

## UNIT - 1

### PART - A

1. Write the expression for the refractive index in graded index fibers.

$$n(r) = n_1 [1 - 2\Delta (r/a)^\alpha]^{1/2} \quad \text{for } 0 \leq r \leq a$$

$$n_1 (1 - 2\Delta)^{1/2} \approx n_1 (1 - \Delta) = n_2 \quad \text{for } r > a$$

$r$  radial distance from fiber axis

$a$  core radius

$n_1$  refractive index at the core

$n_2$  refractive index at the cladding

$\alpha$  shape of the index profile

$\Delta$  index difference

2. Define Mode-field diameter.

The fundamental parameter of a single mode fiber is the mode-field diameter. This can be determined from the mode field distribution of the fundamental LP<sub>01</sub> mode.

3. Give the expression for linearly polarized waves.

The electric or magnetic field of a train of plane polarized waves travelling in a direction  $k$  can be represented in the general form

$$A(x,t) = e_j A_0 \exp[j(\omega t - k \cdot x)]$$

With  $x = x e_x + y e_y + z e_z$  representing a general position vector and

$k = k_x e_x + k_y e_y + k_z e_z$  representing the wave propagation vector.

4. What is Snell's law?

The relationship at the interface is known as Snell's law and is given by

$$n_1 \sin \Phi_1 = n_2 \sin \Phi_2$$

5. **What is the necessity of cladding for an optical fiber?**

- a) To provide proper light guidance inside the core
- b) To avoid leakage of light from the fiber
- c) To avoid mechanical strength for the fiber
- d) To protect the core from scratches and other mechanical damages

6. **What are the uses of optical fibers?** [A/M 2017]

- a) To transmit the information which are in the form of coded signals of the telephone communication, computer data, etc.
- b) To transmit the optical images (Example : Endoscopy)
- c) To act as a light source at the inaccessible places.
- d) To act as sensors to do mechanical, electrical and magnetic measurements.

7. **What is the principle used in the working of fibers as light guides?**

The phenomenon of total internal reflection is used to guide the light in the optical fiber. To get total internal reflection, the ray should travel from denser to rarer i.e. from core to clad region of the fiber and the angle of incidence in the denser medium should be greater than the critical angle of that medium.

8. **What are step index and graded index fibers?**

In the case of graded index fiber, the refractive index of a core is a constant and is larger than the refractive index of the cladding. The light propagation is mainly by meridional rays. In the case of graded index fiber (GRIN fiber) the refractive index of the core varies parabolically from the center of the core having maximum refractive index to the core-cladding interface having constant minimum refractive index. Here the light propagation is by skew rays.

9. **Why do we prefer step index single mode fiber for long distance communication?**

Step index single mode fiber has

- a) Low attenuation due to smaller core diameter
- b) Higher bandwidth and
- c) Very low dispersion.

10. **Define relative refractive index difference.**

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} = \frac{n_1 - n_2}{n_1}$$

Thus relative refractive index difference is the ratio between the refractive index difference (of core and cladding) and refractive index of core.

**11. What are meridional rays?**

Meridional rays are the rays following Zig Zag path when they travel through fiber and for every reflection it will cross the fiber axis.

**12. What are skew rays?**

Skew rays are the rays following the helical path around the fiber axis when they travel through the fiber and they would not cross the fiber axis at any time.

**13. What is V number of fiber or normalized frequency of fiber?**

V number of fiber or normalized frequency of fiber is used to find the number of propagating modes through the fiber.

$$V = \frac{2\pi a}{\lambda} (N.A)$$

In step index fiber number of modes propagating through the fiber =  $\frac{V^2}{2}$

Taking the two possible polarizations, total number of possible modes propagating through the fiber =  $\frac{V^2}{2} * 2 = V^2$

**14. What are the conditions for total internal reflection?**

- a) Light should travel from denser medium to rarer medium.
- b) The angle of incidence should be greater than the critical angle of the denser medium.

**15. Give the relation between numerical aperture of skew rays and meridional rays.**

$(N.A)_{skew} = \cos \gamma (N.A)_{meridional}$  when the fiber is placed in air.

Here  $\gamma$  is the half of the angular change in every reflection.

**16. State Goos-Haenchen effect.**

Goos-Haenchen effect states that there is a lateral shift of the reflected ray at the point of incidence at the core-cladding interface. This lateral shift is called the Goos-Haenchen shift.

**17. When do you have phase shift during total internal reflection of light?**

When the light ray travels from denser medium to rarer medium, if the angle of incidence is greater than the critical angle of core medium, there is a phase shift for both TE and TM waves.

**18. What are hybrid modes? Give two examples.**

Hybrid modes are the mixture of TE and TM modes that can be traveled through the optical fiber.

Examples:

1.  $HE_{1m}$  modes in which  $|E_z| > |H_z|$
2.  $EH_{1m}$  modes in which  $|H_z| > |E_z|$

**19. Define cutoff wavelength of the fiber.**

The cutoff wavelength is defined as the minimum value of wavelength that can be transmitted through the fiber. The wavelengths greater than the cutoff wavelength can be transmitted.

$$\lambda_{\text{cutoff}} = \frac{2\pi a}{V} (\text{N.A.})$$

**20. Mention the rule distinguishing 'mode' and 'order'.**

The rule states that the smaller the modes propagating angle, the lower the order of the mode. Thus the mode traveling precisely along the fiber's central axis is zero mode.

**21. What is fiber birefringence?**

Imperfections in the fiber are common such as asymmetrical lateral stress, non-circular imperfect variations of refractive index profile. These imperfections break the circular symmetry of ideal fiber and mode propagate with different phase velocity and the difference between their refractive index is called fiber birefringence.

$$B = k_0(n_y - n_x)$$

**22. Give the expression for numerical aperture in graded index fibers.**

$$N.A.(r) = N.A.(0) \left(1 - \left(\frac{r}{a}\right)^\alpha\right)^{1/2} \quad \text{for } r \leq a$$

where  $N.A.(0)$  = axial numerical aperture =  $(n_1^2 - n_2^2)^{1/2}$   $a$  is core radius and  $\alpha$  is the refractive index profile.

## PART - A

## 1. What is Intra Modal Dispersion?

Intra Modal dispersion is pulse spreading that occurs within a single mode. The spreading arises from finite spectral emission width of an optical source. This phenomenon is also called as group velocity dispersion.

## 2. What are the causes of intra modal dispersion?

There is two main causes of intra modal dispersion. They are:

- Material dispersion
- Wave guide dispersion

## 3. What is material dispersion?

Material dispersion arises from the variation of the refractive index of the core material as a function of wavelength. Material dispersion is also referred to as chromatic dispersion. This causes a wavelength dependence of group velocity of given mode. So it occurs because the index of refraction varies as a function of optical wavelength. Material dispersion is an intra modal dispersion effect and is of particular importance for single mode wave-guide.

## 4. What is waveguide dispersion?

Wave guide dispersion which occurs because of a single mode fiber confines only about 80% of optical power to the core. Dispersion this arises since 20% of light propagates in cladding travels faster than the light confined to the core. Amount of wave-guide dispersion depends on fiber design. Other factor for pulse spreading is inter modal delay

## 5. What is group velocity?

If  $L$  is the distance traveled by the pulse,  $\beta$  is the propagation constant along axis then the group velocity is the velocity at which energy is a pulse travels along the fiber.

Q8) what are the causes of absorption? [N/D 2016]  
 These mechanisms causing absorption are Dept. of ECE.  
 - Absorption by atomic defects in glass composition  
 - Extrinsic absorption by impurity atoms in glass matrix  
 - Intrinsic absorption by basic constituent atoms of fiber.

$$V_g = C \cdot (d\beta / dk)$$

6. What is group delay? [A/M 2017]

In an optical fiber there are various modes present. Then the optical input, which is propagated along the fiber, will travel in various modes. Because of these modes the velocity of the signal will vary also there may be a delay in the optical signal of these various modes. This is called as the 'Group Delay'.

7. What is polarization?

It is a fundamental property of an optical signal. It refers to the electric field orientation of a light signal which can vary significantly along the length of a fibre.

8. What is pulse Broadening?

Dispersion induced signal distortion is that a light pulse will broaden as it travels along the fiber. This pulse broadening causes a pulse to overlap with neighboring pulses. After a time 't' the adjacent pulses can no longer be individually distinguished at the receiver and error will occur.

9. What is polarization Mode Dispersion (PMD)? [A/M 2018] [N/D 2016]

The difference in propagation times between the two orthogonal polarization modes will result in pulse spreading. This is called as polarization Mode Dispersion.

10. What is Mode Coupling?

It is another type of pulse distortion which is common in optical links. The pulse distortion will increase less rapidly after a certain initial length of fiber due to this mode coupling and differential mode losses. In initial length coupling of energy from one mode to another arises because of structural irregularities, fiber dia. etc.

11. What is Profile Dispersion?

A fiber with a given index profile (alpha) will exhibit different pulse spreading according to the source wavelength used. This is called as Profile Dispersion.

27) Define attenuation. [N/D 2017]  
Attenuation is a measure of decay signal strength or loss of light power that occurs as light pulses propagate through the length of the fiber.

What are bending losses? Name two types.  
→ Optical fibers suffer radiation losses [A/P 2015] which cause the light energy to be radiated from the fiber, whenever an optical fiber undergoes a bend or curves on their path. Types are

- a) Macroscopic bending loss
- b) Microscopic bending loss.

12. What is M-C fiber?

Fibers that have a uniform refractive index throughout the cladding is called as M-C fiber or Matched-cladding fiber.

13. What is D-C fiber?

In depressed cladding fiber the cladding portion next to the core has a lower index than the outer cladding region.

14. Define dispersion shifted fiber.

By creating a fiber with large negative waveguide dispersion & assuming the same values for material dispersion as in a standard single mode fiber the addition of waveguide & material dispersion can then shifted to zero dispersion point to long wavelength. The resulting optical fiber are known as dispersion shifted fiber.

15. Define dispersion flattening?

The reduction of fiber dispersion by spreading the dispersion minimum out over a wide range. This approach is known as dispersion flattening.

16. What is effective cut-off wavelength?

It is defined as the largest wavelength at which the higher order LP<sub>11</sub> mode power relative to the fundamental LP<sub>01</sub> mode power is reduced to 0.1db.

17. What is intramodal dispersion?

The intramodal dispersion depends on wavelength and its effect on signal distortion increases with the spectral width of the optical source. (It is a band of wavelength over which the source emits light)

18. Write a note on scattering losses.

Scattering losses in glass arise from microscopic variation in the material density from compositional fluctuation and from structural inhomogeneities or defects occurring during fiber manufacture

**19. What is Rayleigh scattering?**

The index variation causes a Rayleigh type of scattering of light. Rayleigh scattering in glass is the same phenomenon that scatters light from sun in the atmosphere, giving rise to blue sky.

The expression for Rayleigh scattering loss is given by

$$\alpha_{\text{scat}} = (8\pi^3/3\lambda^2)(n^2-1)^2 k_B T_f \beta_T$$

$n$  = refractive index

$k_B$  = boltzman constant

$\beta_T$  = isothermal compressibility

$T_f$  = fictive temperature,  $\lambda$  = operative wavelength

**20. What is intermodal dispersion?**

Intermodal dispersion is a pulse spreading that occurs within a single mode. The spreading arises from finite spectral emission width of an optical source. it is called group velocity dispersion or intermodal dispersion

**21. What is intramodal delay?**

The other factor giving rise to pulse spreading is intramodal delay which is a result of each mode having a different value of Group velocity at a single frequency.

**22. What is the measure of information capacity in optical wave guide?**

[A/m 2019]

It is usually specified by bandwidth distance product in MHz For a step index fiber the various distortion effects tend to limit the bandwidth distance product to 20MHz.

**23. Mention the losses responsible for attenuation in optical fibers.**

Absorption losses, Scattering losses and bending losses

**24. What do you meant by Extrinsic absorption?**

Absorption phenomena due to impurity atoms present in the fiber.

**25. Define microscopic bending?**

Fiber losses occur due to small bending arise while the fiber is inserted into a cable.

**26. Define macroscopic bending?**

If any bending present in the fiber while cabling, the optical power get radiated

27) Define signal attenuation [A/P 2015.]  
- Signal attenuation within the optical fiber is expressed in logarithmic unit is decibel. Decibel which is used for comparing two power



... may be defined for a particular optical wave length as, "the ratio of the input optical power ( $P_i$ ) into fiber to the output optical power ( $P_o$ ) from the fiber."

EC6702

OPTICAL COMMUNICATION AND NETWORKING

### UNIT - 3

#### PART - A

##### 1. What are the advantages of optical communication?

1. Low transmission loss.
2. Small size and weight.
3. No electromagnetic interference.
4. Electrical isolation.

##### 2. Define direct band gap materials and indirect band gap materials.

In direct band gap materials direct transition is possible from valence band to conduction band. e.g. GaAs, InP, InGaAs. In indirect band gap materials direct transition is not possible from valence band to conduction. e.g. silicon, germanium.

##### 3. What are the advantages of LED?

1. LEDs are less complex circuits than Laser diodes.
2. Fabrication is easier.
3. They have long life.

##### 4. What are the two types of confinement used in LEDs?

1. Optical confinement.
2. Carrier confinement.

##### 5. What are the two types of LED configurations?

1. Homo junction
2. Single and double hetero junction.

##### 6. What are the three requirements of Laser action?

1. Absorption

[N/D 2016]

2. Spontaneous emission
3. stimulated emission.

**7. What are the three types of Laser diode structures?**

1. Gain indexed guide
2. Positive indexed guide
3. Negative indexed guide

**8. What are the fundamental structures of Index guided lasers?**

1. buried hetero structure.
2. Selectively diffused construction
3. Varying thickness structure
4. Bent layer configuration.

**9. What are the three basic methods of current confinement?**

1. Preferential dopant diffusion.
2. Proton implantation
3. Inner strip confinement
4. Re growth of back biased PN junction.

**10. Define modulation.**

The process of imposing information on a light stream is called modulation. This can be achieved by varying the laser drive current.

**11. Define external quantum efficiency. [N/D 2016]**

The external quantum efficiency is defined as the number of photons emitted per radiative electron-hole pair recombination above threshold.

**12. Define threshold current.**

The threshold current is conventionally defined by extrapolation of the lasing region of the power-versus-current curve. At high power outputs, the slope of the curve decreases because of junction heating.

**13. Define longitudinal modes.**

Longitudinal modes are associated with the length of the cavity and determine the typical spectrum of the emitted radiation.

**14. Define lateral modes.**

These modes lie in the plane of the pn junction. They depend on the sidewall preparation and the width of the cavity. It determines the shape of the lateral profile of the laser beam.

**15. Define transverse modes.**

Transverse modes are associated with the electromagnetic field and beam profile in the direction perpendicular to the plane of the pn junction. They determine the laser characteristics as the radiation pattern and the threshold current density.

**16. Define population inversion.**

Stimulated emission will exceed absorption only if the population of the excited states is greater than that of the ground state. This condition is called as population inversion

**17. Define internal quantum efficiency.**

The internal quantum efficiency is the fraction of the electron-hole pairs that recombine radiatively. If the radiative recombination rate is  $R$  and the non-radiative recombination rate is  $R_{nr}$ , then the internal quantum efficiency is the ratio of the radiative recombination rate to the total recombination rate.

**18. Differentiate LEDs and Laserdiodes. [A/M 2017] [N/D 2016]**

S.No.	LED	Laser diode
1.	The output obtained is incoherent.	The output obtained is coherent.
2.	Less expensive and less complex	More expensive and more complex.
3.	Long lifetime.	Less lifetime.

**19. What is mass action law?**

$$P_n = n_i * n_i$$

Where  $p$  -- concentration of holes.

$n$  concentration of electrons.

$N_i$  intrinsic concentration.

## 20. What is an intrinsic and extrinsic semiconductor material?

Intrinsic semiconductors have no impurities.

Extrinsic semiconductors contain impurities like boron and phosphorus.

## 21. Define responsivity [N/D 2016]

The performance of an avalanche photodiode is characterized by its responsivity

$$R_{APD} = \eta q M = R_o M h\nu$$

where

$R_o$  is the unity gain responsivity.

## 22. Define long wavelength cut off related to photodiode.

The upper wavelength cutoff ( $\lambda_c$ ) is determined by the band gap energy  $E_g$  of the material. If  $E_g$  is expressed in units of electron volts (eV), then  $\lambda_c$  is given in units of micrometers ( $\mu m$ ) by

$$\lambda_c (\mu m) = \frac{hc}{E_g} = \frac{1.24}{E_g (eV)}$$

## 23. Give some types of photodetectors.

- Photomultipliers
- Pyroelectric detectors
- Semiconductor- based detectors
- Phototransistors
- Photodiodes

## 24. What are the advantages of photodiodes?

- a. Small size
- b. Suitable material
- c. High sensitivity
- d. Fast response time

32) Give some possible lensing schemes to improve optical source to fiber coupling efficiency [N/D 2017]

The laser emitting area is much smaller than the fiber core, spherical or cylindrical lens or optical fiber tapers are used to improve the coupling efficiency between edge-emitting laser diodes and an optical fibers.

## 25. What are the types of photodiodes?

- PIN photodetector
- Avalanche photodiode (APD)

## 26. Define photocurrent.

The high electric field present in the depletion region causes the carriers to separate and be collected across the reverse-biased junction. This gives to a current flow in the external circuit, with one electron flowing for every carrier pair generated. This current flow is known as photocurrent.

## 27. Define quantum efficiency.

It is defined as the number of the electron - hole pairs generated per incident photon of energy  $h\nu$  and is given by

$$\eta = \frac{\text{No. of electron-hole pairs generated}}{\text{No. of incident photons}}$$

## 28. Define impact ionization.

In order for carrier multiplication to take place, the photo generated carriers must traverse a region where a very high electric field is present. In this high field region, a photo generated electron or hole can gain energy so that it ionizes bound electrons in the valence band upon colliding with them. This carrier multiplication mechanism is known as impact ionization.

## 29. Define avalanche effect.

The newly created carriers are accelerated by the high electric field, thus gaining enough energy to cause further impact ionization. This phenomenon is called avalanche effect.

## 30. What is p+ $\Pi$ p n+ reach- through structure?

The reach-through avalanche photodiode (RAPD) is composed of a high resistivity p-type material deposited as an epitaxial layer on a p+ substrate. A p-type diffusion is then made in the high resistivity material, followed by the construction of an n+ layer. The configuration is called p+  $\Pi$  p n+ reach-through structure.

31) Write Laser diode rate equations. [N/D 2017]

$$\rightarrow \text{Rate of Spontaneous emission} \Rightarrow R_{\text{spont}} = AN_2$$

$$\rightarrow \text{Rate of stimulated emission} \Rightarrow R_{\text{stim}} = BN_2 P_{\text{em}} \quad \text{Dept. of ECE.}$$

$$\rightarrow \text{Rate of absorption} \Rightarrow R_{\text{abs}} = B'N_1 P_{\text{em}}$$

where,  $A, B, B' \rightarrow$  constants +  $P_{\text{em}} \rightarrow$  Spectral density

## PART - A

## 1. Define minimum detectable optical power. [A/M 2017]

It is defined as the optical power necessary to produce a photocurrent of the same magnitude as the root mean square of the total current.

## 2. Define quantum noise.

It is not possible to predict exactly how many electron-hole pairs are generated by a known optical power incident on the detector is the origin of the type of shot noise called quantum noise.

## 3. What is meant by error rate? [A/M 2017] [A/M 2015]

An approach is to divide the number  $N_e$  of errors occurring over a certain time interval  $t$  by the number  $N_t$  of pulses transmitted during this interval. This is called either the error rate or the bit error rate.

$$\text{Bit error rate BER} = \frac{N_e}{N_t} = \frac{N_e}{Bt}$$

$$\text{Where } B = \frac{1}{T_b}$$

## 4. Define quantum limit [A/M 2018] [N/D 2016]

It is possible to find the minimum received optical power required for a specific bit error rate performance in a digital system. This minimum received power level is known as quantum limit.

## 5. Give the classifications of preamplifiers.

- Low impedance (LZ) preamplifier
- High impedance (HZ) preamplifier
- Transimpedance preamplifier

32) List any two advantages of transimpedance amplifiers. [A/M 2015]

- 1) wide dynamic range
- 2) no equalization is required
- 3) easy controllability & stability
- 4) less sensitivity

5) Less susceptible to pick up noise, cross talk etc.

**6. What is meant by excess noise factor?**

The ratio of the actual noise generated in an avalanche photodiode to the noise that would exist if all carrier pairs were multiplied by exactly  $m$  is called the excess noise factor ( $F$ ).

**7. What is meant by inter symbol interference (ISI)?**

ISI results from pulse spreading in the optical fibre. The presence of this energy in adjacent time slots results in an interfering signal. Hence it is called ISI.

**8. Give the advantages of Pin photodiodes.**

[m 2019]

- Very low reverse bias is necessary
- High quantum efficiency
- Large bandwidth
- Low noise level

**9. What do you mean by thermal noise?**

Thermal noise is due to the random motion of electrons in a conductor. Thermal noise arising from the detector load resistor and from the amplifier electronics tend to dominate in applications with low signal to noise ratio.

**10. Give the equation for mean square shot noise.**

The mean square shot noise is given by

$$\langle i_n^2 \rangle = 2qI_B B$$

$I_B$  average output current

$B$  bandwidth of the amplifier

**11. Define multiplication  $M$ .**

The multiplication  $M$  for all carriers generated in the photodiode is defined by

$$M = \frac{I_M}{I_P}$$

$I_M$  average value of the total multiplied output current

$I_P$  primary unmultiplied photocurrent

**12. What is current mode of operation of photodiode?**

In photo conducting mode, the photocurrent is slightly dependent on the reverse bias. For a constant reverse bias, the current is linear. This is called current mode of operation of the photodiode.

**13. What are the system requirements?**

The following are the key system requirements.

- The desired or possible transmission distance
- The data rate or channel bandwidth
- Bit error rate (BER)

**14. What are splices? What are the requirements of splices?**

The splices are generally permanent fiber joints, whereas connectors are temporary fiber joints. Splicing is a sort of soldering. The requirements of splices are:

- Should cause low attenuation
- Should be strong & light in weight
- Should have minimum power loss
- Should be easy to install

**15. What are the methods of fiber splicing?**

There are 3 methods of fiber splicing. They are:

- Electric arc fusion splicing or fusion splicing
- Mechanical splicing
- V-groove splicing or loose tube splicing

**16. What are connectors? What are the types of connectors?**

The connectors are used to join the optical sources as well as detectors to the optical fiber temporarily. They are also used to join two optical fibers. The 2 major types of connectors are:

- Lensed type expanded beam connector
- Ferrule type connector

**17. What are the requirements of a good connector?**

The requirements of a good connector are as follows:



- Low loss
- Repeatability
- Predictability
- Ease of assembly and use
- Low cost & reliability
- Compatibility

**18. Give the 2 analysis that are used to ensure system performance?**

The 2 analysis that are used to ensure system performance are:

- Link power budget analysis
- Rise time budget analysis

**19. Explain briefly about link power budget analysis?**

In the optical power loss model for a pt-to-pt link, the optical power rxed at the photo detector depends on the amount of light coupled into the fiber & losses occurring in the fiber at the connectors & splices. The link loss budget is derived from the sequential loss contribution of each element in the link.

$$\text{Loss} = 10 \log \frac{P_{\text{out}}}{P_{\text{in}}} \quad -$$

The total optical power loss is,

$$P_T = P_S - P_R$$

**20. Give the range of system margin in link power budget?**

The system margin is usually (6-8) db. A positive system margin ensures proper operation of the circuit. A negative value indicates that insufficient power will reach the detector to achieve the required bit error rate, BER.

**21. What are the system components of system rise time?**

The 4 basic system components that contribute to the system rise time are:

- Transmitter (source) rise time
- Receiver rise time
- Material dispersion time of the fiber
- Modal dispersion time of the fiber link

All these 4 basic elements may significantly limit system speed.

**22. Why the attenuation limit curve slopes downwards to the right?**

As the minimum optical power required at the rxer for a given BER becomes higher for increasing data rates, the attenuation limit curve slopes downward to the right.

**23. What are the noise effects on system performance?**

The main penalties are modal noise, wavelength chirp, spectral broadening, mode-partition noise.

**24. Define modal noise?**

It arises when the light from a coherent laser is coupled in to a multimode fiber operating at 400Mbps and higher. It mainly occurs due to mechanical vibrations and fluctuations in the frequency of the optical source.

**25. What are the measures to avoid modal noise?**

The measures are

- use LEDs
- use LASER having more longitudinal modes
- use a fiber with large numerical aperture
- use a single mode fiber

**26. Define mode partition noise?**

The mode partition noise is associated with intensity fluctuations in the longitudinal modes of a laser diode. It becomes more pronounced for the higher bit rates.

**27. What is meant by chirping?**

It means that the dynamic line broadening (line broadening is a frequency chirp) in the laser which oscillates in the single longitudinal mode under CW operation when the injection current is intensity modulated.

**28. What is the best way to minimize the chirping?**

It is to choose the laser emission wavelength close to the zero-dispersion of the wavelength of the fiber.

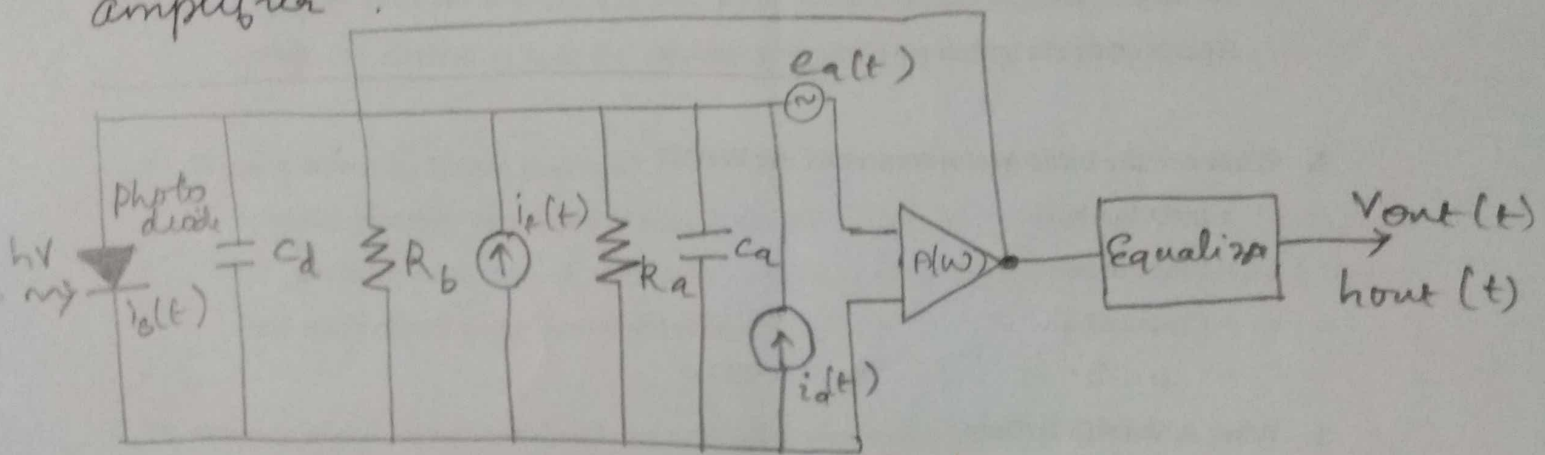
### 29. What is reflection noise?

It is the optical power that gets reflected at the refractive index discontinuities such as in splices, couplers and filters, or connectors. The reflected signals can degrade both the transmitter and receiver performance.

### 30. What are the effects of reflection noise in high speed systems?

They cause optical feedback which leads to optical instabilities that may lead to inter symbol interference and intensity noise.

II 33) Draw the generic structure of transimpedance amplifier.



31) what is cut back method? [N/D 2016]

- cut back method is often used for measuring the total attenuation of an optical fiber.

- cut back method involves comparing the optical power transmitted through longer piece of fiber to the power transmitted through a shorter piece of fiber.

- It measures the output power ( $P$ ) of the test fiber of known length  $L$ .

## UNIT - 5

### PART - A

#### 1. What are the techniques to reduce optical feedback?

- Fiber end faces with a curved surface to the laser emitting facet.
- Index matching oil or gel at air glass interfaces.
- PC connectors
- Optical isolators within the transmitter module.

#### 2. What are the basic performances of the WDM?

- Insertion loss
- Channel width
- Cross talk

#### 3. What is WDM? Define.

WDM is wavelength division multiplexing. The optical beam consists of different wavelengths and several channel information is transmitted over a single channel.

#### 4. What is meant as bidirectional WDM?

A single WDM which operates as both multiplexing and De multiplexing Devices is said as the bidirectional WDM.

#### 5. Define Radiance.

Radiance (or brightness) is a measure, in Watts, of the optical power radiated into a unit solid angle per unit area of the emitting surface.

#### 6. What is meant by 'population inversion'?

In thermal equilibrium, the density of excited electrons is very small. Most photons incident on the system will therefore be absorbed, so that stimulated emission is essentially

negligible. Stimulated emission will exceed absorption only if the population of the excited states is greater than that of the ground state. This condition is known as population inversion.

**7. What are the factors to be considered in link power budget?**

The factors to be considered in link power budget are:

- Transmission speed
- Optical sources & detectors
- Optical fiber

**8. What are the causes of absorption?**

Normally, the system is in the ground state. When a photon of energy  $h\nu_{12}$  impinges on the system, an electron in state  $E_1$  can absorb the photon energy & be excited to state  $E_2$ .

**9. What is meant by hetero junction?**

In hetero junction, two different alloy layers are on each side of the active region. Because of the sandwich structure of differently composed alloy layers, both the carriers & optical field are confined in the central active layer.

**10. What is meant by indirect band gap semiconductor material?**

For indirect band gap materials, the conduction-band minimum & the valence-band maximum energy levels occur at different values of momentum. Here, band-to-band recombination must involve a third particle to conserve momentum, since the photon momentum is very small. Phonons serve this purpose.

**11. What is meant by 'modal noise'?**

It arises when light from a laser is coupled into the multimode fiber.

**12. What is the necessity of cladding for an optical fiber?**

- To provide proper light guidance inside the core
- To avoid leakage of light from the fiber
- To avoid mechanical strength for the fiber
- To protect the core from scratches and other mechanical damages

13) Define Power Penalty? [NLD 2018]  
\* In practical systems, many factors degrade the performance.  
\* To compensate the system degradation, the signal power has to be increased to achieve

the same SNR or BER performance as that of an ideal system.

\* This increase in power is called the Power Penalty.

14) State Detector response time [N/D 2018]

\* The response time of the photocarriers in the depletion region depends on the carrier drift velocity & depletion layer width  $w$ ,  $t_d = \frac{w}{v_d}$ .

(b) Diffusion time of photocarriers outside depletion region

(c) RC-time constant of the circuit.

$$B = \frac{1}{2\pi R_T C_T} \quad (R_T = R_s \parallel R_L \text{ \& } C_T = C_a + C_d)$$

## Part-A.

1) Distinguish between Meridional Rays from skew Rays.

Meridional Rays	Skew Rays
<p>Meridional Rays are the rays following zig-zag path when they travel through fiber.</p> <p>At every reflection, it will cross the fiber axis.</p>	<p>Skew rays are the rays following helical path around the fiber axis when they travel through the fiber.</p> <p>They would not cross the fiber axis at any time.</p>

2) 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 1550nm?

Given:

$$n_1 = 1.480$$

$$n_2 = 1.478$$

$$\lambda = 1550 \text{ nm}$$

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

$$= \sqrt{(1.480)^2 - (1.478)^2}$$

$$= 0.0769$$

$$V = \frac{2\pi a (NA)}{\lambda}$$

$$a = \frac{V\lambda}{2\pi(NA)}$$

$$= \frac{2.405 \times 1550 \times 10^{-9}}{2\pi \times 0.0769}$$

$$= \frac{3.72775 \times 10^{-6}}{0.483}$$

$$a = 7.7 \times 10^{-6} \text{ m}$$

$$2a = 2 \times 7.7 \times 10^{-6}$$

$$2a = 1.54 \times 10^{-5}$$

$$2a = 15.43 \mu\text{m}$$

3) What is polarisation mode dispersion (PMD)?

The difference in propagation times between the two orthogonal polarization modes will result in pulse spreading. This is called as polarization Mode dispersion (PMD).

4) Distinguish between Intermodal and Intramodal dispersions.

Intermodal	Intramodal
Occurs in Multimode fibers.	Occurs in Single mode fibers.
Also called as Modal dispersion, Group velocity dispersion	Also called as chromatic dispersion waveguide dispersion.
pulse broadening arises due to propagation delay differences	pulse broadening depends on wavelength.



Why silicon is not used to fabricate LED or Laser diode?

Silicon is not used to fabricate LED or Laser diode because

- ① It is an indirect bandgap semiconductor
- ② It has  $E_g$  level of 1.1 eV, the radiated emission corresponds to infrared but not the visible light.

6) What is Internal Quantum Efficiency?

Internal Quantum Efficiency is defined as the ratio of Radiative recombination rate to total recombination rate.

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

Where,  $R_r \rightarrow$  Radiative recombination rate.

$R_{nr} \rightarrow$  Non-Radiative recombination rate.

7) Define responsivity.

Responsivity is defined as the ratio of output photo current to incident optical power.

$$R = \frac{I_p}{P_o}$$

$$P_o = \frac{\eta q}{h\nu}$$

Where,  $R \rightarrow$  Responsivity.

$I_p \rightarrow$  Output photocurrent.

$P_o \rightarrow$  Incident optical power.

8) State detector Response time

The response time of the photocarriers in the depletion region

a) depends on the carrier drift velocity and depletion layer width,  $w$ ,  $t_d = \frac{w}{V_d}$ .

b) Diffusion time of photocarriers outside depletion Region

c) RC time constant of the circuit.

$$B = \frac{1}{2 \times R_T \times C_T} \quad [R_T = R_s \parallel R_L \text{ and } C_T = C_a + C_d]$$

9) Define power penalty.

\* In practical system, many factors degrade the performance

\* To compensate the system degradation, the signal power has to be increased to achieve of an ideal system.

\* This increase in power is called the power penalty.

10) What is EDFA?

An erbium-doped fiber amplifier (EDFA) is a device that amplifies an optical fiber signal. A trace impurity in the form of a trivalent erbium ion is inserted into the optical fiber's silica core to alter its optical properties and permit signal amplification.