Numericals:-

1. Snell's Law:-

Proof:-

From Snell's Law,

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

at critical angle,

$$\phi_1 = \phi_c \text{ and } \phi_2 = 90^\circ$$

$$n_1 \sin\phi_c = n_2 \sin 90^\circ \quad (\because \sin 90^\circ = 1)$$

$$n_1 \sin\phi_c = n_2 \Rightarrow \sin\phi_c = \frac{n_2}{n_1}$$

$$\boxed{\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)}$$

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2. There is a demand for the usage of application and gadgets that require high data rates. At your home you are planning to advance your data package from 1Gbps to 5Gbps. If the rise time components are Transmitter rise time = 20ps, Fiber dispersion rise time = 50ps, receiver rise time = 30ps, Sketch an optical communication layout first with the aforementioned data and analyze the concept of rise-time budget analysis for the high-Speed upgradation with the calculation of total system time and what may be the allowed rise time for a Non-return to Zero kind of transmission?

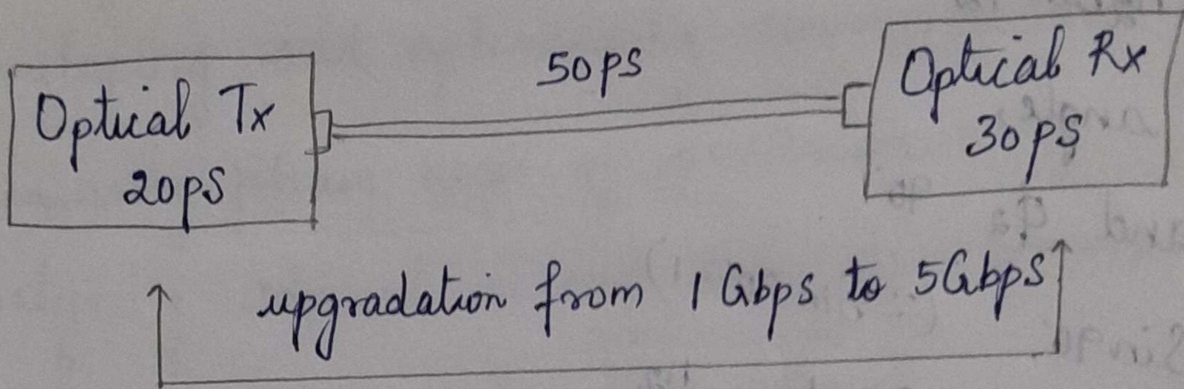
Solution:

given:

Tx rise time = 20ps

Dispersion rise time = 50ps

Rx rise time = 30ps



Rise time budget calculation:-

$$t_{sys} = \sqrt{t_{tx}^2 + t_D^2 + t_{Rx}^2}$$

$$= \sqrt{(20)^2 + (50)^2 + (30)^2}$$

$$= \sqrt{400 + 2500 + 900} = \sqrt{3800} = \boxed{61.644ps}$$

Maximum allowable rise time for Non Return Zero:

$$t_{max} = \frac{0.7}{\text{Bit rate}} = \frac{0.7}{5 \times 10^9} = 140ps$$

$\boxed{t_{sys} < t_{max}}$ for 5Gbps

∴ The upgradation is possible & will Support.

3. Consider a multimode step index Fiber that has a core radius of 50 μm, a core index of 1.48 and an index difference of 0.2%. what are the number of modes in the fiber at wavelengths of 860 nm, 1310 nm and 1550 nm. Also find the percentage of optical power that propagates in the cladding at 860 nm. 10

Solution:

given:

core radius $a = 50\,\mu m = 50 \times 10^{-6}$

refractive index, $n_1 = 1.48$

Index difference, $\Delta = 0.2\% = 0.002$

wavelengths; $\lambda = 860\,nm,\ 1310\,nm,\ 1550\,nm$

Calculate the Numerical Aperture NA:-

$$NA = n_1 \cdot \sqrt{2\Delta}$$

$$NA = 1.48 \times \sqrt{2 \times 0.002} = 1.48 \times \sqrt{0.004}$$

$$NA = 1.48 \times 0.0632 = 0.0935$$

$$\boxed{NA = 0.0935}$$

Calculate (V) For each wavelength:-

(i) $\lambda = 860\,nm = 860 \times 10^{-9}\,m$

$$V = \frac{2\pi a}{\lambda} \times NA = \frac{2\pi \times 50 \times 10^{-6}}{860 \times 10^{-9}} \times 0.0935$$

$$V = 365.1 \times 0.0935 \approx \boxed{34.15}$$

(ii) $\lambda = 1310\,nm = 1310 \times 10^{-9} m$

$$V = \frac{2\pi \times 50 \times 10^{-6}}{1310 \times 10^{-9}} \times 0.0935$$

$$= 239.7 \times 0.0935 \approx \boxed{22.42}$$

(iii) $\lambda = 1550\,nm = 1550 \times 10^{-9} m$

$$V = \frac{2\pi \times 50 \times 10^{-6}}{1550 \times 10^{-9}} \times 0.0935$$

$$= 202.7 \times 0.0935 \approx \boxed{18.95}$$

Calculate no. of modes (M):

(i) At 860 nm:

$$M = \frac{V^2}{2} = \frac{(34.15)^2}{2} = \frac{1167.6}{2} = 584$$

(ii) At 1310 nm:

$$M = \frac{V^2}{2} = \frac{(22.42)^2}{2} = \frac{502.6}{2} = 251$$

(iii) At 1550 nm:

$$M = \frac{V^2}{2} = \frac{(18.95)^2}{2} = \frac{358.9}{2} = 179$$

Calculate % optical Power in cladding at 860nm:

$$\% \text{ of Power in cladding} = \left(\frac{\Delta}{n_1^2}\right) \times 100$$

$$= \frac{0.002}{(1.48)^2} \times 100 = \frac{0.002}{2.1904} \times 100 = 0.0913\%$$

$\therefore$ % of Power in cladding = 0.0913 %

4. The output Power at three ports P1 = 10 μW, P2 = 9 μW and P3 = 0.75 nW. Express the coupling ratio, excess loss, insertion loss from port 0 to port 2 and cross talk in terms of input optical power for the power cases.

Solution:

i) Splitting or Coupling ratio $= \frac{P_2}{(P_1 + P_2)} = \frac{9}{10+9} = \frac{9}{19} = 0.474$

ii) Excess loss $= 10\log[P_0/(P_1 + P_2)] = 10\log\left[\frac{P_0}{19}\right]$

iii) Insertion Loss $= 10\log[P_{in}/P_{out}] = 10\log[P_0/9]$

($\because$ insertion loss from port 0 to port 2)

iv) Crosstalk $= 10\log(P_3/P_0) = \left(\frac{0.75\,nW}{P_0}\right)$

5. For an urban environment an optical fiber communication system is deployed for 10 km range. The system uses 2 connectors, 5 splices and a laser source of power 10 dBm. The system posses connector loss of 2 dB, splice loss of 0.1 dB and attenuation of 0.7 dB/km. The sensitivity of the receiver is −30 dBm. Calculate the total link loss and system margin in dB. Sketch the urban area blue print of the transmitter and receiver scenario.

Solution:-

given:

Fiber length = 10 km

Connector loss = $2 \times 2\,dB = 4\,dB$

Splice loss = 5 splices $\times\ 0.1\,dB = 0.5\,dB$

Fiber attenuation = $0.7\,dB/km \times 10\,km = 7\,dB$

Transmitter (laser) power = $+10\,dBm$

Receiver Sensitivity = $-30\,dBm$

To calculate Total link loss:

Total link loss = Connector loss + Splice loss + Attenuation

$$= 4\,dB + 0.5\,dB + 7\,dB = 11.5\,dB$$

To calculate the System Margin:

System Margin = Transmitter Power − Total link loss − Receiver Sensitivity (in dB)

Margin = 10 dBm − 11.5 dB = −1.5 dBm

Margin = (Received Power) − (Receiver Sensitivity).

Calculating System Margin:

System margin = −1.5 dBm − (−30 dBm)

= −1.5 dBm + 30 dBm

$\boxed{\text{System margin} = 28.5\ dB}$