Index profiles. (5) (ii) Cutoff Wavelength. (3) (iii) Dispersion calculation. (5)	**BTL 1**	**Remembering**

PART-C			
1.	(i) Compose attenuation and formulate the attenuation units in an optical fiber. (3) (ii) When the mean optical power launched into an $8km$ length of fiber is $120\,\mu W$, the mean optical power at the fiber output is $3\,\mu W$. Estimate: a) The overall signal attenuation or loss in decibels through the fiber assuming there are no connectors or splices. b) The signal attenuation per kilometre for the fiber. c) The overall signal attenuation for a $10\,km$ optical link using the same fiber with splices at $1km$ intervals, each giving an attenuation of $1dB$. d) The numerical input and output power ratio in (c). (8) (iii) $150\,\mu W$ Optical power is launched at the input of a $10\,km$ long optical fiber link operating at $850\,nm$. The output power available is $5\mu W$. Estimate the total attenuation in dB over the link length neglecting all connector and splice losses. Evaluate the average attenuation per km? (4)	BTL 5	Evaluating
2.	(i) **A** $\frac{50}{125}mm$ GI fiber with a parabolic index profile has a core refractive index of 1.458 at the centre of the core and a relative index deviation of $\Delta = 0.01$. Estimate the number of modes supported by the fiber at $850\,nm$. The fiber is now uniformly bent with a radius of curvature of $2cm$. Estimate the expected number of modes to be radiated out due to bending of the fiber. (10) (ii) A $\frac{62.5}{125}mm$ step-index fiber has a core and cladding refractive index values of 1.50 and 1.48 respectively at a wavelength of operation of $1330\,nm$.Design the value of the critical radius of curvature from the view point of macro-bending loss. (5)	BTL 6	Creating
3.	Explain the various design techniques for tailoring the dispersion optimization of single mode fibers.	BTL 5	Evaluating

	(i) Dispersion-Shifted and Dispersion-Flattened Fibers (6) (ii) Dispersion-flattened Fiber (DFF) (5) (iii) Polarization Maintaining Fibers. (4)		
4.	(i) A multimode step-index fiber has a numerical aperture of 0.22 and a core refractive index of 1.458. The fiber exhibits an overall intramodal dispersion of $200\, pskm^{-1}$. Compute overall value of the rms pulse broadening per kilometre of the fiber when the LED source operating at $850nm$ has an rms spectral width of $40nm$. Estimate the bandwidth of a $n_1 = 10km$ link based on this fiber. (5) (ii) Develop the Mode-Field Diameter with necessary diagrams and expressions. (10)	**BTL 6**	**Creating**

UNIT III - OPTICAL SOURCES AND DETECTORS

Sources: Intrinsic and extrinsic material-direct and indirect band gaps-LED-LED structures surface emitting LED-Edge emitting LED-quantum efficiency and LED power-light source materials-modulation of LED-LASER diodes-modes and threshold conditions-Rate equations-external quantum efficiency-resonant frequencies-structures and radiation patterns-single mode laser-external modulation-temperature effort. *Detectors:* PIN photo detector-Avalanche photo diodes-Photo detector noise-noise sources-SNR-detector response time-Avalanche multiplication noise-temperature effects -comparisons of photo detectors.

PART-A

Q.No	Questions	BT Level	Domain
1	Show that the indirect band gap material is preferred for optical sources?	BTL 3	Applying
2	Evaluate the peak emission wavelength of an LED that uses Al $_{0.11}$GA$_{0.89}$ AS as active region.	BTL 5	Evaluating
3	Define internal quantum efficiency of LED.	BTL 1	Remembering
4	What is meant by hetero junction? Give it advantages?	BTL 1	Remembering
5	The carrier recombination life time for an LED is 10ns.Estimate the optical bandwidth of the LED.	BTL 6	Creating
6	Why silicon is not used to fabricate LED or Laser diodes?	BTL 1	Remembering
7	Mention the various types of LED structures.	BTL 1	Remembering

8	State the mechanisms behind the lasing action.	BTL 1	Remembering
9	Give the expression for laser diode rate equation.	BTL 2	Understanding
10	Solve for reflectivity's of the mirror, if A Fabry-Perot cavity resonator has uncoated facets working as mirrors. The cavity refractive index is 3.7 and the surrounding medium is air.	BTL 6	Creating
11	Differentiate the optical sources LED and Laser.	BTL 4	Analyzing
12	A FP injection laser diode operating at 850 nm and has cavity 20μm. Determine the divergence angle of emitted beam in lateral and transverse direction of the cavity assuming the thickness of active region is 2μm.	BTL 5	Evaluating
13	Classify the Laser structures.	BTL 4	Analyzing
14	List the advantages of pin photodiodes.	BTL 1	Remembering
15	Point out the drawbacks of avalanche photodiode?	BTL 2	Understanding
16	Illustrate the factors that determine the response time of the photodiode.	BTL 2	Understanding
17	Identify the noise sources in photodiode.	BTL 3	Applying
18	Calculate the photo generated current. Photons of energy 1.53×10^{-19} J are incident on a photodiode which has the responsivity of 0.65 A/W. if the optical power level is 10μW.	BTL 3	Applying
19	Describe the term responsivity and quantum efficiency of photodiode.	BTL 2	Understanding
20	Compare any two parameters of Si, Ge, InGaAs pin and avalanche photodiodes	BTL 4	Analyzing

PART-B

1	(i)	What are direct band gap and indirect band gap semiconductors with necessary diagrams? (7)	BTL 1	Remembering
	(ii)	Select the appropriate materials used for preparation of LED. (6)		
2		With diagram, explain surface and edge emitters of LED structures (13)	BTL 1	Remembering
3	(i)	Derive the expression for internal quantum efficiency and the internal power generated in the LED. (7)	BTL 2	Understanding
	(ii)	A double hetero junction InGaAsP LED emitting at a peak wavelength of 1310 nm has radiative and non-radiative recombination times of 30 and 100 ns resp. The drive current of 40mA. Find bulk recombination time, the internal quantum efficiency, internal power level. (6)		

4	Express about external quantum efficiency and the external power generated in the LED with necessary equation. (13)		BTL 2	Understanding
5	(i)	Propose the concept of modulation in an LED. (3)	BTL 6	Creating
	(ii)	The minority carrier recombination life time for an LED is 5ns.when a constant d.c current is applied to the device the optical power is 300µW. Calculate the optical output power when the device is modulated with an rms drive current corresponding to the d.c drive current at frequencies of (a) 20 MHz (b) 100MHz. Further determine the 3dB optical bandwidth for the device and estimate the 3dB electrical bandwidth assuming gaussian response (10)		
6	(i)	Construct the Fabry-Perot resonator cavity laser diode with necessary diagram also Derive the threshold condition for lasing. (8)	BTL 3	Applying
	(ii)	A Fabry-Perot laser diode with a 400µm long cavity uses GaAs as the material in the active region with uncoated facets. The cavity offers an average loss of 1000 m^{-1} at the operating wavelength. Find the value of the threshold gain assuming the refractive index of GaAs to be 3.6. (5)		
7	(i)	Determine the expression for Laser diode rate equation (8)	BTL 2	Understanding
	(ii)	A given GaAlAs laser diode has an optical cavity length of 300µm and 100µm width. At a normal operating temperature, the gain factor β= $21x10^{-3}Acm^{3}$ and loss coefficient α = 10 cm^{-1}. Assume the reflectivity is R1=R2=R=0.32 for each end face. What is the threshold current density and threshold current for the device. (5)		
8	Classify the various structures of laser diode and its radiation pattern with neat diagram. (13)		BTL 4	Analyzing
9	(i)	Demonstrate double heterostructure laser diode with energy band diagram and refractive index profile. (8)	BTL 3	Applying
	(ii)	A double heterostructure laser diode operating at 0.87µm has an active layer thickness of 0.2µm. The refractive index of active region is 3.59 and that the confining region is 3.25.Estimate the optical confining factor (5)		

10	(i)	Compute the expression for resonant frequency in laser diode. (8)	BTL 3	Applying
	(ii)	A GaAs laser operating at 850nm has a 500μm length and refractive index n=3.7.find the following a) Frequency spacing b) Wavelength spacing c) Number of modes (5)		
11	(i)	Justify how lasing occurs in Lasers with the help of population inversion and optical feedback. (6)	BTL 4	Analyzing
	(ii)	Compare the DFB, DBR and DR laser structures with built in frequency selective resonator gratings. (7)		
12	(i)	Explain the working principle of p-i-n photodiode with a neat diagram. (10)	BTL 1	Remembering
	(ii)	Find the responsivity of p-i-n photo diode if the quantum efficiency is around 90 percent and operating wavelength is 1300nm. (3)		
13	(i)	Describe the working principle of Avalanche photodiode (10)	BTL 1	Remembering
	(ii)	A silicon avalanche photodiode has a quantum efficiency of 65 percent at a wavelength of 900 nm. Suppose 0.5μW of optical power produces a multiplied photocurrent of 10μA.what is the multiplication M? (3)		
14	Asses excess noise in APD and derive the expression for excess noise factor. (13)		BTL 5	Evaluating
Part-C				
1	Elaborate in detail about various LED structures with a neat diagram. (15)		BTL 6	Creating
2	(i)	Discriminate the electro optic phase modulator and electro absorption modulator. (7)	BTL 5	Evaluating
	(ii)	The threshold current of AlGaAs laser diode at $20^{o}C$ is 3100mA.The threshold temperature of the device is To=180K. Evaluate the percentage change in threshold current when the temperature of the device is increased to $60^{o}C$. (8)		
3	(i)	Assess the Signal -to -Noise ratio of p-i-n photo diode. (8)	BTL 5	Evaluating
	(ii)	An InGaAs pin photo diode has the following parameters at a wavelength of 1300 nm.ID=4nA, η=0.90, RL=1000 Ω and the surface		

		leakage current is negligible. The incident optical power is 300nW and the receiver bandwidth is 20MHz. Find the various noise terms of the receiver. (7)		
4	(i)	Compose the different factors that determine the response time of photo detector. (8)	BTL 6	Creating
	(ii)	In Si P-i-n photo detector, the width of i-region is 5μm and a device area is 0.5 x 10^{-7} m^2. The load resistance and input resistance of the amplifier are 1kΩ and 3kΩ resp. The input capacitance of the amplifier is 5pF. The relative permittivity of Si is11.9 and the saturation velocity of the carriers in Si is 10^5 m/s. calculate junction capacitance, bandwidth of photo detector, total resistance and capacitance and bandwidth of photo detector in absence of circuit elements. (7)		

UNIT IV- OPTICAL RECEIVER, MEASUREMENTS AND COUPLING

Fundamental receiver operation-preamplifiers-digital signal transmission-error sources-Front end amplifiers-digital receiver performance-probability of error-receiver sensitivity-quantum limit. Optical power measurement-attenuation measurement-dispersion measurement- Fiber Numerical Aperture Measurements- Fiber cut- off Wave length Measurements- Fiber diameter measurements-Source to Fiber Power Launching-Lensing Schemes for Coupling Management-Fiber to Fiber Joints-LED Coupling to Single Mode Fibers-Fiber Splicing-Optical Fiber connectors.

PART-A

Q.No	Questions	BT Level	Domain
1	Relate surface dark current with bulk dark current.	BTL 1	Remembering
2	List the error sources associated with fiber optic receiver section	BTL 1	Remembering
3	Describe the term ‘Quantum limit’	BTL 2	Understanding
4	Interpret the term ‘bit error rate’	BTL 3	Applying
5	Point out advantages of the Transimpedance amplifier.	BTL 4	Analyzing

6	What is meant by receiver sensitivity?	BTL 1	Remembering
7	Label the methods employed for measuring dispersion in optical fiber?	BTL 1	Remembering
8	State the significance of maintaining the fiber outer diameter constant.	BTL 2	Understanding
9	Demonstrate the cutback technique.	BTL 3	Applying
10	Identify some dispersion measurement techniques for optical fiber.	BTL 4	Analyzing
11	Discriminate Average power from the peak power, also suggest which power measured in digital transmission and reception.	BTL 5	Evaluating
12	An OTDR is used to measure the attenuation of a long length of fiber. If the optical power level measured by the OTDR at 8-km point is 0.5 of the measured value at the 3-km point, what is the fiber attenuation?	BTL 6	Creating
13	Define radiance and write down the expression for lambertian source.	BTL 1	Remembering
14	Mention the principal requirements of a good connector?	BTL 1	Remembering
15	Discuss some lensing scheme to improve optical source to fiber coupling efficiency	BTL 2	Understanding
16	Classify some common end face defects happen in fiber.	BTL 2	Understanding
17	An optical source with circular output pattern is closely coupled to step -index fiber that has a numerical aperture of 0.22. if the source radius Rs = 50μm and fiber core radius a=25μm,Solve for the maximum coupling efficiency from the source into the fiber?	BTL 3	Applying
18	An engineer makes a joint between two identical step-index fibers. Each fiber has a core diameter of 50μm. If the two fibers have an axial or lateral misalignment of 5μm, Inspect the insertion loss at the joint?	BTL 4	Analyzing
19	Two identical step index fibers each have a 25μm core radius and an acceptance angle of 14^{o}.Assume the two fibers are perfectly axially and angularly. Measure the insertion loss for a longitudinal seperation of 0.025mm?	BTL 5	Evaluating
20	Suppose two identical graded index fibers are misaligned with an axial offset of d= 0.3a.what is the power coupling loss between these two fibers?	BTL 6	Creating
PART-B			
1	(i) Draw the block diagram of fundamental optical receciver.Explain each block with the intermediate signals at each stage. (13)	BTL 1	Remembering

2	(i)	With Neat diagrams, explain in detail about the front end amplifiers (7)	BTL 1	Remembering
	(ii)	List out the various error sources associated with the receiver system.(6)		
3	What are the performance measures of a digital receiver? Derive an expression for bit error rate of a digital receiver. (13)		BTL1	Remembering
4	(i)	Define the term 'Quantum limit' and derive the expression for receiver sensitivity of an digital receiver. (13)	BTL1	Remembering
5	(i)	Apply cutback technique for finding the attenuation of optical fiber (8)	BTL 3	Applying
	(ii)	An engineer wants to find the attenuation at 1310 nm of a 4.95-km long fiber. The only available instrument is a photo detector, which gives an output reading in volts. Using this device in a cutback-attenuation setup, the engineer measures an output of 2.21 V from the photodiode at the far end of the fiber, After cutting the fiber 2m from the source, the output voltage from the photo detector now reads 6.58 V. what is the attenuation of the fiber in dB/km? (5)		
6	(i)	Show that the insertion loss method is better to measure the attenuation of cables. (8)	BTL 3	Applying
	(ii)	Evaluate the insertion loss of the device, when the power at the photo detector prior to inserting filter is P_1= 0.51mW and power level with the optical filter in the link P_2=0.43mW. (5)		
7	With suitable diagrams Analyze the cut off wavelength mesaurements of a fiber. (13)		BTL 4	Analyzing
8	(i)	With a typical experimental arrangement, brief the measurement process of diameter of the fiber. (8)	BTL 6	Creating
	(ii)	The shadow method is used for the on-line measurement of the outer diameter of an optical fiber. The apparatus employs a rotating mirror with an angular velocity of 4 rad s^{-1} which is located 10 cm from the photo detector. At a particular instant in time a shadow pulse of width 300μs is registered by the photo detector. Estimate the outer diameter of the optical fiber in μm at this instant in time. (5)		
9	(i)	Criticize the numerical aperture measurement of optical fiber. (10)	BTL 5	Evaluating
	(ii)	The trigonometrical measurement is performed in order to determine the		

		numerical aperture of the step index fiber. The screen is positioned 10. 0 cm from the fiber end face. When illuminated from a wide-angled visible source the measured output pattern size is 6.2 cm. Estimate the approximate numerical aperture of the fiber. (3)		
10	Compare the different types of lensing schemes used to improve the coupling efficiency and also derive the expression for it. (13)		BTL 2	Understanding
11	(i)	Classify the fiber related losses occurs in joining two fibers. Also calculate the coupling loss if the refractive index profiles of receiving and emitting fiber are 1.98 and 2.20 respectively. (10)	BTL 2	Understanding
	(ii)	Consider two step index fibers that are perfectly aligned. What is the coupling loss if the numerical aperture of receiving fiber and emitting fiber is 0.20 and 0.22 respectively. (3)		
12	Distinguish various splicing technique with necessary diagrams and also give the expression for various losses when splicing single mode fibers. (13)		BTL 4	Analyzing
13	Explain connector types; also compare the six popular fiber optic connectors with their features and applications. (13)		BTL 2	Understanding
14	(i)	Demonstrate the process of fiber end face preparation. (7)	BTL 3	Applying
	(ii)	Compute the coupling efficiency of LED power to single mode fiber. (6)		
PART-C				
1	Estimate the expression for probability of error in digital data transmission and reception. (15)		BTL 6	Creating
2	Evaluate the methods of dispersion measurements in optical fiber. (15)		BTL 5	Evaluating
3	Compare the different mechanical misalignments in fiber coupling also derive the loss expression for those misalignments. (15)		BTL 5	Evaluating
4	Develop the expression for power coupling from LED to step index and graded index fibers. (15)		BTL 6	Creating

UNIT V - OPTICAL NETWORKS AND SYSTEM TRANSMISSION			
System design consideration Point – to –Point link design –Link power budget –rise time budget, WDM –Passive DWDM Components-Elements of optical networks-SONET/SDH-Optical Interfaces-SONET/SDH Rings and Networks-High speed light wave Links-OADM configuration-Optical ETHERNET-Soliton.			
PART A			
Q.No	**Questions**	**BT Level**	**Competence**
1.	State the concept of WDM.	**BTL 1**	**Remembering**
2.	Mention any two nonlinear effects present in optical fiber.	**BTL 1**	**Remembering**
3.	Identify the drawbacks of broadcast and select networks for wide area network applications.	**BTL 1**	**Remembering**
4.	Summarize the transmission bit rate of the basic SONET frame in Mbps.	**BTL 1**	**Remembering**
5.	Outline how inter channel cross talk that occurs in a WDM system?	**BTL 1**	**Remembering**
6.	Examine the components involved to form optical network	**BTL 1**	**Remembering**
7.	List the benefits OADM.	**BTL 2**	**Understanding**
8.	Give the significance of solitons.	**BTL 2**	**Understanding**
9.	Define rise time.	**BTL 2**	**Understanding**
10.	Draw the basic structure of STS-1 SONET frame.	**BTL 2**	**Understanding**
11.	Predict the function of optical ETHERNET.	**BTL 3**	**Applying**
12.	Illustrate the key parameters required for analyzing the optical link.	**BTL 3**	**Applying**
13.	Manipulate the difference between fundamental and higher order soliton.	**BTL 3**	**Applying**
14.	Express the various SONET/SDH layers.	**BTL 4**	**Analyzing**
15.	Analyze how the speckle pattern can form?	**BTL 4**	**Analyzing**
16.	Classify the important features of time-slotted optical TDM network.	**BTL 4**	**Analyzing**
17.	Justify the features in DWDM.	**BTL 5**	**Evaluating**
18.	Conclude the advantages of using soliton signals through fiber.	**BTL 5**	**Evaluating**
19.	Develop the basic performance parameters of the WDM system.	**BTL 6**	**Creating**
20.	Propose the three topologies used for fiber optic network.	**BTL 6**	**Creating**
PART-B			
1.	Write about rise time, optical power required to establish secure link with necessary equation. (13)	**BTL 1**	**Remembering**

2.	Draw the architecture of optical network connect and explain. (13)	**BTL 1**	**Remembering**
3.	(i) Define the principle of WDM networks. (7) (ii) State the principles used in SONET. (6)	**BTL 1**	**Remembering**
4.	Explain in brief the blocks and their functions of an optical receiver with schematic diagrams. (13)	**BTL 1**	**Remembering**
5.	Discuss about protection mechanism in UPSR and BLSR ring architecture and point to point architecture with neat sketch. (13)	**BTL 2**	**Understanding**
6.	(i) Illustrate the effects of noise in optical networks. (6) (ii) Extend the perceptions of high speed light wave links. (7)	**BTL 2**	**Understanding**
7.	(i) Summarize the basic concepts of Optical Networks. (7) (ii) Express the factors considered in point to point link system. (6)	**BTL 2**	**Understanding**
8.	(i) Model the Layered architecture of SONET/SDH with neat diagram. (7) (ii) Explore about optical Ethernet and its applications. (6)	**BTL 3**	**Applying**
9.	(i) Demonstrate SONET frame structure with appropriate diagram and build the SONET Network topology. (13)	**BTL 3**	**Applying**
10.	With suitable example, analyze the conditions and constraints in the formulation and solution of routing and wavelength assignment problem in an optimal way. (13)	**BTL 4**	**Analyzing**
11.	Compare and analyze optical switching Methods. (13)	**BTL 4**	**Analyzing**
12.	Analyze the salient feature of Solitons using relevant expressions and diagrams. (13)	**BTL 4**	**Analyzing**
13.	Summarize the function of optical add / drop multiplexer (OADM). (13)	**BTL 5**	**Evaluating**
14.	Discuss the performance and features of optical ETHERNET. (13)	**BTL 6**	**Creating**
	PART–C		
1.	Elaborate the following requirements for the design of an optically amplified WDM link: (15) (a) Link Bandwidth (b) Optical power requirements for a specific BER.	**BTL 6**	**Creating**
2.	An engineer has the following components available: (15) a) GaAlAs laser diode, operating at 850 nm,fiber coupled power 0dbm b) Ten sections of cable each of which is 500 m long, has 4dB/km attenuation has connectors at both ends	**BTL 6**	**Creating**

	c) 2dB/connector connector loss d) A PIN photodiode receiver, -45 dBm sensitivity e) An avalanche photodiode receiver,-56dBm sensitivity The engineer wishes to construct a 5 km link operating at 20 Mb/s. Estimate which receiver should be used if a 6 dB operating margin is required.		
3.	Evaluate the optical power budget for the below system and hence determine its viability. Components are chosen for a digital optical fiber link of overall length 7Km and operating at 20Mbit s^{-1} using an RZ code. It is decided that an LED emitting at 0.85µm with graded index fiber to a p-i-n photodiode is a suitable choice for the system components, giving no dispersion-equalization penalty. An LED which is capable of launching an average of 100µW of optical power (including the connector loss) into a graded index fiber of 50µm core diameter is chosen. The proposed fiber cable has an attenuation of 2.6dBkm^{-1} and requires splicing every kilometer with a loss of 0.5dB per splice. There is also a connector loss at the receiver of 1.5dB. The receiver mean incident optical power of -41dBm in order to give the necessary BER of 10^{-10}, and it is predicted that a safety margin of 6dB will be required. (15)	**BTL 5**	**Evaluating**
4.	A 90 Mb/s NRZ data transmission system that sends two DS3 channels uses a GaAlAs laser diode that has a spectral width of 1 nm. The rise time of the laser transmitter output is 2 ns. The transmission distance is 7 km over a graded index fiber that has 800 MHz km bandwidth –distance product. If the receiver bandwidth is 90 MHz and mode mixing factor q=0.7, Justify the system rise time. What is the rise time if there is no mode mixing? (use 0.07 ns/nm-km). (15)	**BTL 5**	**Evaluating**