

EC6702- OPTICAL COMMUNICATION AND NETWORKING

TWO MARKS QUESTIONS AND ANSWERS

UNIT I - Introduction

1. What are the limitations of optical fiber communication systems?

- Optical fiber is made up of glass. Because of the impurities present with the fiber

It results in absorption, which leads to loss of light in the optical fiber.

- It is costly.
- Maximum limitation of the bandwidth of the signals can be carried by the fiber due to spreading of pulse.

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

The necessity of cladding for an optical fiber is

- To avoid leakage of light from the fiber
- To avoid mechanical strength for the fiber
- To protect core from scratches and other mechanical damages.

3. List the advantages of mono-mode fiber.

The advantages of mono-mode fiber are

- No internal dispersion
- Information capacity of single mode fiber is large.

4. Define - Acceptance Angle

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

5. List the uses of optical fiber.

The uses of optical fibers are as follows

- To act as light source at the inaccessible places
 - To transmit the optical images. (example: endoscopy) To act as sensors to do mechanical, electrical and magnetic measurements
 - To transmit the information which are in the form of coded signals of the telephone communications, computer data etc.
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6. List the disadvantages of mono-mode fiber.

The disadvantages of mono-mode fiber are

- Launching of light into single mode and joining of two fibers are very difficult.
- Fabrication is very difficult and so that fiber is so costly.

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 reflection, the ray should travel from denser region rarer region 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. Define- Refraction

When light travels from air medium to glass medium, bending of light may occur.

This is called refraction.

9. What is critical angle?

When we increase the incident angle with respect to normal, at some incident angle, the dielectric of surface and ϕ_2 becomes 90° and such incident angle is called critical angle.

10. What is Snell's law?

The relationship at the interface is called Snell's Law. It is given by the equation

$$n_1 \sin \phi_1 = n_2 \sin \phi_2$$

11. What is meant by mode coupling?

The effect of coupling energy from one mode to another mode is known as mode coupling. The cause of mode coupling is due to waveguide perturbations such as deviations Of the fiber axis from straightness variations in the core diameter, irregularities at the Core- cladding interface and refractive index variations.

12. What is V number of a fiber?

Normalized frequency or V number is a dimensionless parameter and represent the relationship among three design parameters variables of the fiber viz core radius a , relative refractive index Δ and the operating wavelength λ .

It is expressed as $V = (2\pi \cdot \text{Numerical aperture}(a)) / \lambda$

13. Compare Ray optics and wave optics.

Ray optics	Wave optics
It is used to represent the light propagation	It is used to analyze mode theory
It is used to study reflection and refraction of light	It is used to analyze diffraction and interference of light waves

14. Differentiate between mono-mode fiber and multi-mode fiber.

Mono-mode fiber	Multi-mode fiber
Only one ray passes through the fiber	More than one ray passes through fiber at a time.
Coupling efficiency is less.	Coupling efficiency is large.
LED is not suitable for single mode fiber.	LED is suitable for multi-mode fiber
Intermodal dispersion is not present.	Intermodal dispersion is present
Fabricating single mode fiber is difficult.	Fabricating multi-mode fiber is easy.

15. What is meant by linearly polarized mode?

The field components HE, EH, TE, TM forms linearly polarized modes. Linearly polarized Modes are labeled LP_{jm} where j and m are integers designation mode solutions.

16. What are the three windows of optical communications?

The three wavelengths 850nm, 1300nm, and 1500nm are three optical windows of optical communication system. Since only at this wavelength silica fiber loss is minimum.

17. Define – Fiber Optic system

Fiber optic system is nothing but a fiber-optic cable is essentially light pipe that is used to carry a light beam from one place to another.

18. What are the advantages of graded index fiber?

The advantages of graded index fiber are

- It provides higher bandwidth.
- It exhibits less intermodal dispersion because the different group velocities of the mode tend to be normalized by the index grading.

19. What is step index fiber?

Step index fiber is a cylindrical waveguide that has the central core with uniform refractive index n_1 surrounded by outer cladding with refractive index of n_2 . The refractive index of the core is constant and is larger than the refractive index of the cladding. It makes a step change at the core cladding interface.

20. Why step index single mode fiber preferred for long distance communication?

The step index single mode fiber is preferred for long distance communication because

- They exhibit higher transmission bandwidth because of low fiber losses.
- They have superior transmission quality because of the absence of the modal noise.
- The installation of single mode fiber is easy and will not require any fiber replacement over twenty plus years.

21. Define- Birefringence

Manufactured optical fibers have imperfections such as asymmetrical lateral stresses, non - circular cores and variations in refractive index profiles. These imperfections break the circular symmetry of the ideal fiber and lift the degeneracy of the two modes. These modes propagate with different phase velocity and it is called as fiber birefringence.

22. What types of fibers are used commonly?

Based on refractive index profile- step index fiber, graded index fiber.
Based on propagation – Mono mode or single mode fiber, multi -mode fiber.

23. Define – Wavefront

For plane waves, some constant phase points from a surface which is referred to as wavefront.

24. 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.

25. What are leaky modes in optical fibers?

In leaky modes, the fields are confined partially in the fiber core and attenuated as they propagate along the fiber length, due to radiation and tunnel effect.

26. What is the purpose of cladding?

Cladding provides mechanical strength, reduces scattering loss resulting from dielectric discontinuities at the core surface and protects the core from absorbing surface contaminants with which it could come into contact.

27. What are leaky rays?

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

28. What are the conditions for total internal reflection?

The conditions for total internal reflections are:

- The ray should travel from denser to rarer medium. i.e. from core to clad region of the optical fiber.
- The angle of incidence in the denser should be greater than the critical angle of that medium.

29. What are guided modes?

Guided modes are a pattern of electric and magnetic field distributions that is repeated along the fiber at equal intervals.

30. Define- Mode

Mode is the pattern of distribution of electric and magnetic fields.

Transverse- Electric mode (TE)
Transverse Magnetic mode (TM)

31. Define - Mode-Field Diameter

The fundamental parameter of a single mode fibre is said to be the mode field diameter. It is possible to determine the mode-field diameter with the help of the fundamental LP₀₁ mode.

32. What are meridional rays?

Meridional rays are the rays which follow a zig-zag path when they travel through a fiber and for every reflection it will cross the fiber axis.

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

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

34. State Goos-Haenchen effect.

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

35. Differentiate between meridional rays and skew rays.

A **meridional ray** is a ray that passes through the axis of an optical fiber.

A **skew ray** is a ray that travels in a non-planar zig-zag path and never crosses the axis of an optical fiber.

36. What do you mean by RAY?

In optics a **ray** is an idealized model of light, obtained by choosing a line that is perpendicular to the wavefronts of the actual light, and that points

in the direction of energy flow.^{[1][2]} Rays are used to model the propagation of light through an optical system, by dividing the real light field up into discrete rays that can be computationally propagated through the system by the techniques of ray tracing.

37. What are skew rays?

A **skew ray** is a ray that travels in a non-planar zig-zag path and never crosses the axis of an optical fiber.

38. What are the advantages of optical network?

The advantages of optical network are as follows:

- Low signal attenuation (as low as 0.2 dB/km),
- Immunity to electromagnetic interference
- High security of signal because of no electromagnetic radiation,
- Huge bandwidth
- Low signal distortion, suitable for carrying digital information,
- Low power requirement
- No crosstalk and interferences between fibers in the same cable,
- Low material usage, small space requirement, light weight, non-flammable, cost-effective and high electrical resistance

39. What is an optical network?

An optical network is not necessarily all-optical: the transmission is certainly optical, but the switching could be optical, or electrical, or hybrid. Also, an optical is not necessarily packet-switched.

40. What are the advantages of optical communication?

The advantages of optical communication are

- Low transmission losses
 - Electrical isolation
 - Small size and weight
 - No electromagnetic interference
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41. Define – Longitudinal modes

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

42. Define – Transverse Modes

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

UNIT II- Transmission Characteristics of Optical Fibers

1. Differentiate linear scattering from non-linear scattering.

Linear scattering mechanisms cause the transfer of some or all of the optical power contained within one propagating mode to be transferred linearly into a different mode. Non-linear scattering causes the optical power from one mode to be transferred in either the forward or backward direction to the same or other modes at different frequencies.

2. What is meant by Fresnel reflection? (N/ D 2011)

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

3. What are the types of material absorption losses in silica glass fibers?

The types of material absorption losses in the glass composition are

- Absorption by impurity atoms in the glass material.
- Intrinsic absorption by the basic constituent atoms in the glass material.

4. How do we minimize optical losses at the interface?

Optical losses at the interface can be minimized if

- Jointed fiber ends are smooth
 - Perpendicular to fiber axis
 - Two fiber axes are perfectly aligned
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5. What is meant by attenuation coefficient of a fiber? (N / D 2011)

If $P(0)$ is the optical power in a fiber at the origin (at $Z = 0$), then the power $P(Z)$ at a distance z further down the fiber is

$$P(z) = P(0) e^{-\alpha_{pz}}$$

The above equation can be rewritten as

$$\alpha_p = (1/z) \{ P(0) / P(z) \}. \text{ Where } \alpha_p \text{ is the fiber attenuation coefficient given in units of km}^{-1}$$

6. What is intrinsic absorption in optical fibers?

The absorption caused by the interaction with one or more of the major components of the glass is known as intrinsic absorption.

7. What are the factors that cause Rayleigh scattering in optical fibers? (M / J 2012)

The inhomogeneity's of a random nature occurring on a small scale compared with the wavelength of the light in optical fiber causes Rayleigh scattering.

8. What is meant by dispersion in optical fiber? (A/ M 2008)

Dispersion of the transmitted optical signal causes distortion in both analog and digital signals along optical fibers. Dispersion mechanisms within the fiber cause broadening of the transmitted light pulses as they travel along the channel.

9. What are the ways to reduce macrobending losses? (N / D 09), (N/ D 10)

Ways to reduce macrobending losses are

- Designing fibers with large relative refractive index differences.
- Operating at the shortest wavelength possible.

10. What are the factors that cause Mie scattering in optical fibers?

The nonperfect cylindrical structure of the waveguide by the fiber imperfections causes Mie scattering in optical fibers.

11. Define – Group Velocity Dispersion (GVD) (A/ M 2011), (N/D 2010)

Intra-modal dispersion is pulse spreading that occurs within a single mode. The spreading arises from the finite spectral emission width of an optical source. This phenomenon is known as Group Velocity Dispersion.

12. What is meant by linear scattering?

Linear scattering mechanisms cause the transfer of some or all of the optical power contained within one propagating mode to be transferred linearly into a different mode.

13. Define- Beat Length

Beat Length is defined as the period of interference effects in a bi-refrigent medium. When two waves with different linear polarization states propagate in a bi-refrigent medium, their phases will evolve differently.

14. 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.

15. Why intra modal dispersion occurs?

Intra modal dispersion occurs because colours of light travel through different materials and different waveguide structures at different speeds.

16. What are the causes of intra modal dispersion?

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

- Material Dispersion
- Waveguide Dispersion.

17. What is wave guide dispersion?

Wave guide dispersion occurs because of a single mode fiber confines only about 80% of optical power to the core. Dispersion 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.

18. Compare splices and connectors.

Splices	Connectors
Permanent or semipermanent joints	Temporary joints
Splice loss is low	Connector loss is high

19. Define - Cross Talk in couplers

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

20. Define- Polarization Maintaining Fiber? (PMF)

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

21. 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.

22. What is group velocity?

If L is the distance travelled by the pulse, β is the propagation constant along axis then, the group velocity is the velocity at which energy of a pulse travels along the fiber.

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

23. What is polarization?

Polarization 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 fiber.

24. 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 neighbouring pulses. After a time 't', the adjacent pulses can no longer be individually distinguished at the receiver and error will occur.

25. 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 profile dispersion.

26. What is polarization mode dispersion (PMD)? (A/ M 2007)

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

27. 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.

28. What is fiber birefringence?

Imperfections in the fiber are common such as symmetrical 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.

29. What is mode coupling?

Mode coupling 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 diameter etc.

30. 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 and material dispersion can then be shifted to zero dispersion point to long wavelength. The resulting optical fiber are called as dispersion Shifted Fiber.

31. 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.

32. Define - Cut-off Wavelength of the fiber

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

33. Write a note on scattering losses.

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

34. What is intramodal delay?

The factor which gives rise to pulse spreading is called as intra-modal delay. It is a result of each mode having a different value of group velocity at a single frequency.

35. Mention the losses responsible for attenuation in optical fibers.

The losses which are responsible for attenuation in optical fibers are as follows

- Absorption losses
- Scattering losses
- Bending losses

36. What is the function of coupler? What are the different types of optical couplers?

A coupler is a device which is used to combine and split signals in an optical network..

Different types of couplers are

- Directional coupler
- Star coupler
- Fused fiber coupler
- 2 x 2 coupler

37. What are the requirements of good couplers?

The requirements of good couplers are

- Good optical couplers should have low insertion losses.
- Insensitive to temperature
- Good optical couplers should have low polarization-dependent loss.
- Reliability

38. 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 as group velocity dispersion or intermodal dispersion.

39. Write the light ray guiding condition.

Light ray that satisfies total internal reflection at the interface of the higher refractive index core and the lower refractive index cladding can be guided along an optical fiber.

40. What do you mean by Extrinsic absorption?

Absorption phenomena due to impurity atoms present in the fiber is called as Extrinsic absorption.

41. What is the measure of information capacity in optical waveguide?

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

42. Define - Microscopic Bending

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

43. Write Short notes on Scattering losses.

Scattering losses caused by the interaction of light with density fluctuations within a fiber. Density changes are produced when optical fibers are manufactured. During manufacturing, regions of higher and lower molecular density areas, relative to the average density of the fiber, are created. Light traveling through the fiber interacts with the density areas light is then partially scattered in all directions.

44. 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.

45. Write the expression for Rayleigh Scattering Loss.

The expression for Rayleigh Scattering loss is given by

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

where n= refractive index

k_B = Boltzman constant

T_f = fictive temperature

β_T = isothermal compressibility

λ = operative wavelength

46. When will Rayleigh Scattering Occurs?

Rayleigh scattering is the main loss mechanism between the ultraviolet and infrared regions. Rayleigh scattering occurs when the size of the density fluctuation (fiber defect) is less than one-tenth of the operating wavelength of light.

47. What are the uses of fiber optical connectors?

Optical fiber connectors are used to join optical fibers where a connect/disconnect capability is required.

48. What do you mean by fiber optic coupler?

A **fiber optic coupler** is a device used in optical fiber systems with one or more input fibers and one or several output fibers. Light entering an input fiber can appear at one or more outputs and its power distribution potentially depending on the wavelength and polarization.

49. What do you mean by fiber optic connectors?

An optical fiber connector terminates the end of an optical fiber, and enables quicker connection and disconnection than splicing. The connectors mechanically couple and align the cores of fibers so light can pass. Better connectors lose very little light due to reflection or misalignment of the fibers. In all, about 100 fiber optic connectors have been introduced to the market.

50. List the features of optical connectors.

The features of good connector are:

- Low insertion loss
- Low cost and low environmental sensitivity
- Reliability
- High return loss (*low* amounts of reflection at the interface)
- Ease of use
- Ease of installation

51. What is the need for fiber alignment?

Fiber optic sensors constitute the core of telecommunication markets as well as being important part of automotive and industrial applications. With the recent renewed growth and technology advances in fiber optics, there is an increasing need for automating photonics alignment.

52. What do you mean by micro-bend Losses?

Microbends are small microscopic bends of the fiber axis that occur mainly when a fiber is cabled. Microbend losses are caused by small discontinuities or imperfections in the fiber. Uneven coating applications and improper cabling procedures increase micro-bend loss. External forces are also a source of micro-bends.

53. What do you mean by macro-bend losses?

Macrobend losses are observed when a fiber bend's radius of curvature is large compared to the fiber diameter. Light propagating at the inner side of the bend travels a shorter distance than that on the outer side.

54. List the two major categories of fiber joints.

The two major categories of fiber joints are

- Fiber splices
- Fiber connectors

55. 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 two major types of connectors are

- Lensed type expanded beam connector
- Ferrule type connector.

56. What are splices?

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

57. What are the requirements of splices?

The requirements of splices are

- Should be easy to install
 - Should have minimum power loss
 - Should be strong and light in weight
 - Should cause low attenuation.
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58. What are the methods of fiber splicing?

There are three methods of fiber splicing. They are

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

UNIT –III – Sources and Detectors

1. What are the advantages of LED? (M/ J 2012)

The advantages of LEDs are

- They have long life
- LEDs are less complex circuits than Laser diodes
- Fabrication is easier
- Less expensive
- Used for short distance communication

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

The two types of confinements used in LEDs are

- Carrier confinement
- Optical confinement

3. What are the basic methods of current confinement?

The basic methods of current confinement are

- Inner strip confinement
- Proton confinement
- Preferential dopant diffusion
- RE growth of back biased PN junction.

4. What are the two types of LED configurations?

The two types of LED configurations are

- Homo junction
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- Single and Double hetero junction

5. What are the three requirements of Laser action?

The three requirements of Laser action are

- Absorption
- Spontaneous emission
- Stimulated emission

6. What are the fundamental structures of Index guided lasers?

The fundamental structures of index guided lasers are

- Bent layer configuration
- Selectively diffused construction
- Buried hetero structure
- Varying thickness structure

7. Define-External Quantum Efficiency

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

8. 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 nonradiative recombination ratio is R_{nr} , then the internal quantum efficiency is the ratio of the radiative recombination rate to the total recombination rate.

**9. Define – Quantum Efficiency of a photo detector (A / M 2008),
(M / J 2009)**

Quantum efficiency is defined as the number of the electron-hole carrier pairs generated per incident photon of energy $h\nu$, is given by
 $\eta = (\text{number of electron-hole pairs generated}) / (\text{number of incident photons})$

$$\text{i.e. } \eta = \frac{I_p / q}{\frac{P_o}{h\nu}}$$

where I_p is the photon current

q is the charge of the electron

P_o is the optical output power

ν is the frequency of the optical signal.

10 . In a 100ns pulse, $6 * 10^6$ photons at wavelength of 1300nm fall on an InGaAs photo-detector on the average, $5.4 * 10^6$ electron-hole pairs are generated. Find the quantum efficiency.(N / D 2010)

Given $\frac{I_p}{q} = 5.4 * 10^6$

$$\frac{P_o}{h\nu} = 6 * 10^6$$

where I_p is the photon current
 q is the charge of the electron
 P_o is the optical output power
 ν is the frequency of the optical signal.

$$\text{Quantum efficiency} = 5.4 * 10^6 / 6 * 10^6 = 0.9$$

$$\% \text{ Quantum efficiency} = 90\%$$

10. What do you mean by Laser diode?

A **laser diode**, or **LD**, is an electrically pumped semiconductor laser in which the active medium is formed by a p-n junction of a semiconductor diode similar to that found in a light-emitting diode.

11. Differentiate LEDs and Laser diodes.

LED	Laser diodes
The output obtained is incoherent.	The output obtained is coherent.
Less expensive and less complex.	More expensive and more complex.
Long life time.	Less life time.
Their response is fast	Their response is faster than LED
Bandwidth of LED is moderate	Bandwidth of Laser diode is higher
wide range of wavelengths are available	A small range of wavelength is available

Generation of photon is by spontaneous emission	Generation of photon is by stimulated emission
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12. What do you mean by Avalanche Photo Diode?

An **avalanche photodiode (APD)** is a highly sensitive semiconductor electronic device that exploits the photoelectric effect to convert light to electricity. APDs can be thought of as photo-detectors that provide a built-in first stage of gain through avalanche multiplication.

13. What do you mean by direct band gap Materials?

In some materials a direct transition is possible from valance band to conduction band. Such type of materials is called as direct band gap materials. Ex. GaAs, InP, InGaAs.

14. What do you mean by indirect band gap Materials?

In some materials a direct transition is not possible from valance band to conduction band. Such type of materials is called as indirect band gap materials. Ex. Silicon, Germanium.

15. What is meant by hetero-junction? List the advantages of heterojunction.
(A/ M 2011),((N/D 2007)

A hetero-junction is an interface between two adjoining single crystal semiconductors with different band-gap energies. Devices are fabricated with hetero-junctions are said to have hetero-structure.

Advantages of Hetero-junction are

- Carrier and optical confinement
- High output power
- High coherence and stability.

16. What is the principle of operation of LASER? (N / D 2008)

The principle of operation of LASER is population inversion. The population of the upper energy level is greater than lower energy level i.e. N_2 is $> N_1$. this condition is known as population inversion.

17. What are the three modes of the cavity of LASER Diode? (N / D 2009)

The three modes of the cavity of LASER are

- Longitudinal modes, related to the length L of the cavity
- Lateral modes lie in the plane of the P-N junction. These modes depend upon the side wall preparation and width of the cavity.
- Transverse modes are associated with the Electro Magnetic field and beam profile in the direction perpendicular to the plane of the P-N junction.

These modes determine the radiation pattern of the LASER.

18. What is population inversion? (A /M 2008)

Under thermal equilibrium, the lower energy level E_1 of the two level atomic systems contains more atoms than upper energy level E_2 . To achieve optical amplification, it is must to create non-equilibrium distributions of atoms such that population of the upper energy level is greater than lower energy level i.e. N_2 is $> N_1$.this condition is known as population inversion.

19. What is a DFB LASER? Differentiate DFB LASER from other types of LASERS? (N / D 2009)

In Distributed FeedBack LASER, the lasing action is obtained by periodic variations of refractive index, which are incorporated into multilayer structure along the length of the diode. DFB LASER does not require optical feedback unlike the other LASERS.

20. When an LED has 2V applied to its terminals, it draws 100mA and produce 2mW of optical power. Determine conversion efficiency of the LED from electrical to optical power. (N / D 2008)

Given data $V_{in} = 2V$, $I_{in} = 100 \times 10^{-3} A$, $P_{out} = 2 \times 10^{-3} W$,

Formula: LED conversion efficiency = (P_{out} / P_{in})

$$P_{in} = V_{in} * I_{in} = 2 * 100 \times 10^{-3}$$

$$\text{conversion efficiency} = (P_{out} / P_{in}) = (2 \times 10^{-3} / 2 * 100 \times 10^{-3}) \\ = 0.01$$

21. Distinguish between direct and indirect band-gap materials (N / D 2010)

Direct Band-gap Materials	Indirect Band-gap Materials
The electron and hole have the same momentum value.	The conduction band minimum and the valence band maximum energy level occur at different values of momentum

Direct transmission is possible from valence band to conduction band	Direct transmission is not possible from valence band to conduction band.
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22. Why is silicon not used to fabricate LED or LASER diode? (N / D 2011)

Silicon is not used to fabricate LED or LASER diode because

- It is an indirect band-gap semiconductor
- Its energy level is 1.1eV, radiated emission corresponds to infrared but not the visible light.

23. Distinguish between direct and external modulation of LASER diodes. (N / D 2011)

Direct Modulation	External Modulation
Easy to demonstrate and has low cost.	Complex and expensive
Low gain	High gain

24. Compare surface and edge emitting LEDs (N / D 2012)

Surface Emitting LED	Edge emitting LED
Wider spectral width (typically 125 nm)	Narrow spectral width (typically 75 nm)
Emission pattern is less directional	Emission pattern is more directional

25. Compare the performance of APD with PIN diode. (N / D 2008)

APD	PIN
Excellent Linearity	Linearity is less compared to APD
High sensitivity	Less sensitive compared to APD (15 dB less)
High signal to Noise Ratio	Low signal to Noise Ratio

26. What are the necessary features of a photo detector? (N / D 2007)

The designed features of a photo detector are

- High quantum efficiency
 - Low rise time or faster response
 - Low dark current.
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27. Define – Responsivity of a photo detector (N/ D 2008), (N / D 2010)

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

28. Define- Threshold Current

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

29. Give some types of Photo-detectors.

The types of Photo-Detectors are

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

30. What are the types of photodiodes?

The types of photodiodes are

- Avalanche photodiode (APD)
- PIN photo-detector.

31. 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.

32. 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 current multiplication mechanism is known as impact ionization.

33. 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.

34. Define – Long Wavelength cut off related to photodiode

The upper wavelength cutoff (λ_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 λ_c is given in units of micrometers (μm)

35. 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 output current

36. Give the advantages of Pin Photodiodes.

The advantages of Pin photodiodes are

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

37. What are the advantages of Quantum Well LASERs?

The advantages of Quantum Well LASERs are

- High threshold current density
- High modulation speed
- High line width of the device.

38. An LED has radiative and nonradiative recombination times of 30 and 100ns respectively. Determine the internal quantum efficiency. (N / D 2007)

Given data:

$$\tau_r = 30 * 10^{-9} \text{ sec}$$

$$\tau_{nr} = 100 * 10^{-9} \text{ sec}$$

formula:

$$\eta_{int} = R_r / (R_r + R_{nr})$$

R_r is the radiative recombination rate

R_{nr} is the non- radiative recombination rate.

$$R_r = 1 / \tau_r, R_{nr} = 1 / \tau_{nr}$$

$$\eta_{int} = R_r / (R_r + R_{nr}) = 77\%$$

$$\frac{\frac{1}{30 * 10^{-9}}}{\frac{1}{30 * 10^{-9}} + \frac{1}{100 * 10^{-9}}} = 77\%$$

Unit – IV- FIBER OPTIC RECEIVER AND MEASUREMENTS

1. What is bit rate?

The transmitted signal is two level binary data stream consisting of either 0 or 1 in a time slot of duration T. this time slot is referred to a bit period.

2. List out different methods for measuring refractive index profile.

The different methods for measuring refractive index profile are

- Inter- ferometric method
- Near field scanning method
- End field scanning method.

3. Define – Quantum Limit (M / J 2013)

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 the Quantum Limit.

4. What are the error sources of receiver? (M / J 2013)

The error sources of receiver are

- Thermal noise
 - Dark current noise
 - Quantum noise
-

- 5. A digital fiber optic link operating at 1310 nm, requires a maximum BER of 10^{-8} . Calculate the required average photons per pulse. (N / D 2013)**

The probability error $P_r(o) = e^{-N} = 10^{-8}$

Solving for $N = 8 \log_e 10 = 18.42$

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

- 6. What is Inter Symbol Interference (ISI)?**

Each pulse broadens and overlaps with its neighbors, eventually indistinguishable at the receiver output. This effect is known as Inter Symbol Interference.

- 7. Why silicon is preferred to make fiber optical receivers? (N / D 2010), (A / M 2011)**

Silicon photonic devices can be made using existing semiconductor fabrication technique. Also silicon has been already used as substrate for most integrated circuit; it is possible to create hybrid devices in which the optical and electronic components are integrated onto a single micro-chip.

- 8. How does dark current arise?**

When there is no optical power incident on the photo detector a small reverse leakage current flows from the device terminals known as dark current. Dark current contributes to the total system noise and gives random fluctuations about the average particle flow of the photocurrent.

- 9. Define – Modal Noise and Mode Partition Noise. (A / M 2011), (M / J 2013)**

Disturbances along the fiber such as vibrations, discontinuities, connectors, splices and source / detector coupling may cause fluctuations in the speckle patterns. It is known as modal noise. Phenomenon which occurs in multimode semiconductor LASERS when the modes are not well stabilized is known as mode partition noise.

- 10. What is meant by (1/f)noise corner frequency? (N / D 2009)**

The (1 / f) noise corner frequency is defined as the frequency at which (1/f) noise, which dominates the FET noise at low frequencies and has (1/f) power spectrum.

- 11. What is $P^+ \pi P_n^+$ reach through structure?**

In the P^+ (heavily doped p- type) substrate, high resistivity p- type material is deposited followed by the construction of an n^+ (heavily doped n- type) layer. The π layer is an intrinsic layer.

12. List the advantages of preamplifiers.

The advantages of preamplifiers are

- Low noise level
- High bandwidth
- High dynamic range
- High gain
- High sensitivity.

13. What are the types of preamplifiers?

The types of preamplifiers are

- Low- impedance preamplifier
- High impedance preamplifier
- Trans impedance front end preamplifier

14. What are the standard fiber measurement techniques?

The standard fiber measurement techniques are

- Fiber attenuation measurement
- Fiber dispersion measurement
- Fiber refractive index profile measurement
- Fiber cutoff wavelength measurement
- Fiber numerical aperture measurement
- Fiber diameter measurement.

15. Define – Bend Attenuation

A peak wavelength region, where the radiation losses resulting from the small loop are much higher than the fundamental mode is known as bend attenuation.

16. What is the technique used for measuring the total fiber attenuation?

Total fiber attenuation per unit length can be determined using cut-back method. Taking a set of optical output power measurements over the required spectrum using a long length of fiber usually at least a kilometer is known as cut back technique. The fiber is then cut back to a point 2 m from the input end and maintaining the same launch conditions, another set of power output measurements are taken.

Relationship for the optical attenuation per unit length α_{db} for the fiber may be obtained from

$$\alpha_{db} = \{10 / (L_1 - L_2)\} \log_{10} (P_{02}/P_{01})$$

$L_1 - L_2$ = original and cut-back fiber length respectively

P_{02}/P_{01} = output optical powers at a specific wavelength from the original and cut back fiber lengths.

17. What are the factors that produce dispersion in optical fibers?

The factors that produce dispersion in optical fibers are

- Propagation delay difference between the different spectral components of the transmitted signal
- Variation in group velocity with wavelength.

18. What are the methods used to measure fiber dispersion?

The methods used to measure fiber dispersion are

- Time domain measurement
- Frequency domain measurement

19. What are the methods used to measure fiber refractive index profile?

(M / J 2012)

The methods used to measure fiber refractive index profile are

- Interferometric method
- Near infra scanning method
- Refracted near field method.

20. Define – Minimum Detectable Optical Power

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.

21. What are the noise effects on system performance?

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

22. Why the attenuation limit curve slopes towards to the right?

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

23. What do you mean 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.

24. 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).

25. What are the system requirements?

The key system requirements are as follows

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

26. Give the two analyses that are used to ensure system performance.

The two analyses that are used to ensure system performance are

- Link power budget analysis
- Rise time budget analysis.

27. Define – Extinction Ratio

The extinction ratio ϵ is usually defined as the ratio of the optical energy emitted in the 0 bit period to that emitted during 1 bit period.

28. Define – Modal Noise

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

29. What are the measures to avoid modal noise?

The measures to avoid modal noise are

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

30. 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.

31. 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 bit error rate, BER.

32. What is reflection noise?

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

33. 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.

34. What are the system components of system rise time?

The four basic system components that contribute to the system rise time are

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

35. 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.

UNIT - V OPTICAL NETWORKS

**1. What are the three topologies used for fiber optical network?
(N / D 2011)**

The three topologies used for fiber optical network are

- Bus topology
- Ring topology
- Star topology

2. Calculate the number of independent signals that can be sent on a single fiber in the 1525 – 1565 nm bands. Assume the spectral spacing as per ITU – T recommendation G.692.(A / M 2011).

Given: Mean frequency spacing as per ITU- T is 0.8nm.

Wavelength = 1565nm – 1525nm = 40 nm.

Number of independent channel = (40nm / 0.8nm) = 50 channels.

3. Define – WDM (A / M 2011)

In fiber-optic communications, wavelength –division multiplexing(WDM) is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e. colors) of LASER light. This technique enables bidirectional communications over one strand of fiber, as well as multiplications of capacity.

4. What are the advantages of WDM? (N / D 2007)

The advantages of WDM are

- Various optical channels can support different transmission formats.
- Increase in the capacity if optical fiber compared to point – to –point link.

5. What are the drawbacks of broadcast and select networks for wide area network applications? (M / J 2012)

The drawbacks of broadcast and select networks for wide area network applications are

- Without the use of optical booster amplifiers splitting losses occurs.
- More wavelengths are needed as the number of nodes in the network grows.

6. The specifications of the light sources are converted to equivalent rise time in rise time budget. Why?

A rise time budget is a convenient method to determine the dispersion limitation of an optical link. This is particularly useful for digital systems. For this purpose, the specifications of the light sources (both the fiber and the

photo detector) are converted to equivalent rise time. The overall system rise time is given in terms of the light source rise time, fiber dispersion time and the photo detector rise time.

7. What is EDFA? (A / M 2008), (M / J 2012)

An erbium-doped fiber amplifier (EDFA) is a device that amplifies an optical fiber signal. A trace 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.

8. What is chirping? (N / D 2009)

The d.c. modulation of a single longitudinal mode semiconductor LASER can cause a dynamic shift of the peak wavelength emitter from the device. This phenomenon, which results in dynamic line width broadening under the direct modulation of the injection current, is referred to as frequency chirping.

9. What is the best way to minimize chirping?

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

10. What do you mean by bidirectional WDM?

A single WDM which operates as both multiplexing and demultiplexing device is said to be bidirectional WDM.

11. What are the basic performances of the WDM?

The basic performances of WDM are

- Insertion loss
- Channel width
- Cross talk

12. What are the advantages of using soliton signals through fiber? (M / J 2009)

The advantages of using soliton signals through fiber are, solitons are very narrow, high-intensity optical pulses that retain their shape through the interaction of balancing pulse dispersion with nonlinear properties of an optical fiber.

13. Distinguish between fundamental and higher order soliton. (N / D 2007)

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

14. What are solitons? (N / D 2010)

Solitons are nonlinear optical pulses which have the potential support very high optical transmission rates of many terabits per second over long distances.

15. What is SONET / SDH?

Synchronous optical networking (SONET) or synchronous Digital Hierarchy (SDH) is a standardized protocol that transfers multiple digital bit streams over optical fiber using lasers or highly coherent light emitting diodes. At low transmission rates data can also be transferred via an electrical interface.

16. What are the two different types of WDM?

The two different types of WDM are
Unidirectional WDM
Bidirectional WDM

17. What is DWDM?

Dense Wavelength Division Multiplexing (DWDM) is an optical technology used to increased bandwidth over existing fiber-optic bones. It works by combining and transmitting multiple signals simultaneously at different wavelengths on the same fibers.

18. Define – Crosstalk

Crosstalk is defined as the feed through one of the channel signals into another channel.

19. Give the important features of time-slotted optical TDM network.

The important features of time slotted optical TDM network are

- To provide backbone to interconnect high speed networks
- To transfer quickly very large data blocks
- To switch large aggregations of traffic
- To provide both high- rate.

20. How the speckle pattern can form?

The speckle patterns are formed by the interference of the modes from a coherent source when the coherence time of the source is greater than the intermodal dispersion time within the fiber.

21. Define – Full- Width Half- Maximum(FWHM)

The FWHM is a pulse defined as the full width at its half-maximum power level.

22. What are the types of broadcast and select network?

The types of broadcast and select network are

- Single – hop networks
- Multi – hop networks

23. What is meant by cross- phase modulation (XPM)?

Cross- phase modulation, which converts power fluctuations in particular wavelength channel to phase fluctuations in the copropagating channels.

24. What is meant by 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(dB) is known as the power penalty.

25. Define – Network

Network is defined as to establish connections between these stations; one interconnects them by transmission paths to form a network.

26. What is meant by topology?

The topology is the logical manner in which nodes are linked together by information transmission channels to form a network.
