Solution 2013 Final Exam (1)

Q.1 (a) The number of modes in an optical fiber, having core and cladding refractive index of 1.48 and 1.46 respectively, is 14331. If the wavelength of light is 9000^{o}A, what is the core diameter? **[8 marks]**

Solution:

$$M_n = \frac{V^2}{2}$$

$$V = \sqrt{2M_n} = \sqrt{2 \times 14331}$$

$$V = 169.298$$

$$N.A. = [n_1^2 - n_2^2]^{\frac{1}{2}}$$

$$N.A. = [1.48^2 - 1.46^2]^{\frac{1}{2}} = 0.2424$$

Normalized frequency $V = \left[\frac{2\pi a}{\lambda}\right] \times N.A.$

$$a = (V)(\lambda)/\ (2\pi\ N.A.)$$

$$a = (169.298 \times 9000 \times 10^{-10})/(2\pi \times 0.2424)$$

$$a = 100 \times 10^{-6}\ m = 100\ \mu m$$

$$d = 2 \times a = 200\ \mu m$$

b) Explain the important conditions for TIR to exist in fiber. **[6 marks]**

Total internal reflection takes place under two essential conditions:

1- Refractive index $n_1 > n_2$.
2- Angle of incidence should be greater than critical angle.

Q.2. When a mean optical power is lunched into an 8 km length of fiber is 12 µW, the mean optical power at the fiber output is 3 µW. Determine -
1) Overall signal attenuation in dB.
2) The overall signal attenuation for a 10 km optical link using the same fiber with splices at 1 km intervals, each giving an attenuation of 1dB.

Solution: Given: z =8 km **[14 marks]**
P(0) = 12 uW
P(0) = 3 uW

1) Overall attenuation is given by,

$$\alpha = 10\ log\left[\frac{P(0)}{P(z)}\right]$$

$$\alpha = 10\ log\left[\frac{12}{3}\right]$$

$$\alpha = 6.02 \quad \text{dB}$$ Ans ...

2) Overall attenuation for 10 km,

Attenuation per km $\alpha_{dB} = \frac{6.02}{z} = \frac{6.02}{8}$

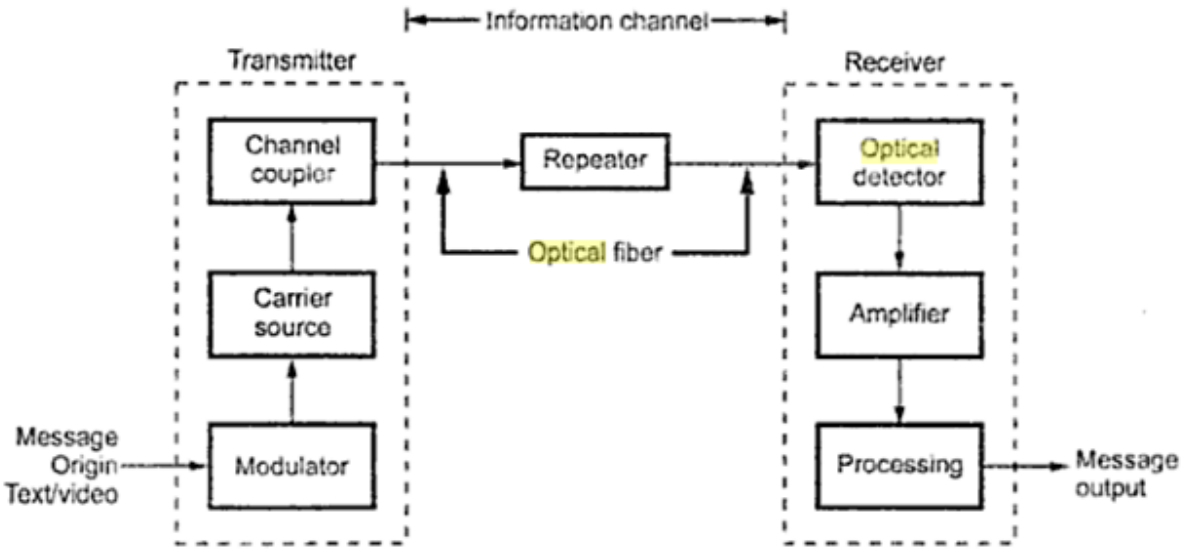
$$\alpha_{dB} = 0.752\ \frac{dB}{km}$$

Attenuation in 10 km link = 0.752 * 10 = 7.5 dB

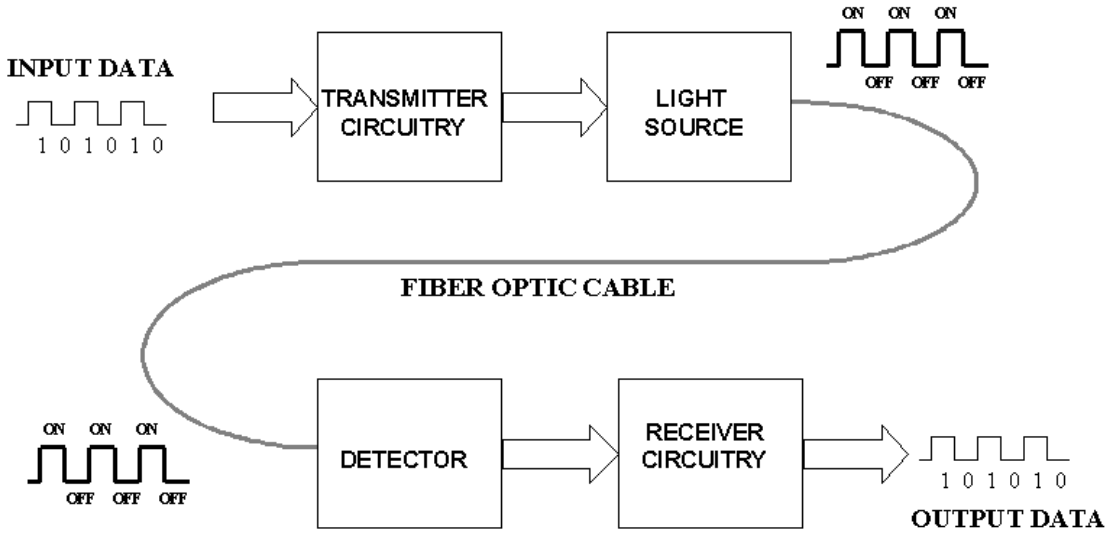
In 10 km link there will be 9 splices at 1 km interval. Each splice introducing attenuation of 1 dB.

Total attenuation = 7.5 dB + 9 dB = 16.5 dB. Ans…

Q.3. (a) Draw the basic block diagram of an optical fiber communication (OFC) system, showing how the message (Text or Video) are processed through the OFC system. **[8 marks]**



Block diagram of OFC systems



(b) On an InGaAs photodetector, a pulse of 85 *ns* emits 6×10^6 photons at 1300 *nm* wavelength. Average e-h pairs generated are 5.4×10^6. Calculate quantum efficiency of detector. **[6 marks]**

Solution: No. of photons emitted = 6×10^6

Average e-h pairs generated $= 5.4 \times 10^6$

The quantum efficiency is given by:

$$\eta = \frac{\text{No. of e} - \text{h pairs generated}}{\text{No. of incident photons}}$$

$$\eta = \frac{5.4 \times 10^6}{6 \times 10^6}$$

$$\eta = 0.9 = 90\ \% \qquad \text{Ans …}$$

Q.4 (a) A double hetrojunction InGaAsP LED operating at a wavelength of 1310 *nm* has radiative and non-radiative recombination life times of minority carriers in the active region of a are 30 nsec and 100 nsec respectively. The current injected is 40 mA. Calculate:

i) Bulk recombination life time.

ii) Internal quantum efficiency.

iii) Internal power level. **[10 marks]**

$$\lambda = 870\ nm = 0.87 \times 10^{-6}\ m$$

$$\tau_r = 30\ ns$$

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

$$\text{I} = 40\ mA = 0.04\ Amp$$

i) Bulk recombination life time τ

$$\frac{1}{\tau} = \frac{1}{30} + \frac{1}{100} = 0.043$$

$$\tau = 23.077\ n\ sec$$

ii) Internal quantum efficiency (η_{int})

$$\eta_{int} = \frac{\tau}{\tau_r} =$$

iii) Internal power level (P_{int})

$$P_{int} = 0.769 \times$$

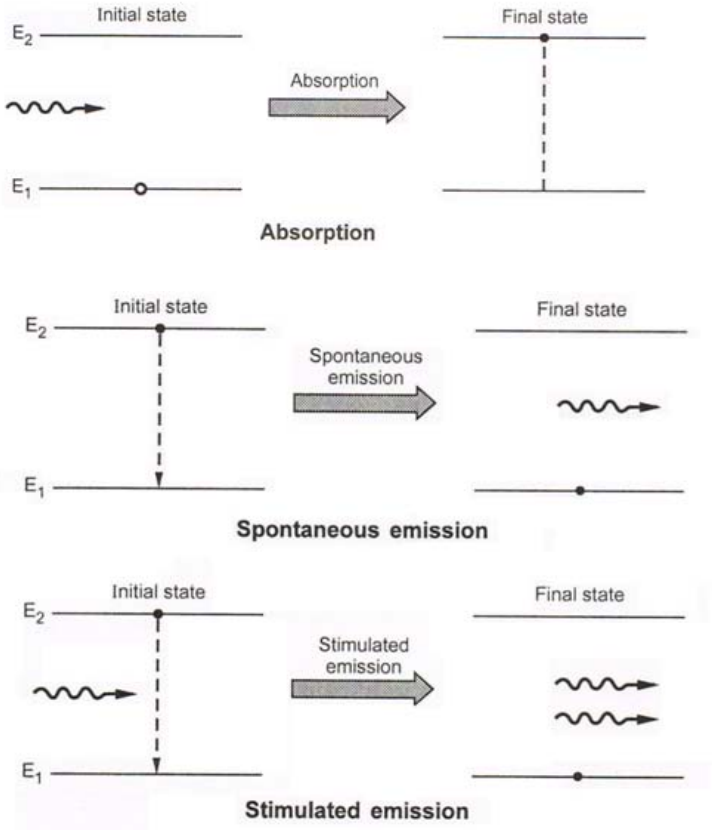
$$P_{int} = 29.145\ mW$$

(b) Draw the three key transition processes involved in laser action.

[4 marks]

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

And:



Q.5: a) Photons having energy 1.53×10^{-19} Joules are incident on a photodiode having responsivity of 0.65 A/W. If output power is 10 µW. Find the generated photocurrent. [4 marks]

Solution : $\Re = 0.65$ A/W

$P_0 = 10$ µW

Responsivity is given as -

$$\Re = \frac{I_p}{P_0}$$

$$\boxed{I_p = \Re P_0}$$

$$I_p = 0.65 \times 10$$

$$I_p = 6.5\ \mu A$$ ... Ans.

(b) Compare LED and LASER diode in a table (write only five points). [10 marks]

	LED	LD
1. Principle of operation:	spontaneous emission	stimulated emission
2. Output beam:	non – coherent	coherent
3. Spectral width:	broad spectrum (20-100 nm)	much narrower (1-5 nm)
4. Data rate:	low	very high
5. *Transmission distance*	smaller	greater

Q.6 (a) The bandgap energy in a direct bandgap material can be controlled by x and y parameters, related to two expressions:

$E_g = 1.424 + 1.266\,x + 0.266\,x^2$, $E_g = 1.35 - 0.72\,y + 0.12\,y^2$

Assuming an $In_{0.74}Ga_{0.26}As_{0.57}P_{0.43}$ alloy to be used in LED, find the wavelength emitted by this LED source. **[4 marks]**

Solution : Comparing the alloy with the quartenary alloy composition.

$In_{1-x}\ Ga_x\ As_y\ P_{1-y}$ it is found that

$$x = 0.26 \text{ and}$$

$$y = 0.57$$

Using $$\boxed{E_g = 1.35 - 0.72\,y + 0.12\,y^2}$$

$$E_g = 1.35 - (0.72 \times 0.57) + 0.12 \times 0.57^2$$

$$E_g = 0.978 \text{ eV}$$

Now $$\boxed{\lambda = \frac{1.24}{E_g}}$$

$\therefore$ $$\lambda = \frac{1.24}{0.978} = 1.2671\ \mu m \approx \mathbf{1.27\ \mu m}$$ **... Ans.**

b) Choose the Correct Answer: **[10 marks]**

1- The optical fibers are made of:

(a) metallic conductor (b) plastic doped with metallic impurities
(c) dielectric material (d) magnetic oxide

2- When *V* parameter is less than 2.405, then the fiber will support

(a) one mode (b) two modes
(c) three modes (d) infinite modes

3- The jacket of an optical fiber enables

(a) to prevent from mechanical abrasions
(b) to prevent interaction with internal atmosphere
(c) to prevent moisture trapping
(d) all of the above

4- Attenuation in an optical fiber is measured by

(a) $loss = -10\ log_{10}\ P_o$ (b) $loss = 10\ log_{10}\ P_i$
(c) $loss = -10\ log_{10}\ \frac{P_o}{P_i}$ (d) $loss = -10\ log_{10}\ \frac{P_i}{P_o}$

5- Spectral width and modulation capabilities in LED and laser diodes are determined by:

d) (a) Device structure (b) Bias network
e) (c) Output light intensity (d) both (a) and (b).