U-2

FOOE

12m:

(1) Given, $L = 6$ km

$n_1 = 1.5$ (core reflective index)

$\Delta = 1\% = 0.01$ (relative refractive index)

$n_2 = 1.5 - 0.01 = 1.49$

Pulse Broadening, $\Delta T = T_{max} - T_{min}$

$$= \frac{n_1}{c}\left(\frac{L}{\sin\phi_c} - L\right)$$

$$= \frac{L n_1^2}{c n_2}\Delta$$

→ RMS of time delay is used for the model delay in a multimode fibre.

→ It is assumed that light ray are uniformly distributed over the acceptance angle, then step-index for multimode fiber can be estimated as:

Lower Order Mode → $\sigma_s \approx \frac{L n_1 \Delta}{2\sqrt{3}c} \approx \frac{L(NA)^2}{4\sqrt{3} n_1 c}$

L is fiber length

NA is numerical aperture

→ This eqn shows that the pulse broading is directly proportional to core-cladding and length of fiber

→

→ In multimode fiber, the ray associated with higher-order modes are near the edges of the core and follow a ~~long~~ longer path through the fiber than lower-order modes.

Higher Order Mode: $\sigma_s \simeq \dfrac{L_1 n_1 \Delta^2}{20\sqrt{3}\, c}$

For Lower Order [Slowest Mode]

$$\sigma_s = \frac{L n_1 \Delta}{2\sqrt{3}\, c} = \frac{6 \times 1.5 \times 0.01}{2\sqrt{3} \times (10^8 \times 3)}$$

$$= 86.62\,ns$$

For Higher Order [Fast Mode]

$$\sigma_s = \frac{L n_1 \Delta^2}{2\sqrt{3}\, C} = \frac{6 \times 1.5 \times 0.01 \times (0.01)^2}{2 \times \sqrt{3} \times 3 \times 10^8}$$

$$= 86.6\,ps$$

## ② Attenuation

→ It is the most imp properties of optical fibre.

→ Also known as fiber loss or signal loss

→ Signal Attenuation is the ~~signal~~ loss of signal length ~~between~~ during transmission.

→ This weaking of the signal's streangth is because of noise, distance or other ext' factors

→ The cost of maintaing and installing is high.

→ The degree of attenuation is used to determine the maximum transmission distance b/w a transmitter and receiver

$$P(z) = P(0)\, e^{-\alpha_p z} \quad , \alpha_p = \frac{1}{z} \ln\left[\frac{P(0)}{P(z)}\right]$$

$P(0)$ : optical power at $z = 0$

$P(z)$ : power at distance $z$

**Absorption:**

→ Absorption is caused by :

(1) Absorption by atomic defects

(2) Extrinsic Absorption by Impurity Atoms

(3) Intrinsic Absorption by constituent of atom.

→ Atomic defects are the impurities in atomic structure of fiber material. These defects can be missing molecules, oxygen defects, etc.

→ These defects are negligible if compared to intrinsic or extrinsic absorption.

→ These can be useful in nuclear reactor environment, in medical radiation therapies, etc.

→ The higher the attenuation level, the higher the attenuation is.

→ Impurities in absorption occurs due to electron transitions b/w the energy levels.

Scattering:

→ It refers to the loss of optical power due to scattering of light by material imperfections in optical fibre

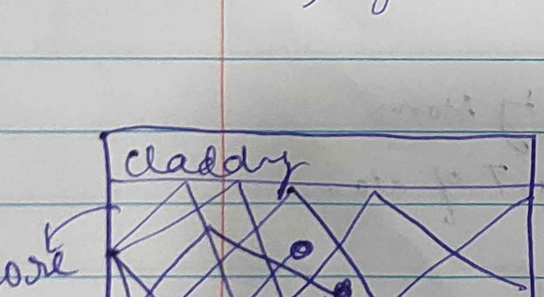
→ Fiber fabrication can cause scattering of light out of fiber

→ These defects may be in form of trapped gas bubbles

→ Scattering losses can be divided into two types:

* Rayleigh Scattering: caused by small interaction of light with fluctuations in fiber material

: It is the process in which the light is scattered by small volume of refractive index such as bubbles, particle etc.




: It can be minimized by improving fabrication.

Bending:

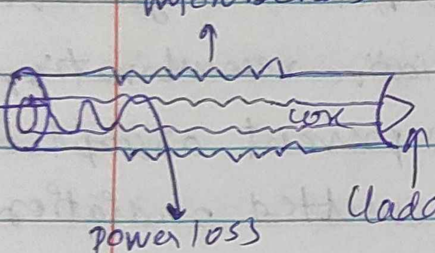
→ This loss is ~~be~~caused by bending of finite radius curvature.

→ Types of curvature:

(1) Macroscopic : large radii

(2) Random Microscopic bends : occurs when fibers are combined into cables

→ Microbending : internal bending




: loss is small or ~~negl~~ negligible.

: As radius decreases, loss increases

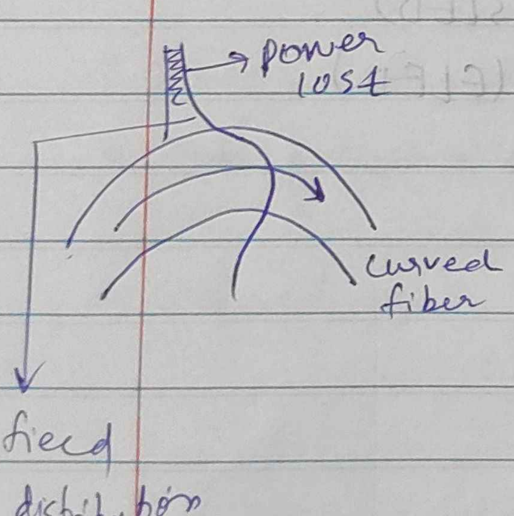
: to minimize the ~~~~ loss, place the cladding jacket over the fiber

→ Macrobending : external bending

: occurs when fiber is bent to visible curvature.

: it is reversible.

: when radius of curvature is small, loss is more




$r \uparrow$ —— $\downarrow$

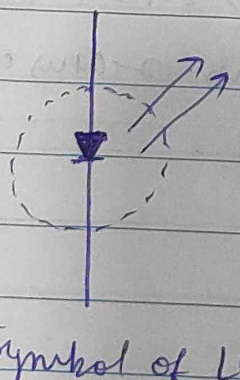
U-3

EOOE

12m

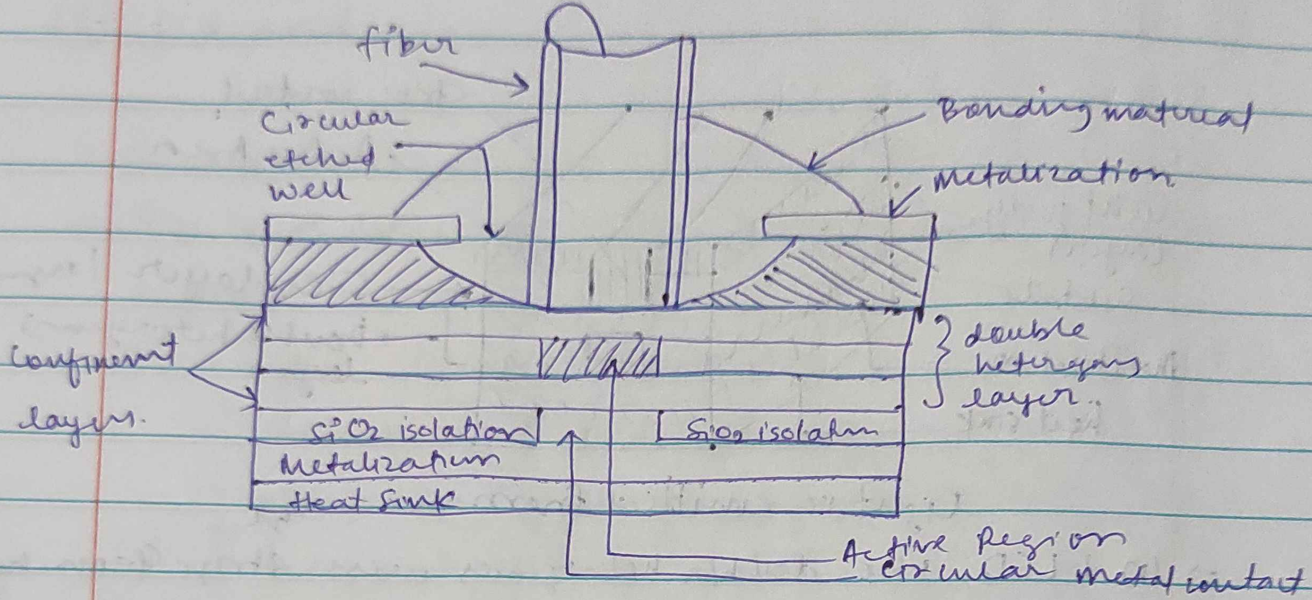
① LED : Light emitting diode
: can achieve high radiance and high quantum efficiency
: has fast response time
: it is measured in watts
: emission response time is the time delay b/w application.
: LED structure can has two carriers.
(1) Carrier confinement : used to Achieve high level of radiative recombination
(2) Optical confinement : used to prevent absorption of the emitted radiation.

LED Design:
Two basic structure of LED are used :
(i) Surface-emitting LED(SLED)
(ii) Edge -emitting LED (ELED)



Symbol of LED

(i) SLED (Surface emitting led)




→ In SLED, the light is emitted in the dirn perpendicular to the plane of PN Junction

→ SLED is referred as Burrus type.

→ Active Region: It is the region where photons are emitted.

: It is below the surface of semiconductor below to the axis of fiber.

→ Circular ethed well: The well is etched into substrate to allow direct coupling of the emitted light.

→ Bonding Material: Here the bonding material is epoxy resin

→ Double hetergens layer: It is above the active region

: contains 2 diffrent layers

→ Confinment layer: There are two types of layer prsnt here

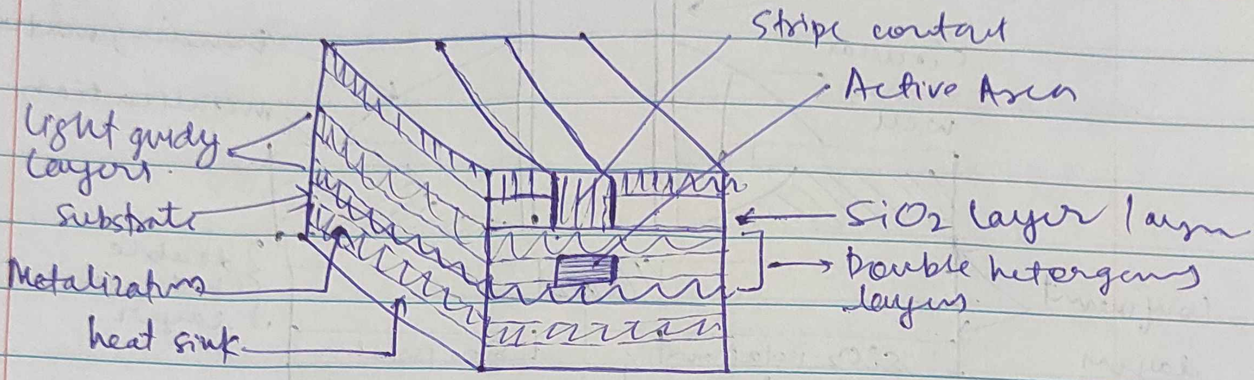
: positive layer

: negative layer

: contains electrons and holes also

$$\therefore \quad P_{int} = \eta_{int} \frac{hcI}{q\lambda}$$

(2) ELED (edge emitting led




Light is emitted from the edge

→ In ELED, the double heterogenous uses stripe geometry.

→ Active region : made of suitable element to emit light

→ Guiding layer : Both the guiding layers have same refractive index

→ Double hetrogenous layer → Contains two types of layers
→ positive
→ -ve layer

→ ~~confining layer~~ :

<u>Adv.</u>
(1) More coupling
(2) high data rate
(3) less power

<u>Disadv</u>
(1) Difficult to design
(2) expensive

④ PIN and avalanche photodiode.

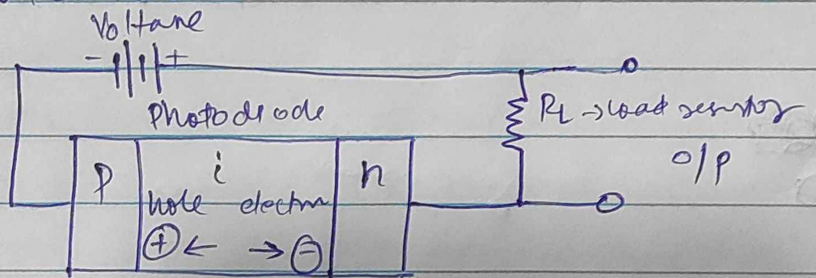
→ Photodiode converts light into electrical signals

→ ~~PIN and Avalanche are type of Internal photoelectric effects~~

→ Two types of Mechanism
  (1) External photoelectric effect
  → electrons become free from the metal surface by energy absorption.
  (2) Internal photoelectric effect
  → free electrons are generated by absorption of incident photons

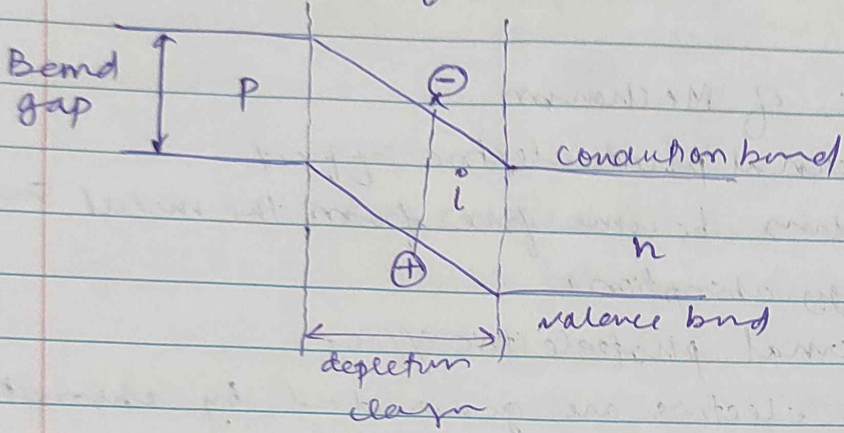
→ PIN and avalanche photodiode are internal photoelectric effect

→ PIN photodiode




→ Principle: In semiconductor, conduction band and valance bands are seperated by a gap
  : Electrons in conduction band are free, when small voltage is applied they move and cause current flow

→ The high electric field present in depletion layer causes photo generated carriers to separate
→ These are collected across reverse-biased junction
→ The current flow is known as photocurrent




energy-band diag. for PIN

Optical power, $P(x) = P_0(1 - e^{-\alpha_s(\lambda)x})$

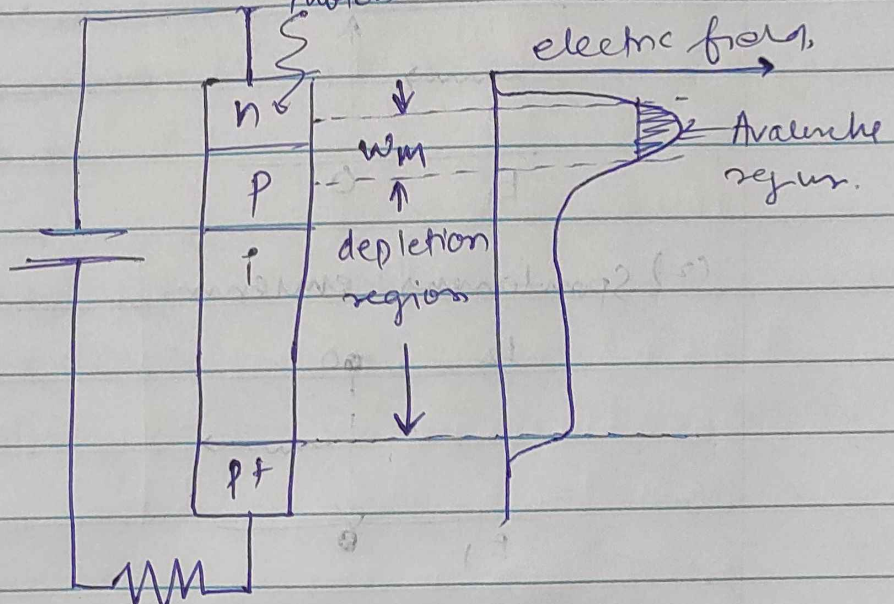
$P_0$ ↑ incident optical power

$\alpha_s(\lambda)$ is absorption coefficient

→ Avalanche photodiode (APD)

→ Avalanche mean, in short period of time, more current flows

→ Here we will multiply the current




→ when light falls on semiconductor material, atoms gets distributed

→ When, electrons gets excess energy it becomes -ve ion at the same time +ve ion also generated

→ The electrons gets into the excited state and hits more no. of atom

→ And generates more photo current

Adv

→ Increase sensitivity

→ wide range

Dis adv

→ Noise more

→ High bias voltage

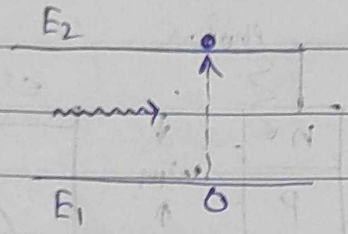
(5) LASER

: Light Amplification by Simulated emission of Radiation

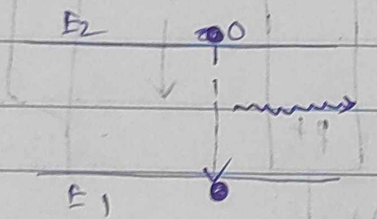
: It is an optical oscillator

Three main process:

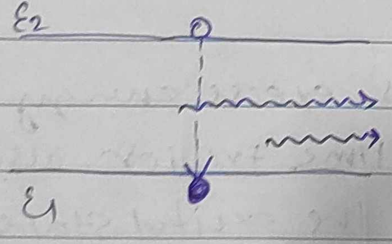
(1) Photon Absorption

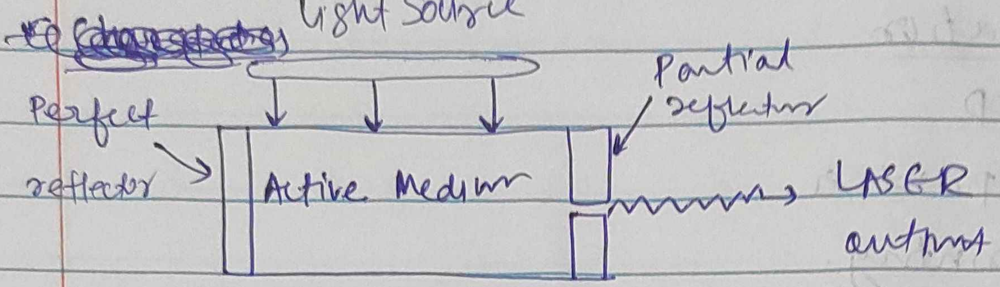


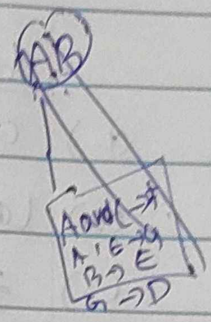

(2) Spontaneous emission.




(3) Stimulated emission






## Working

→ I/p terminals are connected to metal plates which is sandwiched to p and n type layers

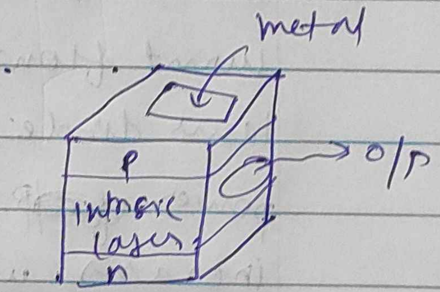
→ The layer b/w p-type and n-type is used to increase the volume of active region

→ when light source is send through these layers, it pass through active medium and produces the single source of o/p.

## Components

Active Region: it is a gas or mixture of gas or crystal semiconductor.

: to acheive population inversion, Active Region is used



Application

(1) CD/DVD

(2) Laser printer

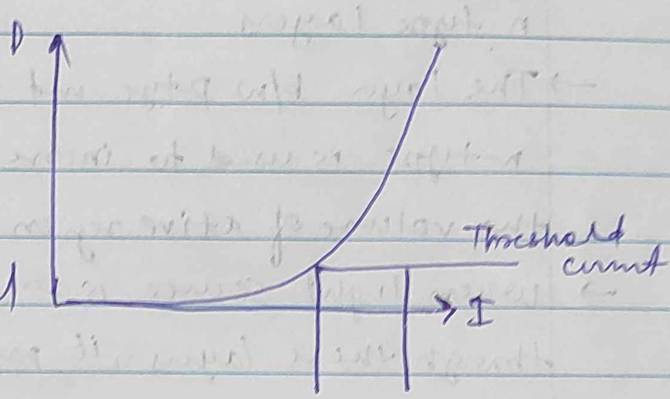
(3) 3D printing.

(4) Medical purpose

Laser Rate eqn:

$$\frac{dN}{dt} = R_{pump} + R_{immigration} + R_{death} + R_{migration}$$

LASER Diode PI char:




* As we increase the current flow of the laser diode, the optical power ~~of~~ gradually increases upto certain threshold.

* This causes the power of o/p light to increase for small increase in i/p current.