SKP Engineering College

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INTRODUCTION TO OPTICAL FIBERS

QUESTION BANK

UNIT-1

Part A

1. **What are the advantages of fiber-optic system over conventional cables? (or)**
   State the reason to opt optical fiber communication.
   (APR/ MAY 2017) (APR/ MAY 2018)
   - Wider bandwidth (upto several thousand GHz)
   - Lower loss (signal Attenuation approximately 0.2 db)
   - Light weight (made by glass & Plastic) and smaller size (diameter of human hair)
   - Security (Cannot be trapped like electrical cables)
   - Interference immunity (free from Electromagnetic interference)
   - Safety (safe and easy installation)

2. **What are the conditions for the light to be propagated inside the fiber?**
   (or)
   Why Partial reflection does not sufficient the propagation of light?
   (NOV/DEC 2016) (NOV/DEC 2017)

   TIR is the condition that the light ray enter into the fiber can propagated

   TIR : The ray has an angle of incidence at the interface which is greater than the critical angle and is totally reflected back into the air at the same angle to the normal. This action is known as Total Internal Reflection.

   Two necessary conditions for TIR occur:

   - The refractive index of the first medium (n_1) must be greater than the refractive index of the second one(n_2).**($n_1 > n_2$)**
   - The angle of incidence exceeds the critical value ($\varphi_1 > \varphi_c$).

3. **Define NA of a fiber?(NOV/DEC 2016)**

   NA is used to describe the light gathering (or) light collecting ability of a fiber.

   NA for light entering the glass fiber from an air medium is described mathematically as

   $NA = \sin\theta_0$

4. **Calculate NA of a silica fiber with its core refractive index (n_1) of 1.48 and cladding refractive index of 1.46. Find NA. (APR/ MAY 2017)**

   $$NA = (n_1^2 - n_2^2)^{1/2}$$

   $$= (1.48^2 - 1.46^2)^{1/2}$$

$$=(2.19 - 2.13)^{1/2}$$

NA = 0.24

5. **A graded index fiber has a core with parabolic index profile which has a diameter of 50 μm. The fiber has NA of 0.2. Calculate the total no of guided odes in the fiber when it has the operating length of 1 μm. (NOV/DEC 2017) (NOV/DEC 2016)**

V number of the fiber

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

$$V = \frac{2\pi}{1 * 10^{-6}}\, 50 * 10^{-6}\ (0.2)$$

$$V = 62.8$$

Number of guided modes

$$m \approx \frac{V^2}{2}$$

$$m \approx \frac{(62.8)^2}{2}$$

$$m \approx 1971$$

Part B

1. **With the help of a block diagram explain different components of optical fiber link ? (NOV/DEC (APR/ MAY 2017) (APR/ MAY 2018) – 8M**

2. **Compare the structure and characteristics of step index and graded index fiber.(NOV/DEC2016) – 12M**

3. **Discuss briefly about the structure of graded index fiber.(APR/MAY 2018)–8 M**

4. **A silica fiber with its core refractive index (n_1) of 1.50 and cladding refractive index of 1.47, Determine (a) Critical Angle (b) NA (c) Acceptance Angle. (APR/MAY 2018) – 8 M**

5. **Explain Phase shift with total internal reflection and evanescent field.(NOV/DEC 2017) – 16 M**

6. **Discuss whether TEM waves exists in optical fiber. If not what type of mode will propagate in a practical optical fiber. (NOV/DEC 2017) – 16 M**

7. **A graded index fiber with parabolic refractive index profile, core has a refractive index of 1.5 and relative index difference of 1%. Estimate the maximum possible core diameter which allows single mode operation at a wavelength of 1.3 μm. (APR/ MAY 2018) – 8M**

8. **Derive the wave equation for the cylindrical fiber. (APR/MAY 2017) – 8 M**

9. **A fiber with its core refractive index (n_1) of 1.48 and cladding refractive index of 1.478,for single mode operation at 1330 nm. Determine (a) NA (b) Acceptance Angle. (APR/MAY 2017) – 8 M**

10. **A step index multimode fiber with NA of 0.2 supports approximately 1000 modes at 850 nm wavelength. What is the diameter of the fiber core? How many modes the fiber supports at 850 and 1550 nm? (APR/MAY 2017)-8 M**

11. **Consider a fiber of 25 μm core radius, core index n1 = 1.48 and Δ = 0.01. if wavelength λ – 1320 nm, what the value of V and how many modes propagate in the fiber. What percentage of optical power flows in the cladding? If the core difference is reduced to Δ = 0.003, how many modes propagate in the fiber and what percentage of optical power flows in the cladding?(NOV/DEC2016) – 8 M**

UNIT-2

Part A

1. **What are the causes of absorption? (NOV/DEC 2016)**

Absorption is caused by three different mechanism.

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

2. **What is Polarization mode dispersion? (NOV/DEC 2016) (APR/MAY 2018)**

- Polarization is the electric field orientation of the light s/g, which can be vary significantly along the fiber length.
- PMD is similar to wave dispersion. PMP leads to pulse broadening due to slightly different propagation velocities of 2 modes

3. **What is meant by intramodal dispersion? (APR/MAY 2017)**

Pulse spreading occurs within a single mode. It arises due to group velocity being function of wave length. The increasing spectral width of the optical source will increase the intramodal dispersion.

Types of intramodal dispersion are

1) Material Dispersion
2) Waveguide dispersion

4. **Define Group Delay. (APR/MAY 2017)**

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

5. **Define attenuation of fiber loss?(or) Define fiber loss. (NOV/DEC2017)**

- This power loss in optical fiber cable called as 'attenuation'.
- Measure of decay of signal strength (or) loss of light power that occurs as light pulse propagates through the length of the fiber.
- It is used to determine the maximum transmission distance between a transmitter and receiver.

6. What is elastic and non- elastic scattering? (APR/MAY 2018)

Linear Scattering Losses:

- Linear scattering transfers linearly the optical power in one propagation mode to different mode.
- These losses will occur in the leaky mode or radiation mode.
- It will not continue to propagate within the core of fiber and is radiated out from the fiber.
- All linear processes there is no change of frequency on scattering.

Non-linear scattering loss

- Optical power from one mode to be transferred in either forward or backward direction to the same (or) other modes at the different frequency.
- This loss depends on " Optical power density with in the fiber"

Part B

1. **Explain in detail about design optimization single mode fiber. (NOV/DEC 2016)**
2. **What is waveguide dispersion? Derive an expression for time delay produced due to waveguide dispersion. (NOV/DEC 2016)**
3. **Derive the expression for pulse broadening in graded index fiber. (APR/MAY 2017)**
4. **What are the causes of signal attenuation? Explain in detail about it. (APR/MAY 2017)**
5. **In detail explain linear scattering losses. (NOV/DEC 2017)**
6. **Explain in detail about the scattering and bending lo9sses that occur in an optical fiber with relevant expression and diagrams. (APR/MAY 2018)- 8M**
7. **Discuss material and waveguide dispersion mechanism with necessary mathematical expressions. (APR/MAY 2018)- 8M**
8. **A multimode graded index fiber exhibits total pulse broadening of 0.1 μs over a distance of 15 km. estimate**
   a) The maximum possible bandwidth on the link assuming no ISI
   b) The pulse dispersion per unit length
   c) The bandwidth- length product for the fiber. (APR/MAY 2018)- 8M

UNIT-3

Part – A

1. **What are the mechanisms behind lasing action? (NOV/DEC 2016)**
   Lasing condition at the light amplification becomes possible in the laser diode. The condition for lasing is that a population inversion can be achieved.
   Lasing Conditions
   - At the lasing threshold a steady state oscillation takes place and a magnitude and phase of the returned wave must be equal to those of the original wave.
   - The conditions of the lasing threshold is then given as,
     (i) For amplitude : I(2L) = I(0)
     (ii) For phase : $e^{-j2\beta L} = I$

2. **Define external quantum efficiency. (NOV/DEC 2016)**
   - The External quantum efficiency is defined as the "ratio of photons emitted from the LED to the number of photons generated internally".

     = Total number of output photons / Total number of internal photons
   - The external quantum efficiency is given by

$$\eta_{ext} = \frac{1}{4\pi}\int_0^{\phi c} T(\phi)\,(2\pi \sin\phi)\,d\phi$$

3. **Compare the optical power LED and LASER. (APR/MAY 2017)**

S. NO	Parameter	LED	LASER
1	Output beam`	In-Coherent	coherent
2	Coupling Efficiency	Low	High
3	Principle of operation	Spontaneous emission	Stimulated Emission
4	Output power	Low	High
5	Date Rate	Low	High
6	Temperature	Less temperature dependent	More temperature dependent
7	Application	Long distance with high data rate	Moderate distance with low data rate

4. **Write the laser diode rate equations. (NOV/DEC 2017)**
   - Relationship between optical output power and the diode drive current can be determined by examining the rate equation that govern the interaction of the photons and electrons
   - For the junction with a cosier conferment region of depth 'd' the rate equation is given by

$$d\phi/dt = c_n\phi + R_{sp} - \phi/\Gamma_{ph}$$

   Simulate emission → spontaneous emission + photon loss

   ϕ→ no of photons

$$dn/dt = J/qd - n/\Gamma_{sd} - c_n\phi$$

Injection+ spontaneous recombination + stimulated emission

5. **Give some possible lensing schemes to improve the optical source to fiber coupling efficiency. (NOV/DEC 2017)**

Types of lensing schemes

- Round end fiber
- Non imaging microsphere
- Imaging microsphere
- Cylindrical lens
- Spherical surface LED
- Taper end fiber

6. **Illustrate the factors determine the response time of the photo diode. (APR/MAY 2018)**

Response time depends on

i) Transmit time of photon carriers within the depletion region.
ii) Diffusion time of photon carriers outside the depletion region.
iii) RC time constant of photodiode & its associated circuit

7. **An LED has radiative and non-radiative recombination times of 30 ns and 100 ns. Determine the internal quantum efficiency. (APR/MAY 2018)**

$\tau_r = 30\ ns \tau_{nr} = 100\ ns$

Recombination life time $\tau = \frac{\tau_r \tau_{nr}}{\tau_r + \tau_{nr}}$

$$\tau = \frac{30 * 100}{30 + 100}$$

$$\tau = 23.1\ ns$$

Internal quantum efficiency $\eta_{int} = \frac{\tau}{\tau_r}$

$$\eta_{int} = \frac{23.1}{30}$$

$$\eta_{int} = 0.77$$

Part B

1. **Explain the working principle of LASER diode and derive its rate equation. (NOV/DEC 2016)(NOV/DEC 2017)**

2. **What is Fiber splicing? Discuss about fusion and mechanical splicing. (NOV/DEC 2016) (APR/MAY 2018) – 8 M**

3. **A double hetrojunction LED emitting at peak wavelength of 1310 nm has radiative and non radiative recombination life time of 45 and 95 ns. The drive current is 35 mA. Determine the internal quantum efficiency and internal power level if n = 3.5, find the power emitted from the device. (NOV/DEC 2016) – 8 M**

4. **Explain the structure of surface emitting and edge emitting LED with neat Sketches.(APR/MAY 2017)**

5. **Explain the different types lensing schemes to improve the optical source to fiber coupling efficiency. (APR/MAY 2017) (APR/MAY 2018)**

6. **With steps, derive the internal quantum efficiency of LED. (NOV/DEC 2017)**

7. **Give a brief account on the resonant frequency of laser diodes. (APR/MAY 2018)**

Unit 4

Part A

1. **Define BER. (0r) Define bit error rate.(APR/MAY 2017) (NOV/DEC 2016)**
   Bit error rate is defined by the ratio between number of errors ***(Ne)*** occuring over a certain time interval t to the number of pulses transmitted ***(Nt)*** during the interval.

$$BER = \frac{N_e}{N_t} = \frac{N_e}{B_t}$$

   where $B = 1/T_b$ is the bit rate (is the pulse transmission rate).

2. **What is cut back method?(NOV/DEC 2016)**
   - Cutback technique is a destructive method requiring access to both ends of the fiber for measuring attenuation.
   - To find the transmission loss, the optical power first measured at the output of the fiber.
   - Without disturbing the Input condition, the fiber is cut off of a few meters from the source, and the output power at this end is measured.

3. **What are the methods employed for measuring the attenuation in optical fiber? (APR/MAY 2017)**
   Three major technique are used
   - ❖ Cut back technique
   - ❖ Insertion loss method
   - ❖ Optical time domain reflectometers (OTDRs) trace

4. **Define the structure of transimpedance amplifier. (NOV/DEC 2017)**
   The transimpedance amplifier is nothing but the low noise high impedance amplifier with a negative feedback ' resistor, the device therefore operates as a current mode amplifier.

5. **Define receiver sensitivity. (NOV/DEC 2017)**
   The sensitivity of the receiver dominated by the noise sources at preamplifier stage.
   The main goal to maximize the receiver sensitivity while maintaining the system bandwidth. Pre amplifiers are used to maximize the sensitivity.

6. **List the error sources associated with fiber optic receiver section. (APR/MAY 2018)**

- Error detection mechanism can arise due to various noise and disturbances associated with the signal.
- The term noise is used customarily to describe unwanted components of an electrical signal that tend to disturb the transmission and processing of the signal in a physical system, and over which we have in complete control.
- The noise sources can be either external or internal to the system. Internal noise are further classified into short noise and thermal noise.

7. **Define quantum limit. (APR/MAY 2018)**
   This condition, it is possible to find the minimum received optical power required for a specific bit-error rate performance in a digital system. This minimum received power level is known as the quantum limit.

Part B

1. **Explain the different methods employed in measuring the attenuation in the optical fiber with neat block diagram. (NOV/DEC 2016)**

2. **What are the performance measures of a digital receiver? Derive an expression for bit error rate of the digital receiver. (NOV/DEC 2016)**

3. **Discuss in detail about the methods used for measuring the intermodal dispersion and chromatic dispersion. (APR/MAY 2017)**

4. **Explain about the operation of an optical receiver and sources of error during transmission. Draw the configuration of the receiver.(APR/MAY 2017)**

5. **Explain the dispersion measurement methods in fiber optic system.(NOV/DEC 2017)**

6. **Explain in detail about Numerical aperture measurements of optical fiber. (NOV/DEC 2017)**

7. **With a typical experimental arrangement brief the measurement process of diameter of the fiber. (APR/MAY 2018)**

8. **Discuss the different structures of the receiver in the optical fiber communication with neat diagram. (APR/MAY 2018)**

Unit 5

1. **Name the two popular architecture of SONET/ SDH network. (NOV/DEC 2016)**
   Synchronous Optical Networking (SONET) or Synchronous Digital Hierarchy (SDH) are standardized multiplexing protocols that transfer multiple digital bit streams over optical fiber using lasers or light – emitting diodes (LEDs). Lower rates can be transferred via an electrical interface.

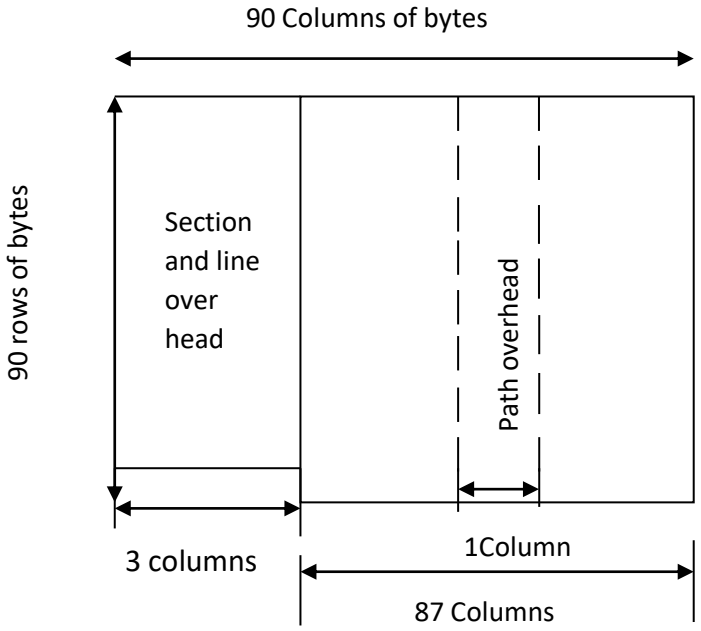
2. **What is an optical layer?(APR/MAY 2017)**
   SONET has four optical interface layers. They are
   (i). Path layer

(ii). Line layer
(iii). Section layer
(iv). Photonic layer

3. What are the key parameters required for analyzing the optical link?(APR/MAY 2017)

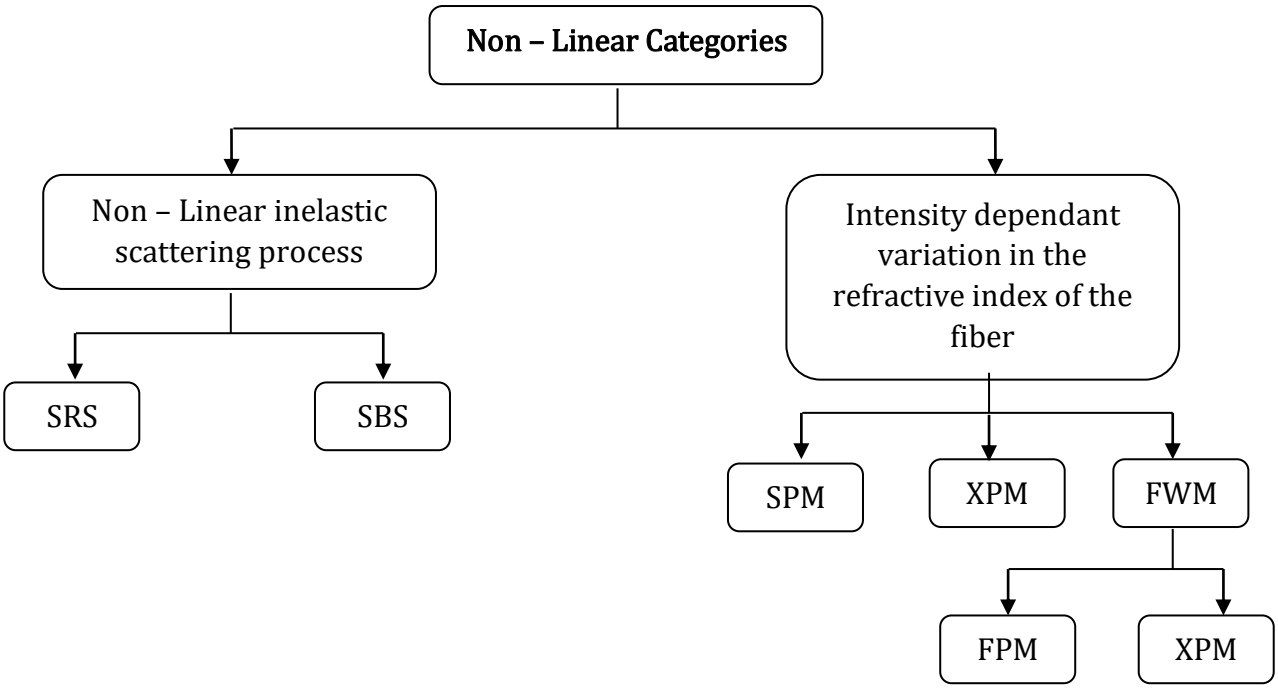
- Group velocity dispersion
- Non uniform gain across the desired wavelength range
- Polarization mode dispersion
- Nonlinear scattering process
- Nonlinear variation in refractive index

4. Draw the structure of STS- 1 SONET frame. (NOV/DEC 2017)



Basic structure of an STS – 1 SONET frame.

5. Mention any 2 nonlinear effects present in optical fiber. (NOV/DEC 2017)



6. **Mention the drawback of broadcast and select networks for WAN applications. (APR/MAY 2018)**
   - Transmission of data purely depends on signal wavelength
   - No direct connection between nodes. An electro opto conversion takes place between transmitter and receiver.
   - Single hop network is the need of rapidly tunable lasers or optical filters.

7. **Write short notes on solitons**. **(APR/MAY 2018)**
   - Solitons are pulses that travel along the fiber without change in shape or amplitude or velocity.
   - Solitons take advantage of non-linear effects in silica, particularly self – phase modulation (SPM). Resulting from the Kerr non linearity, to overcome the pulse – broadening effects of GVD.
   - The term 'Soliton' refers to special kind of waves that can propagate undistorted over long distance and remain unaffected after collisions with each other.

Part – B

1. **Draw the generic configuration of SONET and mention the functions of add drop multiplexers in SONET. (NOV/DEC 2016)(NOV/DEC 2017) (APR/MAY 2018)**

2. **Discuss in detail about the effects of noise on system performance. (NOV/DEC 2016)**

3. **Discuss the principle of optical code division multiple access. (APR/MAY 2017) – 8 M**

4. **Discuss about the protection mechanism in UPSR and BLSR ring architecture with neat sketch. (APR/MAY 2017) – 8 M**

5. **An optical fiber system is to be designed to operate over an 8 km length without repeaters. The rise times of chosen components are:**
   (1) Source (LED) 8 ns
   (2) Fiber intermodal 5 ns km-1
   (3) Intramodal 1 ns km-1
   (4) Detector6 ns
   From system rise time considerations estimate the maximum bit rate that may be achieved on the link when using an NRZ format.(APR/MAY 2017)–8M

6. **Write a note on optical switching methods. (NOV/DEC 2017)**

7. **Discuss in detail about the nonlinear effects on network performance. (APR/MAY 2018)**

8. **Discuss about the concept of routing and wavelength assignment in the wavelength routed networks. (APR/MAY 2018)**