Unit 5

LASER

Laser → LASER is a device or process by which we can produce monochromatic, highly cohrent, highly intensity, collimated and unidirectional beam of Light.

(LASER → LIGHT AMPLIFICATION BY STIMULATED and EMISSION OF RADIATION)

Process used in LASER Action

(i) stimulated absorption

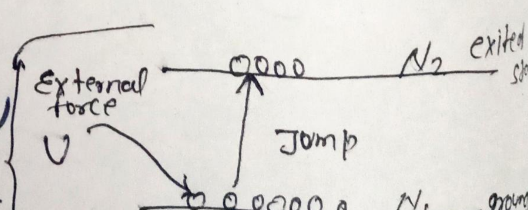
(ii) spontaneous and stimulated emission.

(A) Stimulated absorption

→ This is induced process, when we give the energy to ground state atom. it absorbs the energy and jump into the higher or exited state. This process is known as stimulated absorption.

Stimulated absorption $\propto U$

$\propto N_1$



$$\boxed{\text{Stimulated absorption} = U N_1 B_{12}} \quad \text{—— (A)}$$

where U Energy intensity

N_1 = number of atom in ground state

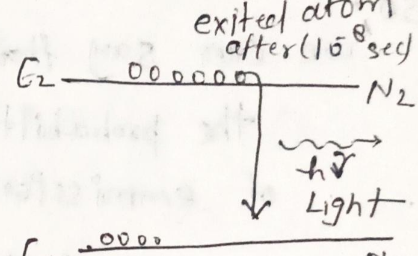
B_{12} = Einsteen con...

(B) SPONTANEOUS - EMMISSION → Sponteneous means naturally when exited atoms naturally comes back to ground state and relesed the energy in form of light radiation this process is known as spontaneous emission.

Sponteneous emission $\propto N_2$

$$\text{Sponteneous emission} = A_{21} N_2 \quad \text{---} (B)$$

where A_{21} is Einstein's cofficient of spontaneous emission

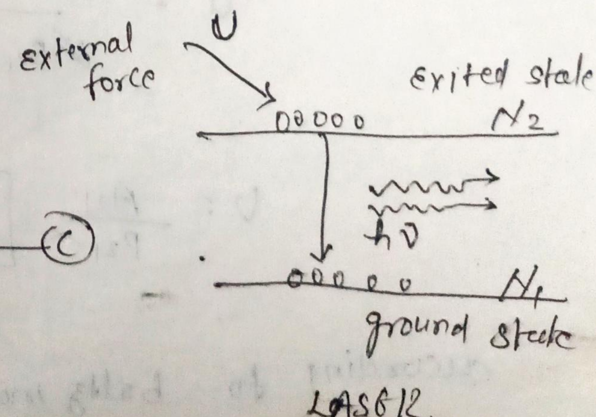


(C) STIMULATED EMISSION → when exited state atom comes back to ground state due to the effect of external force and radiates or emits the energy in form of light of light then this emission is known as stimulated emission.

Stimulated Emission $\propto U$
$\propto N_2$

$$\text{Stimulated Emission} = B_{21} U N_2 \quad \text{———} (C)$$

where B_{21} is Einstein's cofficient of stimulated emission.



Relation between Einstien's cofficient (OR relation b/w transition Probabilty of Emission and Absorption)

In above process, The number of absorption is always equal to number of emission (i.e. if n atoms jump to exited state the n atom also can in ground state).

so;
we can say that
the probabilty of absorption is always equal to probability of emmission.

Number of absorption = Number of emmision

$$N_1 U B_{12} = N_2 U B_{21} + N_2 A_{21}$$

$$U(N_1 B_{12} - N_2 B_{21}) = N_2 A_{21}$$

$$U = \frac{N_2 A_{21}}{N_1 B_{12} - N_2 B_{21}}$$

$$U = \frac{N_2 A_{21}}{N_2 B_{21}\left(\frac{N_1 B_{12}}{N_2 B_{21}} - 1\right)}$$

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

according to boltz man's distribution law

$\left[N_{excited} = N_{ground} \cdot e^{-E/KT} \right]$

$N_1 = N_0 \, e^{-E_1/KT}$, $N_2 = N_0 \, e^{-E_2/KT}$

So $\frac{N_1}{N_2} = \frac{N_0 \, e^{-E_1/KT}}{N_0 \, e^{-E_2/KT}}$ ⇒

$\frac{N_1}{N_2} = e^{(E_2 - E_1)/KT}$ ⇒ $e^{h\nu/KT}$ —— (E)

The value of $\frac{N_1}{N_2}$ put in equ. (D) then we get

$$U = \frac{A_{21}}{B_{21}} * \frac{1}{\left[e^{(E_2-E_1)/KT} \cdot \frac{B_{12}}{B_{21}} - 1 \right]}$$ —— (F)

{ we know that planks radiation law off black body;

$$U = \frac{8\pi h\nu^3}{c^3} \left[\frac{1}{e^{(E_2-E_1)/KT} - 1} \right]$$ —— (G)

c → velocity of light
K = Boltzmann constant)

Compare eq (E) and (G), we get

$$\boxed{\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}}$$

$\therefore \frac{B_{12}}{B_{21}} = 1$

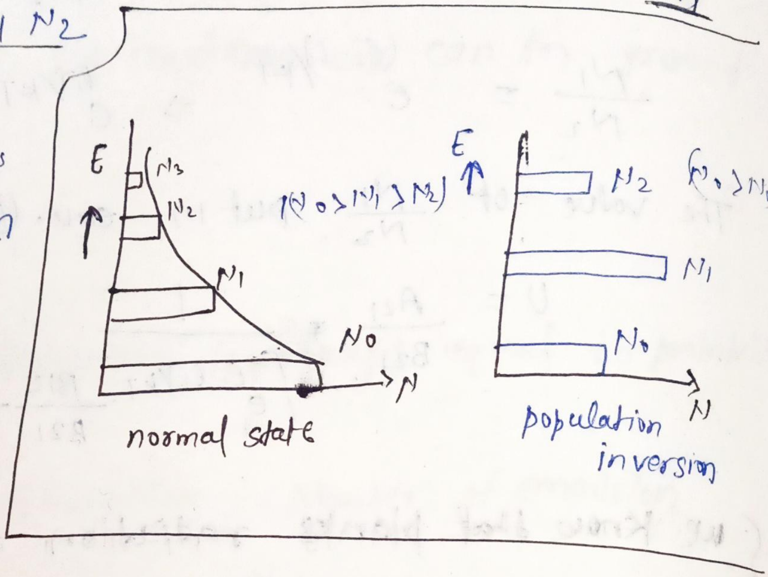
$$\boxed{B_{12} = B_{21}}$$

Imp- POPULATION INVERSION

→ At Normal state in any material number of ground state atom N_1 is always greter than number of atom in exited state N_2 $(N_1 > N_2)$

But by some reayons, if Number of atoms in exited state N_1 and N_2 is greater than ground state atoms N_0, This condition is known as population inverssion.

This population inversion is responsibe for layer ~~action~~ action.



BASIC Part → There are three basic part of any layer.

① Active substance ② Pumping source ③ optical Resonator.

Active substance → Substance which have meta stable state is known as active substance of layer.

Meta stable state energy state are broad energy level which have relaxtion time is the order 10^{-3} sec (normally farell relax. time 10^{-8} sec)

for Ruby Laser — active substance is ruby crystal.
($Al_2CO_3 + Cr^{+++}$)

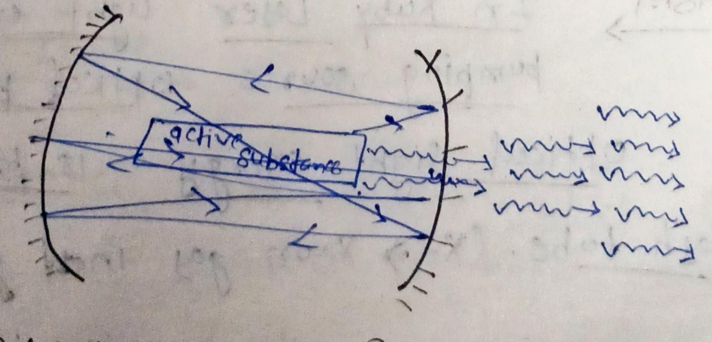
for He-Ne-Laser — active substance is mixture of He Ne gas.

Pumping source → To ~~produce~~ provide energy to ground state atom the exited atom, we use energy source known as pumping source. pumbing is a process by which we get population inversion.

for Ruby Laser — optical pumping is used by Xe flash tube

for He-Ne Laser — electronic pumping is used by ~~...~~ of coils

Optical Resonator OR Resonant cavity → To control laser action loss due to sponteneous emission we use combination of two mirrors M_1, M_2 as in figure. This combination is known as Resonator.



RUBY LASER

(THREE LAVEL LASER OR PULSE LASER) (SOLID (a

Basic part of Ruby Layer

① Active Substance ② pumping source ③ Optical Resonator.

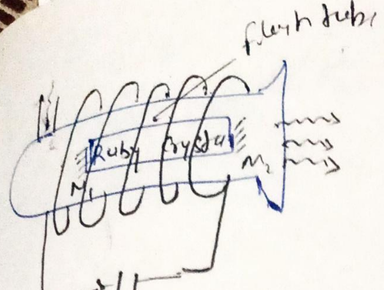
ⓐ Active substance → Substance which have metastable state known ay Active substance.

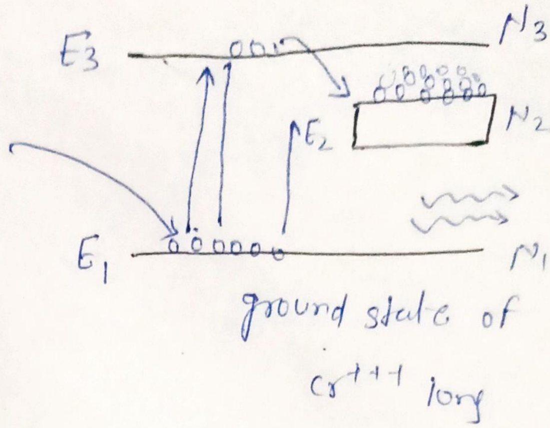
In Ruby laser. Ruby crystal is Active Substance. Ruby crystal is the crystal of Al_2O_3 with Cr^{+++} ions, Cr^{++} work ay Active medicon.

Active crystal → $Al_2O_3 + Cr^{+++}$

ⓑ Pump of machanism → In Ruby Layer light energy is used for pumping source optical pumping is used. Optical light energy is produced by Xe-flash tube. (Xe → Xeon gay inert gas.)

Optical Resonator → It is made by two curved mirror one is fully polished and other is partially pollished





working → when we give the energy to ground state atom of Cr+++ it absorb the energy and jumb into higher state. Due to metastable state E_2 population inversion can produced Layer be.

Ruby Layer produced pulse o/p due to flash action of Xe.tube

He-Ne LASER →

CONSTRUCTION →

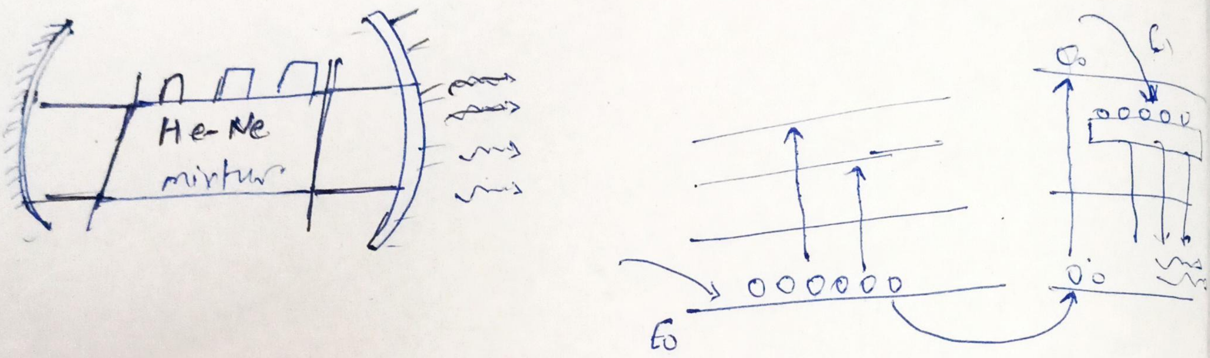
Basic part of LASER →

① Active substance → substance which have metastable state is known as Active substance.

· This is the mixture of He-Ne gas in the ratio 7:1, population inversion in creat in Ne gas.

pumping mchonism → Electrical pumping is used in Gaseous layer Electrical energy is produced by g-f coil or Trayformar.

Optical Resonator, Combination of two mirror m_1 and m_2 and control the Layer action.



working → when electron connected to current electrical charge is produced in the gas. He and Ne gas get exited and create population in version in Ne gas. Due to Next dischrage of electron atom present in metastable state Em, produces contineous Layer beam.

lication of Layer,

(1) Due to hught monochromatic highly Cohrent beam Layer is used in

Interference experiment.

(11) used in earth scattered and Rocket.

(3) use to make HOLOGRAMS

(4) In the optical communication

(5) used for cutting drilling and welding.

OPTICAL FIBRE

Communication → Transportation of any signal or energy from one place to other is known as communication.
eg:- by wire transmission, by air, etc.

Optical fibre is the one of the medium through which we can communicate signal from one place to other in form of light.

wave lenght range = 1.7×10^{-6} m to 0.8×10^{-6} m

Principal of optical fibre → Total internal reflection is the basic principal of fibre. TIR can produced due to substance of different refractive index.

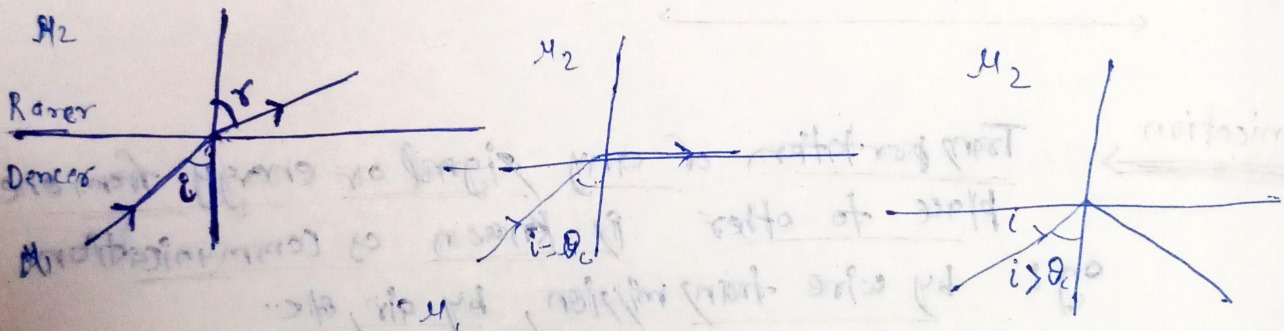
Construction of optical fibre →

Optical fibre is wave guide for light. optical fibre is constructed by

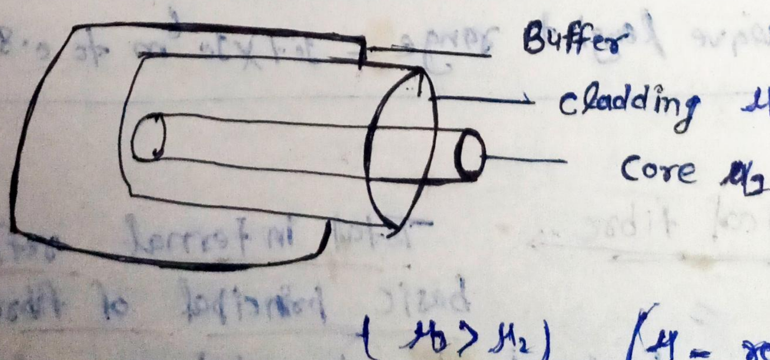
Core – inner part where light propagates.

cladding – middle part or curve of core which is used for TIR

Buffer → protective coating.



TIR $(\mu_1 > \mu_2)$



$(\mu_1 > \mu_2)$ (μ – refractive index)

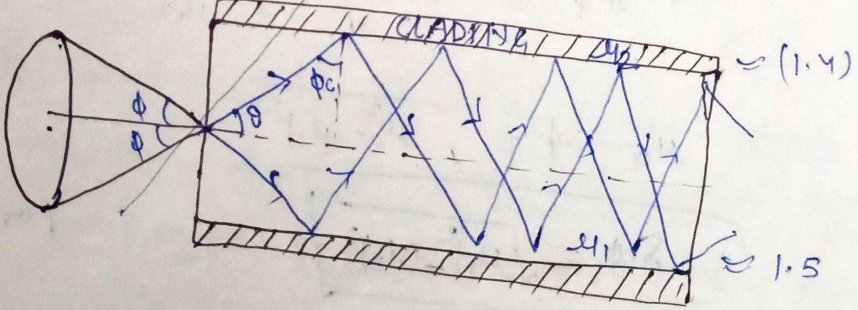
ACCEPTANE ANGLE ACCEPTANCE CONE

(Numericals appere fore) :

① Acceptance angle → acceptance angle (ϕ) is an angle which can cause total internal reflection (TIR) is known as acceptance angle.

② acceptance cone → If we consider acceptance angle as the semi angle of cone and rotate, we get cone shape, which is known as acceptance cone.

All the light beam which passes from the cone produce TIR inside the optical fibre.



ϕ = incident angle ϕ_c = critical angle.

$\mu_a \sin\phi = \mu_1 \sin\theta$ —— (A)

$\mu_1 \sin\phi_c = \mu_2 \sin 90^\circ$ —— (B)

$\theta + \phi_c + 90 = 180^\circ \Rightarrow \phi_c = 90 - \theta$ —— (C)

$\phi, \psi_c = ?$

using B $\quad \sin\psi_c = \dfrac{\mu_2}{\mu_1}$

$$\boxed{\phi_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)}$$

again using (B)

$$\mu_1 \sin\phi_c = \mu_2$$

$$\mu_1 \sin(90-\theta) = \mu_2$$

$$\cos\theta = \frac{\mu_2}{\mu_1}$$

$$\boxed{\theta = \cos^{-1}\left(\frac{\mu_2}{\mu_1}\right)}$$

from (A)

$$\mu_a \sin\phi = \mu_1 \sqrt{1 - \frac{(\mu_2)^2}{\mu_1^2}}$$

$$\mu_a \sin\phi = \sqrt{\mu_1^2 - (\mu_2)^2}$$

$$\boxed{\sin\phi = \sqrt{(\mu_1)^2 - (\mu_2)^2}}$$

for air $\mu_a = 1$

N.A $\quad \boxed{\mu_a \sin\phi = \sqrt{\mu_1^2 - \mu_2^2}}$

$\mu_a \rightarrow$ reflective index

$\mu_1 \rightarrow$ refractive index

$\mu_2 \rightarrow$ refractive index cladding

ϕ = acceptance angle

Attencualtion in fibre ->

Attenceation is the loss or reduction of signal strenght or light power over the lenght of light carrying medium (fibre). The attenuation factor of fibre is very very less than copper and co-axial cable. Low atteration causes no need of amplification to travell more than 100 K.

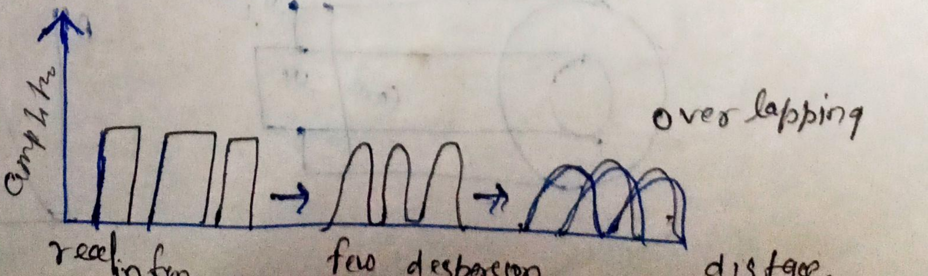
Attenuation

- absorption Loss
- scattering Loss

$$\text{attenuation Loss} = -10 \log_{10}\left(\frac{P_o}{P_i}\right)$$

where P_i -> power inter in fibre
P_o -> power out from fibre

Dispersion -> Braading of signal with lenght which can caus distortion of information. Light signals is known as Dispersion. In digital communication, the information to be transmitted is coded in form of light pulse and then propagate through fibre. The impact of dispersion is just like figure.



Types of Dispersion

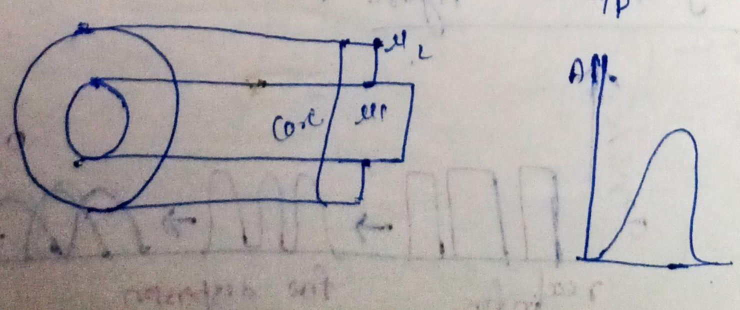
(i) Material dispersion → Due to refractive index of core material pulse can broaded. This is called the material dispersion.

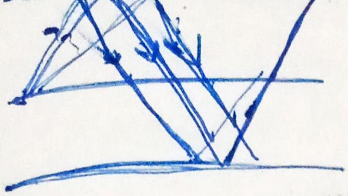
(2) wave guide dispersion → Because of wave (light) guiding structure pulse of light broadens then dispersion is known as wave guide dispersion.

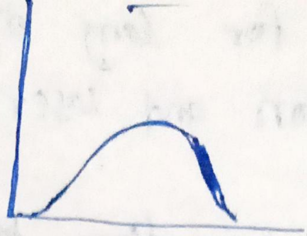
(3) ~~multimode~~ Intermode fibre → In multimode fibre, ~~the~~ broading of signal is caused by spreed in group velocityes, this type of dispersion is known as inter mode dispersion.

Types of optical fibre → On the basic of design ~~and refractive~~ refractive index profile of core and cladding it is devided into three types;

(1) step Index multimode fibre (MMF) ;







diameter range ;

Core — 20– 100 μm

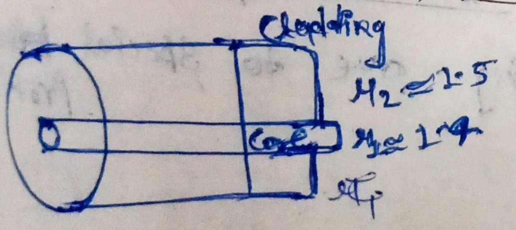
cladding — 100– 200 μm

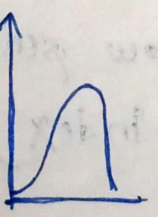
⇒ refractive index difference is larger then other type of index i.e $\mu_1 >>> \mu_2$

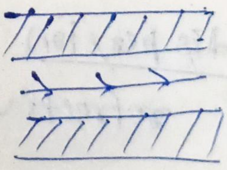
⇒ It is used for short distance (< 200 m) due to dispersion.

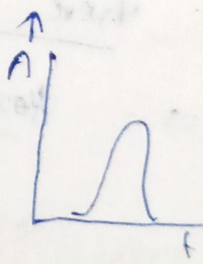
⇒ low cost high efficiency and light propagation is easy to transmit.

⇒ Single mode fibre (SMF)









⇒ diameter range :-

Core → 8 – 10 μm

Cladding → 10 – 100 μm

⇒ refractive index is very close.

⇒ it is used for long distance communication due to low dispersion and laser.

⇒ Only one information passes at a time.

⇒ fabricaloom is very diffcult due to very fine diameters.

③ Graded index multimode fibre → in this type of fibre; refractive index of core is not constant

⇒ diameter range :-

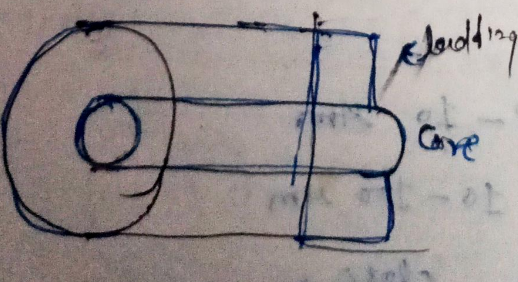
Core - 20 - 80 μm

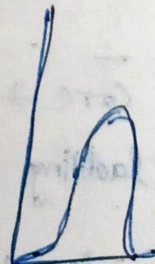
cladding - 80 - 200 μm

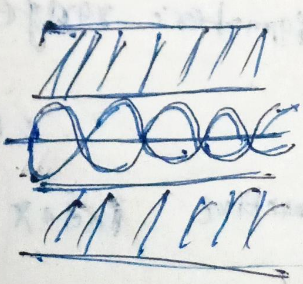
⇒ refractive index of core is increse from surface of core to centre of core.

⇒ propagation of wave is in hellical form because there of no. refrective by cladding boundry

⇒ How dispersion low scattering due to special profile of refractive index;







$t_0 = 4$ years

$t_m = ?$

$v = 0.8c$

$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} =$

Gauss divesion theorem;

$$\oint_s \vec{A} \cdot dA = \oint_v (\nabla \cdot A)\, dV$$

There are three types optical fibers.

(i) index step multimode fibre. (MMF) → core - 20-200; clad → 200-200 μm

(ii) single mode fibre (SMF) → core 8-12; cl. 70-100 μm

(iii) graded index multimode fibre (IMF) → core - 20 μm - 80 μm; clad 80 μm - 200 μm

"जरूरत से ज्यादा आराम और हद से ज्यादा प्रेम इंसान को अपाहिज बना देता है।"