SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution)

S.R.M. Nagar, Kattankulathur - 603 203.

DEPARTMENT OF ELECTRONICS & COMMUNICAITON ENGINEERING

QUESTION BANK

Academic Year: 2022 – 2023 (Odd Semester)

1906702 – OPTICAL COMMUNICATION

IV YEAR, VII SEMESTER

Prepared by

1. **Dr. V. Suresh Kumar, (Sel.G)**
2. **Mr .S . MariRajan, A.P (Sr.G)**
3. **Mr. A. Pandian, A.P (Sr.G)**

Syllabus

1906702 OPTICAL COMMUNICATION L T P C 3 0 0 3

OBJECTIVES:

The student should be made:

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

UNIT – I: INTRODUCTION TO OPTICAL FIBERS 9

Introduction-General optical fiber communication system- Basic optical laws and definitions Optical modes and configurations -Mode analysis for optical propagation through fibers 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 .

UNIT – II: 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 Optimization of single mode fiber-Characteristics of single mode fiber-R-I Profile cutoff wave length-Dispersion calculation-Mode field diameter.

UNIT – III: OPTICAL SOURCES AND DETECTORS 9

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.

UNIT – IV: 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.

UNIT – V: OPTICAL COMMUNICATION SYSTEMS AND NETWORKS 9

Elements of optical networks-SONET/SDH Optical Interfaces-SONET/SDH Rings and Networks-Optical ETHERNET-Soliton.-Optical network concepts - Optical network transmission modes, layers and protocols - Wavelength routing networks - Optical switching networks - Optical network deployment - Optical Ethernet .

TOTAL PERIODS:45

OUTCOMES:

After studying this course, the student should be able to,

- Examine the basic elements in optical fibers, different modes and configurations.
- Analyse 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.
- Understand and Design communication systems and networks.

TEXT BOOKS:

1. P Chakrabarti, "Optical Fiber Communication", McGraw Hill Education (India) Private Limited, 2016.
2. Gerd Keiser, "Optical Fiber Communication", McGraw Hill Education (India) Private Limited. Fifth Edition, Reprint 2013.
3. J.Senior, "Optical Communication, Principles and Practice", Prentice Hall of India, 3rd Edition, 2008.

REFERENCE BOOKS:

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.

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 fibers 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.	Draw the basic block diagram of an optical fiber communication system.	BTL 4	Analyzing
2.	State the reasons to opt for optical fiber communication.	BTL 1	Remembering
3.	Summarize the conditions for light to be propagation inside a fiber.	BTL 2	Understanding
4.	State the Snell's Law.	BTL 2	Understanding
5.	Detect why partial reflection does not suffice the propagation of light?	BTL 4	Analyzing
6.	List out the outdoor fiber optic cables.	BTL 1	Remembering
7.	The refractive indices of the core and cladding of a silica fiber are 1.48 and 1.46 respectively. Find the acceptance angle for the fiber.	BTL 3	Applying
8.	Show the configuration of an optical fiber.	BTL 1	Remembering
9.	Write the transverse electromagnetic modes in a planar waveguide.	BTL 1	Remembering
10.	Infer fiber optical leaky modes.	BTL 2	Understanding
11.	Assume that there is a glass rod of refractive index 1.5, surrounded by air. Find the critical incident angle.	BTL 3	Applying
12.	What is the Meridonial rays?	BTL 1	Remembering
13.	Draw the transverse field distributions of the lowest order transverse electric (TE_{01}) and lowest order transverse magnetic(TM_{01}).	BTL 1	Remembering
14.	List the raw materials used for glass fiber.	BTL 1	Remembering
15.	Brief about PCS fiber. Point out the advantages of this fiber over plastic fiber.	BTL 4	Analyzing
16.	Specify about the term preform and mention its dimensions.	BTL 4	Analyzing
17.	Mention the reason of sintering is not needed in plasma chemical	BTL 2	Understanding

	vapor deposition.		
18.	Define modes.	BTL 2	Understanding
19.	Draw the cross sectional view of secondary coated fiber stranded around a central strength member.	BTL 4	Analyzing
20.	Classify the fibers based on index of refraction and modes.	BTL 3	Applying
21.	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
22.	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 1550 nm.	BTL 3	Applying
23.	Mention the characteristics of graded index fiber.	BTL 3	Applying
24.	Determine the Numerical aperture of graded-index fibers.	BTL 3	Applying
	PART-B		
1.	Label a neat block diagram explain the blocks of a practical optical fiber communication system. (13)	BTL 1	Remembering
2.	Show the ray theory transmission behind the optical fiber communication by reflection, refraction, index of refraction, total internal reflection, Snell's law, critical angle and phase-shift in total internal reflection with neat diagrams. (13)	BTL 3	Applying
3.	(i) Explain 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) Elaborate about 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 4	Analyzing
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.	(i) A multimode step index fiber with a core diameter of 80 μm and a relative index difference of 1.5% is operating at a wavelength of 0.85 μm. If the core refractive index is 1.48, estimate: (a) the normalized frequency for the fiber; (b) the number of guided modes. (7) (ii) A graded index fiber has a core with a parabolic refractive index profile which has a diameter of 50 μm. The fiber has a numerical aperture of 0.2. Estimate the total number of guided modes propagating in the fiber when it is operating at a wavelength of 1 μm. (6)	BTL 4	Analyzing
9.	(i) A step-index fiber has an acceptance angle of 18^0 in air. The fiber has a relative refractive index of 2.5%. Estimate the value of the critical angle at the core-cladding interface of the fiber and also the numerical aperture of the fiber. (8) (ii) A silica optical fiber with a core diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and a cladding refractive index of 1.47. Determine:(a) the critical angle at the core–cladding interface; (b) the *NA* for the fiber; (c) the acceptance angle in air for the fiber. (5)	BTL 4	Analyzing

10.	Derive 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
11.	Give detailed note about the following: (i) Glass fibers. (6) (ii) Fluoride fibers. (7)	BTL 3	Applying
12.	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
13.	(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
14.	Contrast the following fiber fabrication techniques with proper diagrams. (i) Outside Vapor Deposition (OVD). (8) (ii) Vapor Phase Axial Deposition (VAD). (5)	BTL 4	Analyzing
15.	Elaborate the outdoor optical fiber cables with relevant figures. (13)	BTL 1	Remembering
16.	(i) Write the difference between indoor and outdoor fiber optic cables. (5) (ii) Explain the indoor optical fiber cables and connectors with relevant figures. (8)	BTL 3	Applying
17.	Specify the importance of single mode fibers and birefringence in a single-mode fiber. (13)	BTL 3	Applying

PART-C			
1.	Describe the mode analysis for optical propagation through fibers with significant illustration and expressions. (15)	BTL 2	Understanding
2.	Elaborate the following of modes in cylindrical optical fibers (i) Relationship between number of modes and V-number. (5) (ii) Linearly Polarized Modes. (10)	BTL 4	Analyzing

3.	Assess the Transverse Electric(TE)and Transverse Magnetic (TM)modes in cylindrical optical fiberswith necessary diagram. (15)	BTL 4	Analyzing
4.	Write in detail about the following fiber fabrication techniques with suitable figures. (i) Fiber pulling from a preform. (7) (ii) Fabrication of fiber preforms. (3) (iii) Modified Chemical Vapour Deposition (MCVD). (5)	BTL 1	Remembering
5.	(i) Explain the fiber fabrication method without involving preforms. (7) (ii) Write the advantages of optical fiber communication in detail. (8)	BTL 3	Applying

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 4	Analyzing
3.	List the different mechanisms which cause absorption.	BTL 4	Analyzing
4.	How does the scattering loss occur?	BTL 1	Remembering
5.	Define fictive temperature.	BTL 1	Remembering
6.	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	BTL 3	Applying

	stimulated Brillouin scattering.		
7.	How to reduce the Mie scattering?	BTL 4	Analyzing
8.	Why scattering losses occurs more in multimode fibers?	BTL 4	Analyzing
9.	Give note about bending losses. Mention the types of bending losses.	BTL 1	Remembering
10.	Draw and label the significance of microscopic bending.	BTL 1	Remembering
11.	State the causes of dispersion.	BTL 1	Remembering
12.	Rephrase the bandwidth of RZ and NRZ in a fiber.	BTL 2	Understanding
13.	Explain chromatic dispersion.	BTL 2	Understanding
14.	Outline the zero-material dispersion	BTL 2	Understanding
15.	Interpret waveguide dispersion.	BTL 3	Applying
16.	Define polarization mode dispersion and write the expression for it.	BTL 3	Applying
17.	Explore the expression for the delay difference responsible for intermodal dispersion.	BTL 3	Applying
18.	Mention the parameters used in the design optimization of single mode fiber.	BTL 4	Analyzing
19.	Justify the attributes of single mode fibers.	BTL 4	Analyzing
20.	Brief about depressed cladding fibers.	BTL 1	Remembering
21.	Recall the effective cut off wavelength in a fiber.	BTL 1	Remembering
22.	Explain dispersion shifted fiber.	BTL 5	Evaluating
23.	What is large effective core area fibers?	BTL 4	Analyzing
24.	Write note about mode field diameter.	BTL 3	Applying
	PART-B		
1.	Explain the following: (i) Attenuation. (4) (ii) Absorption loss by Intrinsic Absorption. (9)	BTL 1	Remembering
2.	Write in detail about the absorption loss by extrinsic absorption. (13)	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.	Specify the non-linear scattering losses in a fiber and examine the Stimulated Brillouin Scattering and Stimulated Raman Scattering. (13)	BTL 4	Analyzing
5.	Explain the bending losses of an optical fiber with neat diagrams. (13)	BTL 4	Analyzing
6.	(i) With suitable expressions point out the Core-Cladding Loss. (5) (ii) Two step index fibers exhibit the following parameters: (8) (a) A multimode fiber with a core refractive index of 1.500, a relative refractive index difference of 3% and an operating wavelength of 0.82 μm; (b) An 8 μm core diameter single-mode fiber with a core refractive index the same as (a), a relative refractive index difference of 0.3% and an operating wavelength of 1.55 μm. Estimate the critical radius of curvature at which large bending losses occur in both cases.	BTL 3	Applying
7.	Contrast the relationship between Inter Symbol Interference (ISI) and Bandwidth in an optical fiber. (13)	BTL 4	Analyzing
8.	(i) Give short note about Intramodal Dispersion. (4) (ii) A $20\ km$ long optical fiber exhibits an rms 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 $30 nm$. 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 3	Applying
9.	Illustrate the material dispersion mechanisms with necessary mathematical expressions. (13)	BTL 2	Understanding
10.	With suitable mathematical expressions give a brief note about the waveguide dispersion mechanism. (13)		

11.	Outline about waveguide dispersion in a single mode fiber. (13)	BTL 2	Understanding
12.	Briefly explain the Polarization mode dispersion. (13)	BTL 2	Understanding
13.	Write about the Intermodal Dispersion and Pulse broadening in a Multimode Step-Index Fiber with necessary equations. (13)	BTL 1	Remembering
14.	Explore the following (i) RMS Pulse Broadening. (10) (ii) Intermodal Dispersion in a Multimode Graded-Index Fiber. (3)	BTL 3	Applying
15.	Show the functional characteristics of the following with respect to single mode fiber: (i) Refractive-Index profiles. (5) (ii) Cutoff Wavelength. (3) (iii) Dispersion calculation. (5)	BTL 1	Remembering
16.	(i) What is dispersion optimization of single mode fibers? (3) (ii) Explain the dispersion-shifted and dispersion-flattened fibers. (10)	BTL 1	Remembering
17.	(i) A 50 km long optical fiber link operating at 850 nm offers an average attenuation of 0.5 dB / km. An optical power of 100 μW is launched into the fiber at the input. What is the value of optical power at a distance of 30 km from the input? Also express the power in μW and in dBm. What is the output power at the end of the link? (7) (ii) Consider a 10 km optical fiber link using a multimode step-index fiber with the following parameters: Core refractive index, n_1 = 1.458; Relative index deviation Δ = 0.002. Estimate the delay time difference between the axial ray and the most oblique ray. What is the value of rms pulse broadening due to intermodal dispersion? Estimate the bandwidth and the maximum bit-rate of transmission assuming RZ formatting and neglecting intramodal dispersion. (6)	BTL 3	Applying

PART-C			
1.	(i) Elaborate 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 3	Applying
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 $2cm$. Estimatethe 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 3	Applying
3.	Explain the various design techniques for tailoring the dispersion optimization of single mode fibers.	BTL 1	Remembering

	(i) Dispersion-flattened Fiber (DFF) (9) (iii) Polarization Maintaining Fibers. (6)		
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) Discuss about Mode-Field Diameter with necessary diagrams and expressions. (10)	BTL 3	Applying
5.	Explain the optimum refractive-index profile of a graded-index fiber with relevant mathematical expressions. (15)	BTL 2	Understanding

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.	Draw the energy level diagram of P & N type semiconductor.	BTL 3	Applying
3.	Find the peak emission wavelength of an LED that uses $Al_{0.11}GA_{0.89}AS$ as active region.	BTL 3	Applying
4.	Define internal quantum efficiency of LED.	BTL 1	Remembering
5.	What is meant by hetero junction? Give it advantages?	BTL 1	Remembering
6.	The carrier recombination life time for an LED is 10ns.Estimate the optical bandwidth of the LED.	BTL 4	Analyzing

7.	Why silicon is not used to fabricate LED or Laser diodes?	BTL 1	Remembering
8.	Mention the various types of LED structures.	BTL 1	Remembering
9.	What are the several drawbacks of LED when compared to the injection lasers?	BTL 1	Remembering
10.	State the mechanisms behind the lasing action.	BTL 1	Remembering
11.	Give the expression for laser diode rate equation.	BTL 2	Understanding
12.	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 4	Analyzing
13.	Differentiate the optical sources LED and Laser.	BTL 4	Analyzing
14.	Define stimulated absorption.	BTL 2	Understanding
15.	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 4	Analyzing
16.	Classify the Laser structures.	BTL 4	Analyzing
17.	List the advantages of pin photodiodes.	BTL 1	Remembering
18.	Point out the drawbacks of avalanche photodiode?	BTL 2	Understanding
19.	Define modes of cavity.	BTL 2	Understanding
20.	Illustrate the factors that determine the response time of the photodiode.	BTL 2	Understanding
21.	Identify the noise sources in photodiode.	BTL 3	Applying
22.	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
23.	Describe the term responsivity and quantum efficiency of photodiode.	BTL 2	Understanding
24.	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? Explain it with necessary diagrams. (7)	BTL 1	Remembering

	(ii) Select the appropriate materials used for preparation of LED. (6)			
2.	Explain the N-type semiconductor and P-type semiconductor with relevant diagrams. (13)	BTL 2	Understanding
3.	(i) With a neat diagram explain the surface emitting LED. (10) (ii) What is meant by emission response time? (3)	BTL 1	Remembering
4.	Explain the working principle of Edge emitting LED with necessary diagrams. (13)	BTL 2	Understanding
5.	(i) Derive the expression for internal quantum efficiency and the internal power generated in the LED. (7) (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)	BTL 2	Understanding
6.	Express about external quantum efficiency and the external power generated in the LED with necessary equation. (13)	BTL 2	Understanding
7.	(i) Brief the concept of modulation in an LED. (3) (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)	BTL 3	Applying
8.	(i) Construct the Fabry-Perot resonator cavity laser diode with necessary diagram also Derive the threshold condition for lasing. (8) (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)	BTL 3	Applying
9.	(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 $\beta = 21 \times 10^{-3} Acm^3$ and loss coefficient $\alpha = 10\ cm^{-1}$. 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)		
10.		Classify the various structures of laser diode and its radiation pattern with neat diagram. (13)	BTL 4	Analyzing
11.	(i)	Specify the nature of 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)		
12.	(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)		
13.	(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)		
14.	(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 photodiode if the quantum efficiency is around 90 percent and operating wavelength is 1300nm. (3)		
15.	(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)		

16.	Asses excess noise in APD and derive the expression for excess noise factor. (13)		BTL 3	Applying
17.	Discuss the characteristics of a general photo detector. (13)		BTL 3	Applying
Part-C				
1.	Explain in detail about various LED structures with a neat diagram. (15)		BTL 2	Understanding
2.	(i)	Discriminate the electro optic phase modulator and electro absorption modulator. (7)	BTL 4	Analyzing
	(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 3	Applying
	(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)	Explain the different factors that determine the response time of photo detector. (8)	BTL 4	Analyzing
	(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)		
5.		Explain the photo detector and compare the photo detectors by their generic operating parameters of Si, Ge and InGaAs.	BTL 1	Remembering

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.	What is bit period T_b?	BTL 1	Remembering
2.	Define threshold level.	BTL 1	Remembering
3.	List the error sources associated with fiber optic receiver section.	BTL 1	Remembering
4.	Describe the term 'Quantum limit'.	BTL 2	Understanding
5.	Interpret the term 'bit error rate'.	BTL 3	Applying
6.	List out the different types of preamplifiers.	BTL 2	Understanding
7.	Point out advantages of the trans-impedance amplifier.	BTL 4	Analyzing
8.	What is meant by receiver sensitivity?	BTL 1	Remembering
9.	Label the methods employed for measuring dispersion in optical fiber?	BTL 1	Remembering
10.	State the significance of maintaining the fiber outer diameter constant.	BTL 2	Understanding
11.	Write short note about cutback technique.	BTL 3	Applying
12.	Identify some dispersion measurement techniques for optical fiber.	BTL 4	Analyzing
13.	Discriminate average power from the peak power, also suggest which power measured in digital transmission and reception.	BTL 5	Evaluating
14.	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 3	Applying
15.	Define radiance and write down the expression for lambertian source.	BTL 1	Remembering
16.	Mention the principal requirements of a good connector?	BTL 1	Remembering

17.	Discuss some lensing scheme to improve optical source to fiber coupling efficiency	BTL 2	Understanding
18.	Write the 3-dB optical bandwidth.	BTL 2	Understanding
19.	Classify some common end face defects happen in fiber.	BTL 2	Understanding
20.	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
21.	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
22.	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 separation of 0.025mm?	BTL 4	Analyzing
23.	Suppose two identical graded index fibers are misaligned with an axial offset of d= 0.3. What is the power coupling loss between these two fibers?	BTL 3	Applying
24.	Write the formula for the angular coupling efficiency formula.	BTL 2	Understanding

PART-B

1.		Draw the block diagram of fundamental optical receciver.Explain each block with the intermediate signals at each stage. (13)	BTL 1	Remembering
2.		List out the various error sources associated with the receiver system. (13)	BTL 2	Understanding
3.		With neat diagrams, explain in detail about the front end amplifiers. (13)	BTL 1	Remembering
4.		What are the performance measures of a digital receiver? Derive an expression for bit error rate of a digital receiver. (13)	BTL1	Remembering
5.	(i)	Explain receiver sensitivity in detail. (8)	BTL1	Remembering
	(ii)	Define the term 'Quantum limit' and derive the expression for receiver sensitivity of an digital receiver. (5)	BTL 2	Understanding
6.	(i)	Write in detail 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)		
7.	Explain the following		BTL 2	Understanding
	(i)	Power launching and coupling. (4)		
	(ii)	Source output pattern. (4)		
	(iii)	Power coupling calculations. (5)		
8.	(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)		
9.	With suitable diagrams explain cut off wavelength measurements of a fiber. (13)		BTL 4	Analyzing
10.	(i)	With a typical experimental arrangement, brief the measurement process of diameter of the fiber. (8)	BTL 3	Applying
	(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)		
11.	(i)	Describe the numerical aperture measurement of optical fiber. (10)	BTL 4	Analyzing
	(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)		

12.		Compare the different types of lensing schemes used to improve the coupling efficiency and also derive the expression for it. (13)	BTL 2	Understanding
13.	(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)		
14.		Distinguish various splicing technique with necessary diagrams and also give the expression for various losses when splicing single mode fibers. (13)	BTL 4	Analyzing
15.		Explain connector types and compare the six popular fiber optic connectors with their features and applications. (13)	BTL 2	Understanding
16.	(i)	Illustrate the process of fiber end face preparation. (7)	BTL 3	Applying
	(ii)	Compute the coupling efficiency of LED power to SM fiber. (6)		
17.	(i)	Write the fiber related losses in detail. (9)	BTL 2	Understanding
	(ii)	List the features of MU connector. (4)		
		PART-C		
1.		Explain the probability of error in digital data transmission and reception. (15)	BTL 2	Understanding
2.		Analyze the methods of dispersion measurements in optical fiber. (15)	BTL 4	Analyzing
3.		Compare the different mechanical misalignments in fiber coupling also derive the loss expression for those misalignments. (15)	BTL 3	Applying
4.		Derive the expression for power coupling from LED to step index and graded index fibers. (15)	BTL 4	Analyzing
5.	(i)	An optical fiber has a core refractive index of 1.5. Two lengths of the fiber with smooth and perpendicular (to the core axes) end faces are butted together. Assuming the fiber axes are perfectly aligned, calculate the optical loss in decibels at the joint (due to Fresnel reflection) when there is a small air gap between the fiber end faces. (4)	BTL 4	Analyzing
	(ii)	A graded index fiber has a parabolic refractive index profile ($\alpha = 2$) and		

		a core diameter of 50 μm. Estimate the insertion loss due to a 3 μm lateral misalignment at a fiber joint when there is index matching and assuming: (a) there is uniform illumination of all guided modes only. (3) (b) there is uniform illumination of all guided and leaky modes. (3)		
	(iii)	Two single-mode fibers with mode-field diameters of 9.2 μm and 8.4 μm are to be connected together. Assuming no extrinsic losses, determine the loss at the connection due to the mode-field diameter mismatch. (5)		

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 challenges involved in establishment of optical networks.	BTL 1	Remembering
4.	Summarize the transmission bit rate of the basic SONET frame in Mbps.	BTL 1	Remembering
5.	Outline about link budget in optical communication system design.	BTL 1	Remembering
6.	Brief 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.	State the various SONET/SDH layers.	BTL 4	Analyzing
15.	How the speckle pattern can form?	BTL 4	Analyzing
16.	Classify the important features of high speed light wave links.	BTL 4	Analyzing
17.	Justify the features in DWDM.	BTL 4	Analyzing
18.	Enumerate the advantages of using soliton signals through fiber.	BTL 5	Evaluating
19.	List the basic performance parameters of the WDM system.	BTL 2	Understanding
20.	Distinguish between fundamental and higher order soliton?	BTL 4	Analyzing
21.	Write the advantages of WDM approach?	BTL 2	Understanding
22.	Draw the frame format of SONET.	BTL 2	Understanding
23.	List out the benefits of SONET over SDH networks.	BTL 2	Understanding
24.	Name any two splicing techniques.	BTL 1	Remembering
	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 and explain in detail with necessary diagram.(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 WDM and DWDM in detail. (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) Exploreabout optical Ethernet and its applications. (6)	BTL 3	Applying
9.	(i) Draw and explain the SONET frame structure,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	BTL 4	Analyzing

	an optimal way. (13)		
11.	Explore the concept of OADM in detail. (13)	BTL 4	Analyzing
12.	Specify the salient feature of Solitons using relevant expressions and diagrams. (13)	BTL 1	Remembering
13.	Summarize the function of optical add / drop multiplexer (OADM). (13)	BTL 1	Remembering
14.	Analyze the performance and features of optical ETHERNET. (13)	BTL 1	Remembering
15.	Explain Basic optical Ethernet implementation of EPON/GE-PON Architecture? (13)	BTL 1	Remembering
16.	Write a detailed notes on Wide band long-haul and narrowband metro network with example? (13)	BTL 1	Remembering
17.	Describe the Optical layer and explain it along with the physical layer in terms of wavelength. (13)	BTL 2	Understanding
	PART–C		
1.	Explain following requirements for the design of an optically amplified WDM link: (a) Link Bandwidth. (8) (b) Optical power requirements for a specific BER. (7)	BTL 2	Understanding
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 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.	BTL 4	Analyzing
3.	(i) explain an optical network system, elaborate each component of the same. (10)	BTL 2	Understanding

	(ii) Enumerate the special features of high speed light wave links. (5)		
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 4	Analyzing
5.	Derive the expression for Solitons Parameters. (i) Full-Width Half-Maximum (FWHM) (8) (ii) Dispersion Length (L_{disp}) (7)	BTL 4	Analyzing