Q.2
a. List out limitations of optical fiber communication systems.
b. A step index multimode fiber with a numerical aperture of a 0.20 supports approximately 1000 modes at an 850nm wavelength.
(i) What is the diameter of its core?
(ii) How many modes does the fiber support at 1320nm?
c. A fiber has normalized frequency V = 26.6 and the operating wavelength is 1300nm. If the radius of the fiber core is 25 μm, compute the numerical aperture.

Answer:

(a) Limitations of OFC:
High initial cost, Maintenance & repair cost, jointing & testing procedures, Tensile stress, Short links, Short links, Fiber losses (02)

→ Brief explaination about each (04)

(b) (i) No of modes

$$M = \frac{1}{2}\left[\frac{\pi a}{\lambda} \cdot NA\right]^2$$

$$1000 = \frac{1}{2}\left[\frac{\pi a}{(850 \times 10^{-9})} \times 0.20\right]^2$$ (03)

$$a = 60.49\ \mu m$$

(ii) $$M = \frac{1}{2}\left[\frac{\pi \times 60.49 \times 10^{-6}}{1550 \times 10^{-9}} \times 0.20\right]^2 = 300.63$$ (03)

(c) $V = 26.6, \lambda = 1300 \times 10^{-9}$

$a = 25 \times 10^{-6}\ m$

$$V = \frac{2\pi a}{\lambda} \cdot NA \Rightarrow NA = V \cdot \frac{\lambda}{2\pi a}$$

$$NA = 26.6\ \frac{1300 \times 10^{-9}}{2\pi \times 25 \times 10^{-6}} = 0.220$$ (04)

Q.3 b. A continuous 12 km long optical fiber link has a loss of 1.5 dB/km.

(i) What is the minimum optical power level that must be launched into the fiber to maintain an optical power level of 0.3 μW at the receiving end?

(ii) What is the required input power if the fiber has a loss of 2.5 dB/km?

c. An LED operating at 850 nm has a spectral width of 45 nm. What is the pulse spreading in ns/km due to material dispersion?

Answer:

(b) $z = 12\,\text{Km}, \alpha = 1.5\,\text{dB/Km}, P(0) = 0.3\,\mu\text{w}$

(i) $\alpha = 10 \times \frac{1}{z} \log\left(\frac{P(0)}{P(z)}\right)$

$1.5 = 10 \times \frac{1}{12} \log\left(\frac{0.3\,\mu\text{w}}{P(z)}\right)$

$P(z) = 4.76 \times 10^{-9}\,\text{w}$ (03)

(ii) $2.5 = 10 \times \frac{1}{12} \log\left(\frac{P(0)}{4.76 \times 10^{-9}}\right)$ (03)

I/p power, $P(0) = 4.76\,\mu\text{w}$

(c) $\lambda = 850\,\text{nm}, \sigma = 45\,\text{nm}$

$\sigma_m = \sigma L M$, Let $L = 1\text{m}$

Mat. disp. const, $D_{mat} = -\frac{\lambda}{c} \cdot \frac{d^2 n}{d\lambda^2}$

For LED source operating at 850 nm,

$\left|\lambda^2 \frac{d^2 n}{d\lambda^2}\right| = 0.025$

$M = \frac{1}{c\lambda}\left|\lambda^2 \frac{d^2 n}{d\lambda^2}\right| = \frac{1}{(3 \times 10^5)(850)} \times 0.025$ (3/.)

$= 9.8\,\text{ps/nm/Km}$

$\sigma_m = 45 \times 1 \times 9.8 = 441\,\text{ps/Km}$ (04)

Q.4 a. Show that the optical power emitted from an LED is $\frac{P_{int}}{n(n+1)^2}$ where P_{int} is the internally generated optical power, n is the reference index of LED material.

b. Describe the emission patterns of different types of LED and LASER diodes.

Answer:

Q.4 Main steps in the derivation

(a) $\eta_{int} = \frac{R_r}{R_r + R_{nr}}$, $\tau_{nr} = \frac{n}{R_{nr}}$,

$$= \frac{1}{1 + \frac{R_{nr}}{R_r}}$$

$$\frac{1}{\tau} = \frac{1}{\tau_r} + \frac{1}{\tau_{nr}}, \quad \eta_{int} = \frac{\tau}{\tau_r}$$

$$P_{int} = R_r \cdot h\nu$$

$$P = \frac{1}{n(n+1)^2} \cdot P_{int}$$

(b) Emission patterns of LED & LASER

LED v/s LASER Diode

Parameter	LED	LD
Principle of operation	Spontaneous emission	Stimulated emission
output beam	Non-coherent	Coherent
Transmission distance	Smaller	Greater
Coupling efficiency	Very low	High
Cost	Low	High

Q.5 a. Briefly explain the source–to-fiber power launching.

Answer: 5.1 of Text Book

b. A single mode fiber has a normalized frequency V = 2.40, a core refractive index $n_1 = 1.47$, a cladding refractive index $n_2 = 1.465$ and a core diameter 2a = 9 μm. Let us find the insertion losses of a fiber joint having a lateral offset of 1 μm.

Answer: Page Number 230 of Text Book

Q.6 a. Draw and explain the schematic diagram of a typical optical receiver.

Answer: 7.1.3 of Text Book

b. Explain the circuit diagram of high impedance bipolar transistor amplifier. List the benefits of a transimpedance amplifier.

Answer: 7.4.2, 7.4.3 of Text Book

Q.7 a. Write short notes of any **TWO**.

(ii) Photodetector and pre-amplifier noises
(iii) Relative intensity noise (RIN)

Answer: Page Number 361-363 of Text Book

Q.8 a. Write short notes on

(i) RZ codes
(ii) Block codes

Answer: 8.2.2, 8.2.3 of Text Book

b. With help of neat sketch. Explain the basic setup for an automatic-repeat-request (ARQ) error correction scheme.

Answer: 8.3 of Text Book

Q.9 a. Describe (i) SONET/SDH Networks (ii) Frame format of SONET/SDH

Answer:

* Voice, video, data, internet & data from LANs, MANs & WANs will be transported over a SONET or a SDH network.

Adv. of SONET/SDH:

Reduced cost
Integrated N/w elements
Offers network survivability features
- compatible with legacy & future networks.
Remote operation capabilities

b. A 2×2 biconical tapered fiber coupler has an input optical power level of P_0 = 200 μW. The output powers at the other three ports are P_1 = 90 μW, P_2 = 85μW and P_3 = 6.3 μW. Find:-
(i) Coupling ratio
(ii) Excess loss

Answer: Page Number 387-388 of Text Book

Text Book

Optical Fiber Communications, Gerd Keiser, 3rd Edition, McGraw Hill Publications, 2000