ST.ANNE'S

COLLEGE OF ENGINEERING AND TECHNOLOGY

QUESTION BANK

EC 8751 OPTICAL COMMUNICATION

UNIT – I – INTRODUCTION TO OPTICAL FIBER

PART – A

1. **State Snell's La**w. (Apr-May 2015) (R)

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

θ_1 = Incident angle θ_2 = Refracted angle

n_1 = Refractive index of medium 1

n_2 = refractive index of medium 2

2. State law of reflection. (R)

The law of reflection states that the angle of incidence is equal to the angle of reflection

3. Define Refraction. (R)

When light ray travels from medium 1 (air) to medium 2 (glass), bending of light ray may occur. This is called refraction.

4. What is critical angle? (R)

When we increase the incident angle with respect to normal, at some incident angle the refracted ray travels along the boundary or surface. Hence θ_2 becomes 90°. The angel of incidence for which the angle of refraction becomes 90° is called critical angle, $\theta_c = \sin^{-1}(n_2/n_1)$.

5. What is Total Internal Reflection?(Nov-Dec 2015) (R)

What are the conditions for light to be propagated inside a fiber? (Nov- Dec 2016) (R)

When the incident angle (θ_1) is greater than the critical angle (θ_c), the light ray is reflected back to medium-1. There will not be any light transmission (refraction) in medium-2. This is called total internal reflection.
Two necessary conditions for TIR to occur are:

i) The refractive index of first medium (n_1) must be greater than the refractive index of second one (n_2).

ii) The angle of incidence should be greater than the critical angle ($\theta_1 > \theta_c$)

6. Define Numerical Aperture. (Nov-Dec 2014, Nov-Dec 2016) (R)

Numerical aperture determines the light gathering capacity of the fiber. It is dimensionless. Its value ranges from 0 to 1. Numerical aperture is a figure of merit which represents light gathering or collecting capability of the fiber. Numerical aperture for step index fiber can be calculated by the following expression.

$$NA = \sqrt{n_1^2 - n_2^2}$$

7. Define Acceptance angle. (Nov-Dec 2014) (R)

Acceptance angle if the maximum angle with which the light ray may enter into the core to be propagated along the fiber.

8. Differentiate between Mono Mode Fiber and Multimode Fiber. (U)

S.No	Mono Mode Fiber	Multi Mode Fiber
1	Only one ray passes	More than one ray passes
2	Ray passes along the axis-axial ray	MMSI – Meridional and Skew MMGI – Paraxial
3	Core diameter is small typically 10 - 12μm	Core diameter is large typically 50 - 200μm
4	Intermodal dispersion is not present	Intermodal dispersion is present
5	Fabricating single mode fiber is difficult	Fabricating multimode fiber is easy
6	Coupling efficiency is less	Coupling efficiency is large
7	LED is not suitable source for single mode	LED is suitable for multimode

10. Distinguish between Step Index fiber and Graded Index fiber. (AZ)

S.No	Step Index Fiber	Graded Index Fiber
1	The core has uniform refractive index but step change in core-cladding	The core has high refractive index along the axis which gradually decreases towards the clad-coreinterface(radially decreases)
2	Axial ray – SMSI, Meridonial rays & Skew – MMSI	Paraxial rays – MMGI
3	Intermodal dispersion is present in MMSI	Intermodal dispersion is reduced in MMGI
4	Numerical Aperture is constant	Numerical Aperture is a functional of radius
5	Step index profile	Graded index profile · - Profile factor
6	No of modes, m · $v^2 / 2$ Step index supports twice the number of modes than GI	No of modes, m · v^2 /
7	Fabrication is easy	

11. What is Meridional 8Ray?(R)

Meridonial ray is a ray which is passing through fiber axis. Merodonial rays are confined to the meridial planes of the fiber which are the planes that contain the axis of symmetry of the fiber (the core axis). They follow zig-Zag path.

12. What are Skew Rays?(R)

The rays which are not passing through the fiber axis and taking helical path during the propagation are called Skew rays.

13. What are Leaky Rays? (R)

The Leaky rays are only partially confined to the core of the circular optical fiber and attenuate as the light travels along the optical waveguide.

14. Compare Ray Optics with Wave Optics.(AZ)

S.No	Ray Optics	Wave Optics
1	It is used to represent the direction of light propagation	It is used to analyze mode theory
2	It is used to study reflection and refraction of light	It is used to analyze diffraction and Interference of light waves

15. Define Mode.(R)

Mode is the pattern of distribution of electric and magnetic fields

- Transfers Electric Mode TE_{02} ·
- Transfers Magnetic Mode TM_{02} ·

·

16.List out the ways to minimize leaky modes. (A)

A mode remains guided as long as β satisfies the condition $n_2K<\beta n_1K$.

n_1,n_2 → Refractive index of core are cladding

$K = 2\pi/\lambda$

$\beta \geq n_2K$ = To prevent power leaks out of the core.

24.For a Fibre with core refractive index of 1.54 and fractional refractive index difference of 0.01 calculate its numerical aperture. (Nov-Dec 2012) (AZ)

Given n_1 = 1.54 , · · 0.01

Numerical Aperture, $NA \cdot n_1 \sqrt{2\cdot}$

$$= 1.54\sqrt{2\cdot 0.01}$$

25.The refractive indexes of the core and cladding of a silica fiber are 1.48 and 1.46 respectively. Find the acceptance angle for the fiber. (Nov-Dec 2013 , Apr-May 2017) (AZ)

Given n_1=1.48, n_2=1.46

$$\cdot_a \cdot \sin^{\cdot 1} \cdot NA \cdot$$

26.Determine the normalized frequency at 820nm for a step index fiber having a $25 \cdot m$ radius. The refractive indexes of the cladding and the core are 1.45 and 1.47 respectively. How many propagate in this fiber at 820nm? (Nov-Dec 2013) (A)

Given n_1=1.47, n_2=1.45, $\cdot \cdot 820nm$, a=$25 \cdot m$

$$NA\ V \cdot \frac{2\cdot\ a \cdot}{\cdot}$$

$$\cdot \frac{2\cdot \cdot 25\cdot 10^{\cdot 6}}{820\cdot 10^{\cdot 9}} \cdot NA$$

$$NA \cdot \sqrt{n_1^2 \cdot n_2^2}$$

$$\bullet \sqrt{\bullet \ 1.47\bullet^{2} \bullet \ \bullet \ 1.45\bullet^{2}}$$

$$\bullet \ 0.2416$$

$$\bullet \ \frac{2\bullet \ \bullet \ 25\bullet \ 10^{\bullet 6} \bullet \ 0.2416}{820\bullet \ 10^{\bullet 9}}$$

$$V \bullet \ 46.25$$

Modes propagate at 820nm:

$$M = \frac{V^2}{2}$$

$$= \frac{(46.25)^2}{2}$$

$$= \frac{2139.0}{2}$$

$$= 1069.5$$

$$M = 1070 \text{ modes}$$

27. What are the advantages of optical fiber? (Apr-May 2017) (R)
(or) State the reasons to opt for optical fiber communication. (Apr-May 2018) (R)

i) Wider bandwidth
ii) Lower loss
iii) Light weight
iv) Smaller in size
v) Interference immunity
vi) Safety and security

28. Why partial reflection does not suffice the propagation of light?(Nov- Dec 2017) (R)

Partial reflection at the core-cladding interface does not suffice the propagation of light because at each reflection a part of the optical energy launched into the optical fiber would be lost and after a certain distance along the length of the fiber, the optical power would be negligibly low.

29. A graded index fiber has a core with a parabolic refractive index profile which has a diameter of 50μm. 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 1μm? (Nov-Dec 2017) (AZ)

Normalized frequency for the fiber is $V = \frac{2\pi a}{\lambda} NA$

$$= \frac{2\pi \times 25\times10^{-6}\times0.2}{1\times10^{-6}}$$

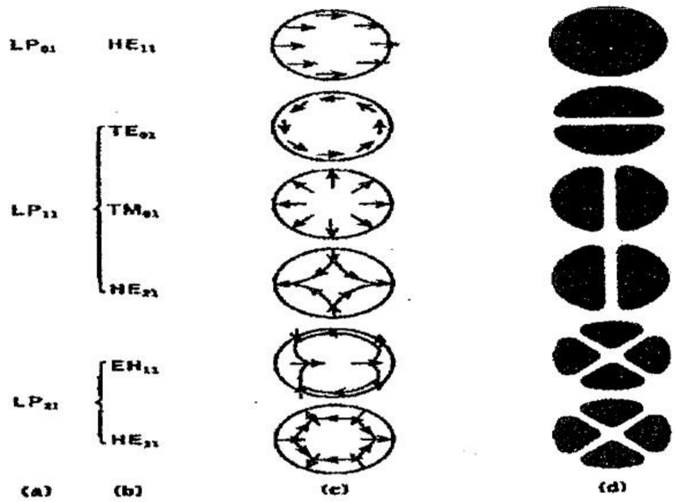
V =31.4

M = $V^2/4$

= $(31.4)^2/4$

M = 247 Modes

30. Sketch the cross sectional view of the transverse electric field vectors for the four lowest order modes in a step index fiber. (Apr-May 2018) (R)



31. Distinguish meridional rays from skew rays .(Nov-Dec 2018) (A)

Meridonial ray is a ray which is passing through fiber axis. Merodonial rays are confined to the meridial planes of the fiber which are the planes that contain the axis of symmetry of the fiber (the core axis). They follow zig-Zag path.

The rays which are not passing through the fiber axis and taking helical path during the propagation are called Skew rays.

32. A manufacturing Engineer wants to make an optical fiber that has a core index of 1.480 and cladding index of 1.478. What should be the core size for single mode operation at 1550 nm?.(Nov-Dec 2018) (A)

$$V \cdot \frac{2\cdot a}{\cdot} NA$$

$$a \cdot \frac{v\cdot \;\cdot}{2x\cdot \; xn_1 \; (2\cdot\;)^{2}} \; NA$$ = (2.405 * 1550 * 10 $^{-9}$) / (2*π*1.480 (2*0.002) $^{1/2}$)

= 6342 nm

33. What are the conditions for single mode propagation?.(Nov-Dec 2018) (R)

Core size or diameter should be small and V approximately should be equal to 2.405.

Part – B

1. i) With the help of neat block diagram explain the different

components or functional blocks of an optical fiber link. (Nov-Dec 2013, Nov-Dec 2016, Apr-May 2017, Apr-May 2018, Nov-Dec 2018) (U)

ii) Compare the optical fiber link with a satellite link. (Nov-Dec 2013) (AZ)

2. Derive an expression for Acceptance angle and Numerical Aperture of a fiber with the help of neat figure showing all the details. (Nov-Dec 2013) (AZ)

3. i) Explain the differences between meridional and skew rays. (Nov-Dec 2013) (U)

ii) Bring out the differences between phase and group velocities. (Nov-Dec 2013) (U)

4. i) Derive the mode equations for a circular fiber using maxwell's equations.(May-June 2013) (A)

ii) Calculate the NA of a fiber having n1 = 1.6 and n2 = 1.49 and another fiber having n1 = 1.448 and n2 = 1.405. Which fiber has greater acceptance angle? (May-June 2013) (AZ)

5. i) Explain the ray theory of a fiber with a special mention about TIR, Acceptance angle and NA. (May-June 2013) (U)

ii) Describe single mode fibers and their mode field diameter. What are the propagation modes in them. (May-June 2013) (U)

6. i) Starting from maxwell's equation, derive an expression for wave equation of an electromagnetic wave propagating through optical fiber.(Nov-Dec 2012) (A)

ii) Describe the ray theory behind the optical fiber communication by total internal reflection. State the application of snell's law in it. (Nov-Dec 2012) (U)

7. i) A SI fiber with silica-core refractive index of 1.458, V=75 and NA=0.3 is to be operated at 820 nm, what should be its core size and cladding refractive index? Calculate the total number of modes entering this fiber. (Nov-Dec 2012) (AZ)

ii) Derive the expression of linearly polarized modes in optical fibers and obtain the equation for V-number. (Nov-Dec 2012) (A)

8. i) Compare the structure and characteristics of step index and graded index fiber. (Nov-Dec 2016)(U)

   ii) A graded index fiber with a core with a parabolic refractive index profile (· =2) and diameter of 50μm. The fiber has numerical aperture of 0.2. Estimate the number of the guided modes propagating in the fiber when the transmitted light has a wavelength 1μm. (Nov-Dec 2016) (AZ)

9. For multi-mode step-index fibre with glass core (n_1 =1.5) and a fused quartz cladding (n_2 =1.46), determine the acceptance angle (θ_{in}) and numerical aperture. The source to fibre medium is air. (Apr-May 2015) (A)

10. Explain the ray propagation into and down an optical fibre cable. Also derive the expression for acceptance angle. (Apr-May 2015) (U)

11. Discuss briefly about the structure of graded index fiber. (Apr-May 2018) (U)

12. Contrast the advantages and disadvantages of step-index, graded- index, single-mode propagation and multi-mode propagation. (Apr-May 2015) (U)

13. Classify fibers and explain them. (Nov-Dec 2015) (U)

14. Describe and derive the modes in planar guide. (Nov-Dec 2015) (AZ)

15. Define the normalized frequency for an optical fiber and explain its use. (Nov- Dec 2014) (U)

16. Explain the features of multimode and single mode step index fiber and compose them. (Nov-Dec 2014) (U)

17. A Single mode step index fiber has a core diameter of 7μm and a core refractive index of 1.49. Estimate the shortest wavelength of light which allows single mode operation when the relative refractive index difference for fiber is 1%. (Nov-Dec 2014) (AZ)

18. A step index multimode fiber with a numerical aperture of 0.2 support approximately 1000 modes at 850 nm wavelength. What is the diameter of its core? How many modes does the fiber supports at 1550 nm? (Apr-May 2017) (AZ)

19. Find the core radius necessary for single mode operation at 1320 nm of a step index fiber with n_1 = 1.48 and n_2 = 1.478. Determine the numerical aperture and acceptance angle of this fiber. (Apr-May 2017) (AZ)

20. Explain phase shift with total internal reflection and evanescent field. (Nov- Dec 2017) (U)

21. Discuss whether TEM waves exists in a optical fiber. If not what type of mode will propagate in a practical optical fiber. (Nov-Dec 2017) (U)

22. Discuss about the mode theory of circular waveguides. (Apr-May 2017) (U)

23. A silical optical fiber with a core diameter large enough to be considered by ray theory analysis has a core refractive . (Apr-May 2018)

24. Discuss in detail the fabrication methods of Optical fibre

ASSIGNMENT QUESTIONS BASED ON BLOOM'S TAXONOMY LEVELS (BTL)

ASSIGNMENT – I

UNIT – 1 INTRODUCTION TO OPTICAL FIBERS

1. A step-index multimode fiber with a numerical aperture of 0.20 supports approximately 1000 modes at an 850-nm wavelength.
   a) What is the diameter of its core? (A)
   b) How many modes does the fiber support at 1320 nm? (A)
   c) How many modes does the fiber support at 1550 nm? (A)

2. (a) Determine the normalized frequency at 820nm for a step-index fiber having a 25μm core radius, n_1=1.48 and n_2=1.46 (A)
   (b) How many modes propagate in this fiber at 820nm? (A) (c) How many modes propagate in this fiber at 1320nm? (A) (d) How many modes propagate in this fiber at 1550nm? (A)
   (e) What percent of the optical power flows in the cladding in each case? (AZ)

3. A graded-index fiber with a parabolic index profile (α=2) has a core index n_1=1.480 and the index difference Δ=0.010
   (a) Show that the maximum value of the core radius for single-mode operation at 1310nm is 3.39μm. (AZ)
   (b) Show that the maximum value of the core radius for single-mode operation at 1550nm is 4.01μm. (AZ)

UNIT – II – TRANSMISSION CHARACTERISTICS OF OPTICAL FIBERS

PART – A

1. Define attenuation? (Nov-Dec 2017) (R)

Attenuation is a measure of decay of signal strength or loss of light power that occurs as light pulses propagate through the length of the fiber.

It is defined as the ratio of the optical output power P_{out} from a fiber of length L to the optical input power P_{in}. It is expressed as

$$\alpha_{dB/Km} = \frac{10}{L}\log\left(\frac{P_{in}}{P_{out}}\right)$$

2. A manufacturer's data sheet lists the material dispersion Dmat = 110ps/nm.km at a wavelength of 860 nm. Find the rms pulse broadening per km due to material dispersion if the optical source has a spectral width = 40 nm at an output wavelength of 860 nm. (Nov-Dec 2017) (A)

Rms pulse broadening is given by

$$\sigma_m = \frac{\sigma_\lambda L}{C}\left|\lambda \frac{d^2 n}{d\lambda^2}\right|$$

$$\sigma_m \approx \sigma_\lambda L D_{mat}$$

Hence , the rms pulse broadening per kilometer due to material dispersion is given as

$$\sigma_m(1km) = 40x1x110x10^{-12}$$

$$= 4.4 \text{ ns km}^{-1}$$

.

3. State Urbach's rule.(R)

$$\alpha_{uv} = ce^{E/E0}$$

Where, α_{uv} is fiber loss in UV region.

C & E_0 are empirical constants. E is photon Energy.

4. What is Rayleigh scattering?(May-June 2013)(R)

Rayleigh scattering is caused by inhomogenetics in the glass of a size smaller than the wavelength of light. The inhomogenetics are manifested in certain region of the fiber as refractive index variations present in the glass due to compositional fluctuations (SiO_2 and Ge_2O_3) during manufacturing.

5. Compare Rayleigh scattering and Mie scattering.(AZ)

S.No	Rayleigh Scattering	Mie Scattering
1	Caused due to refractive index in the core glass.	Caused by fiber imperfections such as variation irregularities in the core –cladding interface, core- cladding refractive index difference along the fiber length, diameter fluctuations, strains and bubbles.
2.	When the inhomegenetics size is smaller than the wavelength of light Rayleigh scattering occurs.	When the inhomegenetics size is greater than the Wavelength of light,Mie scattering Occurs
3.	Scattering occurs both is forward backward direction.	Scattering is mainly in the forward and direction.
4.	Rayleigh scattering can be reduced minimizing the compositional fluctuations by using best manufacturer methods.	Mie scattering can be reduced by by a. Removing imperfections due to the glass manufacturing process. b. Carefully controlled extrusion and coating of the fiber c. Increasing the fiber guidance by increasing the relative refractive index difference.

6. Compare Linear scattering and Non- Linear scattering.(E)

S.No	Linear Scattering	Non-Linear Scattering
1.	Linear scatterings are observed low optical power densities threshold power levels.	Non-Linear scattering are only observed only at at high optical power densities above below the the threshold power levels in long single mode fibers.
2.	There are two types are Linear Scattering namely, a. Rayleigh Scattering b. Mie Scattering	There are two types of Non-Linear scattering namely, a. Stimulated Brillouin Scattering (SBS) b. Stimulated Raman Scattering (SRS)
3.	The Incident light frequency and light frequency is the same. There is no frequency shift during scattering.	The Incident light frequency and scattered light frequency are different. There is a frequency shift during scattering.

7. Compare SRS and SBS. (AZ)

S.No	SRS	SBS
1.	SRS can occur both in forward and direction.	It is mainly backward process. backward
2.	The threshold power level of SRS is times higher than SBS threshold in a particular fiber.	The SBS threshold power level is less. three
3.	The scattering process produces frequency optical phonon.	The scattering process produces high acoustic phonon as well as a scattered photon.

8. What is Macrobending?(R)

Macrobending occurs when a fiber cable turns a corner and macroscopic bends having radius that are large compared with the fiber diameter.

9. What are Micro Bendings?(R)

Micro bending arises when the fibers are incorporated into cables.

10. What are Micro bending losses?(R)

The light power is dissipated through the microbends because if the repetitive coupling of energy between guided modes and leaky modes.

11. How will you minimize the micro bending losses?(R)

Compressible buffer jacket should be used to avoid micro bends. When external forces are applied to this jacket, the jacket will be deformed but the fiber will tend to stay relatively straight.

12. How will you minimize the Macro bending losses?(R)

To minimize Macro bending Losses, Macro bending should be smooth.

This can be achieved by,

(a) Designing Fibers with Large Relative Refractive Index differences
(b) Operating at shortest wavelength possible.

13. What are the causes of intrinsic absorption in optical fiber?(R)

The causes for intrinsic absorption in optical fiber are

(a) Intrinsic absorption in the UV region is caused by electronic absorption bands. Basically, absorption occurs when a light particle (photon) interacts with an electron and excites it to a higher energy level.

(b) The main cause of intrinsic absorption in the IR (Infrared) region is the characteristic vibration frequency of atomic bands. In silica glass, absorption is caused by vibration of silicon oxygen (Si-o) bands. The Interaction between the vibrating bond and the electromagnetic field to the bond.

14. What are the causes or extrinsic absorption in Silica Optical Fiber?(R)

(a) Extrinsic absorption is caused by impurities such as Copper, Nickel and Chromium introduced into the fiber material during manufacturing Process.

(b) It is also caused by the dissolved water (OH ion) in the fiber glass.

15. Write the expression for Critical Radius of Curvature for Macro bending of Fiber Cable? (A)

$$R_C \cdot \frac{3n_1^2}{4\cdot \left(n_1^2 \cdot n_2^2\right)^{\frac{3}{2}}}$$

Where

R_c is the critical radius of curvature for macro bending n_1 is refractive index of core
n_2 is refractive index of cladding

16. Define Dispersion?(R)

While, Light pulses are travelling along a fiber the width of the pulses are broadening. This is Called Dispersion.

17. Write the Expression for Dispersion Parameter and Unit of Fiber?(A)

Dispersion parameter, $$D \cdot \left| \frac{\cdot^2}{\cdot} \frac{d^2 \cdot}{d\cdot^2} \right| P_S\, km^{\cdot 1}\, nm^{\cdot 1}$$

18. List out the types of Dispersion?(A)

(a) Inter-Modal Dispersion

(b) Intra Modal Dispersion

(I) Material Dispersion.

(II) Wave Guide Dispersion.

19. What is Chromatic Dispersion?(R)

Dispersion is sometimes called Chromatic Dispersion to emphasize its wavelength – dependent nature or group – velocity dispersion (GVD) to emphasize the role of group velocity. Material dispersion comes from frequency – dependent response of a material to waves. (Eg) Material dispersion leads to undesired chromatic aberration in a lens on the separation of colours in a Prism.

20. What is Material dispersion? How will you minimize the Material dispersion?(U)

Definition:

Material dispersion can be desirable or undesirable effect in optical application. The Dispersion of light by glass prisms is used to construct spectro radiometers.

Material dispersion can be minimized by using

(a) Narrow spectral width light source like laser. Typically for multimode laser diode the spectral width is around (1 -2) nm and for single mode laser diode, spectral width is around 10^{-2} nm.

(b) Longer wavelength operation, since refractive index variation is small or negligible.

21. What is Waveguide dispersion? How will you minimize waveguide dispersion?(U)

Waveguide dispersion is nothing but for each mode in an optical waveguide, the term used to describe the process by which an electromagnetic signal is distorted by virtue of the dependence of the phase and group velocities on wavelength as a consequence of the geometric properties of a waveguide.

Waveguide dispersion can be minimized

(i) The index differences should be large. (ii)

Short wavelength operation.

22. Write the expression for Material Dispersion Parameters?(A)

$$D_{mat} \cdot \left(\frac{\cdot\, d^2 (n_1)}{d\cdot^2} \right) \text{ ps nm}^{-1} \text{ km}^{-1}$$

Where, λ – wavelength, n1 – Core refractive index.

23. Write the expression for Waveguide dispersion Parameters? (A)

$$D_{wg} = -\left(\frac{n_2 \Delta}{c\lambda}\right)\left(v\frac{d^2(vb)}{dv^2}\right) \text{ ps nm}^{-1}\text{km}^{-1}$$

Where, λ – wavelength
n2 – Cladding refractive index
Δ – Index difference
C – velocity of light
v – normalize frequency

24. What is meant by PMD?(Nov-Dec 2016, Apr-May 2018, Nov-Dec 2018) (R)

The light signal energy at a given wavelength in a single-mode fiber actually occupies two orthogonal polarization states or modes. Due to non- uniformity of the fiber, each polarization mode will encounter different refractive index. Hence each mode will travel at different velocity. The difference in propagation times between the two orthogonal polarization modes will result in pulse spreading. This is called as Polarization Mode Dispersion (PMD).

25. Define Intermodal Dispersion?(R)

In Multimode fiber, different modes travel along the fiber and they will reach at different time at the output end of the fiber. So, there will be a delay experienced between different modes. Because, of this delay pulse broadening occurs. This is Called Intermodal dispersion.
(Eg.) Axial ray will travel faster than Meridional ray.

26. Write the expression for Intermodal delay between Axial ray and Meridional ray?(A)

$$\delta T_s = \frac{L n_1 \Delta}{C}$$

Where, δT_s = Intermodal delay.
L = Length of fiber.
n_1 = Core refractive index.

= index difference. C

= Velocity of light.

27. What is Intramodal dispersion?(Apr-May 2017) (R)

Intramodal dispersion is pulse spreading that occurs within a single mode. It arises due to group velocity being a function of wavelength. The increasing spectral width of the optical source will increase the intramodal dispersion.

28. What is fiber Bi - refrigence?(R)

Fiber bi-refrigence is the optical property of a material having a refractive index that depends on the polarization and propagation direction of light. These optically anisotropic materials are said to be bi-refringence. The bi-refringence is often quantified by the maximum difference in the refractive index within the material.

29. Define Beat length?(R)

Beat length is defined as the period of interference effects in a bi-refringence medium. When two waves with different linear polarization states propagate in a bi-refringence medium, their phases will evolve differently. It is assumed that the polarization of each wave is along the principle directions of the medium (x – axis (or) y – axis), so that this polarization will be preserved during propagation. This means that the phase relation between both waves is restored after integer multiples called the polarization beat length.

Beat length, $L_b \cdot \frac{2\cdot}{\cdot} \cdot$

30. Define PMF (Polarization Mode Fiber)?(R)

PMF is an optical fiber in which the polarization of linearly polarized light waves launched into the fiber is maintained during propagation, with less or no cross-coupling of optical power between the polarization modes. Such fiber is used in special application where processing the polarization is essential.

31. Define insertion loss for using couple in fiber optical communication system. (R)

The insertion loss is defined as the loss obtained for a particular port to port optical path.

Insertion loss (ports 1 to 4) = $10 \log_{10} \frac{P_1}{P} dB$

32. What are Dispersion Flattened Fibers (DFF)? (R)

DFF is a type of glass optical fiber that provides low pulse Dispersion over a broad portion of the light spectrum and as a result can operate at 1300 nm and 1550 nm wavelength simultaneously.

33. What are Dispersion Shifted Fibers (DSF)? (R)

DSF is a type of optical fiber made to optimize both low dispersion and low attenuation.

DSF is a type of single mode optical fiber with a core-clad index profile tailored to shift the zero-dispersion wavelength from the natural 1300 nm in silica-glass fibers to the minimum loss at 1550 nm.

34. What is meant by Fresnel reflection in Fiber cable?(R)

Fresnel reflection at the air-glass interfaces at the entrance and exit of an optical fiber.

35. Define group delay. (Apr-May 2017) (R)

When the signal propagates along the fiber, each spectral component can be assumed to travel independently and to undergo a time delay or group delay per unit length in the direction of propagation.

36. What is elastic and inelastic scattering ? Give examples. (Apr-May 2018) (R)

Elastic scattering is a type of scattering in which the energy of the incident ray is conserved and direction of scattered ray is changed. (e.g) Rayleigh Scattering.

Inelastic scattering is a type of scattering in which the energy of the incident ray is not conserved and direction of scattered ray is changed. (e.g) Raman Scattering.

37.What are bending losses? Name any two types. (Apr-May 2015) (R)

(i) Micro bending losses - The light power is dissipated through the micro bends because if the respective coupling of energy between guided modes and leaky modes.
(ii) Macro bending losses - Macrobending losses occur when fibres are physically bent beyond the point at which the critical angle is exceeded.

38. What are the types of fiber losses which are given per unit distance?(Nov-Dec 2014) (R)

(i)Absorption

(ii) Scattering

(iii)Bending Loss

39.List the factors that cause intrinsic joint losses in a fiber. (N0v-Dec 2014) (R)

(i)Different core and / or cladding diameters

(ii)Different numerical apertures and / or relative refractive index differences.

(iii)Different refractive index profiles.

(iv)Fiber faults.

40.A fiber has an attenuation of 0.5dB/Km at 1500nm. If 0.5mW of optical power is initially launched into the fibre, what is the power level in after 25Km? (Nov—Dec 2015) (AZ)

$$P_{out}\ (dBm) = P_{in}(dBm) - \alpha \left(\frac{dB}{Km}\right) \times l$$

$$P_{in}(dBm) = 10 \log_{10} \frac{P_{in}(dBm)}{1mW}$$

$$= 10 \log_{10} \frac{(0.5 \times 10^{-3})}{(1 \times 10^{-3})}$$

$$= 3.01\ dBm^{-}$$

$$P_{out}\ (dBm) = -3.01 - (0.5 \times 25)$$

$$P_{out}\ (dBm) = -15.51\ dBm$$

41.A continuous 12 kms-long optical fiber link has a loss of 1.5dB/km. What is the minimum optical power that must be launched into the fiber to maintain an optical power level of 0.3 · W at the receiving end?(Nov-Dec 2013) (AZ)

Given

$l \cdot 12km, \cdot \cdot 1.5dB/km, p_{out} \cdot 0.3 \cdot W$

$\cdot \vdots dB \ — \log \cdot \frac{p_{in}}{p} \cdot$

$10 \cdot p \cdot$

$\diagup km \quad l \quad \cdot 10 \quad \cdot \quad out \cdot$

$$1.5 = \frac{10}{12}\log_{10}\left(\frac{p_{in}}{0.3\times 10^{-6}}\right)$$

$$\frac{1.5\times 12}{10} = \log_{10}\left(\frac{p_{in}}{0.3\times 10^{-6}}\right)$$

$$1.8 = \log_{10}\left(\frac{p_{in}}{0.3\times 10^{-6}}\right)$$

$$anti\log(1.8) = \left(\frac{p_{in}}{0.3\times 10^{-6}}\right)$$

$$63 = \left(\frac{p_{in}}{0.3\times 10^{-6}}\right)$$

$$p_{in} = 1.8928\times 10^{-5}$$

$$p_{in} = 18.9\times 10^{-6}$$

$$p_{in} = 18.9\,\mu W$$

42.Define dispersion in multimode fibers. What is its effect? (Nov-Dec 2013) (R)

In multimode fiber many modes are propagating along the fiber at a time. Different modes are taking different ray path and they reach at different time at the output end of the fiber. So a time delay is experienced between modes. This is called intermodal delay and pulse broadening occurs due to intermodal delay is called intermodal dispersion

Effect:

1. It restricts bandwidth of the optical fiber cable.
2. The intermodal dispersion causes the light rays to spread out through the fiber.
3. It accounts for a significant loss occurring in the fiber.

43.What are the two reasons for Chromatic Dispersion? (Nov-Dec 2012) (R)

i. Dispersive Properties of the waveguide material – Material Dispersion
ii. Guidance effects within the fiber structure – Waveguide Dispersion

44.What are the most important non-linear effects of optical fiber communication? (Nov-Dec 2012) (R)

Non linear effects of Scattering are:

i. Stimulated Brillouin Scattering (SBS)

ii. Stimulated Raman Scattering (SRS)

45.What are the causes of absorption? (Nov-Dec 2016) (R)

Absorption loss is related to the material composition and fabrication process of the fiber. It is caused by three different mechanisms.

i) Absorption by atomic defects in the glass composition.

ii) Extrinsic absorption by impurity atoms in the glass material.

iii) Intrinsic absorption by the basic constituent atoms of the fiber material.

46. Distinguish between intramodal and intermodal dispersions. (Nov- Dec 2018) (U)

S.No.	Intramodal dispersion	Intermodal dispersion
1.	It occurs within a single mode fiber.	It occurs in a multimode fiber.
2.	It is also known as chromatic dispersion.	It is also known as modal dispersion.
3.	Less pulse broadening	More pulse broadening
4.	It arises due to the finite spectral emission width of an optical source	It arises as each mode in a multimode fiber travels with a different velocity and they reach the fiber end at different times

Part – B

1. Discuss about the design optimization of single mode fiber.(Nov-Dec 2016) (U)
2. What is waveguide dispersion? Derive and expression for time delay produced due to waveguide dispersion.(Nov-Dec 2016) (A)
3. With necessary diagrams, explain the causes and types of fiber attenuation loss. (Nov-Dec 2015) (U)
4. With diagram, derive the expression for intra modal dispersion. (Nov-Dec 2015) (AZ)
5. What are the loss or signal attenuation mechanism in a fibre? Explain. (Apr- May 2015) (U)

6. Derive an expression for pulse broadening in graded index fibers.(Apr-May 2017) (U)
7. Explain in detail about polarization mode dispersion and intermodal dispersion in SM fibers. (U)
8. Distinguish between intermodal and intramodal dispersions. Explain them with necessary equations and diagrams. (Nov-Dec 2013) (AZ)
9. Describe the linear and non-linear scattering losses in optical fibers. (Nov- Dec 2012 , Nov-Dec 2017) (U)
10. Derive expressions for material dispersion and waveguide dispersion and explain them. (May-June 2013) (AZ)
11. What is meant by critical bending radius of optical fibers? Explain. (Nov- Dec 2014) (U)
12. Explain the following in single mode fiber : Modal birefringence and beat length. (Nov-Dec 2014) (U)
13. An LED operating at 850nm has a spectral width of 45nm. What is the pulse spreading is ns/km due to material dispersion? What is the pulse spreading when a laser diode having a 2nm spectral width is used? (Nov-Dec 2012) (U)
14. Discuss the attenuation encountered in optical fiber communication due to:

 1.Bending 2. Scattering 3.Absorption. (Nov-Dec 2013) (U)

15. What are the causes of signal attenuation in optical fiber? Explain about them in

 detail. (Apr-May 2017)(U)

16. A glass fiber exhibits material dispersion given by $\left|\lambda^2 \frac{d^2 n}{d\lambda^2}\right|$ of 0.055.

Determine the material dispersion parameter at a wavelength of 0.85 μm, and estimate the rms pulse broadening per kilometer for a good LED source with an rms spectral width of 20nm at this wavelength. (Nov-Dec 2017) (A)

ASSIGNMENT QUESTIONS BASED ON BLOOM'S TAXONOMY LEVELS (BTL)

ASSIGNMENT – II

UNIT – 2 TRANSMISSION CHARACTERISTICS OF OPTICAL FIBERS

1.(a) An LED operating at 850nm has a spectral width of 45nm. What is the pulse spreading in ns/km due to material dispersion? What is the pulse spreading when a laser diode having a 2-nm spectral width is used? (A)

(b) Find the material-dispersion-induced pulse spreading at 1550nm for an LED with a 75-nm spectral width. (A)

2. Consider graded-index fibers having index profiles α=2.0, cladding refractive indices n2 = 1.478, and index differences Δ = 0.01. Compare the ratio M_{eff}/M for a 1550-nm wavelength for R = 2.5 cm when α=25 μm and 50 μm. (AZ)

3. Calculate the wavelength dispersion at 1320nm in units of [ps/(nm^2-km)] for a single-mode fiber with core and cladding diameters of 9μm and 125 μm, respectively. Let the core index n_1=1.48 and let the index difference Δ=0.22 percent. (A)

4. A glass fiber exhibits material dispersion given by $\left|\lambda^2 \frac{d^2 n}{d\lambda^2}\right|$ of 0.055.

Determine the material dispersion parameter at a wavelength of 0.85 μm, and estimate the rms pulse broadening per kilometer for a good LED source with an rms spectral width of 20nm at this wavelength. (A)

UNIT – III – OPTICAL SOURCES AND DETECTORS PART – A

1. What are the advantages of LEDs? (May 2012) (R)

   - Cheapest light source.
   - Simple driver circuit.
   - No thermal and optical stabilization.

2. What are the disadvantages of LEDs? (R)
   - Low output power
   - Wide spectral width (typically 20nm to 40nm)

3. What are the advantages of laser source over with LED? (R)
   - High output power.
   - Narrow spectral width (typically 1nm to 2nm for multimode laser).

4. Give an example each for direct band gap and indirect band gap materials (May 2012) (U)
   - Examples for direct band gap materials are GaAlAs and InGaAsP.
   - Si,Ge are examples for indirect band gap materials.

5. Define quantum efficiency of LED (Nov-Dec 2014,May 2012 ,April 2010, Nov-Dec 2018) (R)

   The internal quantum efficiency in the active region is the fraction of electron- hole pairs that recombine radiatively.The total recombination rate is sum of radiative recombination rate and non-radiative recombination rate it is given by

   Internal quantum efficiency $\eta_{int} = \frac{R_r}{R_r + R_{nr}}$

6. Why silicon is not used to fabricate LED or laser diode? (Nov 2011) (U)
   Silica is an indirect band gap materials so recombination of electron hole pair is less efficient so amount of photons emitted is less and amount of light emitted will also be less so silica is not used to fabricate LED or laser diode.

2.26

7. Differentiate between direct band gap material and indirect band gap material.(U)

S.No	Direct band gap material	Indirect band gap material
1.	Direct band gap material, the valence band maximum of the minimum of the con occur at the different value momentum.	Indirect band gap material, maximum of the valence band and And minimum duction band conduction band occur at the of same value of momentum.
2.	Recombination of electrons to produce photons as it must (Third phonon).	Recombination process is less efficient and holes be mediated by phonon. is more efficient.
3.	Direct band gap materials like used to make optical are not used LED's and but diode, transistor laser.	Indirect band gap materials like silicon GaAs are to make optical devices Devices like can be fabricated. semiconductor

8. List out the disadvantages of direct band gap materials.(U)

- Direct band gap materials are not used for making conventional diodes as recombination process is efficient, it produce narrow spectral width.
- As a result, recombination of electrons and holes, then mobile carriers get reduced, there will be decline conduction takes place.

9. Define Hetero junction.(R)

- When two semi conductor materials with different band gap energy are adjoined then it forms a Hetero junction.
- This is used in fiber transmission system as they provide adequate power over large range of application.

10. What are the advantages of double hetero structure optical sources? (April 2011) (R)

- High quantum efficiency.
- High brightness (Radiance).

11. What is population inversion? (R)

Population inversion is the condition in which number of electrons in the conduction band is greater than the number of electrons in the valence band.

12. What is lasing condition?What are the mechanisms behind lasing action. (Nov-Dec 2016) (R)

When the optical gain overcomes the total losses that arise in the laser cavity, lasing occurs.

The mechanisms behind lasing action are:

1) Photon absorption
2) Spontaneous emission
3) Stimulated emission

13. Compare and contrast between surface and edge emitting LEDs. (Nov 2012)(AZ)

S.No	Surface Emitting LED	Edge Emitting LED
1.	Wider spectral width(typically 125nm)	Narrow spectral width (typically 75nm)
2.	Emission pattern is less directional.	Emission pattern is more directional.

14.Define Quantum efficiency of laser diode?(R)

The Quantum efficiency is defined as the number of photons emitted per radioactive electron-hole pair recombination above threshold.

15.Distinguish between direct and external modulation of laser diodes. (Nov 2010) (AZ)

S.No	Direct Modulation	External Modulation
1.	Easy to demonstrate and has low cost.	Complex and expensive.
2.	Low gain.	High gain.

16. Define responsivity of photodiode. (Nov-Dec 2013, April 2010, Nov-Dec 2018) (R)

The performance of photodiode is often characterized by the responsivity. Responsivity means speed of response of photodiode.

$$R \cdot \frac{I_p}{P_{in}}$$

17. Define quantum efficiency of a photo detector and write the expression (Nov-Dec 2013, Nov-Dec 2011) (R)

The quantum efficiency · is the number of electron hole carrier pairs generated per incident photon of energy.

$$\cdot \quad \cdot \quad \frac{I_p / e}{P_{in} / h\nu}$$

18. Why silicon is preferred for fabrication of photo receiver? (U)

- Silica is used for fabrication photo receiver, because it has larger band gap, it generates low noise and it supports multiple channels as it has larger bandwidth.
- Silicon is available plenty in nature.

19. Why are semiconductor based photo detectors preferred to other types of photo detectors? (April-May 2011) (U)

Semiconductor laser diode generates low noise and they support multiple channels as they have larger band width.

20. What is the significance of intrinsic layer in PIN diodes (Nov-Dec 2012) (R)

To increase absorption region, intrinsic layer is sandwiched between p-type and N-type semiconductors.

21. Why is silicon not used to fabricate LED or Laser diode. (Nov-Dec 2018) (A)

Only in direct band gap semiconductor material, the radiative recombination is sufficiently high to produce an adequate level light. Silicon is an indirect band gap material. Hence silicon is not used to fabricate LED or Laser diode.

22. Define impact ionization or avalanche effect?(R)

In high field region, a photo generated electron or hole can gain enough energy so that it ionizes bound electrons in the valence band upon colliding with them. This carrier multiplication mechanism is known as impact ionization. The newly created carriers are also accelerated by the high electric field, thus gaining enough energy to cause further impact ionization. This phenomenon is the avalanche effect.

23. What are the requirements of photo detector?(R)

- The photo detector must have high quantum efficiency to generate a large signal power.
- The photo detector and amplifier noises should be kept as low as possible.

24. Define quantum noise or shot noise? (R)

The quantum or shot noise arises from the statistical nature of the production and collection of photo electrons when an optical signal is incident on a photo detector.

25. Define dark current?(R)

The photo diode dark current is the current that continues to flow through the bias circuit of the device when no light is incident on the photo diode.

26. Define Johnson or thermal noise?(R)

When current is flowing continuously across the load resistor, heat will be dissipated. This is called thermal noise.

27. What is known as detector response time? (May 2012 , Nov-Dec 2018)(R)

It is defined as the time taken for the photo detector to respond to an optical input pulse. The response time determines the bandwidth available for signal modulation and data transmission.

28. Illustrate the factors that determine the response time of the photodiode. (Apr-May 2018) (U)

- Transit time of the photo carriers in the depletion region.
- Diffusion time of the photo carriers generated outside the depletion region.
- RC time constant of the photodiode and its associated circuit.

29.Compare PIN and APD?(U)

S.No.	PIN	APD
1.	Thermal noise current dominates photo detector noise current.	Photo detector noise current dominates thermal noise current.
2.	Low responsivity	High responsivity
3.	Low dark current noise	High dark current noise
4.	Suitable for high intensity application	Suitable for low intensity application
5.	Require low reverse bias voltage	Require high reverse bias voltage

30.Define power- bandwidth product.(Apr-May 2015) (R)

High output power and high bandwidth are two important parameters in the design of photo-detector. The Product of photo detector bandwidth and power at which bandwidth is measured.

31.Contrast the advantages of PIN diode with APD diode. (Apr-May 2015) (U)

(i) Low dark current
(ii) It is affected but only thermal noise
(iii) No speed limitation due to capacitance effect

32.Calculate the Band gap energy for an LED to emit $850nm$? (May-June 2013) (A)

Solution: $\lambda = 850nm = 0.85\mu m$

$$E_g = \frac{hc}{\lambda} = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{0.85 \times 10^{-6}} = 2.33 \times 10^{-19} = 1.45\, eV$$

$$E_g = 1.45\, eV$$

33.Define external quantum efficiency.(Nov-Dec 2016). (R)

The external quantum efficiency is defined as the ratio of the photons emitted from the LED to the number of internally generated photons.

34.Write two difference between a Laser diode and a LED. (Nov-Dec 2013) (U)

S.no	Laser Diode	LED
1.	Coherent radiation takes place.	In coherent radiation takes place.
2.	Narrow spectral width	Wider Spectral width

35. Write the laser diode rate equations. (Nov-Dec 2017) (U)

$$\frac{P_S}{\tau_{ph}} = R_{sp} + \frac{1}{qd}(J - J_{th})$$

$$P_s = \tau_{ph} R_{sp} + \frac{\tau_{ph}}{qd}(J - J_{th})$$

36. An LED has radiative and non-radiative recombination times of 30 ns and 100 ns respectively. Determine the internal quantum efficiency.
(Apr-May 2018) (U)

Bulk recombination life time $\tau = \frac{\tau_r \tau_{nr}}{\tau_r + \tau_{nr}} = \frac{30\,x100}{30 + 100} = 23.1$ ns

Internal Quantum efficiency $\eta = \frac{\tau}{\tau_r} = \frac{23.1}{30} = 0.77$

Part – B

1. Explain the working principle of laser diode and derive its rate equation. (Nov- Dec 2016) (U)
2. With neat sketch, explain the working of a light emitting diode. (Apr-May 2015, Nov-Dec 2013) (U)
3. Derive an expression for the quantum efficiency of a double hetro-structure LED. (Apr-May 2015, Nov-Dec 2013, **Nov-Dec 2017)** (AZ)
4. Draw and compare LED and Injection Laser Diode structures. (Nov-Dec 2015) (AZ)
5. Discuss about optical detection noise. (Nov-Dec 2015) (U)
6. Explain laser modes and lasing conditions. (U)
7. Discuss about surface emitting LED and edge emitting LED with neat sketch. **(Apr-May 2017, Nov-Dec 2018)** (U)
8. Explain gain guided and Index guided laser diodes. (U)
9. With a neat diagram, explain the structure of LASER diode and its radiation pattern. **(Nov-Dec 2017)** (U)
10. What is meant by detector response time? Explain. (Nov-Dec 2014,Nov-Dec 2012) (U)
11. A Photodiode is constructed of GaAs which has a band gap energy of 1.43eV at 300K. Find the long wavelength cut-off. (Apr-May 2015) (AZ)
12. What do you understand by optical-wave confinement and current confinement in LASER diode? Explain with suitable structures. (Nov-Dec 2013) (U)
13. Give a brief account on the resonant frequencies of laser diodes. (Apr-May 2018) (U)
14. A double hetero junction InGaAsP LED emitting at a peak wavelength of 1310 nm has radiative and non radiative recombination times of 45ns and 95ns respectively. The drive current is 35mA. Determine the internal quantum efficiency and internal power generated by the LED. Find the power emitted from the device if the refractive index of the light source is n =3.5 (Nov-Dec 2016,Nov-Dec 2018) (A)
15. A planar LED is fabricated from gallium arsenide which has a refractive index of 3.6.

a) Calculate the optical power emitted into air as a percentage of the internal optical power for the device when the transmission factor at the crystal-air interface is 0.68.

b) When the optical power generated internally is 50% of the electric power supplied, determine the external power efficiency. (Apr-May 2018) (A)

16. Discuss various noise sources available in APD and also derive the expression for the optimum gain at maximum signal to noise ratio.(May-June 2016) (U)

17. i)Draw and explain double hetero-structure light emitter with energy band diagram and refractive index profile.

ii)Why is the double hetero-structure preferred for optical fiber communication? Justify your answer.

iii)Derive with relevant mathematical expression of optical power emitted from LED. (May-June 2016) (U)

18. What are the characteristics required for an optical source? (Nov-Dec 2018) (R)

19. Explain in detail the working of PIN photo diode

20. Explain in detail the working of Avalanche photo detector

ASSIGNMENT QUESTIONS BASED ON BLOOM'S TAXONOMY LEVELS (BTL)

ASSIGNMENT – III

UNIT – 3 OPTICAL SOURCES AND DETECTORS

1. An engineer has two $Ga_{1-x}Al_xAs$ LEDs: One has a bandgap energy of 1.540eV and the other has x=0.015.

(a) Find the aluminium mole fraction x and the emission wavelength of the first LED. (AZ)

(b) Find the bandgap energy and the emission wavelength of the other LED. (AZ)

2. (a) A GaAlAs laser diode has a 500μm cavity length, which has an effective absorption coefficient of $10cm^{-1}$. For uncoated facets the reflectivities are 0.32 at each end. What is the optical gain at the lasting threshold?

(b) If one end of the laser is coated with a dielectric reflector so that its reflectivity is now 90 percent, what is the optical gain at the lasing threshold? (A)

(c) If the internal quantum efficiency is 0.65, what is the external quantum efficiency in cases (a) and (b)? (AZ)

3. A laser emitting at λ_0=850 nm has a gain-spectral width of σ = 32 nm and a peak gain of g(0) = 50 cm^{-1} . Plot $g(\lambda)$ from Eq.4.41. If α_t = 32.2 cm^{-1}, show the region where lasting takes place. If the laser is 400 μm long and n=3.6, how many modes will be excited in this laser? (E)

4. A planar LED is fabricated from gallium arsenide which has a refractive index of 3.6.
   a) Calculate the optical power emitted into air as a percentage of the internal optical power for the device when the transmission factor at the crystal-air interface is 0.68.
   b) When the optical power generated internally is 50% of the electric power supplied, determine the external power efficiency. (A)

UNIT – IV – OPTICAL RECEIVER, MEASUREMENTS AND COUPLING PART – A

1. What is Mode Coupling and what are its causes?(R)

It is another type of pulse distortion which is common in optical links. The pulse distortion will be increased less rapidly after a certain initial length of fiber, due to this mode coupling and differential mode losses occur.

2. Define Quantum limit (Q). (May-June 2013, Apr-May 2018) (R)

The minimum received power level required for a specific BER of digital system is known as Quantum limit.

3. List out the methods used to measure fiber refractive index profile. (A)

   1. Inter-ferometric method
   2. Near field scanning method
   3. End field scanning method

4. What are the error sources in fiber optic receiver? (May-June 2013, Nov- Dec 2012, Apr-May 2018) (R)

The error sources in fiber optic receiver are

- Shot Noise
- Dark Current
  - Bulk Dark Current
  - Surface Dark Current
- Thermal Noise.
- Amplifier noise

5. What are the different techniques for determining attenuation in optical fiber?(R)

The different techniques for determining attenuation are i) Cut-back ii) Insertion-loss

6. Write the expression to measure attenuation using cut back method.(A)

$$\alpha_{dB} = \frac{10}{L_1 - L_2}\log_{10}\frac{V_1}{V_2}$$

Where L_1 = original fiber length

L_2 = Cut-back fiber length

V_1 and V_2 are the output voltages

7. Define BER.(Nov-Dec 2016, April-May 2015) (R)

Bit Error rate (BER) = $\frac{N_e}{N_t} = \frac{N_e}{Bt}$

Where , B= $\frac{1}{T_b}$ is the bit rate.

N_e = Number of errors occurring over a specific time interval.

N_t = Number of pulses transmitted during the interval.

8. What is Cut-back method?(Nov-Dec 2016) (R)

The cut back method involves taking a set of optical power measurements over the required spectrum with the help of a long length of fibre which is uncabled having only a primary protective coating. The fibre is then cut back to a point 2m from the input end maintaining the same launch condition.

9.List any two advantages of trans-impedance amplifiers.(Apr-May 2015) (U)

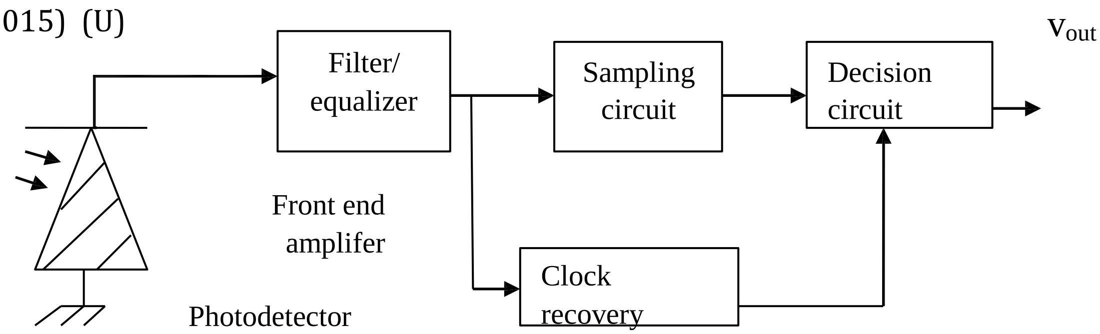
(i) Reduces thermal noise

(ii) Provide wide bandwidth

10. State the significance of maintaining the fiber outer diameter constant.(Nov-Dec 2014) (R)

It is essential during the fiber manufacturing process (at the drawing stage) that the fiber outer diameter (cladding diameter) is maintained constant to within 1%. Any diameter variations may cause excessive radiation losses and make accurate fiber – fiber connection difficult.

11. Draw and describe the operation of fiber optic receiver. (Nov-Dec 2015) (U)



An optical receiver system converts optical energy into electrical signal amplify the signal and process it. Therefore the important blocks of optical receiver are

(i) Photodiode / Front – end

(ii) Amplifier / Linear channel

(iii) Signal processing circuitry / Data recovery.

12. Mention few fiber diameter measurement techniques. (Nov-Dec 2015) (R)

There are two very broad classifications of diameter measurements techniques

(i) Contacting or destructive methods

(ii) Non-contacting and nondestructive methods

13. What is dark current? (Nov-Dec 2012) (R)

The photo diode dark current is the current that continues to flow through the bias circuit of the device when no light is incident on the photo diode.

14. A digital fiber optic link operating at 1310 nm, requires a maximum BER of 10^{-8}. Calculate the required average photons per pulse. (Nov- Dec 2013) (AZ)

Solution:

Given

Probability error $P_r(0) = e^{-N} = 10^{-8}$

$$N = 8\log_e 10 = 18.42 \approx 18$$

An average of 18 photons per pulse ie required for this BER.

15. The photo detector output in a cutback attenuation set up is 3.3V at the far end of the fiber. After cutting the fiber at the near end, 5 m from the far end, photo detector output read was 3.92 V. What is the attenuation of fiber in dB/km? (Nov-Dec 2013) (AZ)

Solution:

Consider fiber cut back length is 2m.

$$\alpha_{dB} = \frac{10}{L_1 - L_2}\log_{10}\left(\frac{V_1}{V_2}\right)$$

$$\alpha_{dB} = \frac{10}{5}\log_{10}\left(\frac{3.92}{3.3}\right)$$

$$= 0.002$$

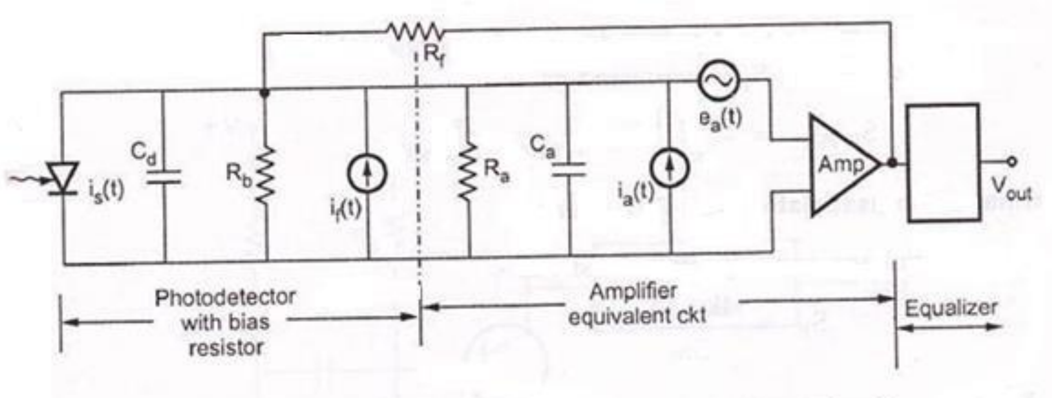
$$= 0.149$$

5

16. Define receiver sensitivity. (Nov-Dec 2017) (U)

The receiver sensitivity of a receiver (or) detection device is the minimum magnitude of input signal required to produce a specified output signal having a specified signal-to-noise ratio, or other specified criteria.

17. Draw the generic structure of transimpedance amplifer. (Nov-Dec 2017) (U)



Transimpedance preamplifier equivalent circuit

18. What are inherent connection problems when joining fibers? (U)

The inherent connection problems when jointing fibers are,

- Different core and/or cladding diameters.
  - Different numerical apertures and/or relative refractive index differences.
  - Different refractive index profiles.
  - Fiber faults(core elliptically, core concentricity etc)

19. List out the different types of mechanical misalignments during fiber connection? (A)

The three possible types of misalignment which may occur when joining compatible optical fibers are,

a) Longitudinal misalignment b) Lateral misalignment
c) Angular misalignment

20.What is fiber splicing?(R)

Fiber splicing is the process of joining two fibers by melting the fiber ends.

21.Compare splices and connectors.(AZ)

S.No	Splices	Connectors
1	Permanent or semi permanent joints	Temporary joint
2	Splice loss is low	Connector loss is high

22.Define cross talk in couplers? (R)

Crosstalk is a measure of isolation between two input or two output ports.

23.What is meant by Mechanical splicing? (May-June 2013) (R)

Mechanical splicing, in which the fibers are held in alignment by some mechanical means, may be achieved by including the use of V- groove into which the butted fibers are placed (or) the use of tubes around the fiber ends.

24. List out the advantages of elastic tube splicing?(A)

The advantages of elastic tube splicing are,

a) This type of splicing allows accurate and automatic alignment of axes of the two fibers to be joined.
b) In this method the fibers to be splices do not have to be equal in diameter.

25. List out the advantages of V-groove splicing?(A)

a) There is no thermal stress.
b) No change in refraction index of the two fibers.

Part – B

1. What is fiber splicing? Discuss about fusion splicing and mechanical splicing. (Nov-Dec 2016,Apr-May 2018) (U)
2. Explain the different methods employed in measuring the attenuation in optical fiber with neat block diagram. (Nov-Dec 2016) (U)
3. What are the performance measures of a digital receiver? Derive an expression for bit error rate of a digital receiver. (Nov-Dec 2016,Nov-Dec 2015) (AZ)
4. Explain how attenuation and dispersion measurements could be done. (Nov- Dec 2015, Nov-Dec 2013 Nov-Dec 2017) (U)
5. Explain the following. (Apr-May 2018) (U)
   i) Fiber outer diameter measurement ii)
   Core diameter measurement
5. Draw the three types of front end optical amplifiers (preamplifiers) and explain. (May-June 2013, Nov-Dec 2012, Nov-Dec 2013, Nov-Dec 2018) (U)
6. Explain with a neat block diagram, the measurement of
   i) Numerical aperture and acceptance angle. (Nov-Dec 2014,Nov-Dec 2017)

(U)

ii) Refractive index profile**.** (Nov-Dec 2012, Nov-Dec 2014, May-June 2016, Nov-Dec 2018) (U)

7. With schematic diagram, explain the blocks and their functions of an optical receiver. (Apr-May 2015, Nov-Dec 2014, Apr-May 2018) (U)
8. A digital fibre optic link operationg at 850nm requires a maximum BER of 10^{-9}. Find the quantum limit in terms of the quantum efficiency of the detector and the energy of the incident photon. (Apr-May 2015) (E)
9. Write detailed notes on the following. (May-June 2013) (U)

   (i) Fibre refractive index profile measurement.

   (ii) Fibre cut of wavelength measurement. (Nov-Dec 2012, Nov-Dec 2018) (U)

10. Estimate the terms: Quantum limit and Probability of Error with respect to a receiver with typical values. (Nov-Dec 2018) (U)
11. Measurements are made using calorimeter and thermocouple experimental arrangement. Initially a high absorption fiber is utilized to obtain a plot of $(T_\infty - T_t)$ on a logarithmic scale against t. It is found from the plot that the readings of $(T_\infty - T_t)$ after 10 and 100 seconds are 0.525 and 0.021 μV respectively. The test fiber is then inserted in the calorimeter and gives a maximum temperature rise of $4.3 * 10^{-4}$ ºC with a constant measured optical power of 98mW at a wavelength of 0.75 μm. The thermal capacity per kilometer of the silica capillary and fluid is calculated to be $1.64 * 10^4$ JºC $^{-1}$. Determine the absorption loss in dB km -1, at a wavelength of 0.75 μm, for the fiber under test. (Apr-May 2018) (AZ)
12. A He-Ne laser operating at a wavelength of 0.63 μm was used with a solar cell cube to measure the scattering loss in a multimode fiber sample. With a constant optical output power the reading from the solar cell cube was 6.14 nV. The optical power measurements at the cube without scattering were 153.38 μV. The length of the fiber in the cube was 2.92 cm. Determine the loss due to scattering in dB km $^{-1}$ for the fiber at a wavelength of 0.63 μm. (Apr-May 2018) (AZ)
13. A trignometrical measurement is performed in order to determine the numerical of a 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. Calculate the approximate numerical aperture of the fiber. (Apr-May 2018) (AZ)
14. Explain in detail with necessary circuit diagram and advantages of Transimpedance amplifier (May-June 2016) (U)

15. Consider a digital fiber optic link operating at a bit rate of 622 Mbps at 1550 nm. The InGaAs pin detector has a quantum efficiency of 0.8. Find the minimum number of photons in a pulse required for a BER of 10^{-9}. Find the corresponding minimum incident power. (May-June 2016) (A)
16. Write short notes on (U)
    i) Lensing schemes
    ii) Power Launching and Coupling
17. What are the different types of fiber splices and misalignments. (R)
18. Describe the various types of fiber connectors and couplers. (May-June 2013) (U)
19. Explain fiber alignment and joint losses. (May-June 2013) (U)
20. Describe various fiber splicing techniques with their diagrams. (May-June 2013) (U)
21. Describe the three types of fiber misalignment that contribute to insertion loss at an optical fiber joint. (Nov-Dec 2014) (U)
22. Describe about connectors, splices and couplers. (Nov-Dec 2015) (U)
23. Illustrate the different lensing schemes available to improve the power coupling efficiency. (Apr-May 2017, Apr-May 2018) (U)

ASSIGNMENT QUESTIONS BASED ON BLOOM'S TAXONOMY LEVELS (BTL)

ASSIGNMENT – IV

UNIT – 4 OPTICAL RECEIVER, MEASUREMENTS AND COUPLING

1. In a avalancHe photodiodes, the ionization ratio k is approximately 0.02 for silicon and 0.35 for indium gallium arsenide. Show that for gains 9, 25, and 100 in Si and gains of 4, 9 and 25 in InGaAs, the excess noise factor $F(M)$ can be approximated to within 10percent by M^x, where x is 0.3 for Si and 0.7 for InGaAs. (AZ)

2. An LED operating at 1300nm injects 25μW of optical power into a fiber. If the attenuation between the LED and the photodetector is 40dB and the photodetector quantum efficiency is 0.65, what is the probability that fewer than 5 electron-hole pairs will be generated at the detector in a 1-ns interval? (AZ)

3. Consider a quantum-noise-limited analog optical fiber system that uses a *pin* photodiode with a responsivity of 0.85 A/W at 1310nm. Assume the system

uses a modulation index of 0.6 and operates in a 40-MHZ bandwidth. If we neglect detector dark current, what is the signal-to-noise ratio when the incident optical power at the receiver is -15dBm? (AZ)

4. Measurements are made using calorimeter and thermocouple experimental arrangement. Initially a high absorption fiber is utilized to obtain a plot of $(T_\infty - T_t)$ on a logarithmic scale against t. It is found from the plot that the readings of $(T_\infty - T_t)$ after 10 and 100 seconds are 0.525 and 0.021 μV respectively. The test fiber is then inserted in the calorimeter and gives a maximum temperature rise of $4.3 * 10^{-4}$ ºC with a constant measured optical power of 98mW at a wavelength of 0.75 μm. The thermal capacity per kilometer of the silica capillary and fluid is calculated to be $1.64 * 10^4$ JºC $^{-1}$. Determine the absorption loss in dB km -1, at a wavelength of 0.75 μm, for the fiber
under test. (AZ)

UNIT – V – OPTICAL COMMUNICATION SYSTEMS AND NETWORKS PART – A

1. What is a Soliton?(Nov-Dec 2014, Apr-May 2017, Apr-May 2018) (R)

   Soliton is a self trapped beam and it is a special kind of pulses and does not change in shape during propagation. This is also called as fundamental soliton.

2. What is WDM (Wavelength Division Multiplexing)? ?(Nov-Dec 2014) (R) A

   Powerful aspect of an optical communication link is that many different wavelengths can be sent along the fibre simultaneously. The technology of combining a number of wavelengths onto the same fibre is known as Wavelength –Division Multiplexing or WDM.

3. What are the drawbacks of broadcast and select network for wavelength multiplexing? (Apr-May 2018) (R)

   The problems that arise in broadcast and select networks are:

   1. More wavelengths are needed as the number of nodes in the network grows.
   2. Without the width spread use of optical booster amplifiers, due to this splitting loss is high.

4. Distinguish SONET and SDH. (Nov-Dec 2015) (AZ)

SONET	SDH
1. It means synchronous optical network developed by ANSI. 2. Basic signaling unit is OC-I (51.84Mbps) 3. SONET uses the term section, line and path.	1. It means synchronous digital hierarchy developed by ITU 2. Basic signaling unit is STM-1 (155.52 Mbps) 3. SDH uses the term path, multiplex section and regenerator section.

5. Name two popular architectures of SONET/SDH network.(Nov-Dec 2016) (R)

   The two popular architectures of SONET/SDH networks are:

   i) UPSR - Unidirectional Path Switched Ring, two-fiber.
   ii) BLSR – Bidirectional Line Switched Ring, two-fiber or four-fiber.

6.Obtain the transmission bit rate of the basic SONET frame in Mbps.(Nov-Dec 2013, Apr-May 2017(2008 reg)) (E)

STS-1 frame rate = (810 bytes/frame)*(8000 frames/sec)

= 51.840 Mbps.

7.Illustrate inter-channel cross talk that occurs in a WDM system.(Nov- Dec 2013, Apr-May 2017(2008 reg)) (A)

Inter-channel crosstalk arises when an interfacing signal comes from a neighboring channel that operates at a different wavelength. This nominally occurs when a wavelength selecting device imperfectly rejects or isolates the signals from other near-by wavelength channels.

9.What is a broadcast and select network?(May-June 2013) (R)

In broadcast and select networks, a node sends its transmission to the star coupler on the available wavelength using a laser which produces an optical information stream. The information stream from multiple sources is optically combined by the star and the signal and the signal power of each stream is equally spilt and forwarded to all the nodes on their receiver fiber.

10.What is SONET?(Apr-May 2015) (R)

SONET means synchronous optical network which is developed by ANSI, standardized protocol that transfer multiple digital bit stream synchronously over optical fiber using laser.

11.What were the problems associated with PDH networks?(Nov-Dec 2012) (AZ)

PDH- Plesiochronous Digital Hierarchy

i) It is difficult to “pick out” (drop) a low bit rate stream out of a high bit rate stream it is completely demultiplexing stream. ii)

Expensive and compromises network reliability.

12.Enumerate the various SONET/SDH layers. ?(Nov-Dec 2012) (R)

The various SONET/SDH layers are, i)

Photonic layer

ii) Section layer

iii) Line layer

iv) Path layer.

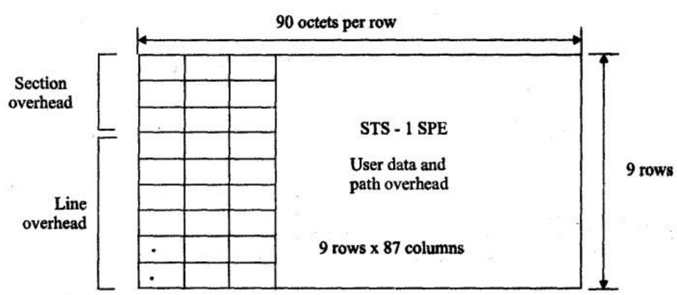
14. Define power penalty. (Nov-Dec 2018) (R)

When nonlinear effects contribute to signal impairment, an additional amount of power will be needed at the receiver to maintain the same BER. This additional power (in dB) is known as the power penalty.

15. What are the requirements in analyzing a link? (Apr-May 2017) (R)

For analyzing a link the following requirements are needed. i) The desired (or possible) transmission distance.
ii) The data rate or channel bandwidth. iii)
The Bit Error Rate (BER).

16. Draw the basic structure of STS-1 SONET frame. (Nov-Dec 2017) (R)



Part – B

1. Draw the generic configuration of SONET and explain the functions of add drop multiplexer in SONET.(Nov-Dec 2016)(U)
2. Discuss in detail about the effect of noise on system performance.(Nov-Dec 2016) (U)
3. Explain SONET layers and frame structure with diagram. (Nov-Dec 2015, Nov-Dec 2018, Apr-May 2018) (U)
4. Discuss the performance improvement of WDM.(Nov-Dec 2015,Apr-May 2015, Nov-Dec 2014) (U)
5. Discuss the non-linear effects on optical network performance.(Apr-May 2015, Nov-Dec 2012, Nov-Dec 2018, Apr-May 2018) (U)
6. Explain Optical Ethernet.(Nov-Dec 2012, Apr-May 2017) (U)
7. Discuss about Ultra High Capacity Networks. (Apr-May 2015,Nov-Dec 2014) (U)
8. Explain in detail different types of broadcast and select network in detail.

(Nov-Dec 2013, May-June 2016, Apr-May 2017(2008 reg)) (U)

9. What is a 'four-fiber BLSR' ring in a SONET? Explain the reconfiguration of the same during node or fiber failure. (Nov-Dec 2013, Apr-May 2017(2008 reg)) (U)

10. Explain the following requirements for the design of an optically amplified WDM link. (Nov-Dec 2013, Nov-Dec 2017) (U)

    1.Link Band width 2. Optical power requirements for a Specific BER.

11. Write a note on optical switching methods. (Nov-Dec 2017) (U)
12. Define and explain the principle of WDM networks.(Nov-Dec 2018) (U)
13. Explain SONET / SDH Networks. (Nov-Dec 2017) (U)
14. Explain the layered architecture and transmisson formats of SONET. (May-June 2016) (U)
15. Explain with neat sketch two popular architectures of SONET.(May-June 2016) (U)
16. Discuss about the protection mechanism in UPSR and BLSR ring architecture with neat sketch. (Apr-May 2017) (U)
17. 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, What is the system rise time? What is the rise time if there is no mode mixing? (use 0.07 ns/(nm-km)) (Nov-Dec 2016) (U)
18. Discuss about the concept of routing and wavelength assignment in the wavelength routed networks. (Apr-May 2018) (U)

19. What is optical power budgeting? Determine 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 7 km and operating at 20 Mbits / sec using an RZ code. It is decided that an LED emitting at 0.85 μm with graded index fiber to a pin photodiode is a suitable choice for the system components, giving no dispersion equalization penalty. An LED which is capable of launching an average of 100 μW of optical power (including the connector loss) into a graded index fiber of 50 μm core diameter is chosen. The proposed fiber cable has an attenuation of 2.6 dB/km and requires splicing every kilometer with a loss of 0.5 dB per splice. There is also a connector loss at the receiver of 1.5 dB. The receiver mean incident optical power of -41 dBm in order to give the necessary BER of 10^{-10}, and it is predicted that a safety margin of 6 dB will be required. (Apr-May 2018) (AZ)
20. Discuss in detail about DWDM and its passive components.

21. Explain Optical Add/ Drop multiplexer.
22. Discuss about High speed lightwave link.

ASSIGNMENT QUESTIONS BASED ON BLOOM'S TAXONOMY LEVELS (BTL)

ASSIGNMENT – V

UNIT – 5 OPTICAL COMMUNICATION SYSTEMS AND NETWORKS

1. An engineer has the following components available:
   (a) GaAlAs laser diode operating at 850nm and capable of coupling 1mW(0dBm) into a fiber.
   (b) Ten sections of cable each of which is 500m long, has a 4-dB/km attenuation, and has connectors on both ends.
   (c) Connector loss of 2dB/connector. (d)
   A *pin* photodiode receiver.
   (e) An avalanche photodiode receiver.

   Using these components, the engineer wishes to construct a 5-km link operating at 20Mb/s. If the sensitivities of the *pin* and APD receivers are -45 and -56 dBm respectively, which receiver should be used if a 6-dB system operating margin is required? (AZ)

2. A 90-Mb/s NRZ data transmission system that sends two DS3(45-Mb/s) channels uses a GaAlAs laser diode that has a 1-nm spectral width. The rise time of the laser transmitter output is 2 ns. The transmission distance is 7km over a graded-index fiber that has an 800- MHz.km bandwidth-distance product.
   (a) If the receiver bandwidth is 90 MHz and the mode-mixing factor q=0.7, what is the system rise time? Does this rise time meet the NRZ data requirements of being less than 70 percent of a pulse width? (AZ)
   (b) What is the system rise time if there is no mode mixing in the 7-km link; that is, q =1.0? (U)

3. What is optical power budgeting? Determine 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 7 km and operating at 20 Mbits / sec using an RZ code. It is decided that an LED emitting at 0.85 μm with graded index fiber to a pin photodiode is a suitable choice for the

system components, giving no dispersion equalization penalty. An LED which is capable of launching an average of 100 μW of optical power (including the connector loss) into a graded index fiber of 50 μm core diameter is chosen. The proposed fiber cable has an attenuation of 2.6 dB/km and requires splicing every kilometer with a loss of 0.5 dB per splice. There is also a connector loss at the receiver of 1.5 dB. The receiver mean incident optical power of -41 dBm in order to give the necessary BER of 10^{-10}, and it is predicted that a safety margin of 6 dB will be required. (AZ)

EC 8751 - OPTICAL COMMUNICATION

TOPICS TO BE CONCENTRATED MORE FOR UNIVERSITY EXAM

UNIT - 1

1. Block diagram of Optical Communication System.
2. Numerical Aperture and Acceptance angle derivation, Normalized frequency.
3. Ray Optics - Law of Reflection, Refraction, Snell's law, critical angle, Total internal reflection
4. Types of rays - Axial , Meridional and Skew rays.
5. Types of fibers - Single mode, Multi mode, Step Index and Graded Index fibers.
6. Linearly Polarized Modes Theory , Derivation for Linearly Polarized Modes , Scalar Wave Equation derivation (Maxwell's equation).

7. Problems on Numerical aperture, critical angle, no.of modes, normalized frequency.

8. Fabrication methods of Optical fibre

UNIT - 2

1.Attenuation Loss - Absorption, Scattering (Linear and Non-linear) and Bending Loss

2. Dispersion - Material and Waveguide dispersion (Theory and derivation)

3. Design optimization of SM fibers.

4. Pulse broadening in Graded Index fibers.

UNIT - 3

1. LED - Double heterojunction structure (diagram and explanation), Types of LED (SLED and ELED), Internal Quantum efficiency derivation.

2. LASER - Double heterojunction structure (diagram and explanation), Types (Gain guided and Index guided), Resonant frequency & Lasing Threshold condition, Rate equation derivation.

3. Quantum Well LASER

4. Photo Detector- PIN & Avalanche

7. Photodetector - Signal to Noise ratio expressions and detector response time.

UNIT - 4

1. Measurement of Attenuation - Cutback and Insertion Loss methods.

2. Measurement of Dispersion - Time domain and frequency domain.

3. Measurement of Numerical Aperture - Trignometric and Rotating edge methods.

4. Measurement of Refractive Index - Mach Zender, Near Field Scanning & End Reflection methods.

5. Measurement of Cut-off Wavelength

6. Measurement of Diameter

7. Optical Receiver block diagram and explanation

8. Types of Pre or Front end amplifiers

9. Fiber Splicing

10. Lencing schemes

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1. SONET - Generic configuration, frame structure, layers, architecture

2. Broad cast and select DWDM Network and its passive components

3. Solitons

4. High speed lightwave links

5. OADM

6. Optical Ethernet

7. Non-linear effects on network performance

8. Noise effects on system performance

9. Rise time and Link Power Budget.