

- **Semiconductor materials and 2 primarily sources are:**
 - **Light Emitting Diode (LED) and**
 - **Laser Diode (LD)**

How do, They make these sources?

- These sources are primarily based on **Semiconductor** optical materials.
- Semiconductor materials and 2 primarily sources are:
 - **Light Emitting Diode (LED) and**
 - **Laser Diode (LD)**

Light Emitting Diode(LED) :

In any optical communication system when the requirement are: -

- Bit rate of 100-200 Mb/sec.**
- Optical power in tens of microwatts.**

LEDs are best suitable optical source.

Examples - example -1

Compute the emitted wavelength from an optical source having $x=0.07$.

Solution :

$$x = 0.07$$

$$E_g = 1.424 + 1.266x + 0.266x^2$$

$$E_g = 1.424 + (1.266 \times 0.07) + 0.266 \times (0.07)^2$$

$$E_g = 1.513 \text{ eV}$$

Now

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

$$\lambda = \frac{1.24}{1.513}$$

$$\lambda = 0.819 \mu\text{m}$$

$$\lambda \approx 0.82 \mu\text{m}$$

... Ans

Example 2

For an alloy $\text{In}_{0.74}\text{Ga}_{0.26}\text{As}_{0.57}\text{P}_{0.43}$ to be used in LED. Find the wavelength emitted by this source.

Solution : Comparing the alloy with the quaternary alloy composition.

$\text{In}_{1-x}\text{Ga}_x\text{As}_y\text{P}_{1-y}$ it is found that

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

$$y = 0.57$$

Using

$$E_g = 1.35 - 0.72y + 0.12y^2$$

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

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

Now

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

$\therefore$

$$\lambda = \frac{1.24}{0.978}$$

$$\lambda = 1.2671 \mu\text{m}$$

$$\lambda \approx 1.27 \mu\text{m}$$

LED configuration

- At present there are two main configuration types of **LED** used in optical fiber links -
 1. **Surface Emitting LED.**
 2. **Edge Emitting LED.**

Applications of LED

- ❖ Used as indicator
- ❖ Used in remote control
- ❖ In fiber optic communication
- ❖ Lighting decoration



Examples

Problem of Rise time Budget

An Optical fiber System is to be designed to operate an 8 km length without repeaters. The rise times of the chosen components are

Source (LED) : 8 nsec

Fiber cable : 5 ns/km

Intermodal : 1 ns/km

detector (PIN) : 6 nsec.

Estimate maximum bit rate using NRZ and RZ format.

Solution

$$L = 8 \text{ km}$$

$$t_{tx} = 8 \text{ nSec}$$

$$t_{mat} = 5 \text{ ns} \times 8 = 40 \text{ nSec}$$

$$t_{mod} = 1 \text{ ns} \times 8 = 8 \text{ nSec}$$

$$t_{rx} = 6 \text{ nSec}$$

→ Total Rise time.

$$t_{sys} = \sqrt{t_{tx}^2 + t_{mat}^2 + t_{mod}^2 + t_{rx}^2}$$

$$= \sqrt{8^2 + 40^2 + 8^2 + 6^2}$$

$$= 42 \text{ nSec}$$

Continue

→ Total Rise time.

$$\begin{aligned}t_{sys} &= \sqrt{t_{tx}^2 + t_{mult}^2 + t_{med}^2 + t_{rx}^2} \\&= \sqrt{8^2 + 40^2 + 8^2 + 6^2} \\&= 42 \text{ nsec}\end{aligned}$$

→ Max. bitrate for RZ

$$B_T = \frac{0.35}{t_{sys}} = \frac{0.35}{42 \times 10^{-9}} = 8.3333 \text{ Mbps}$$

→ max. bitrate for NRZ

$$B_T = \frac{0.70}{t_{sys}} = \frac{0.70}{42 \times 10^{-9}} = 16.6666 \text{ Mbps}$$

Construction of Laser Diode

Construction of a Laser Diode

A simple semiconductor laser diode is made up of the following parts in order:

- Metal Contact
- P-type Material
- Active/Intrinsic Region (N-type Material)
- N-type Material
- Metal Contact

Example 1

A laser emits 16 mJ of energy in 2 ms.
Calculate the power delivered

Using

$$P = \frac{E}{t}$$

$$P = \frac{16 \times 10^{-3}}{2 \times 10^{-3}} = 8 \text{ mW}$$

More example

Example 2

A laser diode with an average optical power output of 2W outputs 5000 pulses per second. Each pulse has a duration of 200 ns.

What is the peak power delivered by each pulse?

Using $E = P \times t$ the energy delivered by each pulse, $E = \frac{2}{5000} = 0.0004 \text{ J}$

This energy is delivered in time $t = 200 \text{ ns}$,

so the peak power, $P = \frac{E}{t} = \frac{0.0004}{200 \times 10^{-9}} = 2000 \text{ W}$

LASER vs. LED

LED Versus Laser

Characteristic	LED	Laser
Output power	Lower	Higher
Spectral width	Wider	Narrower
Numerical aperture	Larger	Smaller
Speed	Slower	Faster
Cost	Less	More
Ease of operation	Easier	More difficult

What are the light sources used in optical communication?

Optical Sources –

LED

LASER

Gain-Guided LASER

Index-Guided LASER

Quantum-Well LASER

Performance parameters

- The performance parameters of photodetector are:
 - Cut- off wavelength
 - Quantum efficiency
 - Responsivity
 - Response time
 - Dark current

Numerical

Question:-

A photodiode has a quantum efficiency of 65% when photons of energy $1.5 \times 10^{-19} \text{ J}$ are incident upon it.

- (a) At what wavelength is the photodiode operating?
- (b) Calculate the incident optical power required to obtain a photocurrent of $2.5 \mu\text{A}$ when the photodiode is operating as described above.

Answer:-

- (a) $1.32 \mu\text{m}$.
- (b) $3.60 \mu\text{W}$

solution

Solution

(a). The photon energy $E = hf = \frac{hc}{\lambda}$. Therefore

$$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34} \times 2.998 \times 10^8}{1.5 \times 10^{-19}}$$

$$= 1.32 \mu\text{m}$$

The photodiode is operating at a wavelength of $1.32 \mu\text{m}$.

Continued...

(b). Responsivity

$$R = \frac{\eta e}{hf} = \frac{0.65 \times 1.602 \times 10^{-19}}{1.5 \times 10^{-19}}$$

$$= 0.694 \text{ A W}^{-1}$$

$$R = \frac{I_p}{P_{in}}$$

$$P_{in} = \frac{I_p}{R}$$

Therefore,

$$P_{in} = \frac{25 \times 10^{-6}}{0.694} = 3.60 \mu\text{W}$$

The incident optical power required is $3.60 \mu\text{W}$.

Example – 1 :

*Compute the cut-off wavelength for silicon and germanium PIN diodes.
Their bandgap energies are 1.1 eV and 0.67 eV respectively.*

Solution : For silicon

Cut-off wavelength is given as

$$\lambda_c = \frac{1.24}{E_g}$$

$$\lambda_c = \frac{1.24}{1.1}$$

$$\lambda_c = 1.12 \mu\text{m}$$

... Ans.

For germanium :

$$\lambda_c = \frac{1.24}{0.67}$$

$$\lambda_c = 1.85 \mu\text{m}$$

... Ans.

Example - 2

Example – 2 :

A PIN photodiode is fabricated by GaAs which has bandgap energy of 1.43 eV at 300 °K. Find its upper cut-off wavelength.

Solution :

$$E_g = 1.43 \text{ eV}$$

$$\lambda_c = \frac{1.24}{E_g}$$

$$\lambda_c = \frac{1.24}{1.43}$$

$$\lambda_c = 0.867 \text{ } \mu\text{m}$$

$$\lambda_c = 867 \text{ nm}$$

... Ans.

Example 3

Example – 3:

On an In GaAs 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.

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

Average e-h pair generated = 5.4×10^6

The quantum efficiency is given by -

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

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

$$\eta = 0.9 = 90 \%$$

... Ans.

Example 4

Example – 4 : Photons having energy 1.53×10^{-19} Joules are incident on a photodiode having responsivity of 0.65 A/W . If output power is $10 \text{ }\mu\text{W}$. Find the generated photocurrent.

Solution :

$$\mathfrak{R} = 0.65 \text{ A/W}$$

$$P_0 = 10 \text{ }\mu\text{W}$$

Responsivity is given as -

$$\mathfrak{R} = \frac{I_p}{P_0}$$

$$I_p = \mathfrak{R} P_0$$

$$I_p = 0.65 \times 10$$

$$I_p = 6.5 \text{ }\mu\text{A}$$

Example - 5

Example – 5 :

Compute the bandwidth of a photodetector having parameters as

Photodiode capacitance = 3 pF

Amplifier capacitance = 4 pF

Load resistance = 50 Ω

Amplifier input resistance = 1 M Ω

Solution : Sum of photodiode and amplifier capacitance

$$C_T = 3 + 4 = 7 \text{ pF}$$

Combination of load resistance and amplifier and input resistance

$$R_T = 50 \Omega \parallel 1 \text{ M}\Omega = 50 \Omega$$

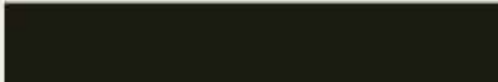
$$\text{Bandwidth of photodetector } B = \frac{1}{2\pi R_T C_T}$$

$$B = \frac{1}{2\pi 50 \times 7 \times 10^{-12}}$$

$$B = 454.95 \text{ MHz}$$

PHOTO DETECTOR TYPES

Pin diode
APD diode
MSM



Comparison of PIN and APD

Comparison of PIN and APD

	Parameters	PIN	APD
1	Sensitivity	Less sensitive (0 - 12 dB).	More sensitive (5 to 15 dB).
2	Biasing	Low reverse biased voltage (5 to 10 V).	High reverse biased voltage (20 - 400 volts).
3	Wavelength region	300 - 1100 nm.	400-100 nm.
4	Gain	No internal gain.	Internal gain.
5	S/N ratio	Poor.	Better.
6	Detector circuit	Simple.	More complex.
7	Conversion efficiency	0.5 to 1.0 Amps/watt.	0.5 to 100 Amps/watt.
8	Cost	Cheaper.	More expensive.

Recommended Questions for Optical Detector :

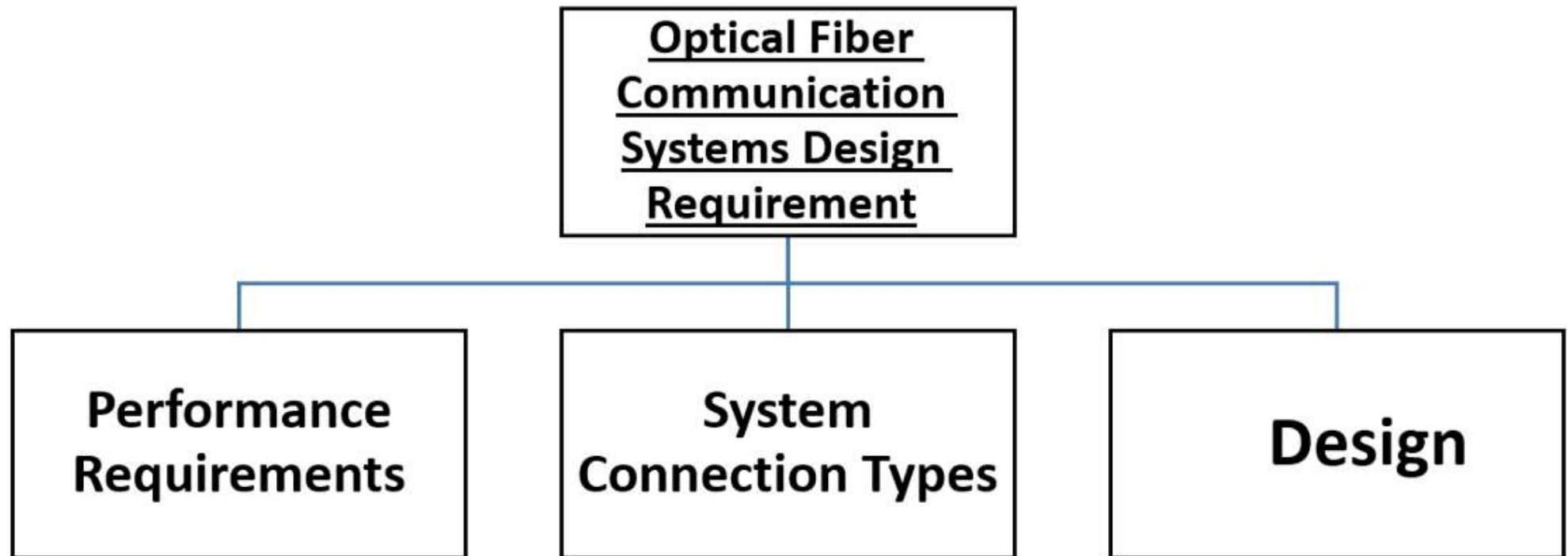
With a proper sketch briefly explain the structure of PIN diode.

Explain the following term relating to PIN photodiode with proper expressions.

- i. Cut-off wavelength.
- ii. Quantum efficiency.
- iii. Responsivity.

Important points to be consider in OF system design

FIG. 1



	Components	Characteristics
1)	Optical fiber (multimode/single mode)	i) Core size ($2a$) ii) Core refractive index (n_1) iii) Bandwidth (B) iv) Attenuation v) Numerical aperture (NA)
2)	Optical source (LED/Laser)	i) Emission wavelength (λ) ii) Output power (P) iii) Emission pattern iv) Number of modes (M)
3)	Optical detector (PIN/APD)	i) Responsivity ($\mathcal{R}_0$) ii) Operating wavelength (λ) iii) Speed iv) Sensitivity

Fiber optic communication system design steps

- **System design depends on system operation limitations, which are:**
 - **Total losses**
 - **Dispersion**
 - **Non linearity of fiber**

- Two important analysis for deciding performance of any fiber link are:

- I. Link power budget / Power budget

- II. Rise time budget / Bandwidth budget

- Important factors must be considered, are:
 - a. Signal dispersion
 - b. Data rate
 - c. Transmission distance
 - d. Cost
 - e. Optical power coupling
 - f. Circuit complexity

Examples

Example 5-1 :

Design an optical fiber link for transmitting 15 Mb/sec of data for a distance of 4 kms with BER of 10^{-9} .

Solution :

$$\text{Bandwidth} \times \text{Length} = 15 \text{ Mb/sec} \times 4 \text{ km} = (60 \text{ Mb/sec}) \text{ km}$$

Selecting optical source : LED at 820 nm is suitable for short distances. The LED generates -10 dBm optical power.

Selecting optical detector : PIN-FET optical detector is reliable and has -50 dBm sensitivity.

Selecting optical fiber : Step-index multimode fiber is selected. The fiber has bandwidth length product of 100 (Mb/s) km.

Link power budget :

Assuming :

Splicing loss $l_s = 0.5$ dB/slice

Connector loss $l_c = 1.5$ dB

System link power margin $P_m = 8$ dB

continue

Connector loss $l_c = 1.5$ dB

System link power margin $P_m = 8$ dB

Fiber attenuation $\alpha_f = 6$ dB/km

$$\text{Actual total loss} = (2 \times l_c) + \alpha_f L + P_m$$

$$P_T = (2 \times 1.5) + (6 \times 4) + 8$$

$$P_T = 35 \text{ dB}$$

Maximum allowable system loss :

$$P_{\max} = \text{optical source output power} - \text{optical receiver sensitivity}$$

$$P_{\max} = 10 \text{ dBm} - (-50 \text{ dBm})$$

$$P_{\max} = 60 \text{ dBm}$$

Since actual losses in the system are less than the allowable loss, hence the system is functional.

Example 5-2 :

A transmitter has an output power of 0.1 mw. It is used with a fiber having $NA = 0.25$, attenuation of 6 dB/km and length 0.5 km. The link contains two connectors of 2 dB average loss. The receiver has a minimum acceptable power (sensitivity) of -35 dBm. The designer has allowed a 4 dB margin. Calculate the link power budget.

Solution :

Source power $P_s = 0.1 \text{ mw}$

$$P_s = -10 \text{ dBm}$$

Since $NA = 0.25$

$$\begin{aligned}\therefore \text{Coupling loss} &= -10 \log(NA^2) \\ &= -10 \log(0.25^2) \\ &= 12 \text{ dB}\end{aligned}$$

$$\text{Fiber loss} = \alpha_f \times L$$

$$l_f = (6 \text{ dB/km})(0.5 \text{ km})$$

$$l_f = 3 \text{ dB}$$

$$\text{Connector loss} = 2 (2 \text{ dB})$$

$$l_c = 4 \text{ dB}$$

$$\text{Design margin } P_m = 4 \text{ dB}$$

$$\begin{aligned}\therefore \text{Actual output power } P_{\text{out}} &= \text{Source power} - (\sum \text{Losses}) \\ P_{\text{out}} &= 10 \text{ dBm} - [12 \text{ dB} + 3 + 4 + 4]\end{aligned}$$

$$P_{\text{out}} = -33 \text{ dBm}$$

Since receiver sensitivity given is -35 dBm .

$$\text{i.e. } P_{\text{min}} = -35 \text{ dBm}$$

As $P_{\text{out}} > P_{\text{min}}$, the system will perform adequately over the system operating life.

Example 5-3 :

In a fiber link the laser diode output power is 5 dBm, source-fiber coupling loss = 3 dB, connector loss of 2 dB and has 50 splices of 0.1 dB loss. Fiber attenuation loss for 100 km is 25 dB, compute the loss margin for i) APD receiver with sensitivity -40 dBm ii) Hybrid PINFET high impedance receiver with sensitivity - 32 dBm.

: Power Budget Calculations

Source output power	5 dBm
Source fiber coupling loss	3 dB
Connector loss	2 dB
Splicing loss (50×0.1)	5 dB
Fiber attenuation	25 dB

Total loss	35 dB
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Available power to receiver : $(5 \text{ dBm} - 35 \text{ dBm}) = -30 \text{ dBm}$

i) APD receiver sensitivity $= -40 \text{ dBm}$

Loss margin $[-40 - (-30)]$ 10 dBm

ii) H-PIN FET high-impedance receiver $= -32 \text{ dBm}$

Loss margin $[-32 - (-30)]$ 2 dBm

More examples

Optical communication – Examples- •

Example 1 •

Optical transmitter has an O/P power of 0.1 mW, connected to an optical cable of 0.5 Km length.

The cable has following properties:

- Attenuation factor = 6 dB / Km, NA = 0.25,
- it has two connectors of 2 dB per connector

The receiver has minimum acceptable power(sensitivity) of -35dBm

The allowed margin is 4 dB

Continue

- Solution:

1. Cable losses = $6 \times 0.5 = 3 \text{ dB}$

2. Connector losses = $2 \times 2 = 4 \text{ dB}$

3. Coupling losses = $-10 \text{ Log (NA)}^2 = -10 \text{ Log}(0.25)^2 = 12 \text{ dB}$

Total actual losses = $3+4+12+4 = 23 \text{ dB}$

Transmitted power in dB = $10 \text{ Log}(0.1 \times 10^{-3}) = 10 \text{ Log}(10^{-4}) = -40 \text{ dB}$

The minimum received power is given = -35 dBm

Allowed losses = transmitted power – Sensitive power(received power)

Now we have some quantity in dB and other in dBm, to solve this problem, we have to be able to convert dB to dBm or vice versa

Example

Example on Link power Budget

Components chosen for a digital Fiber link of overall length 10 km and operating at 20 mbps are as follows:

- i) LED capable of launching an average power 0.1 mW at 0.85 μ m.
- ii) Fiber attenuation 2.5 dB/km
- iii) Requires Splicing every 2 km with a loss of 0.3 dB per splice
connector loss is of 1.5 dB.
- iv) The receiver power needed of -46 dBm in order to get 10^{-10} BER
- v) Predicted safety margin 6 dB.

Find Link power budget for this given problem.

Q1) Select correct answer (select 5)

25 MARKS

1. Quantum efficiency in photodetector indicates

A) The ability of a detector to convert incident light into electrons

b) The maximum light intensity the detector can handle c) The physical size of the sensor

2. Which of following describe the behavior of photo diode when reverse biased

A) It conducts light B) It operates as a current amplifier C) It becomes less sensitive to light

3. The dark current in photo diode is refer to

A) Current in absence of light B) Current when exposed to light C) Current in a power outage

4. What is the primary advantage of using lasers in optical communication?

A) Low-cost B) High coherence and monochromaticity C) Large size

5. Which of the following statements about LEDs in optical communication is true

A) They have a very long response time. B) They emit light in a narrow spectral range.

C) They are less efficient than lasers.

6. What is the principle behind LASER operation?

A) Spontaneous emission B) Stimulated emission D) Reflection

Q2) A silicon photodiode has a nominal quantum efficiency η , of 80% at a wavelength of 600 nm. If this photodiode is illuminated with monochromatic light at this wavelength with an intensity of $P = 1 \text{ m. W/cm}^2$,

75 MARKS

Calculate:

1. The number of photons incident on the photodiode per second (assuming normal incidence).
With, Incident photon /sec. (N), $N = P/E$
2. The number of electrons generated in the photodiode per second due to the incident light.
3. The total photocurrent produced if the charge of an electron is $e = 1.6 \times 10^{-19} \text{ C}$

Given: $h = 6.625 \times 10^{-34} \text{ J.S}$ (Plank Constant)

1. The number of photons incident on the photodiode per second (per unit area).

- Relevant Law: Planck-Einstein Relation for photon energy ($E = hf = hc/\lambda$) and the relationship between Intensity, Photon Flux, and Energy per photon (Intensity = Photon Flux $\times$ Energy per photon).

- Energy per photon, E :

$$E = \frac{hc}{\lambda}$$

$$E = \frac{(6.625 \times 10^{-34} \text{ J}\cdot\text{s}) \times (3 \times 10^8 \text{ m/s})}{600 \times 10^{-9} \text{ m}}$$

$$E = \frac{19.875 \times 10^{-26} \text{ J}\cdot\text{m}}{600 \times 10^{-9} \text{ m}}$$

$$E = 0.033125 \times 10^{-17} \text{ J}$$

$$E = 3.3125 \times 10^{-19} \text{ J}$$

- Incident photon flux (Number of incident photons per second per unit area), Φ_{incident} :

$$\Phi_{\text{incident}} = \frac{\text{Intensity}}{E} = \frac{P}{E}$$

$$\Phi_{\text{incident}} = \frac{1 \times 10^{-3} \text{ J/s/cm}^2}{3.3125 \times 10^{-19} \text{ J/photon}}$$

$$\Phi_{\text{incident}} = \frac{1 \times 10^{-3}}{3.3125 \times 10^{-19}} \text{ photons/s/cm}^2$$

$$\Phi_{\text{incident}} \approx 0.30188 \times 10^{16} \text{ photons/s/cm}^2$$

$$\Phi_{\text{incident}} \approx 3.019 \times 10^{15} \text{ photons/s/cm}^2$$

Given:

- Quantum efficiency, $\eta = 80\% = 0.8$
- Wavelength, $\lambda = 600 \text{ nm} = 600 \times 10^{-9} \text{ m}$
- Light Intensity, $P = 1 \text{ mW/cm}^2 = 1 \times 10^{-3} \text{ W/cm}^2 = 1 \times 10^{-3} \text{ J/s/cm}^2$
- Charge of an electron, $e = 1.6 \times 10^{-19} \text{ C}$
- Planck's constant, $h = 6.625 \times 10^{-34} \text{ J}\cdot\text{s}$
- Speed of light, $c \approx 3 \times 10^8 \text{ m/s}$ (standard constant)

$$E = \frac{hc}{\lambda}$$

$$E = \frac{(6.625 \times 10^{-34} \text{ J}\cdot\text{s}) \times (3 \times 10^8 \text{ m/s})}{600 \times 10^{-9} \text{ m}}$$

$$E = \frac{19.875 \times 10^{-26} \text{ J}\cdot\text{m}}{600 \times 10^{-9} \text{ m}}$$

$$E = 0.033125 \times 10^{-17} \text{ J}$$

$$E = 3.3125 \times 10^{-19} \text{ J}$$

$$\Phi_{\text{incident}} = \frac{\text{Intensity}}{E} = \frac{P}{E}$$

$$\Phi_{\text{incident}} = \frac{1 \times 10^{-3} \text{ J/s/cm}^2}{3.3125 \times 10^{-19} \text{ J/photon}}$$

$$\Phi_{\text{incident}} = \frac{1 \times 10^{-3}}{3.3125 \times 10^{-19}} \text{ photons/s/cm}^2$$

$$\Phi_{\text{incident}} \approx 0.30188 \times 10^{16} \text{ photons/s/cm}^2$$

$$\Phi_{\text{incident}} \approx 3.019 \times 10^{15} \text{ photons/s/cm}^2$$

$\Phi_{\text{generated}}$:

$$\eta = \frac{\Phi_{\text{generated}}}{\Phi_{\text{incident}}}$$

$$\Phi_{\text{generated}} = \eta \times \Phi_{\text{incident}}$$

$$\Phi_{\text{generated}} = 0.8 \times (3.019 \times 10^{15} \text{ electrons/s/cm}^2)$$

$$\Phi_{\text{generated}} \approx 2.415 \times 10^{15} \text{ electrons/s/cm}^2$$

$$J = \Phi_{\text{generated}} \times e$$

$$J = (2.415 \times 10^{15} \text{ electrons/s/cm}^2) \times (1.6 \times 10^{-19} \text{ C/electron})$$

$$J = (2.415 \times 1.6) \times 10^{15} \times 10^{-19} \text{ C/s/cm}^2$$

$$J = 3.864 \times 10^{-4} \text{ A/cm}^2$$

solution

→ $L = 10 \text{ km}$, data rate = 20 mbps

$$P_s = 0.1 \text{ mW} = 0.1 \times 10^{-3} \text{ W} = 10^{-4} \text{ W} \rightarrow P_s = 10 \log 10^{-4}$$

$$\lambda = 0.85 \mu\text{m}$$

$$= -40 \text{ dB}$$

$$\alpha = 2.5 \text{ dB/km}$$

$$l = 2 \text{ km}$$

$$L_{sp} = 0.3 \text{ dB}$$

$$L_c = 1.5 \text{ dB}$$

$$P_R = -46 \text{ dBm} = -46 - 30 = -76 \text{ dB}$$

Predicted Safety margin = 8 dB

$$\rightarrow \text{total loss} = \underbrace{\alpha L}_{\text{Attenuation}} + \underbrace{2L_c}_{\text{Connectors}} + \underbrace{nL_{sp}}_{\text{splices}} + \text{Safety Margin}$$

! → Allowed loss (total Allowed loss)

$$P_T = P_s - P_R$$

$$= -40 - (-76)$$

$$= 36 \text{ dB}$$

$$\rightarrow \text{total loss} = \underbrace{\alpha L}_{\text{Attenuation}} + \underbrace{2L_c}_{\text{Connectors}} + \underbrace{nL_{sp}}_{\text{Splitters}} + \text{Safety Margin}$$

$$\rightarrow \text{Attenuation} = \alpha L = 2.5 \times 10 = 25 \text{ dB.}$$

$$\rightarrow \text{Connectors} = 2L_c = 2 \times 1.5 = 3 \text{ dB}$$

$$\rightarrow \text{Splitters} = nL_{sp} = \left(\frac{L}{l} - 1\right)L_{sp} = 4 \times 0.3 = 1.2 \text{ dB.}$$

$$\rightarrow \text{Safety margin} = 6 \text{ dB}$$

$$\rightarrow \text{total loss} = 25 + 3 + 1.2 + 6 = \underline{35.2 \text{ dB.}}$$

$\rightarrow$ total loss (35.2 dB) is less than allowed loss (36 dB). So signal can be received without problem.

Network Topologies

- Three commonly used topologies are -
 1. Linear bus topology
 2. Ring topology
 3. Star topology
-

Example

- Prepare a power budget for a linear bus LAN having 10 stations with following individual losses are measured.

$$L_{\text{Tap}} = 10 \text{ dB}$$

$$L_{\text{Thru}} = 0.9 \text{ dB}$$

$$L_i = 0.5 \text{ dB}$$

$$L_c = 1.0 \text{ dB}$$

The stations are separated by distance = 500 m and fiber attenuation is 0.4 dB / Km

- Compute total loss in dBs

Solution

$$L = 500\text{m} = 0.5 \text{ Km}$$

$$\alpha = 0.4 \text{ dB/Km}$$

$$\text{Total loss} = N(\alpha L + 2L_c + L_{\text{thru}} + L_{\text{I}}) - \alpha L - 2L_{\text{thru}} + 2L_{\text{tap}}$$

$$= 10(0.4 \times 0.5 + 2 \times 1 + 0.9 + 0.5) - (0.4 \times 0.5) - (2 \times 0.9) + (2 \times 10)$$

$$= 54 \text{ dB}$$

Table .(5-1). Comparison between TDM and CDM

Sr. No.	Parameter	TDM	CDM
1.	Technique	Sharing of time of the satellite transponder.	Sharing of bandwidth and time both.
2.	Interference effects	Interference between the user of adjacent time slots generated because of incorrect synchronization.	Performance is affected because of adjacent time and frequency slots. But due to frequency hopping the effect is less.
3.	Synchronization	Time synchronization is essential.	No synchronization is required.
4.	Code word	No code is required.	Code words are required by the ground station.