

# **EC8751 - OPTICAL COMMUNICATION**

## **2 Marks Questions and Answers**

### **UNIT - 1 - INTRODUCTION TO OPTICAL FIBERS**

#### **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 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  $90^\circ$ .

Critical angle of incidence  $\Phi_c = \sin^{-1}(n_2 / n_1)$  where  $n_1$  is the refractive index of medium 1  $n_2$  is the refractive index of medium 2

### 12. 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.

### 13. 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.

### 14. Write the expression for the refractive index in graded index fibers.

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

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

$r \rightarrow$  radial distance from fiber axis     $a \rightarrow$  core radius

$n_1 \rightarrow$  refractive index at the core     $n_2 \rightarrow$  refractive index at the cladding

$\rightarrow$  shape of the index profile     $\Delta \rightarrow$  index difference

**15. 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

**16. Define relative refractive index difference.**

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

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

**18. 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<sub>01</sub> mode.

**19. 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.

**20. 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.

**UNIT- II - TRANSMISSION CHARACTERISTIC OF OPTICAL FIBER**

**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

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

$n$ =refractive index

$\beta_T$ = isothermal compressibility

$\lambda$ =operative wavelength

$k_B$ = Boltzmann's constant

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

## 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.

## **UNIT III - OPTICAL 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  $120^\circ$  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. What is spontaneous emission?**

If a photon of energy  $h\nu_{12}$  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  $h\nu_{12}$ . This occurs without any external stimulation and is called spontaneous emission.

**19. What is stimulated emission?**

If a photon of energy  $h\nu_{12}$  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  $h\nu_{12}$ . This emitted photon is in phase with the incident photon and the resultant emission is known as stimulated emission.

**20. 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.

## **UNIT - IV - OPTICAL RECEIVER, MEASUREMENTS AND COUPLING**

### **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 impedance (LZ) preamplifier
- High impedance (HZ) preamplifier
- Transimpedance 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

$$N_e N_t$$

$$\text{Bit error rate, BER} = \frac{N_e}{N_t B t} \text{ where } B = 1/T_b$$

## 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 COMMUNICATION SYSTEMS AND 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 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. 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