Ajay Kumar Garg Engineering College, Ghaziabad

Department of ECE

Model Solution Sessional Test-2

Course:	B.Tech	Semester:	VII
Session:	2017-18	Section:	EC-1, 2, 3
Subject:	Optical Communication	Sub. Code:	NEC-701
Max Marks: 50		Time: 2 hour	

Note : Answer all sections

Section-A

Q.A Attempt all parts

Q1 What is chromatic Dispersion?

Ans chromatic Dispersion is also known as Intramodal Dispersion, it results from finite spectral line width of the optical source. This causes broadening of each transmitted mode or propagation delay difference b/w different spectral components of transmitted signal.

Q2 How the Information carrying capacity of an optical fiber is specified? Give example.

Ans Information carrying capacity is specified in terms of Bandwidth Length product. For eg. Multimode step Index fiber have 20 MHz Km Information carrying capacity.

Q3 What are the advantages of Intensity Modulation?

Ans It is easy to implement in both digital and analog signal, provides high signal to Noise ratio, can be used for long distance range.

Q4 Explain fiber Bending losses.

Ans:- optical fiber suffer radiation losses at the bends. This is due to the energy in the evanescent field at the bend exceeding the speed of light in cladding, hence light energy to be radiated out from the fiber.

Two types - Macrobending losses and Microbending losses.

Q5 Name some material used for fabrication of LEDs depending upon operating wavelength.

Ans 5 For shorter wavelength - GaAs, AlGaAs

For longer wavelength - InP, InGaAsP.

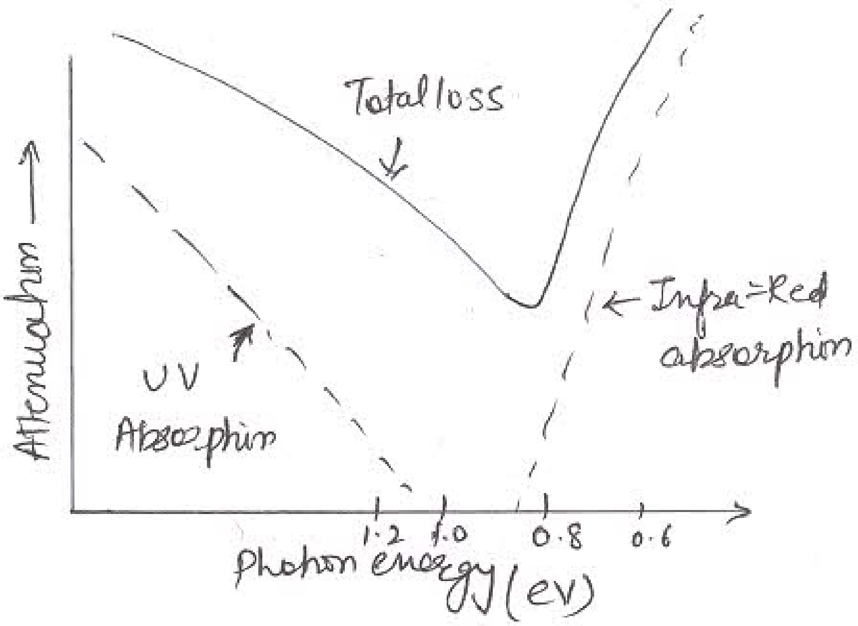
SECTION-B

Q6 Explain the Absorption losses mechanism with their causes in Silica Glass fibers.

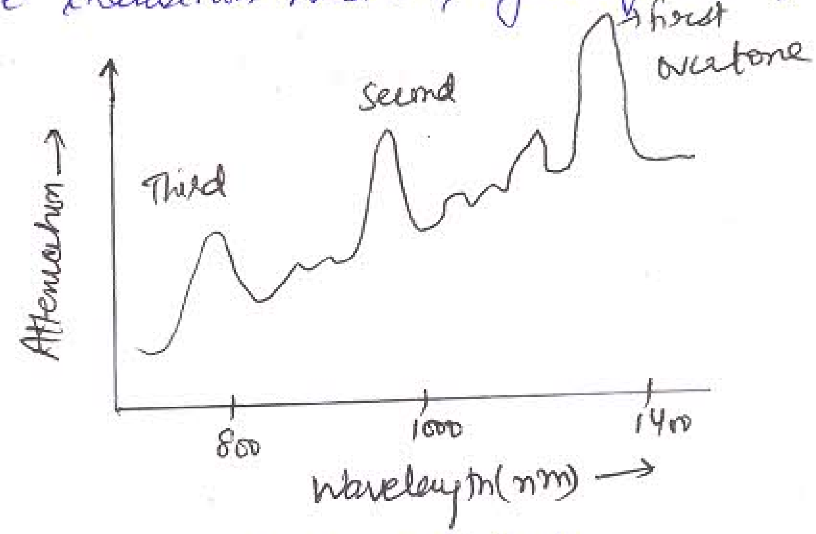
Ans Material Absorption is a loss mechanism related to the material composition and fabrication process for the fiber, which results in dissipation of some of the transmitted optical power. Absorption of light may be Intrinsic and Extrinsic

Intrinsic Absorption :- It is caused by the interaction with one or more of the major components of the glass.

It has two major intrinsic absorption at ultraviolet region and Intrinsic Infra-Red region.



Extrinsic absorption:- It caused due to the impurities in glass i.e transition metal; Hydroxyl ions, Cu^{2+}, Cr^{3+}, Mn^{3+}



Absorption due to OH^- ions.

Q7 What is Kerr effect? A multimode step Index has a N.A of 0.4 and core refractive Index 1.45. The internal material dispersion parameter for the fiber is 375 ps nm^{-1} km^{-1} which makes material dispersion the totally dominating chromatic dispersion mechanism. Estimate (a) total rms pulse broadening per Km when the fiber is used with LED source of rms spectral width 75 nm (b) Corresponding Bandwidth length product for the fiber.

Ans Kerr effect is a Non linear effect which causes a change in refractive index of optical fiber at high intensity of input optical signal.

Kerr effect

- SPM
- CPM
- Four Wave Mixing

SPM - (self Phase Modulation) → High intensity signal causes phase shift in fiber, results in different transmission phase for the peak of pulse compared with leading and trailing pulse edges.

CPM (Cross phase Modulation) is similar to SPM except it also causes the phase modulation of overlapping pulse. CPM is act as Cross talk between channel. It ↑ses with number of channels.

The beating between the light causes at different frequencies causes phase modulation of channels and hence generation of modulation sidebands at new frequencies. This is FWM (Four Wave Mixing) for e.g. $\omega_4 = \omega_1 + \omega_2 - \omega_3$.

<u>Numerical</u>:- Given:- $M = 375$, $\sigma_\lambda = 75$, $NA = 0.4$, $n_1 = 1.45$

(a) $\sigma_M = \sigma_\lambda L M$
$= 75 \times 1 \times 375$
$= 28.12 \text{ ns Km}^{-1}$

$$\sigma_S = \frac{L(NA)^2}{4\sqrt{3}\, n_1 C} = \frac{10^3 \times (0.4)^2}{4\sqrt{3} \times 1.45 \times 3 \times 10^8} = 53.1 \text{ ns Km}^{-1}$$

$$\sigma_T = (\sigma_M^2 + \sigma_S^2)^{1/2} = 60.08 \text{ ns Km}^{-1}$$

(b) $$B_{opt} \times L = \frac{0.2}{\sigma_T} = \frac{0.2}{60.08} = 3.32 \text{ MHz}$$

Q Explain the Non linear scattering losses. The beat length in a single mode fiber is 10cm when light from injection laser with spectral line width of 2nm and a peak wavelength of 0.85 um is launched into it. Determine modal birefrigence, coherence length and phase difference b/w propagation constant.

Ans Non linear scattering losses cause disproportionate attenuation at high optical power levels. This non linear causes optical power from one mode to another mode to be transferred in either backward or forward direction to the same or other mode, at different frequency.

Non linear scattering losses are of two types SBS and SRS.

SBS [Stimulated Brillouin Scattering] :- Modulation of light through thermal molecular vibrations within fiber. Incident photon produces acoustic phonon of acoustic frequency. Causes frequency shift in backward direction.

$$P_B \text{ [Threshold power]} = 4.4 \times 10^{3} d^2 \lambda^2 \alpha_{dB} \nu \text{ watts.}$$

SRS [Stimulated Raman Scattering] :- In this high frequency phonon is generated. SRS can occur in both forward & Backward dirn.

$$\text{Threshold power } P_R = 5.9 \times 10^{-2} d^2 \lambda \alpha_{dB} \text{ watts}$$

$$\uparrow\uparrow\uparrow\uparrow \xrightarrow[SRS]{} \uparrow\uparrow\uparrow$$

Numerical :-

$$B_f = \frac{\lambda}{L_B} = \frac{0.85 \times 10^{-6}}{0.1} = 8.5 \times 10^{-6}$$

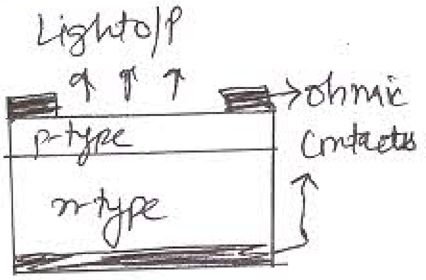
$$\text{Coherence Length } L_{BC} \sim \frac{\lambda^2}{B_f \delta\lambda} = \frac{(0.85 \times 10^{-6})^2}{(8.5 \times 10^{-6}) 2 \times 10^{-9}} = 42.5\,m$$

Difference between propagation Constant $\beta_x - \beta_y = \frac{2\pi}{L_B} = \frac{2\pi}{0.1} = 62.8$

Q9 Explain any three types of LED structures. The total efficiency of an injection laser with GaAs active region is 24%. The voltage applied to the device is 2.8V and bandgap energy for GaAs is 1.27 eV. Compute the external power efficiency.

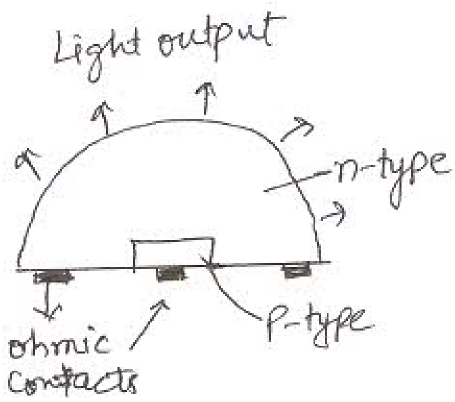
Ans 9:- LED Structures:-

(i) Planar LED :-



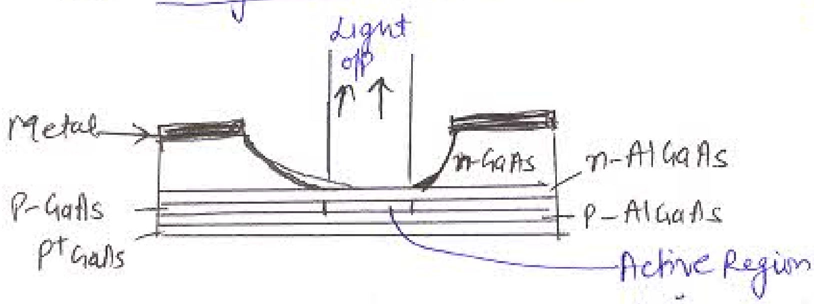
- Fabricated by epitaxial process.
- gives Lambertian spontaneous emission
- low efficiency
- wide active region.

ii) Dome LED



- High efficiency than Planar LED
- Radiance reduces.
- Wide emission area.

iii) Surface Emitter LEDs :-



- Higher Efficiency
- High radiance emission
- high Coupling efficiency
- Narrow Active Region

Numerical :- Given $\eta_T = 0.24$ $E_g = 1.27$, $V = 2.8$, $\eta_{ext.} = ?$

$$\eta_{ext.} = \eta_T \times \left(\frac{E_g}{V}\right) \times 100$$

$$= 0.24 \times \left(\frac{1.27}{2.8}\right) \times 100 = 10.88\%$$

Q10 Define and Derive expression for Efficiency and power of LED.

Ans10:- Consider a constant current is flowing into the Junction diode, after certain time equilibrium is achieved.

$$\Delta n = \Delta n(0)\, \exp(-t/\tau)$$

Rate equation for carrier recombination in LED

$$\frac{d(\Delta n)}{dt} = \frac{J}{ed} - \frac{\Delta n}{\tau}$$

where $J \rightarrow$ Current density

$\Delta n \rightarrow$ small fraction of majority carriers

$\Delta n(0) \rightarrow$ initial injected electrons

$\tau \rightarrow$ Carrier life time

At equilibrium $\frac{d(\Delta n)}{dt} = 0$

$$\therefore \frac{J}{ed} = \frac{\Delta n}{\tau} \Rightarrow \Delta n = \frac{J\tau}{ed}$$

$$\Rightarrow r_t = \frac{J}{ed} = r_r + r_{nr}$$

where r_t - total recombination rate per ...

$r_r \rightarrow$ radiative recombination rate per ...

$r_{nr} \rightarrow$ non-radiative recombination rate per

$$\Rightarrow R_t = i/e$$

$\downarrow$

Total No. of Recombinations

∴ LED internal quantum efficiency is ratio of radiative recombination rate to the total recombination rate.

$$\eta_{int} = \frac{r_r}{r_t} = \frac{r_r}{r_r + r_{nr}} = \frac{R_r}{R_t}$$

$$\therefore R_r = \eta_{int} \cdot i/e$$

If energy of one photon is hf joules then optical power generated internally by LED P_{int}.

$$P_{int} = \eta_{int} \cdot \frac{i}{e} hf \quad (W)$$

$$\boxed{P_{int} = \eta_{int} \cdot \frac{hci}{e\lambda}} \quad \text{Watt}$$

Also, $\eta_{int} = \frac{1}{1 + \frac{r_{nr}}{r_r}} = \frac{1}{1 + \tau_r/\tau_{nr}} = \frac{\tau}{\tau_r}$

External power efficiency η_{ep} is defined ratio of the optical power emitted externally P_e to the electric power provided to the device P

$$\boxed{\eta_{ep} \approx \frac{P_e}{P} \times 100\,\%}$$

optical power P_e emitted into medium of low refractive index from the face of LED

$$\therefore P_e = \frac{P_{int} \cdot F n^2}{4 n_x^2}$$

F → Transmissive Factor

Coupling efficiency defines the how much power is actually coupled into the optical fiber $\boxed{\eta_c = \sin^2\theta_a = (NA)^2}$

where NA → Numerical Aperture of fiber.

Q Explain the Working principle of LED and Injection laser. A Ruby laser crystal is 5cm long (n=1.75). The peak emission wavelength is 0.55 um. Determine the no. of longitudinal modes and frequency separation.

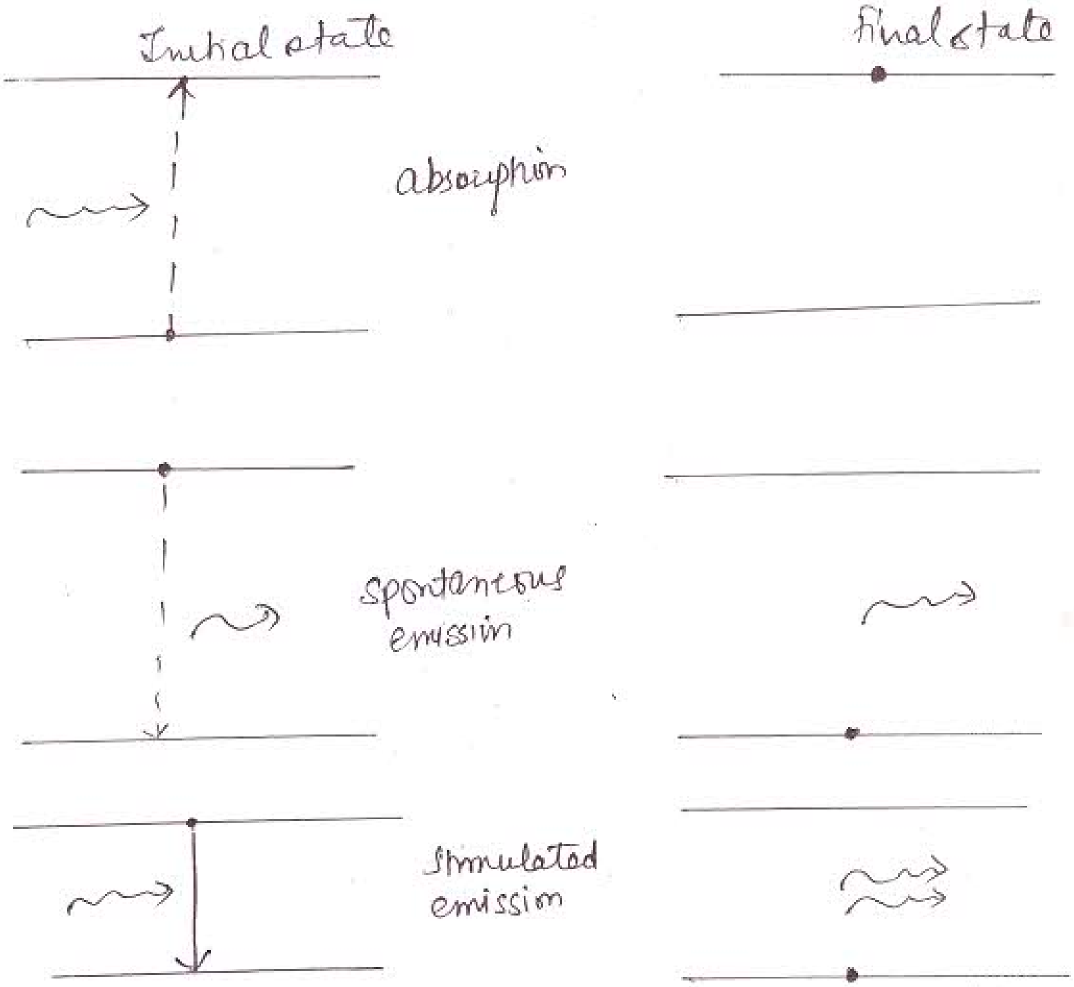
Ans The Working principle of LED is based on the quatum theory. It says when the e^- comes down from the higher energy level to the lower energy level, then the energy emits from the photon. The photon energy is equal to the energy gap between these two level. The Working principle of LED is spontaneous emission

The pn-junction diode is in the forward biased then the current flows through the diode. The flow of current in the semiconductors is caused by the both flow of free e^- in opposite direction of current. Hence there will be recombination due to the flow of these charge carriers.

On recombination of e^- & holes, a photon is released whose wavelength is equal to the Wavelength of emitted light.

Working Principle of Injection laser:- Working principle of LASER is stimulated emission. In this when a photon with energy E_2-E_1 is incident on atom, it may excited into higher energy state E_2 through the absorption of photon. On coming back to the lower energy state, emission of incident photon and another photon is released which same phase. This gives LASER as a Coherent source.

This means that when an atom is stimulated to emit light energy by an incident Wave, the liberated energy can add to the wave in a constructive manner, providing amplification.



Working Principal of LED (b) and LASER (c)

Numerical :- Number of Longitudinal mode

$$q = \frac{2nL}{\lambda} = \frac{2 \times 1.75 \times 5 \times 10^{-2}}{0.55 \times 10^{-6}} = 3.18 \times 10^{5}$$

Frequency separation of the mode is

$$\delta f = \frac{c}{2nL} = \frac{2.998 \times 10^{8}}{2 \times 1.75 \times 5 \times 10^{-2}} = 1.713 \text{ GHz}$$

Minimum time taken by fastest ray (i.e Axial Ray)

$$T_{Min} = \frac{L}{c/n_1} = \frac{Ln_1}{c}$$

Maximum Time taken by slowest Ray (i.e Extreme Meridional Ray)

$$T_{Max} = \frac{L/\cos\theta}{c/n_1} = \frac{Ln_1}{c\cos\theta}$$

$$\sin\phi_c = \frac{n_2}{n_1} = \cos\theta$$

$$T_{Max} = \frac{Ln_1^2}{cn_2}$$

Delay difference i.e $\delta T_s = T_{Max} - T_{min}$

$$= \frac{Ln_1^2}{cn_2} - \frac{Ln_1}{c}$$

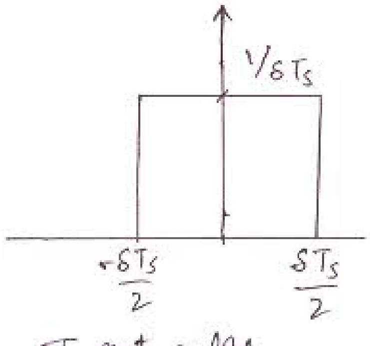
when $\Delta << 1$ then $\Delta \simeq \frac{n_1 - n_2}{n_2}$

$$\delta T_s = \frac{Ln_1}{c}\left(\frac{n_1 - n_2}{n_2}\right) = \frac{Ln_1\Delta}{c}$$

$$\delta T_s \simeq \frac{L(NA)^2}{2n_1 c}$$

Now consider the input to the optical fiber is a unit pulse of unit area such that

$$\int_{-\infty}^{\infty} P_i(t)\,dt = 1$$



Input pulse

Q What is Modal Noise? Derive an expression for Intermodal Dispersion in Step Index fiber?

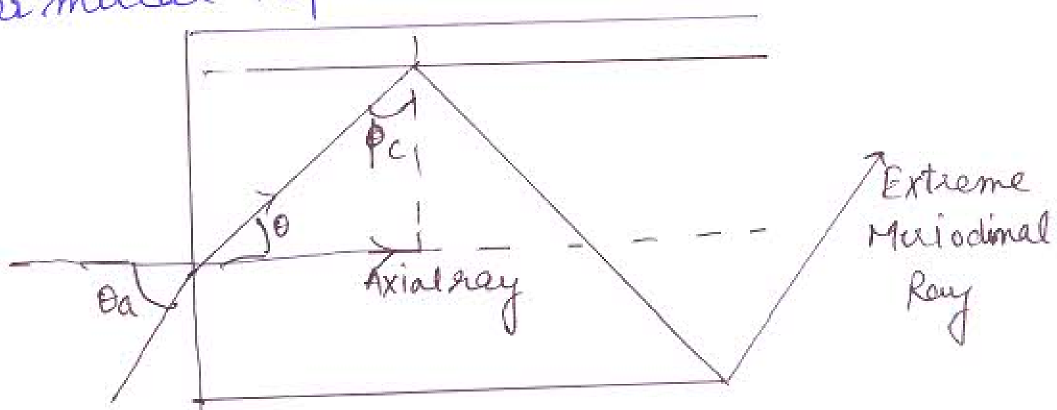
Ans Intermodal Dispersion of multimode optical fibers affects the transmitted signal on the optical channel. It is exhibited within speckle patterns observed in multimode fiber as fluctuations which have characteristic times longer than resolution time of detector and is Known as Modal Noise or Speckle Noise.

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

Modal Noise occurs when

$$\delta f \gg \frac{1}{\delta T}$$

Intermodal Dispersion in Multimode step Index fiber.



Path Taken by Ray [fastest and slowest Ray]

Rms pulse broadening at the fiber output is given by σ_s

$$\sigma_s^2 \text{ (Variance)} = M_2 - M_1^2$$

where $M_1 = \int_{-\infty}^{\infty} t\, P_i(t)\, dt$

$$M_2 = \int_{-\infty}^{\infty} t^2 P_i(t)\, dt$$

Assume $M_1 = 0$

$$\therefore \sigma_s^2 = M_2 = \int_{-\infty}^{\infty} t^2 P_i(t)\, dt$$

$$\sigma_s^2 = \int_{-\delta T_s/2}^{\delta T_s/2} \frac{1}{\delta T_s} t^2\, dt$$

$$= \frac{1}{\delta T_s} \left[\frac{t^3}{3}\right]_{-\delta T_s/2}^{\delta T_s/2} = \frac{1}{3}\left(\frac{\delta T_s}{2}\right)^2$$

$$\therefore \sigma_s = \frac{L n_1 \Delta}{2\sqrt{3}\, c} \approx \frac{L(NA)^2}{4\sqrt{3}\, n_1 c}$$