# OPTICAL COMMUNICATION AND NETWORKING

## 2 Marks Questions and Answers

## UNIT - 1 - INTRODUCTION

**1. Define a fiber optic system.**

Fiber optic system consists of a fiber optic cable, a light source and a light detector. The optic fiber is used to carry the light beam from one place to another.

**2. What are the uses of optical fibers?**

a) To transmit the information of telephone communication, computer data, etc. which are in the form of coded light signals

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.

**3. Differentiate between glass and plastic fiber cables.**

Fiber optic cables are made from glass and fiber. Glass has the lowest loss but it is brittle. Plastic is cheaper and more flexible but has high attenuation.

**4. Mention the advantages of optical fiber communication.**

1. Large information capacity
2. Long distance transmission
3. Small size and low weight
4. Electrical isolation
5. Immunity to crosstalk and EMI
6. Increased signal security
7. Enhanced safety
8. Ruggedness and flexibility
9. System reliability and easy maintenance
10. Low cost

**5. Define reflection.**

The law of reflection states that the angle at which the ray strikes the interface is exactly equal to the angle that the reflected ray makes with the imaginary perpendicular normal.

**6. Define refraction.**

Refraction occurs when light ray passes from one medium to another i.e. the light ray changes direction at the interface. The refraction (bending) takes place because light travels at different speed in different mediums.

**7. What is Snell's law?**

Snell's law states how light ray reacts when it meets the interface of two mediums having different refractive indices. Hence it is the relationship at the interface of two mediums and is given by

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

where $n_1$ is the refractive index of medium 1

$n_2$ is the refractive index of medium 2

$\Phi_1$ is the angle of incidence

$\Phi_2$ is the angle of refraction

**8. What is total internal reflection?**

When the incidence angle is increased beyond the critical angle, the light ray does not pass through the interface into the other medium. This gives the effect of mirror existing at the interface with no possibility of light escaping outside the medium. In this, the angle of reflection is equal to the angle of incidence. This action is called the total internal reflection of the beam.

**9. 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.

**10. What is internal reflection?**

When the reflection of light is of a less optically dense material, it is called internal reflection.

**11. What is external reflection?**

When light travelling in a certain medium is reflected off an optically denser material it is referred to as external reflection.

**12. What is meant by refractive index of a material?**

The amount of refraction or bending that occurs at the interface of two materials of different densities is expressed as refractive index of two materials. It is the ratio between the speed of light in air and the speed of light in the material and is given by n = c /v.

**13. What is critical angle of incidence?**

The critical angle is the angle of incidence that causes the refracted light to travel along the interface between two different mediums. It is also defined as the minimum angle of incidence at which the ray strikes the interface of two media and causes an angle of refraction equal to $90^0$.

Critical angle of incidence $\boldsymbol{\Phi_c = \sin^{-1} (n_2 / n_1)}$ where $\mathbf{n_1}$ is the refractive index of medium1

$\mathbf{n_2}$ is the refractive index of medium 2

**14. Define acceptance angle. (Nov 14)**

The maximum angle '$\Phi_{max}$' with which a ray of light can enter through the entrance end of the fiber and still be totally internally reflected is called acceptance angle of the fiber.

**15. Define acceptance cone.**

Rotating the acceptance angle '$\Phi_{max}$' around the fiber axis, a cone shaped pattern is obtained. It is called the acceptance cone of the fiber input. In other words, the acceptance cone is the angle within which the light is accepted into the core and is able to travel along the fiber.

**16. Write the expression for the refractive index in graded index fibers.**

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

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

r →radial distance from fiber axis a→ core radius

$n_1$→ refractive index at the core $n_2$→refractive index at the cladding

α →shape of the index profile Δ→ index difference

**17. 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 provide mechanical strength for the fiber
d) To protect the core from scratches and other mechanical damages
e) To protect the core from absorbing surface contaminants

**18. Define relative refractive index difference.**

$\Delta = n_1^2 - n_2^2 / 2n_1^2 \approx n_1 - n_2 / n_1$

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

**19. Define Numerical aperture of a step index fiber. (Nov 14)**

Numerical aperture (N.A) of the fiber is the light collecting capability of the fiber and is the measure of the amount of light rays that can be accepted by the fiber. It is equal to the sine of acceptance angle.

$N.A = \sin\Phi_{max} = (n_1^2 - n_2^2)^{1/2} = n_1(2\Delta)^{1/2}$ where $n_1$ and $n_2$ are the refractive indices of core and cladding respectively and $\Delta$ is the index difference

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

$N.A.(r) = N.A.(0)\ [1-(r/a)^{\alpha}]^{1/2}$ 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.

**21. What is an index profile?**

The index profile of an optical fiber is a graphical representation of the magnitude of the refractive index across the fiber.

**22. Define Mode-field diameter.**

The mode-field diameter (MFD) is the fundamental parameter of a single mode fiber. This can be determined from the mode field distribution of the fundamental $LP_{01}$ mode.

**23. Why do we prefer step index single mode fiber for long distance communication? Or List the advantages of single mode fibers. (Nov 14)**

Step index single mode fiber has

a) low attenuation due to smaller core diameter
b) higher bandwidth and
c) very low dispersion.

**24. What is tunnel effect?**

The leaky modes are continuously radiating their power out of the core as they propagate along the fiber. This power radiation out of the waveguide due to a quantum mechanical phenomenon is known as the tunnel effect.

**25. 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.

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

If the refractive index of the core in a fiber is uniform throughout and undergoes abrupt change (or step) at the cladding boundary, it is called step index fiber. The light propagation is mainly by meridional rays.

If the refractive index of the core in a fiber is made to vary as a function of the radial distance from the centre of the fiber, it is called graded index fiber, i.e. the refractive index decreases as the radial distance increases. Here the light propagation is by skew rays.

**27. What are leaky modes in optical fibers?**

Leaky modes are the modes that are partially confined to the core region and attenuate continuously by radiating their power out of the core as they propagate along the fiber.

**28. What is V number or normalized frequency of fiber? (Nov 2014)**

V number of fiber or normalized frequency of fiber is used to find the number of propagating modes through the fiber. $\mathbf{V = 2\pi a\,(N.A) / \lambda}$

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

Taking the two possible polarizations, total number of possible modes propagating through the fiber = $\mathbf{V^2 / 2 * 2 = V2}$.

**29. What are meridional rays?**

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

**30. What are skew rays?**

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

**31. What is fiber birefringence?**

Fiber imperfections such as asymmetrical lateral stress, non circular imperfect variations of refractive index profile break the circular symmetry of ideal fiber and modes propagate with different phase velocity and the difference between their refractive index is called fiber birefringence. $\mathbf{B=k_o(n_y-n_x)}$

**32. Define phase velocity.**

For plane waves, the constant phase points form a surface called wave front. As a monochromatic light wave propagates along a waveguide in the z direction these points of constant phase travel at a phase velocity $v_p$ given by $\mathbf{v_p= \omega/\beta}$, where $\boldsymbol{\omega}$ is the angular frequency of the wave and $\boldsymbol{\beta}$ is the wave propagation constant.

**33. Define group velocity.**

The light energy is composed of a sum of plane wave components of different frequencies. When a group of waves with closely similar frequencies propagate, their resultant forms a packet of waves. This wave packet does not travel at the phase velocity of the individual waves but moves at a group velocity $\mathbf{v_g = \delta\omega/\delta\beta}$.

**34. What is a wave front?**

Within all electromagnetic waves, there are points of constant phase. For plane waves these constant phase points form a surface called wave front.

**35. Define wavelength.**

Wavelength is the distance travelled by one cycle of an electromagnetic wave.

Wavelength ($\lambda$) = c/f = speed of light in air / frequency

# UNIT- II - TRANSMISSION CHARACTERISTICS OF OPTICAL FIBERS

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

Absorption losses, scattering losses and radiative losses

**2. Define fiber loss or signal attenuation.**

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 helps to determine the maximum transmission distance between a transmitter and a receiver.

**3. What are the three different mechanisms which cause absorption?**

1. Absorption by atomic defects in the glass composition
2. Extrinsic absorption by impurity atoms in the glass material
3. Intrinsic absorption by the basic constituent atoms of the fiber material.

**4. What do you mean by extrinsic absorption?**

Absorption phenomena due to impurity atoms present in the fiber.

**5. Mention the factors that cause Scattering losses.**

Scattering losses in glasses arise from

1. Microscopic variations in the material density
2. Compositional fluctuations
3. Structural inhomogeneities (or) defects occurring during fiber manufacture.

**6. What are the types of scattering losses?**

a) Linear scattering loss — 1. Rayleigh scattering — 2. Mie scattering

b) Non-Linear scattering — 1. Stimulated Brillouin scattering — 2. Stimulated Raman scattering

**7. What is Rayleigh scattering?**

Due to Microscopic variations in the material density and compositional fluctuations, there will be refractive index variations within the glass. This 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 a blue sky.

The expression for Rayleigh scattering loss is given by

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

$n$=refractive index — $k_B$= Boltzmann's constant

$\beta_T$= isothermal compressibility — $T_f$=fictive temperature

**8. Define macroscopic bending losses.**

Macroscopic bending occurs when the radius of curvature of bend is greater than the fiber diameter. As the radius of curvature of bend decreases, the loss increases exponentially until at a certain critical radius, the curvature loss becomes observable.

**9. Define microscopic bending.**

Micro bends are repetitive small- scale fluctuations in the radius of curvature of the fiber axis. They are caused either by non-uniformities in the manufacturing of the fiber or by non-uniform lateral pressures created during the cabling of the fiber.

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

The cutoff wavelength is defined as the minimum value of wavelength that can be transmitted through the fiber. i.e. The light with wavelengths greater than the cutoff wavelengths can be transmitted. $\lambda_{cutoff} = 2\pi a\ (N.A) / V$

**11. What is Mode Coupling?**

The waveguide non uniformities such as deviations of the fiber axis from straightness, variations in the core diameter, irregularities at the core-cladding interface and refractive index variations may change the propagation characteristics of the fiber. This produces the effect of coupling energy from one mode to another which is called as mode coupling.

**12. What is effective cut-off wavelength?**

It is defined as the largest wavelength at which the higher order LP11 mode power relative to the fundamental LP01 mode power is reduced to 0.1db.

**13. Define dispersion in optical fibers.**

Dispersion of the transmitted signal causes distortion of both analog and digital transmission along optical fibers. It causes broadening of the transmitted light pulses as they travel along the channel.

**14. 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 certain time, the adjacent pulses can no longer be individually distinguished at the receiver and error will occur.

**15. What is Intra Modal Dispersion or group velocity dispersion (GVD)?**

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 (GVD).

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

a) Intra modal dispersion.
1. Material dispersion
2. Wave guide dispersion
3. Group velocity dispersion (GVD) or modal dispersion

b) Intermodal dispersion

**17. What is material dispersion or chromatic dispersion?**

Material dispersion arises due to 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 any given mode; i.e. pulse spreading occurs even when different wavelengths follow the same path.

**18. What is waveguide dispersion?**

Wave guide dispersion occurs because a single mode fiber confines only about 80% of optical power to the core and the remaining 20% of light which propagates in cladding travels faster than the light confined to the core since the refractive index is lower in the cladding. Amount of wave-guide dispersion depends on fiber design.

**19. What is polarization Mode Dispersion (PMD)?**

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.

**20. What is intermodal dispersion or modal delay?**

Intermodal dispersion or modal delay is the result of each mode having a different value of the group velocity at a single frequency in a multimode fiber. The pulse width at the output is dependent upon the transmission times of the slowest and fastest mode.

**21. What is group delay?**

The multimode fiber contains number of modes. The optical input, which is propagated along the fiber, will travel in various modes. As the signal propagates along the fiber, each spectral component travels independently and undergoes a time delay. This is called as the 'Group Delay'.

**22. Define dispersion flattening.**

Dispersion flattening is a method to reduce the fiber dispersion by distributing the dispersion minimum over a wide spectral range.

**23. Define dispersion shifted fiber.**

By creating a fiber with larger negative waveguide dispersion and assuming the same values for material dispersion as in a standard single mode fiber, the addition of waveguide and material dispersion can then shift the zero dispersion point to longer wavelengths. The resulting optical fiber is known as dispersion shifted fiber.

**24. What are the major fiber joints?**

a) Fiber splices: These are semipermanent or permanent joints

b) Demountable fiber connectors or simple connectors: These are removable joints

**25. What is Fresnel reflection?**

Even when the two jointed fiber ends are smooth and perpendicular to the fiber axes, and the two fiber axes are perfectly aligned, a small portion of the light may be reflected back into the transmitting fiber causing attenuation at the joint. This is known as Fresnel reflection.

**26. What are the types of misalignment?**

a) Longitudinal misalignment

b) Lateral/radial/axial misalignment

c) Angular misalignment

**27. List the factors that cause intrinsic joint losses in a fiber. (Nov 14)**

a) different core and/or cladding diameters

b) different numerical apertures and /or relative refractive Index differences

c) different refractive index profiles

d) fiber faults (core ellipticity, core concentricity, etc.,)

e) Fresnel reflection

**28. 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

**29. What are the techniques used in splicing?**

a) Fusion splicing

b) V-groove mechanical splicing

c) Elastic tube or elastomeric splicing

d) The Springroove splicing

**30. Define fiber coupler.**

An optical fiber coupler is a device that distributes light from a main fiber into one or more branch fibers.

**31. Mention the three types of fiber couplers.**

a) Three and four port couplers
b) Star couplers
c) Wavelength division multiplexing devices

**32. What are the loss parameters associated with four port couplers?**

a) Excess loss
b) Insertion loss
c) Crosstalk
d) Split ratio

**33.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

**34. Distinguish between intramodal and intermodal dispersion. (Nov 2014)**

| Sl.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 |

**35. What is meant by mechanical splice?**

Mechanical splicing is one of the permanent joint techniques in which the fibers are held in alignment by some mechanical means.

Some of the methods are

a). The use of tubes around the fiber ends (tube splices)
b). V-grooves into which the butted fibers are placed (groove splices)

**36. Define normalized propagation constant. (AU Nov/Dec 2005)**

The number of modes that can exist in a waveguide as a function of V may be represented in terms of a normalized propagation constant defined by

$$b = a^2 w^2 / v^2 = (\beta / k) - n_2^2 / n_1^2 - n_2^2$$

# UNIT - III - SOURCES AND DETECTORS

**1. What is meant by hetero junction? What are its advantages?**

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 and optical field are confined in the central active layer. The band gap differences of adjacent layers confine the charge carriers, while the differences in the indices of refraction of adjoining layers confine the optical field to the central active layer.

This dual confinement leads to both high efficiency and high radiance.

**2. 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.

**3. 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. Eg. GaAs, InP, InGaAs.

In indirect band gap materials direct transition is not possible from valence band to Conduction band. Eg. Silicon, Germanium.

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

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.

**5. What are the two types of confinement used in LEDs?**

1. Optical confinement. 2. Carrier confinement.

**6. Why is carrier confinement used in LED?**

Carrier confinement is used to achieve a high level of radiative recombination in the active region of the device, which yields high quantum efficiency.

**7. Why is optical confinement important in LED?**

Optical confinement is used to prevent absorption of the emitted radiation by the material surrounding the pn junction.

**8. What is radiance or brightness?**

Radiance is a measure in watts of the optical power radiated into a unit solid angle per unit area of the emitting surface.

**9. What are the two types of LED configurations?**

1. Surface emitter LEDs
2. Edge emitter LEDs

**10. What are the advantages of LED?**

1. Simpler fabrication
2. Less costly
3. More reliability
4. Less temperature dependence
5. Simpler drive circuitry

**11. Compare and contrast between surface and edge emitting LEDs.**

| Sl.No | Surface emitter LEDs | Edge emitter LEDs |
|---|---|---|
| 1 | The plane of the active light emitting region is perpendicular to the fiber axis | The active region has two guiding layers which form a wave guide channel. |
| 2 | The emission pattern is less directional | The emission pattern is more directional |
| 3 | Radiates more power into high NA fibers | Radiates more power into low NA fibers |
| 4 | Less modulation bandwidth | More modulation bandwidth |

**12. What is Lambertian pattern?**

In surface emitter LED, the emission pattern is essentially isotropic with a 120° half-power beam width. This isotropic pattern is called a Lambertian pattern. In this pattern the source is equally bright when viewed from any direction, but the power diminishes as cos $\theta$, where $\theta$ is the angle between the viewing direction and the normal to the surface.

**13. What are the characteristics needed for an LED to be used in fiber transmission?**

1. High radiance output
2. Fast emission response time
3. High quantum efficiency

**14. Define modulation bandwidth of an LED?**

Modulation bandwidth of an LED is electrically defined as the point where the electrical signal power has dropped to half its constant value resulting from the modulated portion of the electrical signal.

**15. Name the factors to determine frequency response of an LED.**

1. Doping level in the active region
2. The injected carrier lifetime in the recombination region
3. Parasitic capacitance of the LED

**16. What is active or recombination region?**

When pn junction of the diode is forward biased, electrons and holes are injected into the p and n regions, respectively. These minority carriers can recombine either radiatively (a photon is emitted) or non-radiatively (recombination energy is dissipated in the form of heat). This pn junction is known as the active or recombination region.

**17. What are the three requirements of Laser action?**

1. Absorption 2. Spontaneous emission 3. Stimulated emission.

**18. Define lasing.**

Lasing is the condition at which light amplification becomes possible in the laser diode. The condition for lasing is that a population inversion is achieved.

**19. What is spontaneous emission?**

If a photon of energy $hv_{12}$ impinges on the system, an electron in the ground state can absorb the photon energy and go to the higher energy state. Since this is an unstable state, the electron will shortly return to the ground state, thereby emitting a photon of energy $hv_{12}$. This occurs without any external stimulation and is called spontaneous emission**.**

**20. What is stimulated emission?**

If a photon of energy $hv_{12}$ impinges on the system while the electron is still in its excited state, the electron is immediately stimulated to drop to the ground state and give off a photon of energy $hv_{12}$. This emitted photon is in phase with the incident photon and the resultant emission is known as stimulated emission.

**21. 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 state is greater than that of the ground state. This condition is known as population inversion.

**22. Define modulation.**

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

**23. Define external quantum efficiency.**

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

**24. List the various modes of laser diode.**

1. Longitudinal modes 2. Lateral modes 3. Transverse modes

**25. 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.

**26. Define longitudinal modes.**

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

**27. 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.

**28. Define coupling efficiency.**

It is defined as a measure of the amount of optical power emitted from source that can be coupled into a fiber. **Coupling efficiency, $\eta = P_F / P_S$**

where $P_F$ - Power coupled into fiber and $P_S$ - Power emitted from light source.

**29. Define internal quantum efficiency. (Nov 14)**

The internal quantum efficiency is the fraction of the electron-hole pairs that recombine radiatively. If the radiative recombination rate is $R_r$ 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. $\eta_{int} = R_r / (R_r + R_{nr})$

**30. What is an intrinsic and extrinsic semiconductor material?**

Intrinsic semiconductors have no impurities.

Extrinsic semiconductors contain impurities like boron and phosphorus.

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

The product of two types of carriers remains constant at a given temperature.

$$pn = n_i^2$$

Where p - concentration of holes.

n -concentration of electrons.

$n_i$- intrinsic concentration.

**32. What is flylead or pigtail?**

Flylead or pigtail is nothing but a short length of optical fiber (1m or less) already attached to the sources by the suppliers in an optimum power coupling configuration. The flylead reduces many power launching problems and make the coupling easier because it is just a coupling from one fiber to the other.

**33. Differentiate LEDs and Laser diodes. (Nov 2014)**

| 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 | Short lifetime. |
| 4 | Output power less | Output power more |
| 5 | Less temperature dependant | More temperature dependant |

**34. Give different types of photo detectors.**

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

**35. What are the requirements of a photodetector? (Nov 2014)**

1. High response or sensitivity in the emission wavelength of the source
2. A minimum addition of noise to the system
3. A fast response speed
4. Sufficient bandwidth for desired data rate
5. Insensitive to temperature variations
6. Compatible with the fiber
7. Reasonable cost
8. A long operating life

**36. What are the types of photodiodes?**

- pin photodetector
- Avalanche photodiode (APD)

**37. What are the advantages of photodiodes?**

1. Small size
2. Suitable material
3. High sensitivity
4. Fast response time

**38. What is the significance of intrinsic layer in PIN diodes?**

For longer wavelength operations where the light penetrates more deeply into the semiconductor material a wider depletion layer is necessary. To achieve this, the intrinsic material is added between the P and N type regions.

**39. Define photocarriers.**

When an incident photon has energy greater than or equal to the band gap energy of the semiconductor material, the photon can give up its energy and excite an electro from the valence band to the conduction band. This process generates mobile electron-hole pairs. These electrons and holes are called photocarriers.

**40. Define photocurrent.**

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

**41. Define responsivity.**

The responsivity characterizes the performance of a photodiode. This parameter is very useful, since it specifies the photocurrent generated per unit optical power. The responsivity is related to the quantum efficiency by

$$R = I_P / P_{in} = (\eta q / h\nu)$$

For Avalanche photodiode, the responsivity is given by

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

Where $R_o$ is the unity gain responsivity.

**42. Define long wavelength cut off related to photodiode.**

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

$$\lambda_c(\mu m) = hc/ E_g = 1.24 / E_g(eV)$$

**43. Define quantum efficiency of a detector.**

It is defined as the ratio of number of electron – hole pairs generated to the number of incident photons. **η = No.of electron-hole pairs generated /No. of incident photons**

**44. 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 enough energy to ionize bound electrons in the valence band upon colliding with them. This carrier multiplication mechanism is known as impact ionization.

**45. Define avalanche effect.**

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

**46. What is p+ π 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. 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.

**47. Define ionization rate.**

The average number of electron hole pairs created by a carrier per unit distance travelled is called ionization rate.

**48. What are the conditions for a high signal- to- noise ratio in a Photodetector?**

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

**49. Define sensitivity or minimum detectable optical power of a photodetector.**

The sensitivity of a photodetector in an optical fiber communication system is described in terms of the minimum detectable optical power. This is the optical power necessary to produce a photocurrent of the same magnitude as the root mean square (rms) of the total noise current or a signal-to-noise ratio of 1.

**50. Give the advantages of pin photodiodes.**

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

**51. Define multiplication M.**

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

$$M = I_M / I_P$$

$I_M$ → average value of the total multiplied output current

$I_P$ → primary unmultiplied photocurrent

**52. Define response time and list the factors that influence the response time of a photo diode.**

Detector response time is defined as the time taken for the photodetector to respond to an optical input pulse. This response time depends on three factors

1. The transit time of the photo carriers in the depletion region
2. The diffusion time of the photo carriers generated outside the depletion region
3. The RC time constant of the photodiode and its associated circuit

**53. What are the drawbacks of Avalanche photo diode? (Nov 14)**

a) fabrication difficulties due to more complex structure
b) increased cost
c) the random nature of the gain mechanism
d) high bias voltage requirement
e) the variation of gain with temperature

# UNIT - IV - FIBER OPTIC RECEIVER AND MEASUREMENTS

**1. List out the various error sources.**

a) Quantum or shot noise
b) Dark current noise
c) Leakage current noise
d) Thermal noise
e) Amplifier noise
f) Inter symbol interference

**2. Define quantum noise.**

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

**3. Define dark current noise.**

The photodiode dark current is the current that continues to flow through the bias circuit of the device when no light is incident on the photodiode. This is a combination of bulk and surface currents.

**4. Define bulk dark current.**

The bulk dark current arises from the electrons and/or holes which are thermally generated in the pn junction of the photodiode.

**5. Define surface dark current.**

The surface dark is also referred to as a surface leakage current or simply the leakage current. It is dependant on surface defects, cleanliness, bias voltage and surface area.

**6. 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.

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

When a pulse is transmitted in a given time slot, most of the pulse energy will arrive in the corresponding time slot at the receiver. However, because of the pulse spreading induced by the fiber, some of the transmitted energy will progressively spread into neighboring time slots. The presence of this energy in adjacent time slots results in an interfering signal. Hence it is called Inter Symbol Interference.

**8. 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 exactly by M is called the excess noise factor F and is defined by $F = \langle m^2 \rangle / \langle m \rangle^2 = \langle m^2 \rangle / M^2$

**9. What is a preamplifier? Give the classifications of preamplifiers.**

The electric current produced by the photodetector is very weak. Hence a front end amplifier or preamplifier boosts it to a level that can be used by the following devices.

The classifications are

- Low impedence (LZ) preamplifier
- High impedence (HZ) preamplifier
- Transimpedence preamplifier

**10. What is meant by bit error rate?**

To measure the rate of error occurrences in a digital data stream, a simple approach is to divide the number 'Ne' of errors occurring over a certain time interval 't' by the number 'Nt' of pulses transmitted during this interval. This is called either the error rate or the bit-error rate or BER

$$\text{Bit error rate, BER} = \frac{N_eN_e}{N_tBt} \quad \text{where } B = 1/T_b$$

**11. What are the advantages of a trans-impedance amplifier? (Nov 14)**

1. Wide dynamic range 2. Less susceptible to pick up noise 3. Less sensitivity
4. Little or no equalization is required 5. It is very easily controllable and stable

**12. Define the probability of error**.

Probability of error is defined as the probability that a transmitted '1' is misinterpreted as a '0' or a transmitted '0' is misinterpreted as a'1' by the receiver due to the noise interference.

It is a good measure for performance of the detector.

**13. Define quantum limit.**

Assuming an ideal photodetector with unity quantum efficiency, quantum limit is the minimum received optical power required for a specific bit error rate performance in a digital system.

**14. List the standard test methods.**

**a) Reference test methods (RTM).**

It measures a particular characteristic with high degree of accuracy and reproducibility.

**b) Alternative test methods (ATM).**

It measures with less accuracy but more suitable for practical use.

**15. Mention the various optical fiber measurements.**

a) Fiber attenuation measurements
b) Fiber dispersion measurements
c) Fiber refractive index profile measurements
d) Fiber cutoff wavelength measurements
e) Fiber numerical aperture measurements
f) Fiber diameter measurements

**16. What are the methods for the measurement of attenuation of fiber?**

1. Insertion loss method
2. Cut-back method
3. Optical Time-Domain Reflectometry (OTDR)

**17. What are mode scramblers or mode filters?**

The devices which simulate mode equilibrium over a short length of fiber are known as mode scramblers or mode filters.

**18. Mention the different techniques used for measurement of fiber refractive profile.**

a) Interferometric method
b) Near Field Scanning Method
c) Refracted Near field Method

**19. State the significance of maintaining the fiber outer diameter constant. (Nov 14)**

It is essential to maintain the fiber outer diameter constant. Any diameter variation may cause excessive radiation losses and make accurate fiber to fiber connection difficult.

# UNIT - V - OPTICAL NETWORKS

**1. Define a network.**

To establish connections between collections of devices called stations, transmission paths run between them to form a collection of interconnected stations called a network.

**2. List the different network categories.**

a) Local Area Network (LAN)
b) Metropolitan Area Network (LAN)
c) Wide Area Network (WAN)
d) Access Network
e) Enterprise and Public Networks

**3. What are the different network layers?**

a) Physical Layer
b) Data Link Layer
c) Network Layer
d) Transport Layer
e) Higher Layers

**4. Mention the four common topologies used for fiber optic networks.**

a) Linear-bus topology
b) Ring topology
c) Star topology
d) Mesh configurations

**5. Discuss the concepts of SONET/SDH.**

With the advent of high capacity fiber optic transmission lines, the serviced providers established a standard format called synchronous optical network (SONET) in North America and synchronous digital hierarchy (SDH) in other parts of the world. To ensure interconnection compatibility between equipment from different manufacturers, the SONET and SDH specifications provide details for the optical source characteristics, the receiver sensitivity and the transmission distances for various types of fibers.

**6. What is WDM? (Nov 2014) (Nov 14)**

Since the light sources emit in a narrow wavelength band of less than 1 nm, many different independent optical channels can be used simultaneously in different segments of this wavelength range. The technology of combining a number of such independent information carrying wavelengths onto the same fiber is known as wavelength division multiplexing or WDM.

**7. What are the basic performance criteria of the WDM?**

- Insertion loss
- Channel width
- Cross talk

**8. What is meant by bidirectional WDM?**

A single WDM which operates as both multiplexing and demultiplexing devices is called the bidirectional WDM.

**9. Mention the key features of WDM?**

1. Increase in the capacity of an optical fiber.
2. Various optical channels can support different transmission formats.

**10. Define Broadcast-and-select WDM network.**

A WDM network that shares a common transmission medium and employs a simple broadcasting mechanism for transmitting and receiving optical signals between network nodes is referred to as Broadcast-and-select WDM network.

**11. Define wavelength-routed WDM network.**

A WDM network that employs wavelength routing to transfer data traffic is referred to as a wavelength-routed WDM network. A wavelength-routed WDM network typically consists of routing nodes interconnected by point-to-point fiber links in an arbitrary mesh topology.

**12. What are the most important non-linear effects of optical fiber communication?**

| **Nonlinearity category** | **Single-channel** | **Multiple-channel** |
|---|---|---|
| Index related | Self-phase modulation | Cross-phase modulation<br>Four-wave mixing |
| Scattering related | Stimulated Brillouin scattering | Stimulated Raman Scattering |

**13. Define power penalty.**

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.

**14. Define Self-phase modulation.**

Self-phase modulation is produced by the nonlinearity in the refractive index in single wavelength links. It converts optical power fluctuations in a propagating light wave to spurious phase fluctuations in the same wave.

**15. Define Cross-phase modulation.**

Cross-phase modulation is produced by the nonlinearity in the refractive index in WDM systems. It converts optical power fluctuations in a particular wavelength channel to phase fluctuations in another copropagating channel.

**16. Define Stimulated Brillouin scattering.**

Stimulated Brillouin scattering arises when a strong optical signal generates an acoustic wave that produces variations in the refractive index. It causes lightwaves to scatter in the backward direction toward the transmitter.

**17. Define Stimulated Raman scattering.**

Stimulated Raman scattering is an interaction between light waves and the vibrational modes of silica molecules. This process generates scattered light at a wavelength longer than that of the incident light.

**18. Define Four-wave mixing.**

Four-wave mixing (FWM) is a third-order nonlinearity in silica fibers that is analogous to intermodulation distortion in electrical systems. When wavelength channels are located near the zero-dispersion point, three optical frequencies will mix to produce a fourth intermodulation product. It can cause severe cross talk.

**19. What is EDFA?**

EDFA means Erbium Doped Fiber Amplifier which is used to amplify the multiple lightwave signals completely in the optical domain. It is a 10 to 30 m length of silica optical fiber that has been lightly doped with the rare earth element, Erbium and inserted in the optical fiber link. Here the photons are used to directly raise electrons into excited state. This process is called optical pumping.

**20. What do you mean by solitons? (Nov 14)**

Solitons are very narrow, high intensity optical pulses that retain their shape through the interaction of balancing pulse dispersion with non linear properties of an optical fiber. Thus the soliton pulses travel through the optical fiber without any loss or dispersion.

**21. Distinguish fundamental and higher order solitons.**

Depending on the particular shape of the soliton pulse chosen, the pulse either does not change its shape as it propagates, or it undergoes periodically repeating changes in shape.

The family of pulses that do not change in shape are called fundamental solitons, and those that undergo periodic shape changes are called higher-order solitons.

**22. What are the different layers in SONET/SDH?**

a) Path layer b) Line layer c) Section layer d) Photonic layer

**23. What are the drawbacks of broadcast and select networks for wide area network applications?**

1). More wavelengths are needed as the number of nodes in the network grows.

2). Without the widespread use of optical booster amplifiers, a large number of users spread over a wide area cannot be readily be interconnected with a broadcast and select network

**24. What were the problems associated with PDH networks?**

1. Rigid asynchronous structure.
2. Restricted management capacity.
3. No world standard on the digital formats.
4. No optical interfaces
5. Only point-to-point configuration (linear working) is possible.
6. There are no common standards among vendors.

**25. List out the benefits of SONET over PDH networks.**

1. Flexible synchronous structure
2. capability of powerful management
3. world standard digital format
4. optical interfaces
5. easy traffic cross connection capacity and add and drop facility
6. reduced networking cost due to the transversal compatibility
7. forward and backward compatibility

**26. Define intrachannel and interchannel crosstalk that occur in WDM systems.**

Crosstalk is the effect of other signals on the desired signal.

When the crosstalk signal is at the same wavelength as that of the desired signal or sufficiently close to it that the difference in wavelengths is within the receiver's electrical bandwidth, the crosstalk is called as intrachannel cross talk.

When the crosstalk signal is at a wavelength sufficiently different from the desired signal's wavelength that the difference is larger than the receiver's electrical bandwidth, the crosstalk is called as interchannel cross talk.

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