Part-C

① A 6Km optical link ... and also derive the expression involved in it.

For Slowest mode:

$$\sigma_s = \frac{L n_1 \Delta}{2\sqrt{3}\, c}$$

$L = 6 \quad n_1 = 1.5 \quad \Delta = 0.01 \ (1\%)$

$C = 3 \times 10^8$

$$= \frac{6 \times 1.5 \times 0.01}{2\sqrt{3} \times 3 \times 10^8}$$

$$= \frac{0.09}{10.3923 \times 10^8}$$

$$= 8.660 \times 10^{-3} \times 10^{-8}$$

$$= 8.66 \times 10^{-11}$$

$$= 86.6 \times 10^{-12} = 86.6 \text{ ps}.$$

For Fastest mode

$$\sigma_s = \frac{L n_1 \Delta^2}{20\sqrt{3}\, c}$$

$$= \frac{6 \times 1.5 \times 0.01 \times 0.01}{20 \times \sqrt{3} \times 3 \times 10^8}$$

$$= \frac{9 \times 10^{-4}}{103.923 \times 10^8}$$

$$= 0.086 \times 10^{-4} \times 10^{-8}$$

$$= 0.0866 \times 10^{-12} \Rightarrow 0.0866 \text{ ps}$$

② Discuss the attenuation encountered in optical fiber due to Bending, Scattering and Absorption

→ Signal Attenuation (signal loss) is one of the most important properties of optical fiber because it largely determines the unamplified seperation between transmitter and a receiver.

→ Basic mechanisms are due to bending, scattering and absorption.

1) Absorption

caused by 3 different mechanisms

- atomic defects
- extrinsic absorption
- Intrinsic absorption

Atomic defects

→ imperfection in atomic structure..
→ Eg: missing molecules, high-density atom grps
→ Atomic defects absorption are negligible compared with extrinsic & intrinsic

Extrinsic absorption:

→ impurity in glass material
→ They contain transition metal impurities
Fe, Cu, Co, Ni
→ Pure silica fibers with low Ge doping → lowest loss
→ Dominant factor in silica fiber is the presence of minute quantities of impurities

Intrinsic absorption:

→ by basic constituent atom of the fiber material

→ For silica molecules electronic resonance in UV region, Vibrational resonance in IR region.

2) Scattering Losses.

Scattering can occur due to structural discontinuities, compositional fluctions, microscopic variations, defects in manufactures.

→ Spreading of light

Formula :- $\frac{8\pi^3}{3\lambda^4}(n^2-1)^2 K_B T_f \beta_T$

K_B → Boltzmann const

β_T → iso thermal compressibility

T_f → Fictive temp

n → refractive index

Rayleigh Scattering:-

Scattering of light rays that are smaller than the light rays is called Rayleigh Scattering.

constituents to 96% of scattering loss.

96% of loss → unavoidable thing.

3) Bending:

- Microscopic bending (wrt internal)
- macroscopic bending (wrt external)

When radius of curvature is small loss is more

when radius " " large loss is small.

③ Discuss & compare surface emitting & edge emitting LED structures

Surface emitting LED :-

→ Construction of LED is easier.
→ LED has faster emmission
→ It has high radiance
→ LED has isotropic radiation
→ Finite direction of intensity
→ Best light source choice

Surface emitting LED:

→ Light source contain III - V ternary & quaternary compounds
→ Double heterojunction layer :- 2 diff combination of materials to spread charge carriers evenly.
→ Heat sink to cool off.
→ metalisation to provide metal contact
SiO_2.
→ To avoid dispersion of light we use substrate.

Edge emitting diode:

→ used for generating narrow band signals.
→ central active layer is made using InGaAs.
→ They have two cladding layers.
→ Light is emitted from edge of the LED.
→ output has low divergence in vertical direction.
→ This increases the efficiency of coupling

Adv:

→ Greater coupling efficiency
→ better modulation
→ radiates less power
→ High data rate.

Disad:

→ Difficult to design heat sink
→ structure is complex.
→ Expensive.

comparison

Surface	Edge
→ Easy to fabricate	→ Difficult
→ Easy to handle	→ Difficult to handle
→ less reliable	→ highly reliable.
→ LED emitted from surface	↔ from edge
→ wide spectral width	→ narrow spectral width
→ efficiency 60%.	60% to 80%.

4) with a neat sketch explain the principle & operation of PIN & avalanche photo diode.

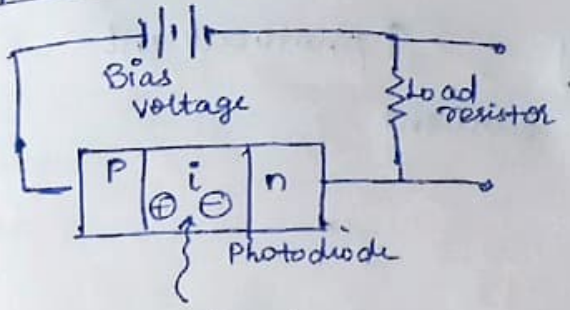
photo detectors converts light to electrical signals.

PIN & avalanche photo diode comes under the mechanism called Internal photo electric effect.

Internal photo electric effect:

Free charge carriers are generated by absorption of incident photons in semiconductor junction detectors.

PIN photo diode :



The high electric field present in the depletion region causes photo-generated carriers to seperate and be collected across the reverse-biased junction. This give rise to a current flow in an external circuit known as photo current.

Energy band diagram

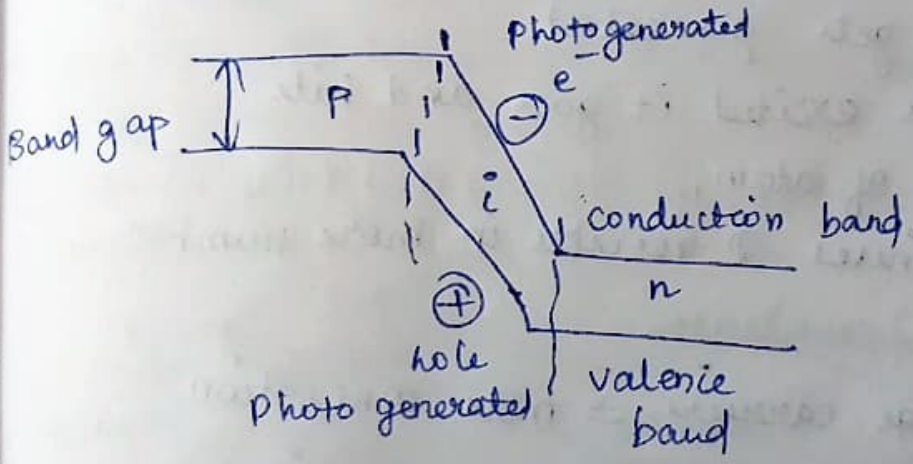


Photo current :

$$I_p = \frac{q}{h\nu} P_o \left(1 - e^{-\alpha s(\lambda) w}\right)\left(1 - R_f\right)$$

Quantum efficiency :

$$\eta = \frac{\frac{I_p}{q}}{P_o / h\nu}$$

Responsivity $= \frac{A}{W}$

Advantages:

1) ↑ width, ↑ light energy → ↑ photocurrent
2) ↑ width, faster drift current.

Avalanche photodiode:

Avalanche :- short period of time more current flows.

In avalanche photodiode we multiply the current.

When light falls on sc material, atoms gets disturbed, e^- jumps out. when e^- gets excess energy it becomes -ve ion, at the same time +ve ion gets generated.

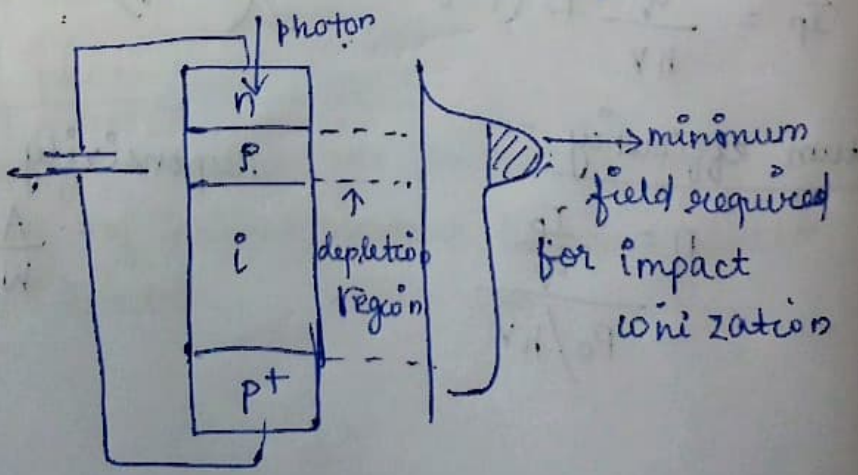
The e^-, h^+ gets excited it goes and hits more number of atom.

This process continues ⇒ results in more number of photocurrent.

more charge carriers ⇒ more ionisation

↳ this is called impact ionisation

↳ this creates: avalanche photodiode



5) Illustrate microbending and macrobending losses with suitable diagram.

→ Losses occur whenever an optical fiber undergoes a bend of finite radius of curvature

→ micro bending (wrt internal) / macroscopic (wrt external)

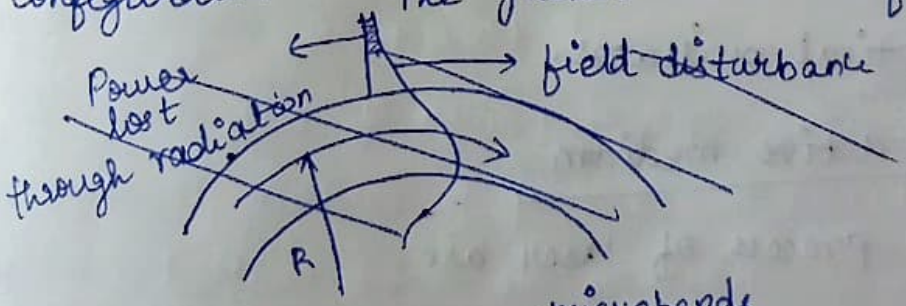
Micro bending:

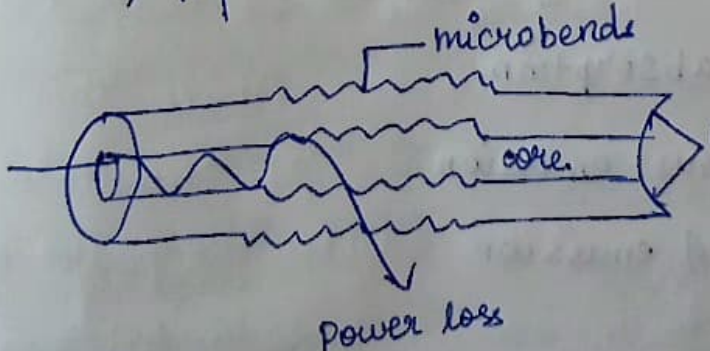
→ Micro bends are repetitive small scale fluctuations in the radius of curvature.

→ caused by non-uniformities in manufacturing or by uniform lateral pressures.

→ can be minimised by placing a compressible jacket over the fiber.

→ when external forces are applied to this configuration the jacket can be deformed.





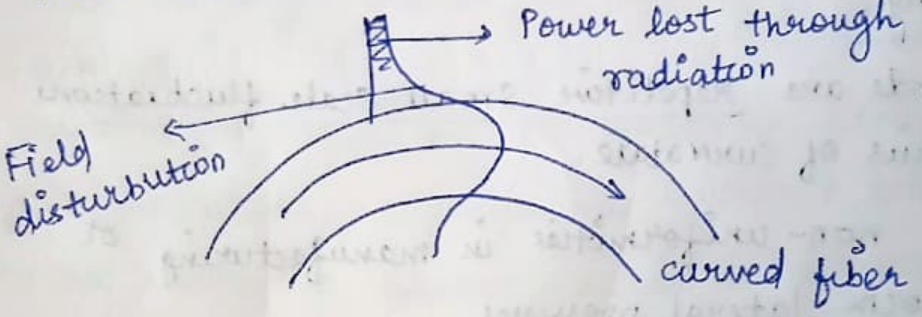
Macro bending :

→ Macro bending occurs when Fiber is bent into visible curvature. Usually due to incorrect installation.

→ Macro bending is reversible.

→ when roc is small loss is more

→ when roc is ↑ " " small



6) Laser

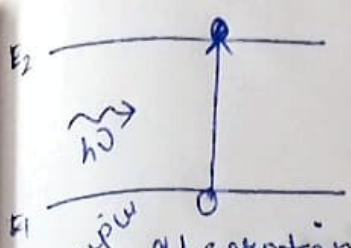
→ Light Amplification by Stimulated Emission Of Radiation.

→ It is an optical oscillator.

~~3 main active medium~~

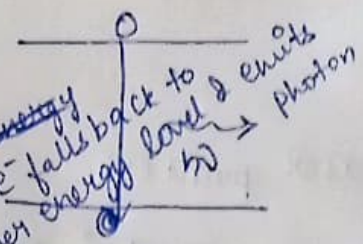
3 main process of laser are

1) Photon absorption
2) Spontaneous emission
3) Stimulated emission

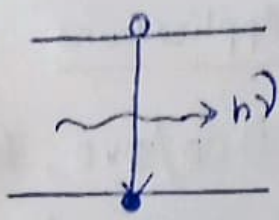


e⁻ occupies higher energy level by absorption

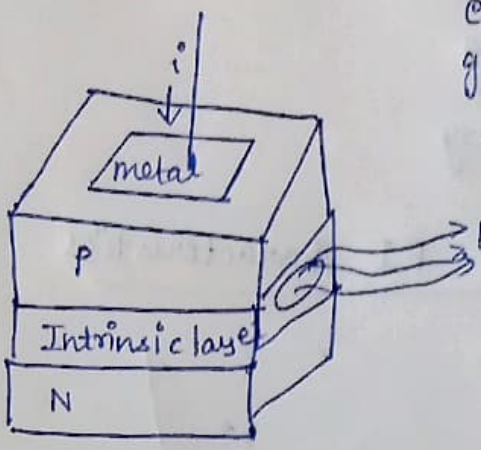
construction:



Spontaneous emission



stimulated emission
e⁻ returns to ground state.



working:

→ The input terminals are connected to a metal plates which are sandwiched to n type and p-type layers.

→ The intrinsic layer between P-type and n-type is used to increase the volume of active region. so that more no of holes & e⁻ can accumulate at the junction.

→ This allows more no of e⁻ to recombine with h^+ to get better power

→ The laser light is emitted from elliptical region.

Applications

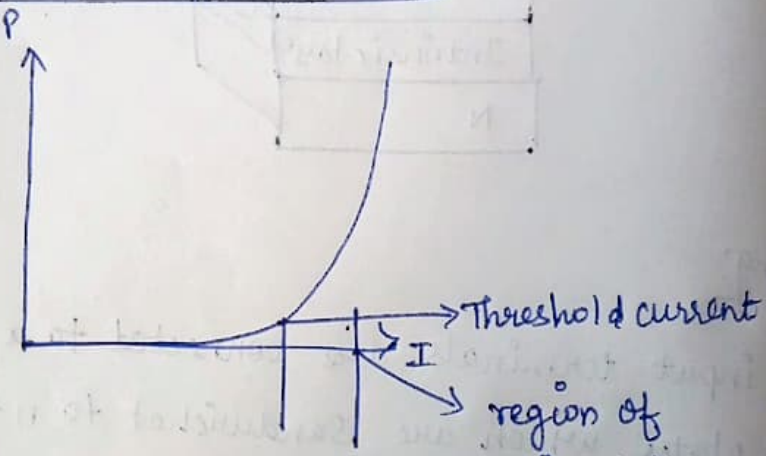
1) CD/DVD, Laser printers.

2) Laser Diode are used in machines used to remove unwanted tissues.

3) 3D printing

4) Spectrometry.

Laser Diode PI characteristics



As we increase the current flow to the laser diode, the optical power of output light gradually increases up to certain threshold. Until this point, most of the light emitted is due to spontaneous emission. Above this threshold current, the process of stimulated emission increases. This causes the power of output light to increase a ~~liven~~ lot even for smaller increases in input current.