UNIT - V

1 mark Questions and Answers

Q1. Define population Inversion? $\boxed{\text{IM- BL1, CO-C112.1}}$

(A) The process of making of higher population in higher energy level than the population in lower energy level is known as "population Inversion".

i.e $N_1 > N_2$ to $N_2 > N_1$

Where $N_1 \rightarrow$ population of Lower energy level.

$N_2 \rightarrow$ population of higher energy level.

Q2. Define coherence? $\boxed{\text{IM–BL–L1–CO–C112.1}}$

A. A predictable correlation of the amplitude and phase at any one point with any other point is called coherence

$\boxed{\text{IM-BL-L2-CO-C112.2}}$

Q3 Mention any four Applications of Lasers?

A. 1) Lasers are used in Medical field as endoscope

2) Lasers are used in communication

3) Lasers are used in Industry

4) Lasers are used in Computers

3marks Questions and Answers

Q1) Interpret the difference between spontaneous Emission and stimulated Emission

3M - BL - L_1 - CO - C112.6
C112.1

A.

Spontaneous emission	stimulated emission
1). Polychromatic Radiation	1) Monochromatic Radiation
2) Less Intensity	2) High Intensity
3) Less directionality	3) High directionality
4) specially and temporally Incoherent Radiation	4). specially and temporally coherent radiation
5) spontaneous emission takes place when excited atoms make transistion to Lower energy level. voluntarily without any external stimulation.	5) stimulated emission takes place when a photon. of energy equal to $h\nu = E_2 - E_1$ stimulates an excited atom to make transition. to Lower energy level.

Q2) Explain pumping? classify the types of pumping?

3M - BL - L_2 - CO - C112.2
C112.6

A. The Method of raising the particles from Lower energy state to higher energy state is called pumping.

There are different methods of pumping the energy to create population Inversion. They are.

Optical pumping:-

In this method, light is used to supply energy to the laser medium. An external light source. like xenon flash Lamp is used to produce more electrons. in the higher energy level of the laser medium.

Electrical discharge:-

In this method of pumping, electrical discharge acts the pump source (or) energy source. A high voltage electric discharge is passed through the laser medium (or) gas.

chemical Reaction:-

If an atom (or) molecules is produced through some chemical reaction and remains in an excited state at the time of production, then it can be used for pumping.

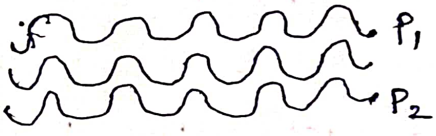
Thermal pumping:- In thermal pumping, heat acts as the pump source. In this method, population Inversion is achieved by supplying heat into the laser medium.

Q3 Discuss spatial coherence and temporal coherence ?

3M – BL – L2 – CO – C112.2 C112.6

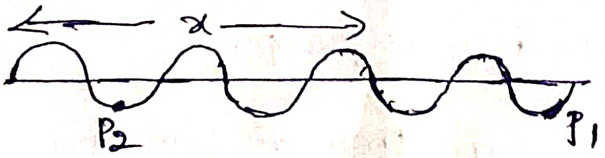
A) **Spatial coherence**

The two light fields at diffelent point space maintain a constant phase diffyence over any time (t) they ale said to be spatial coherence. When we choose two spatial points P_1 and P_2 on the cross section of the output beam, if the are in phase with one another (or) maintain same phase differences. then they ale in spatially coherent.

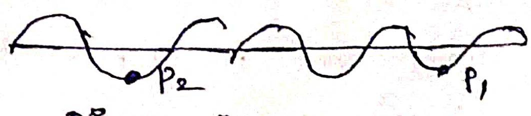


Temporal coherence:

The correlation of amplitude and phase between any two points on wave train over a peariod of ~~train~~ time is called temporal coherence. if two points P_1, and P_2 which ale on the same wave train caries same phase and amplitude then it is said to be temporal coherence.



Contineous wave



Discontineous wave.

5 Marks Questions

5M_BL-L2-CO-C112.2 C112.6

Q4) What are the characteristics of Lasers? Explain

A) The Four characteristics of laser radiation over conventional light sources are

(1) Laser is highly directional

(2) Highly monochromatic

(3) Highly coherent

(4) Highly Intensity

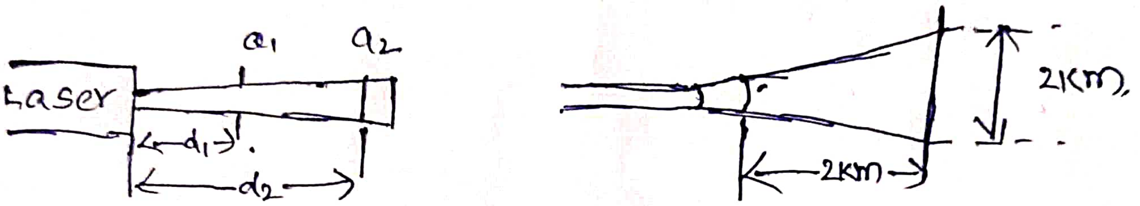
Highly monochromatic:-

The band width of ordinary light is about 1000Å. The band width of Laser light is about 10Å. The narrow band width of laser light is called high monochromacity.

The spread of the wavelength about the wavelength of maximum Intensity is band width. Laser light is more monochromatic than that of a conventional light source. Because of this monochromaticity large energy can be concentrated in to an external small band width.

Highly directionality

In conventional light source photons ~~the~~ will travel in random directions. Therefore, these light sources emit light in all directions on the other hand, in laser, all photons will travel in same direction. Therefore, Laser emits light only in one direction. This is called directionality of laser light. The width of laser beam is extremely narrow. Hence, a laser beam can travel to long distances without spreading.



ordinary light

~~In any ordin~~.

fig Directionality of laser

In any ordinary light travels a distance of 2km. it spreads to about 2km. in diameter. on the other hand, if a laser light travels a distance of 2km, it spreads to a diameter less than 2cm.

Coherence:-

Laser beam is spatially and temporally coherent.

Spatial coherence:- If wave maintains a constant phase difference or in phase at two different points on the wave over time 't', then the wave is said to have spatial coherence. For He-Ne laser coherence length is about 600km. for ordinary light coherence length about 3cm.

Temporal cohrence :-

It referes to the correlation between light fields at different times at a point on the wave. If there is no change in phase over time 't' at a point on the wave then it is said to be coherent temporally during that time. For laser source temporal coherence time is 2×10^{-3} sec where as ordinary source temporal coherence time is 10^{-10} sec.

Brightness (or) High Intensity :-

Lasers are bright and Intense light sources because of coherence and directionality Intensity of a wave is the energy per unit time flowing through a unit area. The light from ordinary source spreads out uniformly in all directions and form spherical wave fronts around it.

[5M_BL-L2-CO-C112.2]

(Q2) Demonstrate construction and working of Ruby laser?

A) The Ruby Laser is first constructed and demonstrated in 1960 by T.H maiman.

characteristics :- Ruby rod $(Al_2O_3 + 0.05\% \ Cr_2O_3)$

Active Element : Cr^{3+}

Energy source : Xenon flash lamp.

optical cavity : Ruby rod of silver polished surfaces.

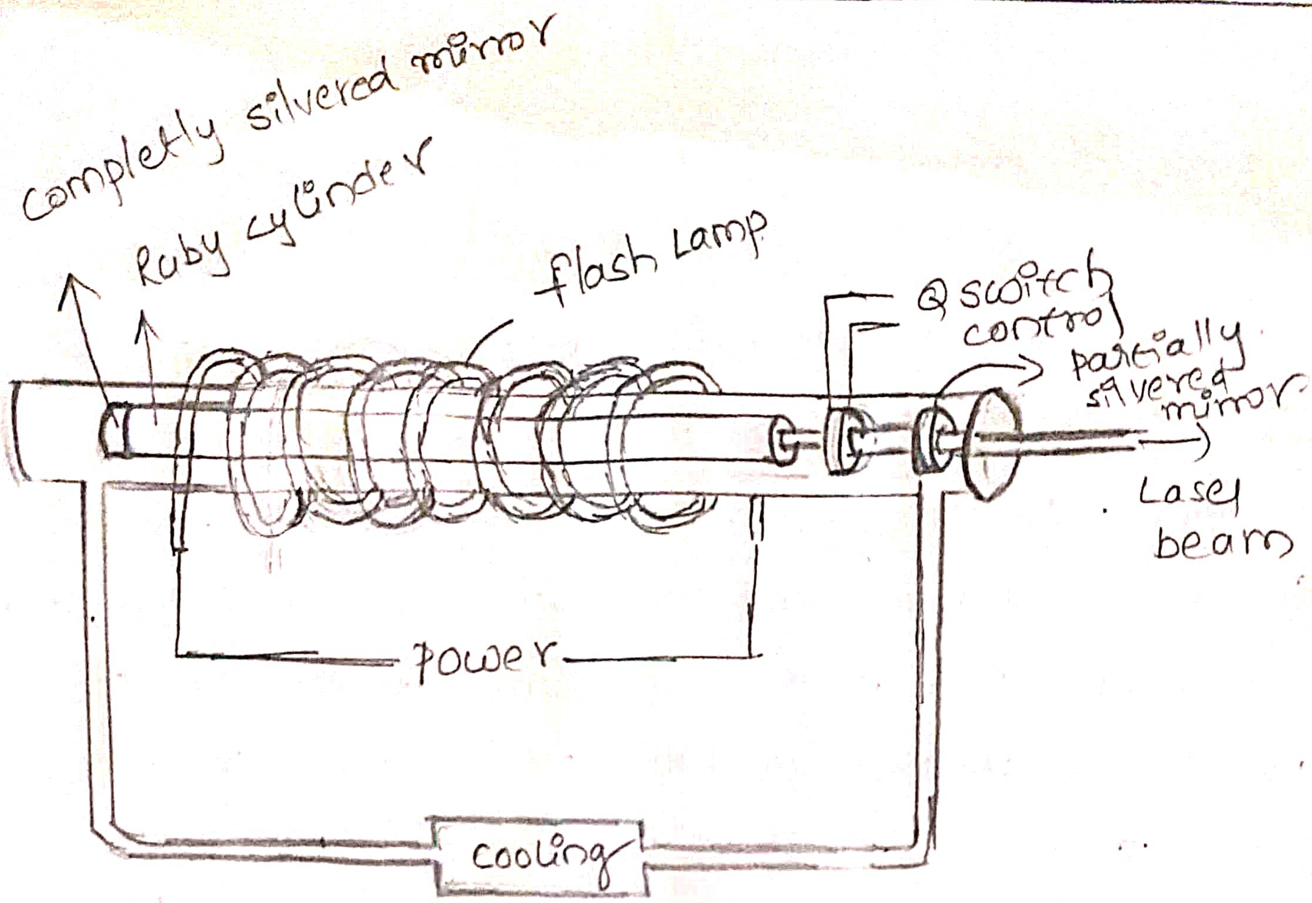
Construction :- A Ruby rod of approximately 10cm length and 0.5cm diameter is polished an.

grounded on either end to have the end faces exactly parallel and coated with highly reflecting material. External mirror arrangement is also used. For pumping mechanism helical xenon lamp (or) Linear flash lamp with an elliptically cavity as a reflector is used. To prevent over heating of the crystal, cooling system is also arranged.

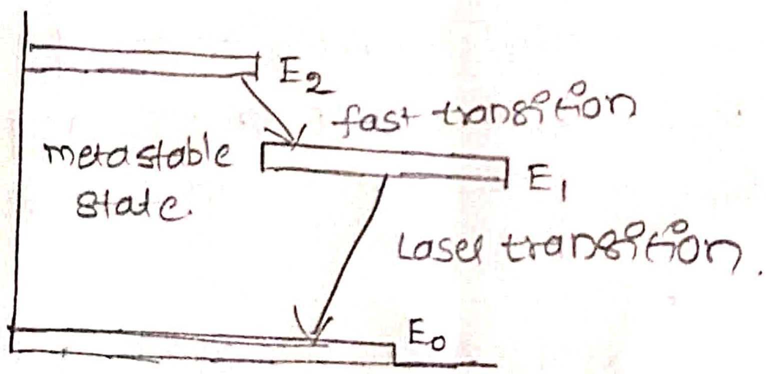
Working:

The Xenon flash lamp is an energy source with a small discharge time. some part of this energy excites the chromium atom. chromium atom absorbs the light of photon 15600Å and goes to the excited state E_1 and by absorbing energy 4200Å they excite to E_2 state. The excited atoms shifts to the metastable state E_1 by non-radiative transition. i.e no of atoms are Increased at E_1 Level, acheving population Inversion between E_1 and E_2

After completion of life time in E_1, the chromium ions decay spontaneously to E_0 giving a photon wavelength 6943Å. The emitted photons move parallel between the reflected surfaces in the active medium there by Increasing the stimulated emission of chromium ions in E_1. When the beam is Intense, it escape from the semi silvered mirror in the form of laser of wavelength 6943Å. The output of ruby laser is pulsed wave. It is a low power wave



completly silvered mirror
Ruby cylinder
flash Lamp
Q switch control
partially silvered mirror
Laser beam
power
cooling



E_2
fast transition
metastable state.
E_1
Laser transition.
E_0

10 Marks Questions and Answers

10M. El-1.2.C

Q1) Explain the Interaction of Radiation with matter? Derive the relation between Einstien coefficients

(A) In 1916, Albert Einstien proposed that there are three processes occuring in the formation of an atomic spectral line. The three processes are reffered to as spontaneous emission, stimulated emission, and absorption. With each is associated an Einstein coefficient which is a measure of probability of that particular process occuring. Einstien considering the case of Isotropic radiation of frequency ν, and energy density $\rho(\nu)$

Let us consider N_1 and N_2 be the populations in the energy levels of energies E_1 and E_2 respectively in a system of atoms at a thermal equillibrium of temperature

upward transition:-

Absorption is the process by which a photon is absorbed by the atom, causing an electron to jump from a lower energy level E_1 to a higher one E_2. This process is described by the Einstien coefficient B_{12}

The absroption rate is directly propostional to N_1 and $\rho(\nu)$.

Therefore, Rate of absorption $= B_{12} N_1 \rho(\nu) \longrightarrow (1)$

$B_{12} \rightarrow$ Einstien coefficient of absorption

Stimulated emission rate is directly proportional to N_2 and $\rho(\nu)$

The Rate of stimulated emission $= B_{21} N_2 \rho(\nu) \rightarrow (3)$

$B_{21} \rightarrow$ Einstien coefficient of stimulated emission.

Considel an Ideal material with only two non-degenerate energy levels, at thermal equillibrium,

Absorption = spontaneous emission + stimulated emission $\rightarrow (4)$

i.e $B_{12} N_1 \rho(\nu) = A_{21} N_2 + B_{12} N_2 \rho(\nu) \rightarrow (5)$

$$B_{12} N_1 \rho(\nu) - B_{12} N_2 \rho(\nu) = A_{21} N_2$$

$$[B_{12} N_1 - B_{21} N_2] \rho(\nu) = A_{21} N_2$$

$$\rho(\nu) = \frac{A_{21} N_2}{[B_{12} N_1 - B_{21} N_2]} \quad (\text{or}) \quad \rho(\nu) = \frac{A_{21} N_2}{B_{21} N_2 \left\{ \left[\frac{N_1}{N_2} \left(\frac{B_{12}}{B_{21}} \right) \right] - 1 \right\}}$$

$$(\text{or}) \quad \rho(\nu) = \frac{A_{21}}{B_{21}} \cdot \frac{1}{\left\{ \left[\frac{N_1}{N_2} \left(\frac{B_{12}}{B_{21}} \right) \right] - 1 \right\}} \rightarrow (6)$$

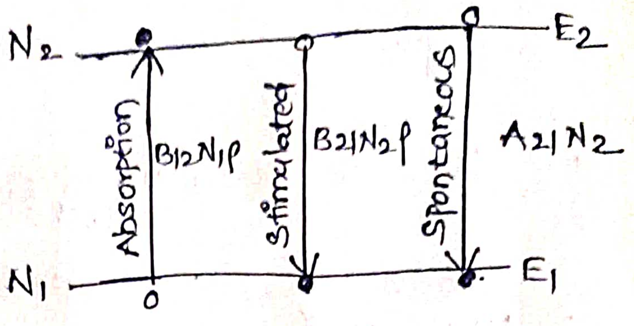
But in thermal equillibrium, the Boltzman distribution Law applies, so.

$$N_1 = N_0 \exp\left(\frac{-E_1}{K_B T}\right) \text{ and } N_2 = N_0 \exp\left[\frac{-E_2}{K_B T}\right]$$

Where, N_0 is population in ground slate and K_B is the Boltzman's constant

Therefore, $\frac{N_1}{N_2} = \exp\left[\frac{E_2 - E_1}{K_B T}\right] = \exp\left[\frac{h\nu}{K_B T}\right] \rightarrow (7)$

sub



Downward transition

Spontaneous emission is the process by which an electron spontaneously decays from E_2 to E_1. The process is described by the Einstien coefficient (A_{21})

The absorption Rate ~~is directly propotional to N_1 and $\rho(\nu)$~~

~~Therefore, Rate of absorption $= B_{12} N_1 \rho(\nu) \rightarrow (1)$~~

spontaneous emission directly propotional to N_2 only

Therefore, Rate of spontaneous emission $= A_{21} N_2 \rightarrow (2)$

$A_{21} \rightarrow$ Einstein's coefficient of spontaneous emission

Stimulated emission :-

Stimulated emission is the process by which an atomic electron in the excited E_2 is interacting with a photon of certain frequency may drop to a lower energy level (E_1) transfering energy to that photon. A new photon created in this manner has the same phase, frequency and directional of travel as same as Incident photon. The process is described by Einstien coefficient B_{21}.

sub eq (7) in eq (6) we get

$$\rho(\nu) = \frac{A_{21}}{B_{21}} \frac{1}{\left\{\left[\exp\left(\frac{h\nu}{K_B T}\right)\left(\frac{B_{12}}{B_{21}}\right)\right] - 1\right\}} \longrightarrow (8)$$

According to planck's law of black body radiation at temperature T we have the energy ~~en~~density $\rho(\nu)$ at frequency ν is

$$\rho(\nu) = \frac{8\pi h\nu^3}{c^3} \frac{1}{\left\{\exp\left(\frac{h\nu}{K_B T}\right) - 1\right\}} \longrightarrow (9)$$

comparing eq (8) and eq (9) we get.

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3} \longrightarrow (10)$$

$$\cancel{\frac{B_{12}}{B_{21}} \neq \frac{8\pi h\nu^3}{}} \qquad \frac{B_{12}}{B_{21}} = 1 \longrightarrow (11)$$

eq (10) and (11) show the relations b/w Einstein's coeffients B_{12}, B_{21} and A_{21}.

From the above relation eq (10) shows that the ration of rate of spontaneoes (A_{21}) to rate of stimulated emission (B_{21}) is proportional to cube of the frequency of the Incident radiation.

Q2 Explain construction and working of a semiconductor laser: [10M—BL—L3—CO—C112.3]

A) Semiconductor lasers also known as quantum well lasers are smallest, cheapest, can be produced in mass, and are easily scalable. They are basically p-n junction diode, which produces light of certain wavelength by recombination of charge carriers when forward biased, very similar to the light-emitting-diodes. LEDs possess spontaneous emission, while laser diodes emit radiation by stimulated emission.

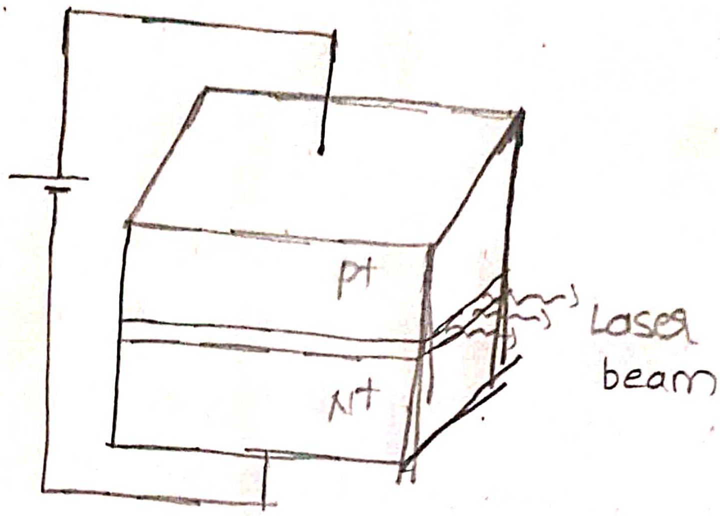
Principle:- In the case direct band gap semiconductors there is a large possibility for direct recombination of hole and electron emitting a photon. GaAs is a direct band gap (1.44eV) semiconductor and hence it is used to make lasers and light emitting diodes. The wavelengths of the emitted light depend on the band gap of the material.

Construction:-

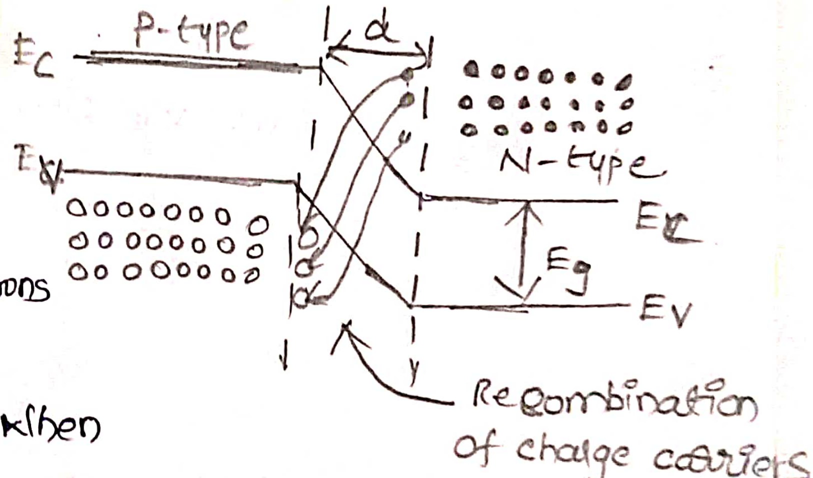
The p^+ and N^+ regions of the diode are obtained by heavily doped p and n regions of GaAs. The thickness of p-n junction layer is very narrow at the junction. The side walls are well polished and parallel to each other. Since the refractive index of GaAs is high, the reflectance at the material air interface is sufficiently large so that external mirrors are not necessary to produce multiple reflections.

The p-n Junction is forward biased by connecting positive terminal to p-type and negative terminal to n-type.

Working:-



The population Inversion can be obtained by Injecting electrons and holes in to the Junction from the n-region and p-region by means of forward bias voltage. When the forward bias is not connected, no electrons and holes present in the depletion region. When



a small forward bias voltage is given to the p-n Junction then small number of electrons and holes will Injected into the depletion regions from respective regions. When relatively a large current of the order of $10^4 A/cm^2$ is passed through the Junction then Large no of electrons and holes will be Injected into the depletion region as shown in above fig. Then the direct recombination processes take place between holes and electrons in the depletion region and release the photons.

Further emitted photons Increase the rate of recombination. Thus more no of photons produced having same phase and frequency of the Induced photons.

The wavelength of the emitted radiation depends on the energy band gap of the semiconductor material. The energy gap of GaAs semiconductor is 1.44eV. then it emits laser light of wavelength 8600 Å.

$$\lambda = \frac{hc}{E_g} = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{1.44} = 8626 \text{Å}$$

Applied physics :- Fiber optics

1 Marks

1) Define Numerical Aperture ? [1M - BL - L1 - CO - C112.1]

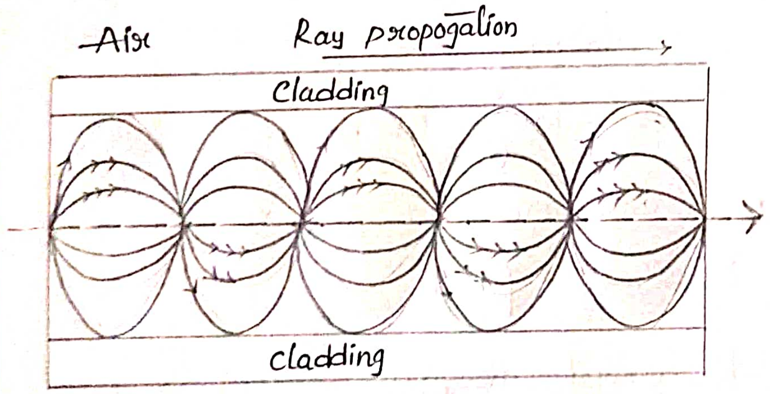
Numerical Aperture :- The numerical aperture (NA) is defined as the sine of the acceptance angle.

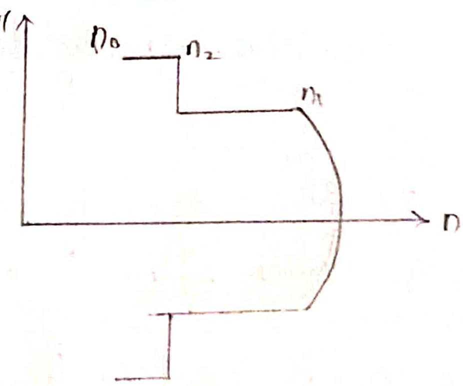
$$NA = \sin i_m$$

$$NA = \left(\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right)$$

Numerical aperture determines the light gathering ability of the fiber. It is a measure of amount of light that can be accepted by a fiber. NA depends only on the refractive indices of the core and cladding materials. A large NA implies that a fiber will accept large amount of light from the source.

2) Sketch the ray propagation in multimode Graded Index optical fiber. [1M - BL - L3 - CO - C112.2]





3) 3 Marks

How will you classify the optical fibers ? [3M - BL - L2 - CO - C112.2]

Optical fibers are classified into three major categories

i) The types of material used

ii) The number of modes

iii) The refractive index profile

Optical fibers are based on

- Material
  - Glass fiber
  - plastic fiber
- No. of modes
  - Single mode fiber
  - Multi mode fiber
- Refractive index profile
  - Step index fiber
  - Graded index fiber GRIN fiber

Based on the type of the material used, they are classified into two types

→ <u>Glass fiber</u> :-

Example :

Core : SiO_2 cladding: SiO_2

core : $GeO_2 - SiO_2$ cladding : SiO_2

→ <u>plastic fiber</u> :-

Example :

Core : polymetyl methacrylate : cladding : Co-polymer

Core : polystyreme : cladding : Methyl methacrylate

Based on the number of modes, they are classified as

1) Single mode fiber 2) Multimode fiber

Based on the refractive index profile, they are classified as

1) Step-index fibex 2) Granded index fiber

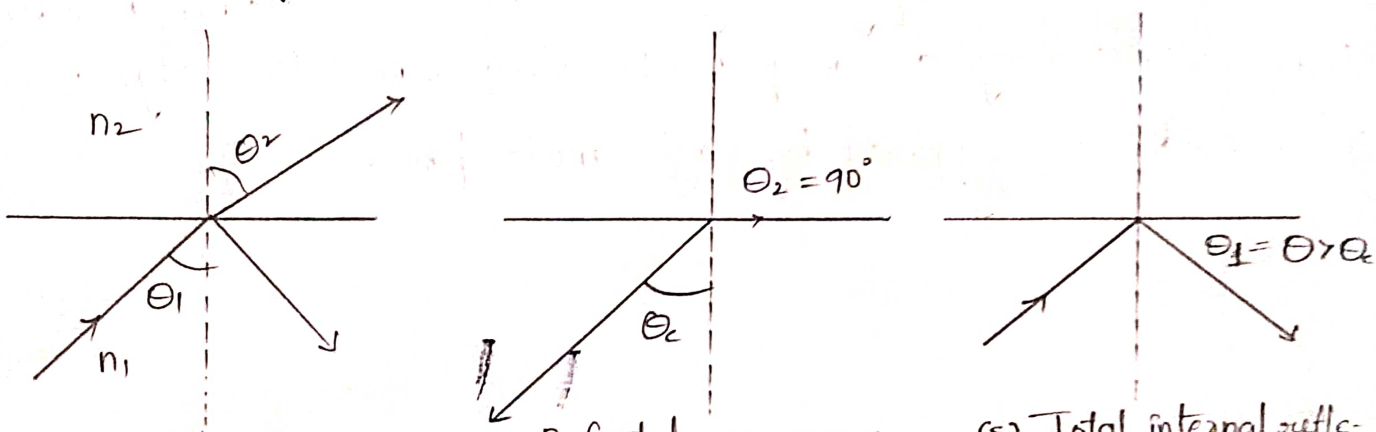
2) Explain total internal reflection ? $\boxed{\text{BM-BL-L2-CO-C112.2}}$

The transmission of light is an optical fiber is based on the principal of total internal reflection. According to the law of reflection, when a ray of light travels from denser medium to rarer medium and if the angle of incidence is greater than the critical angle, the light gets totally reflected. That is if the light ray is incident at an angle greater than the critical angle for the two media, the ray is totally reflected back into the medium. This phenomeon is known as total internal reflection.

The total internal reflection takes place only when the following two conditions are satisfied.

1) The refleractive index of the core material n_1 must be greater than that of the cladding n_2 surrounding it. i.e, $n_1 > n_2$.

2) At the core and cladding interface, the angle of incidene θ_i must be greater than the critical angle θ_c. ie $\theta_i > \theta_c$



(a) Some part of the incident beam is transmitted through n_2 when $\theta_1 < \theta_c$

(b) Refracted ray passes through the core-cladding interface, when $\theta_1 = \theta_c$

(c) Total internal reflection occurs when $\theta_1 > \theta_c$

When light ray travels from core of refractive index n_1 to cladding of refractive index n_2, refraction occurs. Since light travels from denser to rarer medium the angle of refraction is greater than the angle of incidence as shown

(a) With the increase in angle of incidence the angle of refraction also increase and for a particular angle of incidence ($\theta_i = \theta_c$) the refracted ray simply passes through the interface between the core and cladding which is shown above.

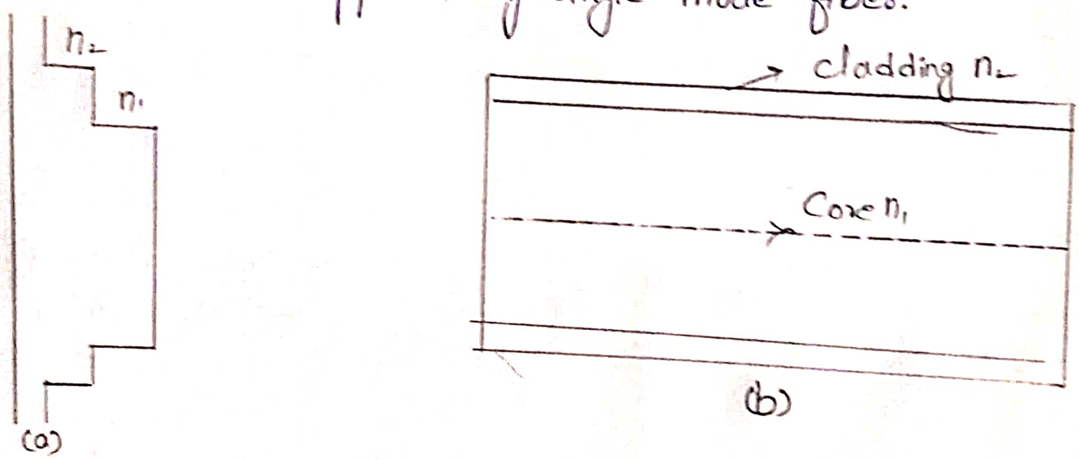
(b) When the angle of incidence is further increased, the ray the reflected back into the core. This phenomenon is called total internal reflection.

5 Marks

1) Describe the structure of different types of optical fibers with ray paths. [5M-BL-L1-CO C112.1]

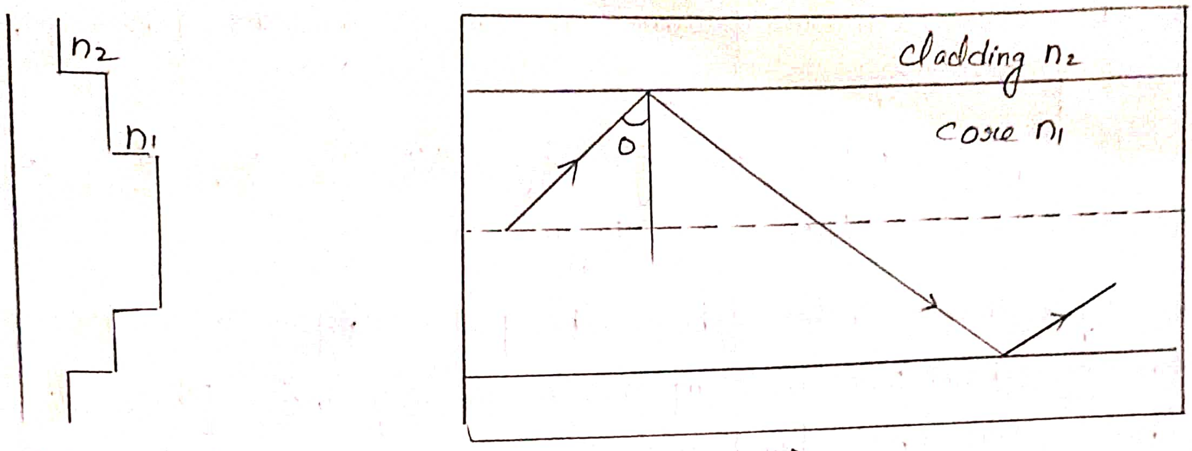
The different types of optical fiber and their ray paths are :-

1) Single mode step index fiber :- A single mode step index fiber consists of a very thin core of uniform refractive index surrounded by a cladding of refractive index lower than that of core. The refractive index abruptly changes at the core cladding boundary. Light travels along a side path, i.e along the axis only. So zero modes is supported by single mode fiber.



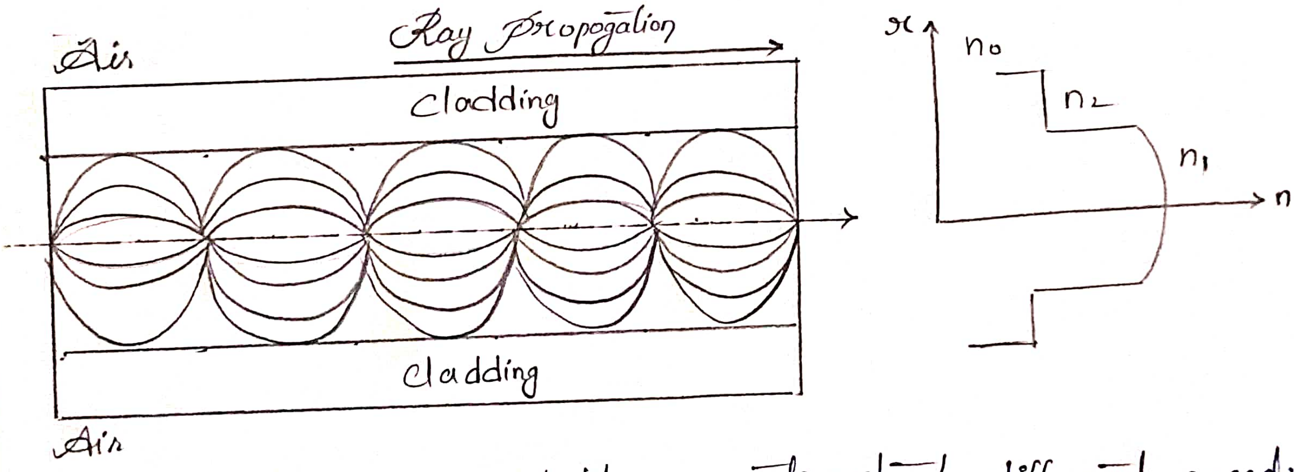
2) Multimode step index fiber :- A multimode step index fiber consists of a core of uniform refractive index surrounded by cladding of refractive index lower than that of the core. The refractive index abruptly changes at the core cladding boundary. The core is of large diameter. Light follows zigzag paths inside the fiber. Many such zigzag paths of propagation are permitted in Multi Mode fiber.

is he numerical Aperture of a multi mode fiber is larger as the core diameter of the fiber is large.



(a) (b)

(3) Graded index fiber :- GRIN fiber is one in which refractive index varies radially, decreasing continuously in a parabolic manner from the maximum value of n_1, at the center of the core to a constant value of n_2, at the core cladding interface.



In graded index fiber, light rays travel at different speeds in different parts of the fiber because the refractive index varies through out the fiber. Near the outer edge, the refractive index is lower. As a result, rays near the outer edge travel faster than the rays at the center of the core. Because of this rays arrive at the end of the fiber at approximately the same time. In effect light rays arrive at the end of the fiber are continuously refocused as they travel down the fiber. All rays take the same amount of time in traversing the fiber: this leads to small pulse dispersion.

The pulse dispersion is given by $\Delta\tau = \tau_{max} - \tau_{min} = \frac{n_1 L}{2c}\Delta^2$

Here $\Delta = \frac{n_1 - n_2}{n_2}$

For a parabolic index fiber, the pulse dispersion is reduced by a factor of about 200 in comparision to step index fiber. It is because of this reason that first and second generation optical communication system used near parabolic index fibers.

(ii) Propagation of light in grin fiber :- Let n_a, n_b, n_c, n_d etc. be the refractive index of different layers in graded index fiber is as shown in the figure.

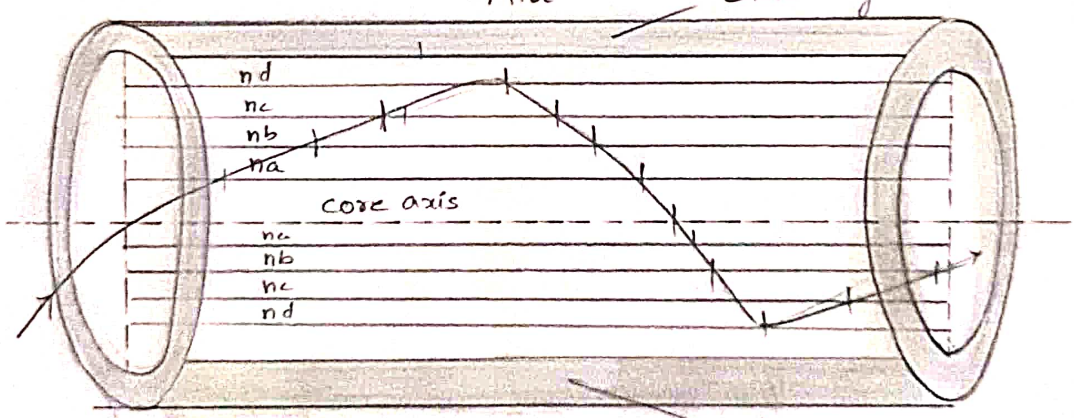


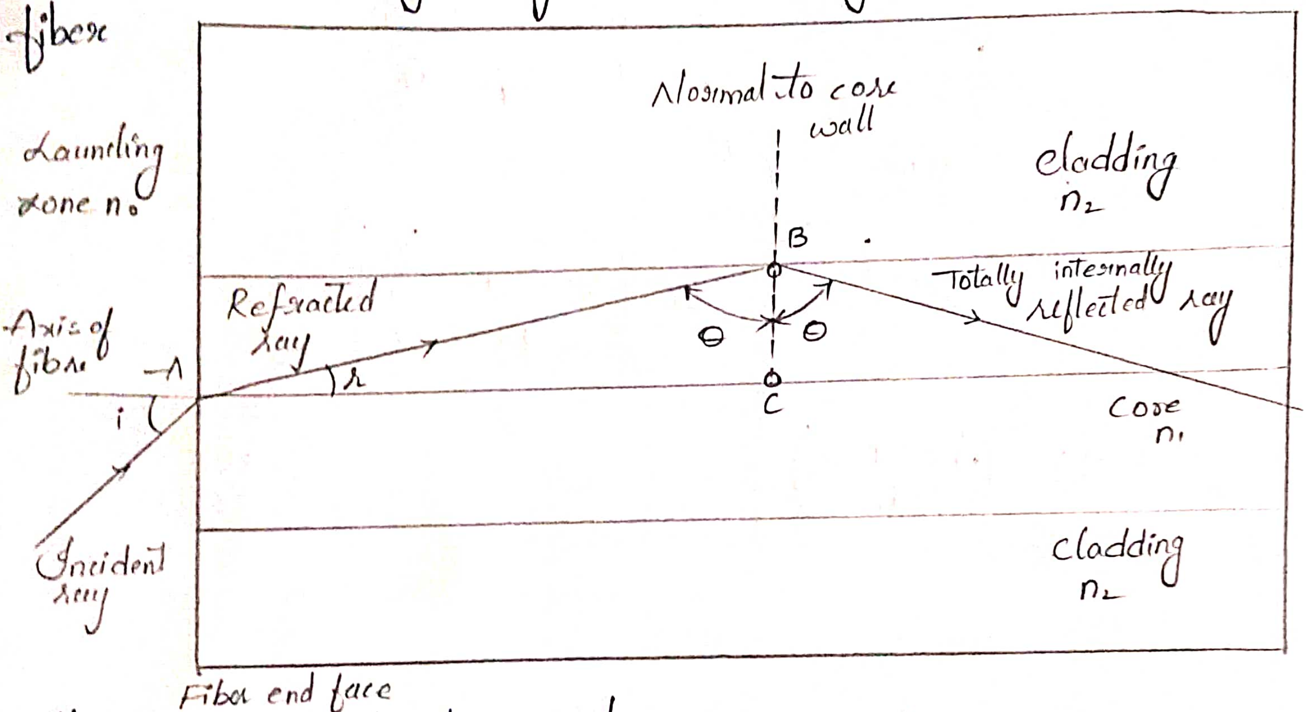
Fig 3.15

Here, Since $n_a > n_b$ the ray gets refracted. Similarly since $n_b > n_c$, the ray gets refracted and so on. In a similar manner, due to decrese in refractive index the ray get gradually curved towards the upward direction and at one place, where in it satisfied the condition for the total internal reflection ($\phi > \phi_c$) it is totally internally reflected.

Derive an expression for the numerical aperture of an optical fiber.

Consider an optical fiber through which the light is being sent. The end at which light enters is called launching end. Let the refractive indices of the core and cladding be n_1 and n_2 respectively $n_1 > n_2$:
Let the refractive index of the medium from which the light is launched be n_0.

Let the light ray enter at an angle i to the axis of the fiber



The ray refracts at an angle r.

The ray strikes the core-cladding interface at an angle θ. If θ greater than the critical angle θ_c, the ray undergoes total internal reflection at the interface.

Let us now find out upto what maximum value of i at A total internal reflection at B is possible.

In triangle ABC $r = 90 - \theta \longrightarrow (1)$

From snell's law $\dfrac{\sin i}{\sin r} = \dfrac{n_1}{n_0} \longrightarrow (2)$

$$\sin i = \frac{n_1}{n_0}\sin r = \frac{n_1}{n_0}\sin(90-\theta) = \frac{n_1}{n_0}\cos\theta$$

If θ is less than the critical angle θ_c, the ray will be lost by refraction. Therefore limiting value for containing the beam inside the core by total internal reflection is θ_c. Let i_m be the maximum possible angle of incidence at the fiber end face A for which $\theta = \theta_c$.

$$\sin i_m = \frac{n_1}{n_0} \cos\theta_c \longrightarrow (3)$$

$$\text{But } \sin\theta_c = \frac{n_2}{n_1}$$

$$\cos\theta_c = \sqrt{1-\sin^2\theta_c} = \sqrt{1-\frac{n_2^2}{n_1^2}} = \sqrt{\frac{n_1^2-n_1^2}{n_1}}$$

$$\therefore \sin i_m = \frac{\sqrt{n_1^2-n_2^2}}{n_0}$$

or

$$\boxed{i_m = \sin^{-1}\left(\frac{\sqrt{n_1^2-n_2^2}}{n_0}\right)}$$

$$\boxed{NA = \left(\frac{\sqrt{n_1^2-n_2^2}}{n_0}\right)}$$

be lost am le

write the important application of optical fibers. 5M-BL-L1-CO-C112.1

1) Optical fibers are used in communication system.
2) Optical fibers are used in pressure and active sensors
3) Reference fiber are used in environment
4) Optical fiber are used in liquid level sensor
5) Optical fibers are used in medical endoscope
6) Optical fibers are used in bloodless surgeries.

10 MARKS

1) Discuss the various factors contributing to attenuation in optical fiber. 10M-BL-L2-CO-C112.2

When light propogates through an optical fiber, a small percentage of light is lost through different mechanisms. The loss of optical power is measured in terms of decibels per km for attenuation losses.

ATTENUATION:

It is defined as the ratio of optical power output (Pout) from a fiber of length 'L' to the power output (Pin)

$$\text{Attenuation } (\alpha) = \frac{-10}{L} \log \frac{P_{in}}{P_{out}} \text{ dB/KM}$$

Since attenuation plays a major role in determining the transmission distance, the following attenuation mechanisms are to be considered in designing an optical fiber

1. Absorption:

Usually absorption of light occurs due to imperfections of the atomic structure such as missing molecules, (OH), hydroxyl ions, high density cluster of atoms etc, which absorbs light.

2. Scattering:

Scattering is also a wavelength dependent loss, which occurs inside the fibers. Since the glass is used in fabrication of fibers, the disordered structure of glass will make some variation in the refractive index inside the fiber. As a result, if light is passed through the atoms in the fiber, a portion of light is scattered (elastic scattering) this type of scattering is called

Raleigh scattering.

$$\text{Raleigh scattering loss} \propto \frac{1}{\lambda^4}$$

3. Radiative loss:

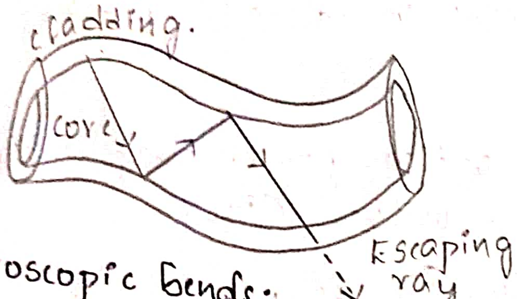
Radiative loss occurs in fibers due to bending of finite radius of curvature in optical fibers. The types are bends are

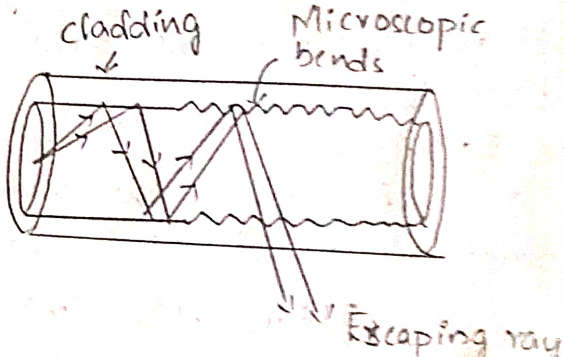
a. Macroscopic bends.

b. Microscopic bends.

a. Macroscopic bends:

If the radius of the core is large compared to fiber diameter, it may cause large-curvature at the position where the fiber cable turns at the corner. At these corners the light will not satisfy the condition for total internal reflection and hence it escapes out from the fiber. This is called as macroscopic / macro bending losses. Also note that this loss is negligible for small bends.





b. Microscopic Bends:

Micro-bends losses are caused due to non-uniformities or micro bends inside the fiber as shown. This micro bends in fiber appears due to non uniform pressure created during the cabling of the fiber or even during the manufacturing itself. This lead to loss of light by leakage through the fiber.

Remedy:

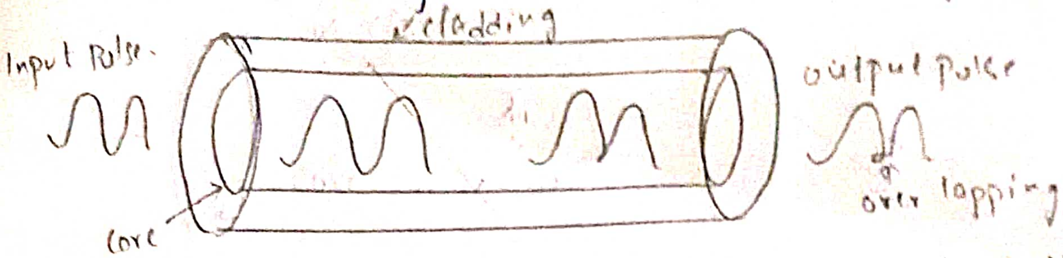
Micro-bend losses can be minimized by extruding (squeezing out) a compressible jacket over the fiber. In such cases, even when the external forces are applied, the jacket will be deformed but the fiber will tend to say relatively straight and safe, without causing more loss.

DISTORTION AND DISPERSION

The optical signal becomes increasingly distorted as it travels along a fiber. This distortion is due to dispersion effect

Dispersion:

When an optical signal or pulse it sent into the fiber the pulse spreads / broadens as it propogates through the fiber. This phenomenon is called dispersion as shown in figure.



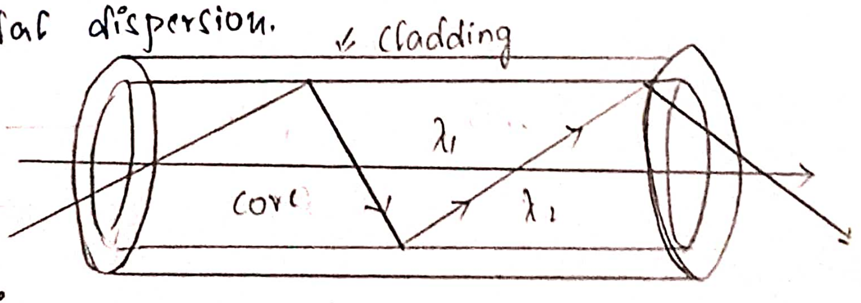
From figure we can see that the pulse received at the output is wider than the input pulse. Hence the output pulse is said to be distorted. due to dispersion effect.

The pulse broadening or dispersion will occur in three ways, viz--,

1. Inter - modal dispersion.
2. Material dispersion or chromatic dispersion.
3. Waveguide dispersion

Intermodal dispersion:

When more than one mode is propogating through the fiber, then the inter modal dispersion will occur. Since many modes are propogating, they will have different wavelengths and will take different time to propogate through the fiber which leads to intermodal dispersion.



Explanation:

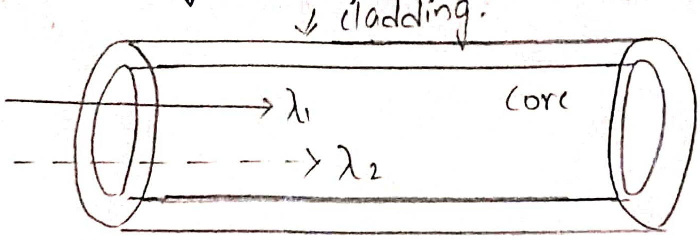
When a ray of light is launched into the fiber, the pulse is dispersed. in all possible paths through the core, so called differrent modes.

Each mode will be different wavelength and has different velocity as shown in the figure. Hence, they reach the end of the fiber at different time. This results in the elongation or streching of data in the pulse. Thus causes the distored pulse.

This is called intermodal dispersion.

Material dispersion:

In material dispersion, the dispersion occurs due to different wavelength travelling at different speed inside the fibers shown in figure.



Remedy:

The material dispersion can be minimized at certain wavelengths say 870nm, 1300 nm and 1550nm ; these wavelengths are termed Zero Dispersion wavelength (ZDW).

Whether light wavelength is lesser than Zero Dispersion wavelength, it travels slower and when it is higher than ZDW it travels faster. Thus the speed is altered and adjusted in such a way that all the waves passing through the fiber will move with constant speed and hence the material dispersion is minimized.

Note: this dispersion will not occur in single mode fibers