MODULE - 01

LASERS AND OPTICAL FIBERS

LASERS

The word Laser stands for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. It is a device which amplifies light. It has properties like Coherence, Unidirectional, Monochromatic, Focus ability, etc.

Interaction of an electromagnetic wave with matter leads to transition of an atom or a molecule from one energy state to another. If the transition is from lower state to higher state it absorbs the incident energy. If the transition is from higher state to lower state it emits a part of its energy.

Emission or Absorption takes through quantum of energy called photons. $h\nu$ is called quantum energy or photon energy.

$h = 6.626\times10^{-34}$ Joules Second is Planck's constant and 'ν' is the frequency.

If ΔE is the difference between the two energy levels,

Then $\Delta E = (E_2 - E_1)$ Joule

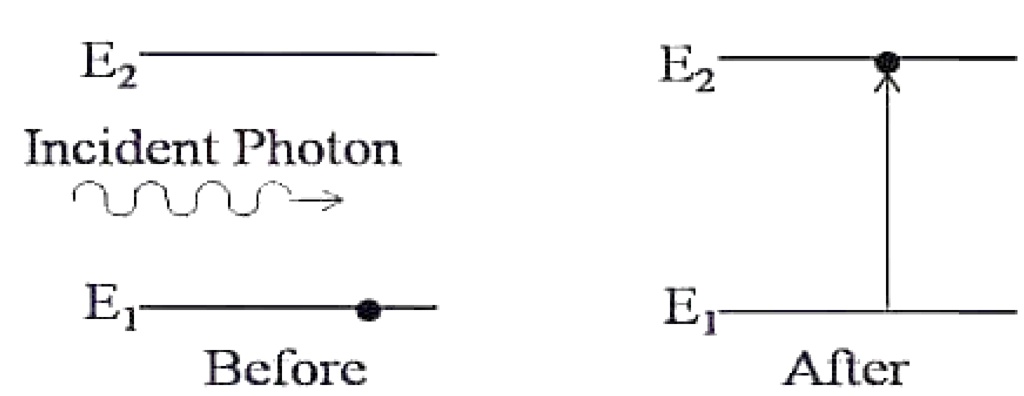
According to Max Planck, $\Delta E = h\nu = (E_2 - E_1)$

$\nu = (E_2 - E_1)/h$ Hz.

Three types of interactions, which are possible, are as follows:

1)Induced Absorption:

Induced absorption is the absorption of an incident photon by system as a result of which the system is elevated from a lower energy state to a higher state, wherein the difference in energy of the two states is the energy of the photon.



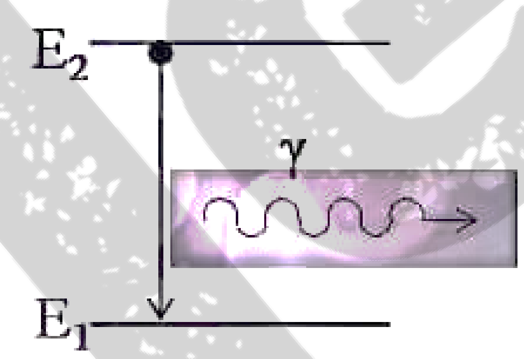
Consider the system having two energy states E_1 and E_2, $E_2 > E_1$. When a photon of energy $h\nu$ is incident on an atom at level E_1, the atom goes to a higher energy level by absorbing the energy.

When an atom is at ground level (E_1), if an electromagnetic wave of frequency ν is applied to the atom, there is possibility of getting excited to higher level (E_2). The incident photon is absorbed. It is represented as

$$\text{Atom} + \text{Photon} \rightarrow \text{Atom}^*$$

2) Spontaneous Emission: The emission of a photon by the transition of a system from a higher energy state to a lower energy state without the aid of an external energy is called spontaneous emission.

Let 'E_1' and 'E_2' be two energy levels in a material, such that $E_2>E_1$. E_1 is ground level and E_2 is the higher level. $h\nu=E_2-E_1$ is the difference in the energy. The atom at higher level (E_2) is more unstable as compared to that at lower level (E_1).



The life time of an atom is less in the excited state, In spontaneous emission atom emits the photon without the aid of any external energy. It is called spontaneous emission. The process is represented as

$$\text{Atom}^* \rightarrow \text{Atom} + \text{Photon}$$

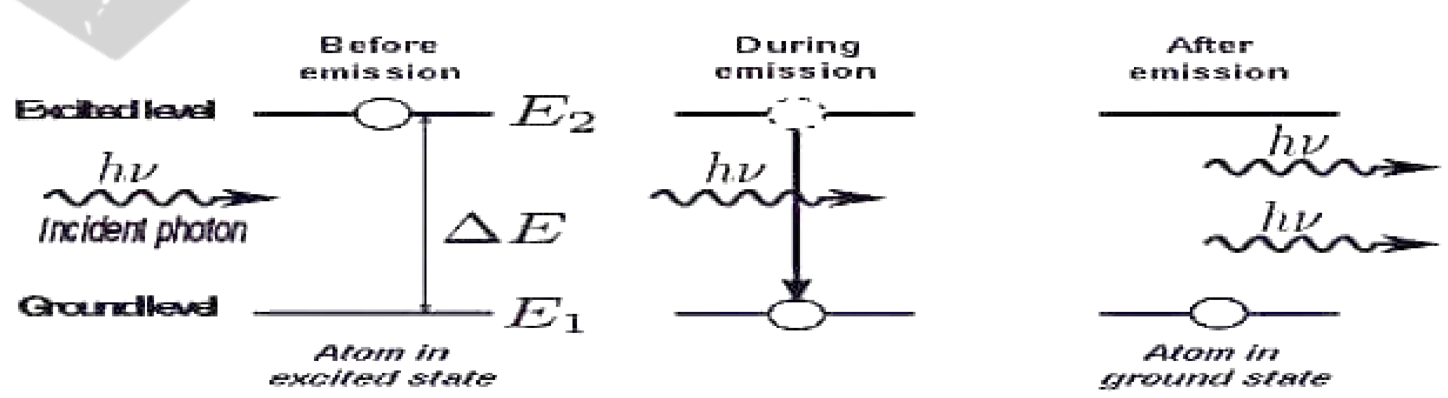
The photons emitted in spontaneous emission may not have same direction and phase similarities. It is incoherent.

Ex: Glowing electric bulbs, Candle flame etc.

3) Stimulated Emission:

Stimulated emission is the emission of a photon by a system under the influence of a passing photon of right energy due to which the system transits from a higher energy state to a lower energy state.

The photon thus emitted is called stimulated photon and will have the same phase, energy and direction of movement as that of the passing photon called the stimulation photon.



$$E_2 - E_1 = \Delta E = h\nu$$

Initially the atom is at higher level E_2. The incident photon of energy hν forces the atom to get de-excited from higher level E_2 to lower level E_1.

i.e. $h\nu = E_2 - E_1$ is the change in energy.

The incident photon stimulates the excited atom to emit a photon of exactly the same energy as that of the incident photons. The emitted two photons have same phase, frequency, direction and polarization with the incident photon and results in coherent beam of radiation. This kind of action is responsible for lasing action.

$$Atom^* + Photon \rightarrow Atom + (Photon + Photon)$$

Expression for energy density in terms of Einstein's Coefficients

Consider two energy levels E_1 and E_2 of a system of atoms with N_1 and N_2 are population of energy levels respectively.

Let U_ν be the energy density of incident beam of radiation of frequency γ.

Let us consider the absorption and two emission process

1) Induced absorption:

Induced absorption is the absorption of an incident photon by system as a result of which the system is elevated from a lower energy state to a higher state.

The rate of absorption is proportional to $N_1 U_\nu$

Rate of absorption = $B_{12} N_1 U_\nu$ .... (1)

Where 'B_{12}' is the proportionality constant called Einstein Coefficient of induced absorption.

2) Spontaneous emission:

The emission of a photon by the transition of a system from a higher energy state to a lower energy state without the aid of an external energy is called spontaneous emission.

Spontaneous emission depends on N_2 and independent of energy density.

The rate of spontaneous emission = $A_{21} N_2$ ....(2)

Where 'A_{21}' is called proportionality constant called Einstein coefficient of spontaneous emission.

3) Stimulated emission:

Stimulated emission is the emission of a photon by a system under the influence of a passing photon of just the right energy due to which the system transits from a higher energy state to a lower energy state

The rate of stimulated emission is directly proportional to N_2U_γ.

The rate of stimulated emission = $B_{21}N_2U_\nu$ .... (3)

Where 'B_{21}' is the proportionality constant called Einstein's Coefficient of stimulated emission.

At thermal equilibrium,

Rate of absorption = (Rate of spontaneous emission + Rate of stimulated emission)

$$B_{12}N_1U_\nu = A_{21}N_2 + B_{21}N_2U_\nu$$

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

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

$$\text{i.e. } U_\nu = \frac{A_{21}}{B_{21}}\left[\frac{N_2}{\left(\frac{B_{12}}{B_{21}}N_1 - N_2\right)}\right]$$

$$U_\nu = \frac{A_{21}}{B_{21}}\left[\frac{1}{\left(\frac{B_{12}N_1}{B_{21}N_2}\right) - 1}\right] \rightarrow (4)$$

By Boltzmann's law, $N_2 = N_1 e^{-\left(\frac{E_2 - E_1}{KT}\right)} = N_1\, e^{-h\nu/KT}$

i.e., $N_1/N_2 = e^{h\nu/KT}$

Eqn. (4) becomes $$U_\nu = \frac{A_{21}}{B_{21}}\left[\frac{1}{\left(\frac{B_{12}}{B_{21}} e^{\left(\frac{h\nu}{kT}\right)} - 1\right)}\right] \rightarrow (5)$$

By Planck's law, $U_\upsilon = \frac{8\pi h\upsilon^3}{c^3}\left[\frac{1}{\left(e^{\left(\frac{h\upsilon}{kT}\right)}-1\right)}\right]$ → (6)

Comparing equation (5) & (6)

$\frac{A_{21}}{B_{21}} = 8\pi h\nu^3/c^3$ & $\frac{B_{12}}{B_{21}} = 1$ i.e. $B_{12} = B_{21}$

The probability of induced absorption is equal to the stimulated emission.

Therefore, $A_{12}$is written as A and B_{12}, B_{21} written as B.

Equation (5) becomes

$$U_\upsilon = \frac{A}{B}\left[\frac{1}{\left(e^{\left(\frac{h\upsilon}{kT}\right)}-1\right)}\right]$$

Above equation is the expression for energy density

Condition for laser action:

***1)* Meta Stable State:**

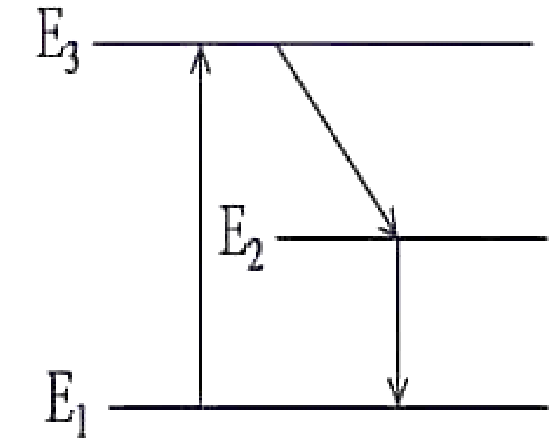
It is the special type of excited state where in the life time of atom is more than the normal excited state.

- This state plays an important role in lasing action.
- In metastable state, atoms stay for a time period of the order of 10^{-3} to 10^{-2} second.
- In normal excited state other than metastable atom stay of the order of 10^{-8} to10^{-9} seconds.
- It is possible to achieve population inversion condition in certain system which possesses a metastable state.

***2)* Population Inversion:**

It is the state of the system at which the population of a higher energy level is greater than that of the lower energy level.

Let E_1, E_2, E_3 be the energy levels of the system $E_3 > E_2 > E_1$. E_2 is the metastable state of the system. Atoms get excited from the state E_1 to E_3 by means of external source and stay there for short time. These atoms undergo spontaneous transitions to E_2 and E_1. The atoms at the state E_2 stay for longer time. A stage is reached in which the number of atoms at state E_2 is more than the number of atoms at E_1 which is known as population inversion.

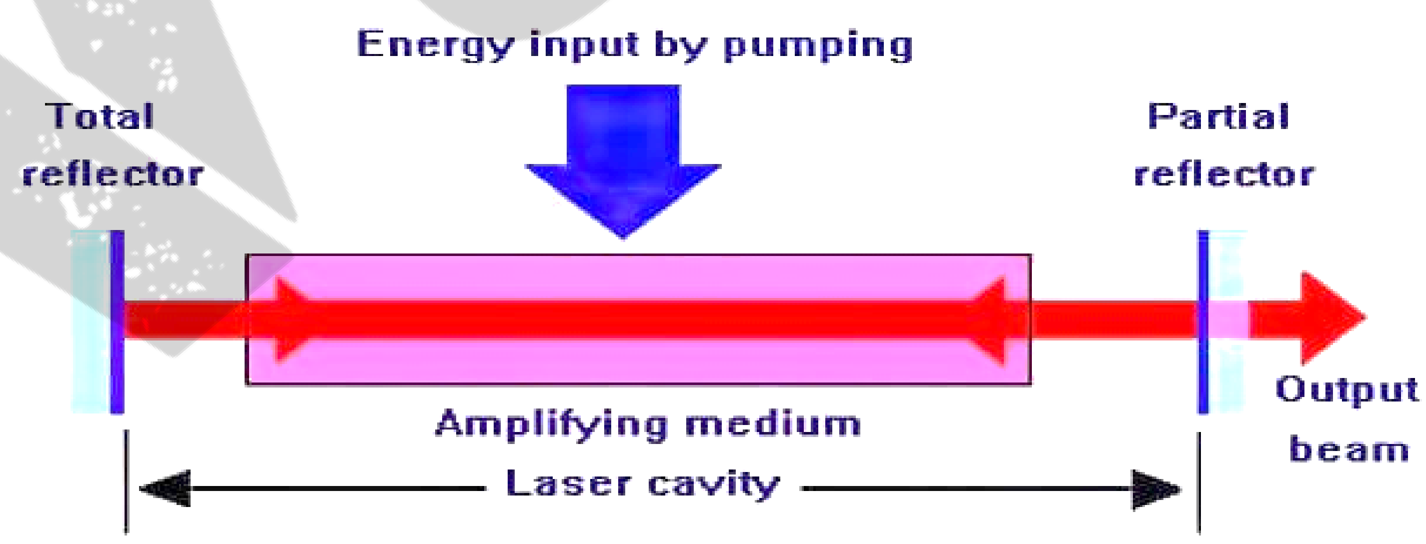


Requisites of a Laser System:

1) **The pumping process:**
It is the process of supplying energy to the medium in order to transfer it to the state of population inversion is known as pumping process
Optical Pumping: It is the process of exciting atoms from lower energy level to higher energy level by using high intensity light or by operating flash tube as an external source called optical pumping.
Electrical pumping: It is the process of exciting atoms from lower energy level to higher energy level by using dc power supply as an external source called electrical pumping.

2) **Active medium:**
It is a medium which supports population inversion and promotes stimulated emission leading to light amplification
Active centers: In a medium consisting of different species of atoms only small fraction of the atoms of a particular type are responsible for stimulated emission and consequent light amplification they are known as Active centers

3) **Laser cavity**.
An active medium bounded between two mirrors is called as a laser cavity.

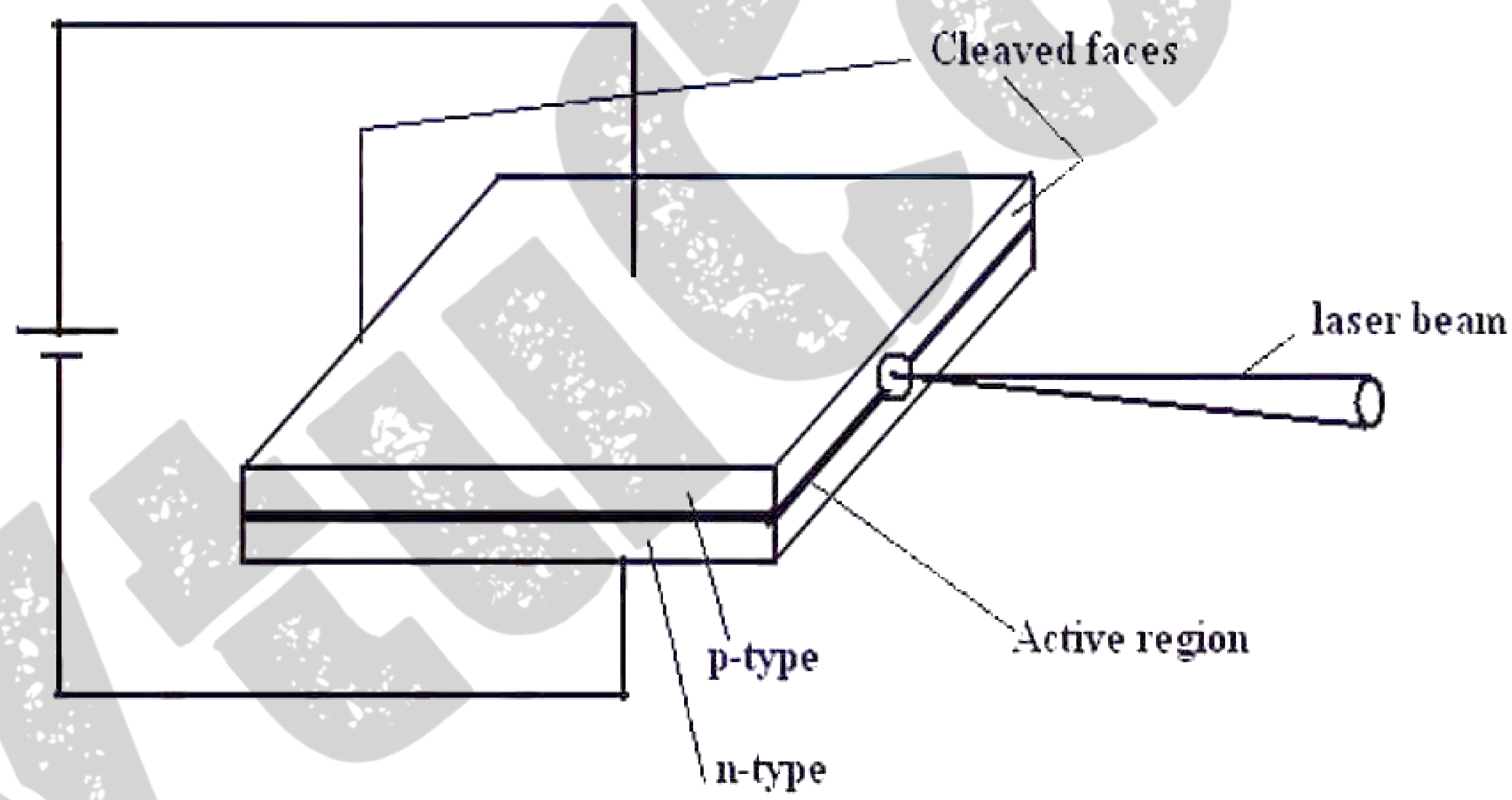


Gallium-Arsenide Laser Semiconductor laser:

A Semiconductor diode laser is one in which the active medium is formulated by semiconducting materials.

Construction:

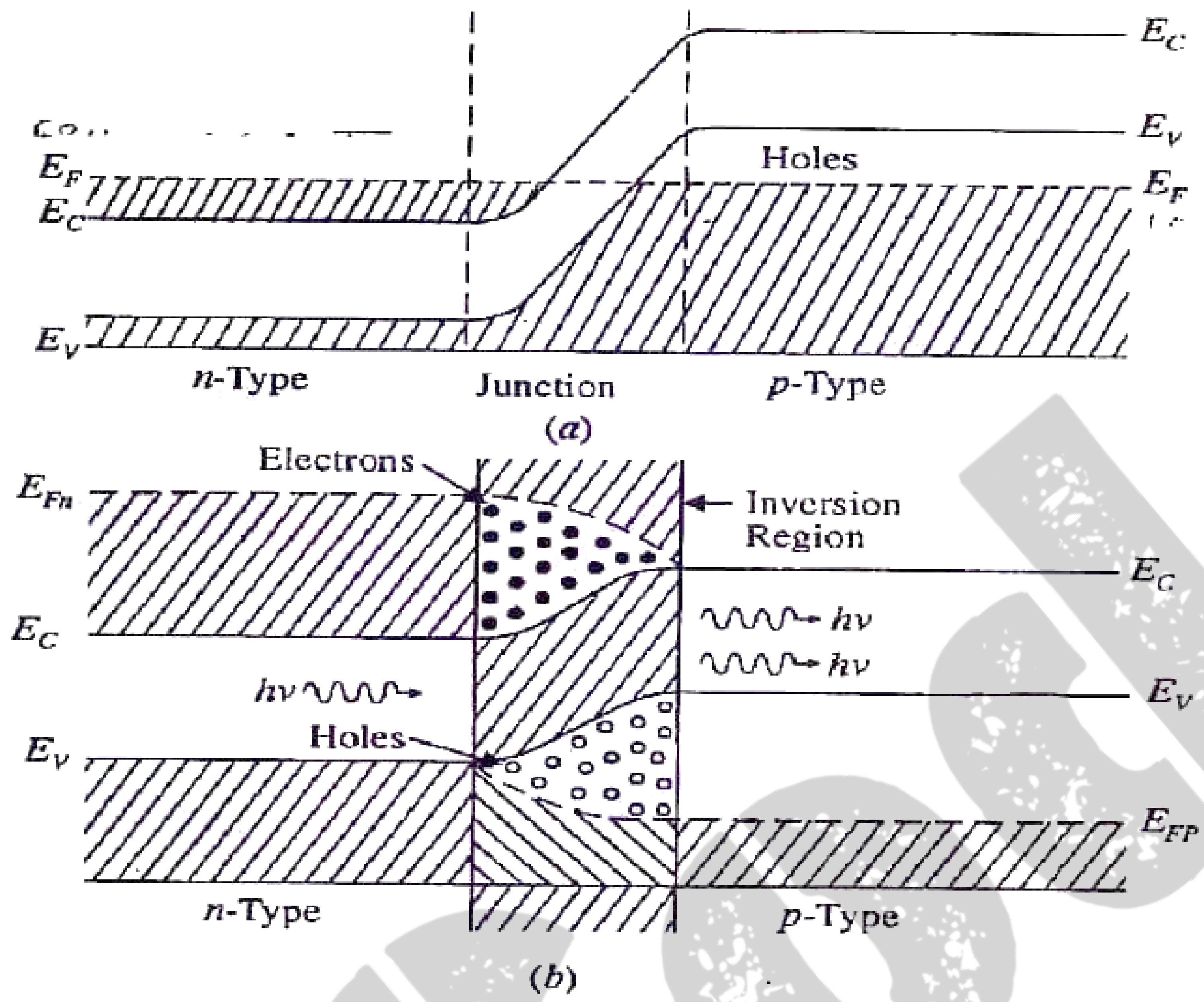
- Gallium-Arsenide Laser is a single crystal of GaAs consists of heavily doped n-type and p-type.
- The diode is very small size with sides of the order of 1mm.
- The width of the junction varies from 1-100μm.
- The top and bottom surfaces are metalized and Ohmic contacts are provided for external connection.
- The front and rear faces are polished. The polished faces functions as the resonant cavity. The other two faces are roughened to prevent lasing action in that direction.



Working:

- The energy band diagram of heavily doped p-n junction is as shown. At thermal equilibrium the Fermi level is uniform.
- Because of very high doping on **n- side**, the Fermi level is pushed in to the conduction band and electrons occupy the portions of the conduction band that lies below the Fermi level and

- on **p-side**, the Fermi level lies within the valence band and holes occupy the portions of the valence band that lies above the Fermi level.



Energy level diagram

(a) Before biasing (b) After biasing

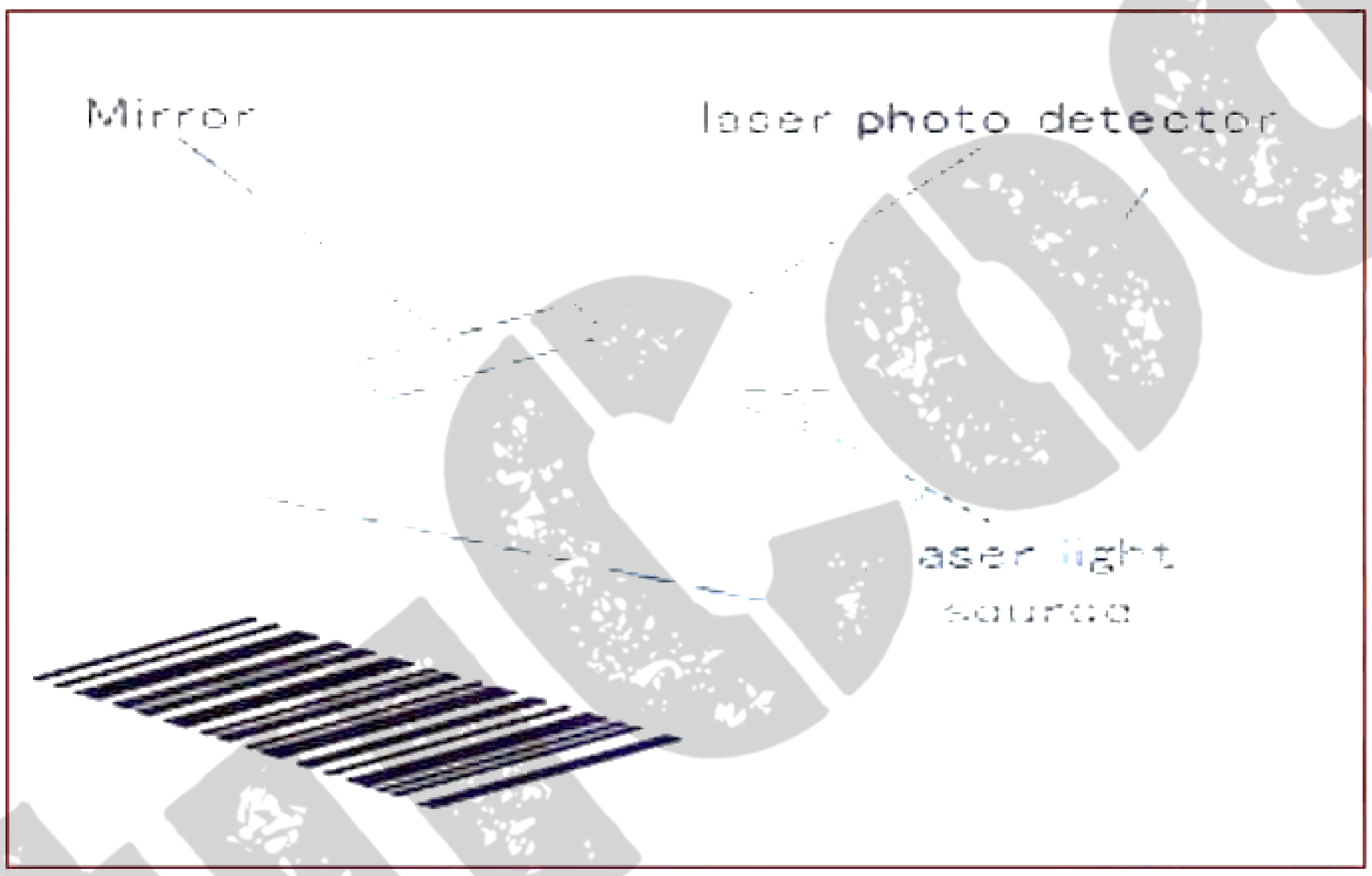
- A suitable forward bias is applied to overcome the potential barrier. As a result, electrons from n-region and holes from p-region injected into the junction.
- The current begins to flow following which there will be a region in junction in which the population inversion can be achieved.
- Initially concentration of electrons in the energy levels at the bottom of the conduction band will be less than that of energy levels at top of valence band. So that the recombination of electrons and holes result only in spontaneous emission.
- When the current exceeds the threshold value, population inversion is achieved in the active region which is formulated in the junction.
- At this stage the photons emitted by spontaneous emission triggers stimulated emission, over a large number of recombination leading to build up laser.
- Since the energy gap of GaAs is 1.4eV, the wavelength of emitted light is 8400 A° .

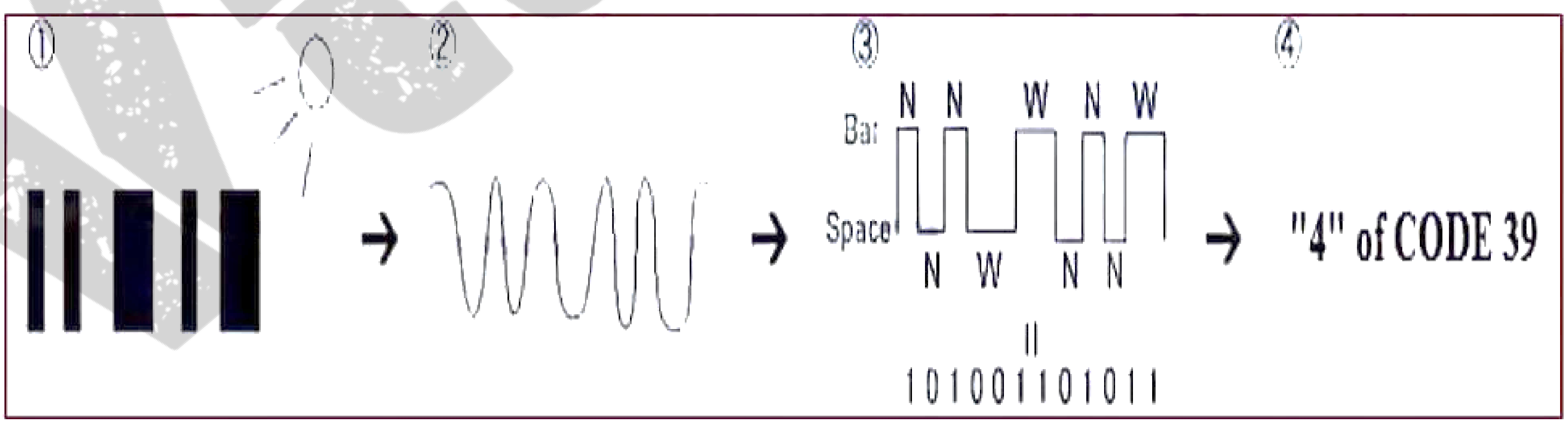
Properties of laser:

1. ***Coherence*:** The emitted radiation after getting triggered is in phase with the incident radiation.
2. ***Monochromaticity*:** The laser beam is highly monochromatic than any other radiations.
3. ***Unidirectionality*:** Laser beam travels in only one direction. It can travel long distance without spreading.
4. ***Focusability*:** A laser beam can be focused to an extremely fine spot.

Applications of Laser:

1. Laser barcode reading





➢ A bar code consists of a series of strips of dark and white bands. Each strip has a width of about 0.3 mm and the total width of the bar code is about 3 cm.

- Laser light reflected off a mirror is shine on the label surface and its reflection is captured by a sensor (laser photo detector) to read a bar code.
- Data retrieval is achieved when the photo detector captures the reflected light and replace the black and white bars with binary digital signals.
- Reflections are strong in white areas and weak in black areas. A sensor receives reflections to obtain analog waveforms.
- The analog signal is converted into a digital signal via an A/D converter.
- Data retrieval is achieved when a code system is determined from the digital signal obtained. (Decoding process).

NOTE: Information such as the country of origin, manufacturer of the product, the direction of scan, price, reading error checking, weight of the product, and expiry date can be stored in the pattern of dark and white strips. By a simple scanning, complete information regarding the product can be obtained.

2. Laser Printing:

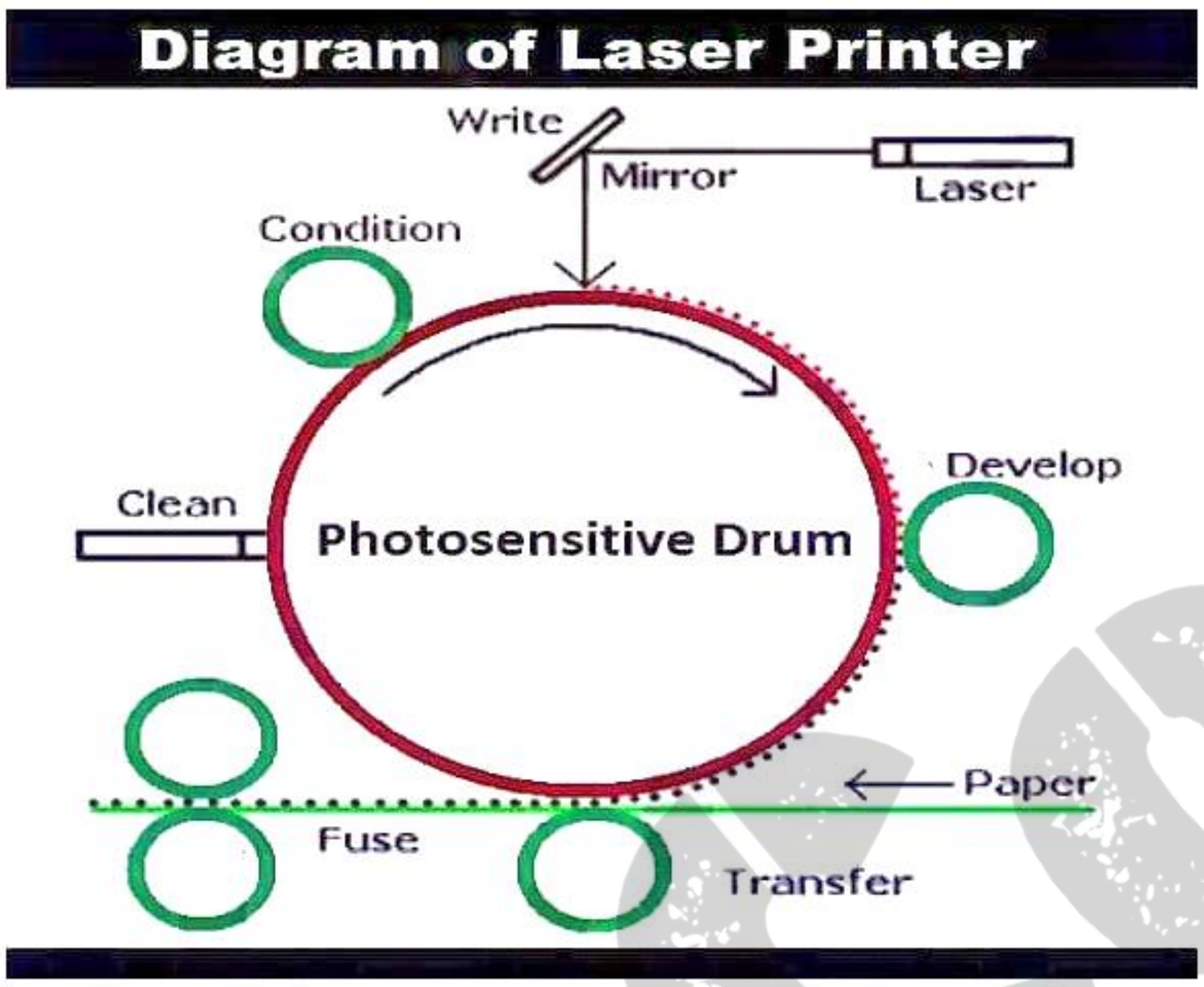
It is a digital printing device that are used to create the high quality text and graphics on a plain paper**. It reads the electronic data from your computer and beam this information onto a drum inside the printer which builds up a patron.**

It mainly consists of six steps as follows

1. **Image Processing:** Once you click on print command on a certain document the computer immediately send the information to laser printer internal memory and prepare for image processing.
2. **Charging:** The printer starts warmer, the corona wire heats up and get ready to transfer its positive static charge to the metallic drum.
3. **Exposing:** When the drum rotates it receives a positive charge throughout its surface. A laser is then activated and reflected throughout the drum surface. The reflected laser beam creates an outline of print through the negative electrical charge.
4. **Developing:** In the areas where the laser beam hits the drum, the charge is changed from negative to positive using developer. The positive charged areas now represent where toner particles will adhere to the drum and be directly transferred onto the paper. The ink roller now begins to coat the drum with toner.
5. **Transferring:** When a paper is now passed close to the drum, charged toner particles adhere onto the page in the same pattern of the Image.

6. **Fussing:** The paper, now containing the inked content, is passed into the fuser unit where the rollers fuse the toner particles to the paper. The page is then passed through the other side of the copier and you now have one successful printout.

Before Drum completes its revolution it is cleaned from residual toner using cleaner.



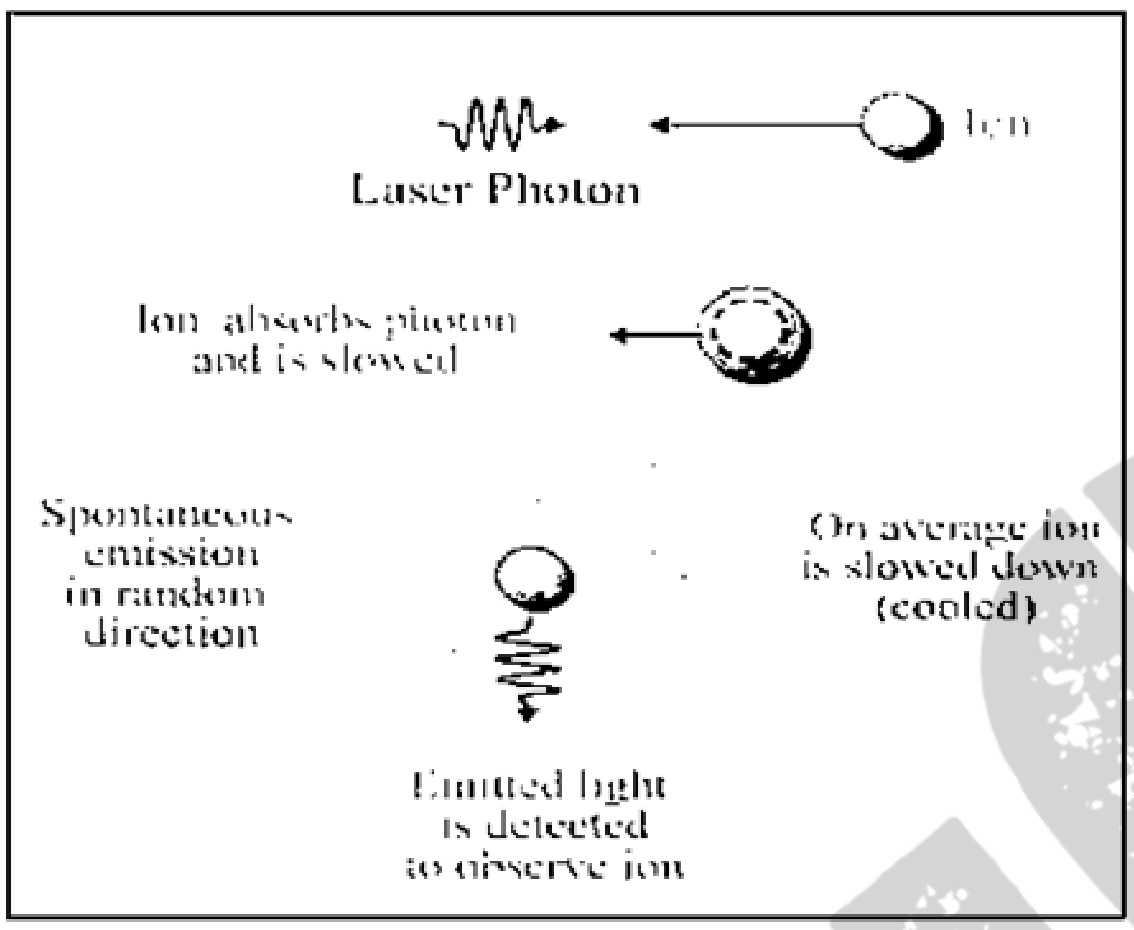
Negatively charged Drum

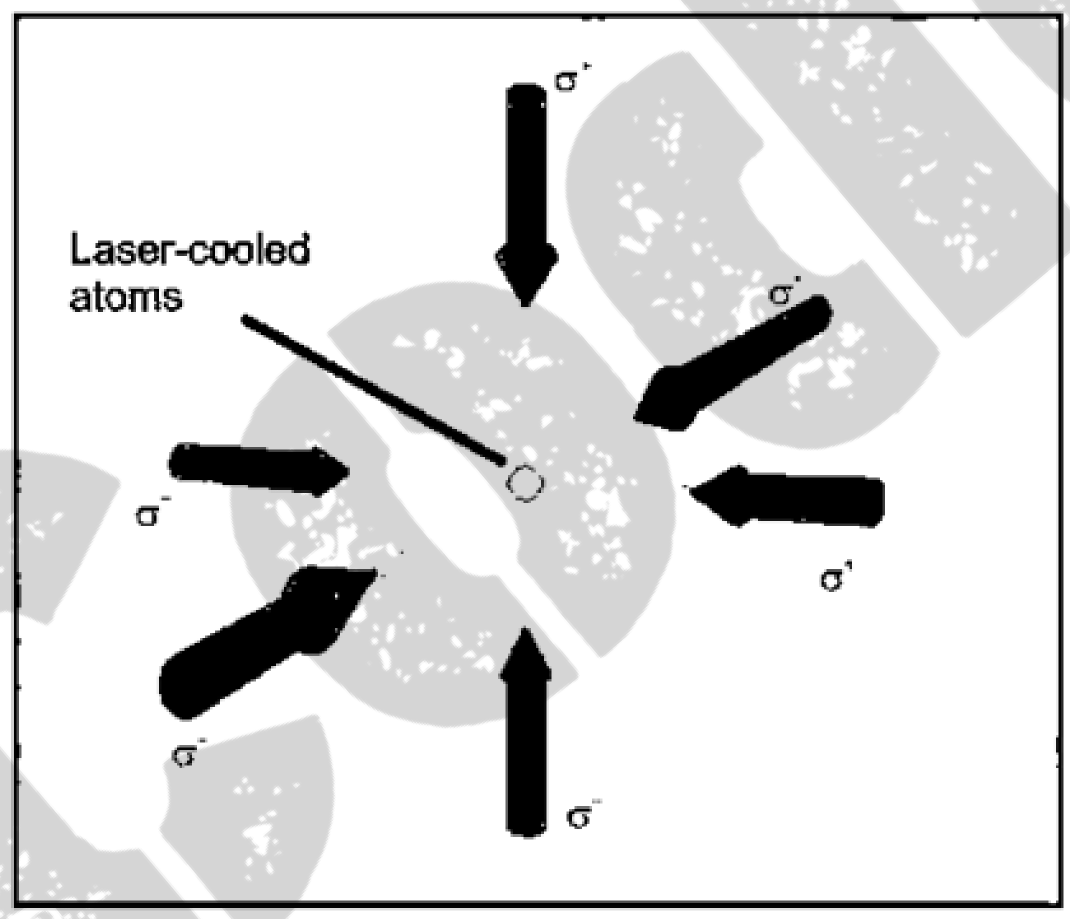
Advantages of Laser Printer

- The main advantage of Laser printer is its speed & efficiency at which prints high quality graphics & text.
- Laser printers produce high-quality output as compared to other printers.
- Laser printers are quite and does not produce disturbing sounds.
- They are also capable to produce color prints.

3. Laser cooling

- In this technique, heat can be removed optically with the help of laser.
- Atoms can be cooled using lasers because light particles from the laser beam are absorbed and re-emitted by the atoms, causing them to lose some of their kinetic energy.
- Reduction in the momentum results in the reduction in temperature of atom i.e $P = \frac{E}{C} = \frac{h}{\lambda}$.
- After thousands of such impacts, the atoms will be chilled near to zero Kelvin.
- This cooling is also called Doppler cooling.





OPTICAL FIBERS

An optical fiber is a cylindrical wave guide made of transparent dielectric material (glass or plastic) which guides light waves along its length by total internal reflection.

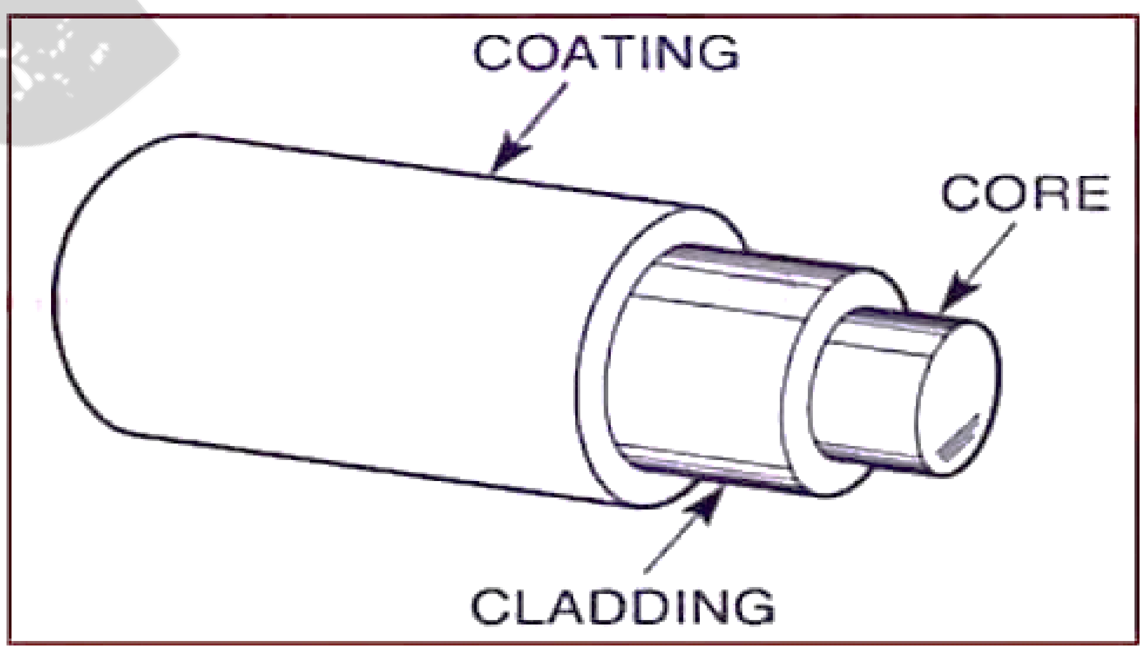
Principle

The propagation of light in an optical fiber from one end to the other end is based on the principle of Total internal reflection(TIR). They are used in optical communication.

When a light enters one end of the fiber, it undergoes successive total internal reflections from side walls and travels down the length of the fiber along zigzag path.

Construction

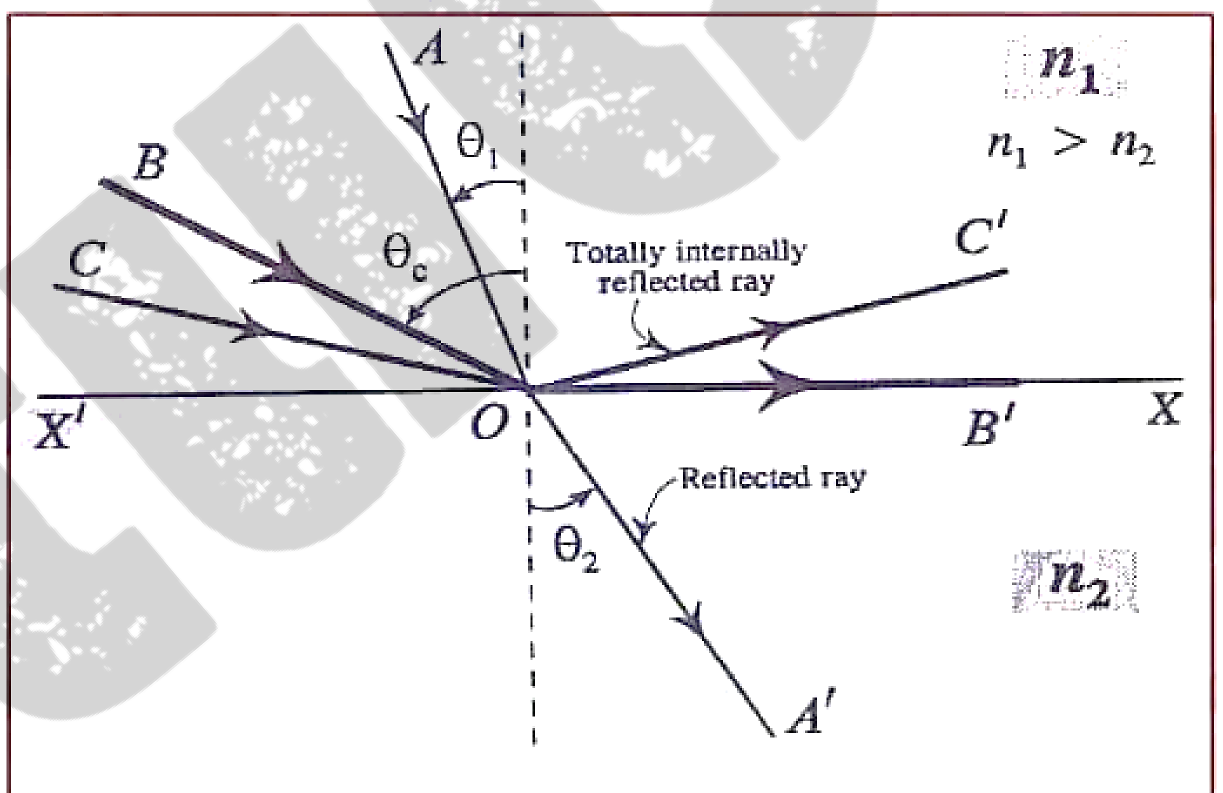
- A practical optical fiber is cylindrical in shape and has three regions.
- The innermost cylindrical region is the light guiding region called as core which is usually made up of glass or plastic.
- The outer part which is a concentric cylinder surrounding the core is called as cladding and is also made up of similar material but of lesser refractive index.
- The outermost region is called a Sheath or Protective buffer coating, nothing but the plastic coating providing a physical and environmental protection for the fiber. Number of such fibers is grouped to form a cable.



Total Internal Reflection:

- When a ray of light travels from denser to rarer medium it bends away from the normal.
- As the angle of incidence increases in the denser medium, the angle of refraction also increases. For a particular angle of incidence called the "*critical angle*" (θ_c), the refracted ray grazes the surface separating the media or the angle of refraction is equal to 90°.
- If the angle of incidence is further increased beyond the critical angle, the light ray is reflected back to the same medium. This is called *"Total Internal Reflection"*.
- In total internal reflection, there is no loss of energy. The entire incident ray is reflected back.

Let XX^1 is the surface separating medium of refractive index n_1 and medium of refractive index n_2, $n_1 > n_2$. AO and OA^1 are incident and refracted rays. θ_1 and θ_2 are angle of incidence and angle of refraction, $\theta_2 > \theta_1$. For the ray BO, θ_c is the critical angle. OB^1 is the refracted ray which grazes the interface. The ray CO incident with an angle greater than θ_C is totally reflected back along OC^1.



TOTAL INTERNAL REFLECTION

From Snell's law,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

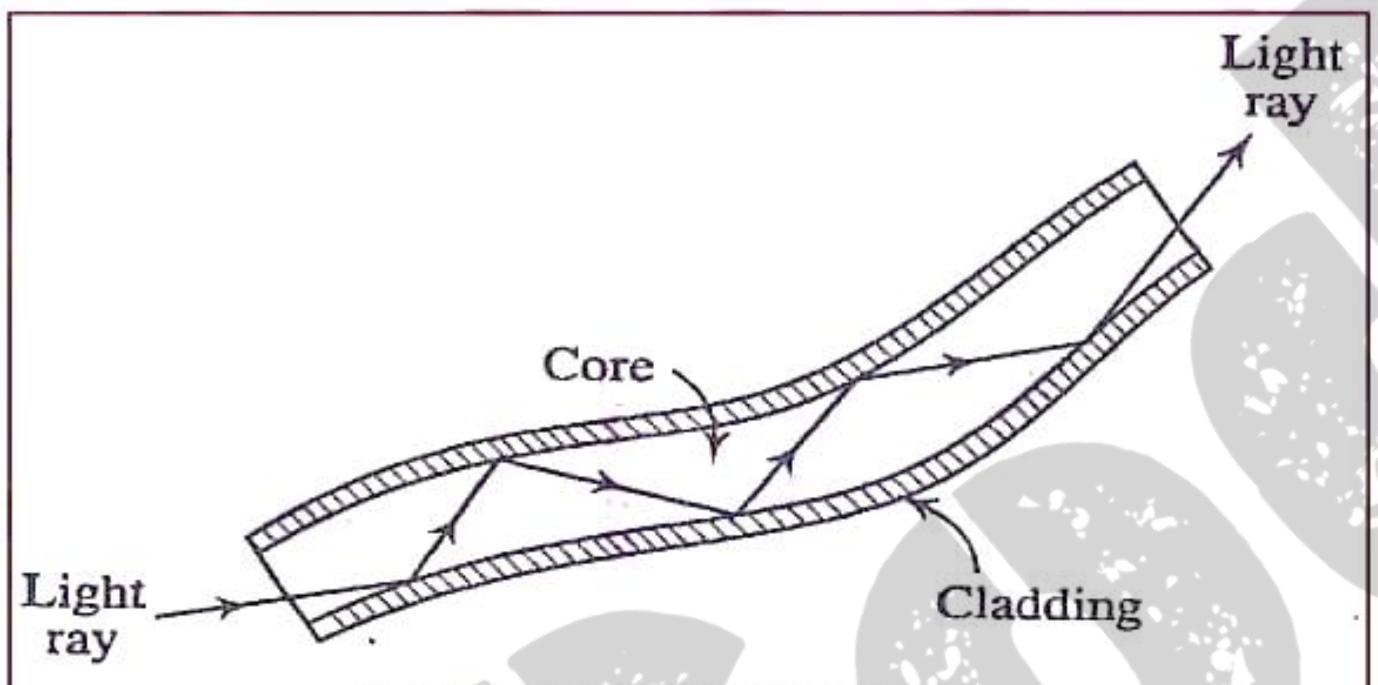
For total internal reflection, $\theta_1 = \theta_c$ and $\theta_2 = 90°$

$$n_1 \sin\theta_c = n_2 \qquad \text{(because } \sin 90° = 1\text{)}$$

$$\therefore \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

In total internal reflection there is no loss or absorption of light energy. The entire energy is returned along the reflected light. Thus is called Total internal reflection.

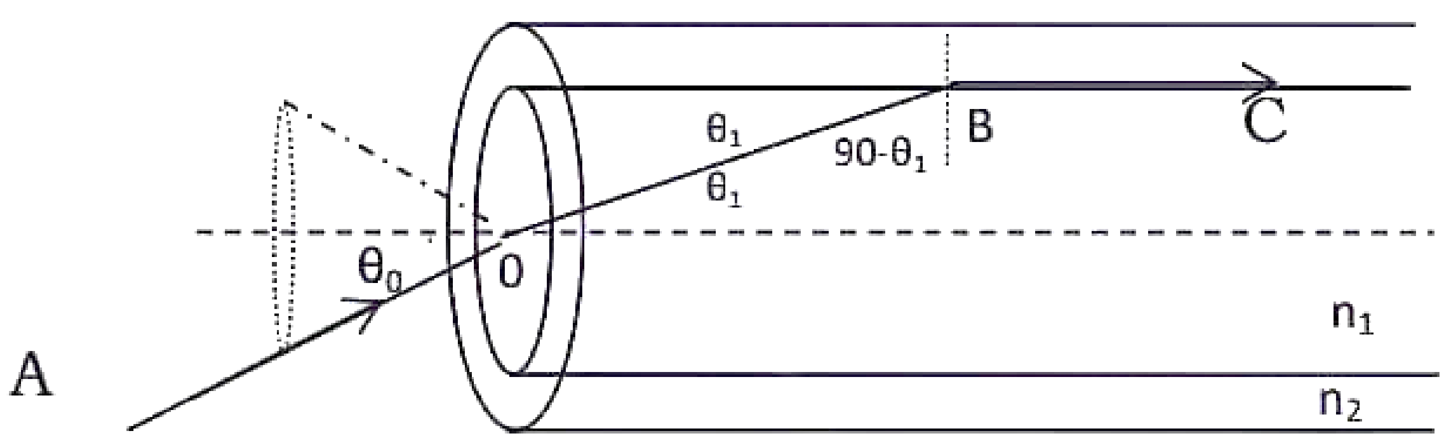
Propagation mechanism



FIBER AS A WAVEGUIDE

- The cladding in an optical fiber always has a lower refractive index than that of the core.
- The light signal which enters into the core and strikes the interface of the core and cladding with an angle greater than the critical angle will undergo total internal reflection.
- Thus the light signal undergoes multiple reflections within the core and propagates through the fiber.
- Since each reflection is a total internal reflection, there is no absorption of light energy at the reflecting surface.
- Therefore, the signal sustains its strength and also confines itself completely within the core during the propagation.
- After series of such total internal reflection, it emerges out of the core. Thus the optical fiber works as a waveguide. Care must be taken to avoid very sharp bends in the fiber because at sharp bends, the light ray fails to undergo total internal reflection.

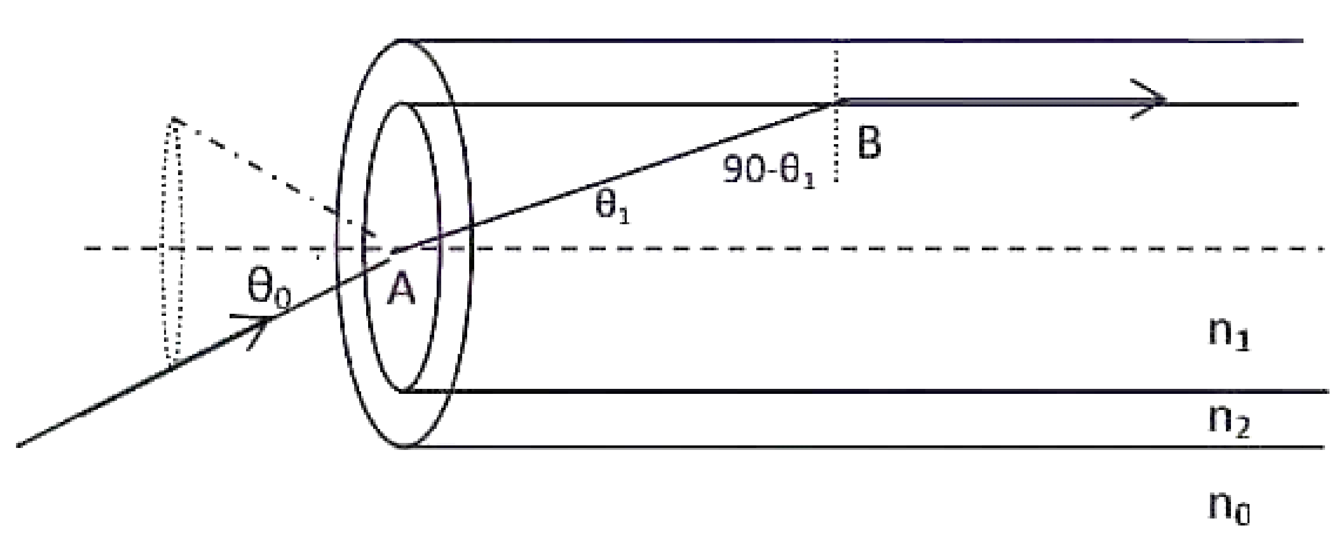
Acceptance angle and numerical aperture



Surrounding medium (n_0)

- Consider a light ray entering into the core of an optical fiber with an angle of incidence(θ_0), such that after entering, the ray incidents on the core-cladding interface with an angle of incidence equal to the critical angle.
- From figure it is clear that any ray which enters into the core with an angle more than θ_0, will have to be incident at an angle less than the critical angle at the core-cladding interface.
- Therefore, the ray does not undergo total internal reflection and the ray will be lost. Thus for any ray to propagate through the fiber it must enter with an angle less than θ_0. This maximum angle is called as 'Acceptance angle' and the conical surface described by the ray when rotated about the axis of the fiber is called 'Acceptance cone'.
- Thus acceptance angle is defined as **"The maximum angle that a light ray can take relative to the axis of the fiber to propagate through the fiber".**
- **Sine of the acceptance angle of an optical fiber is called as "Numerical aperture".**

Expression for Numerical aperture and condition for propagation



Consider a light ray entering into the core of an optical fiber with an angle of incidence(θ_0), such that after entering, the ray incidents on the core-cladding interface with an angle of incidence equal to the critical angle.

Let n_0, n_1 and n_2 are the refractive indices of the surrounding medium, core and cladding respectively.

Now, applying Snell's law at the point of entry of the ray i.e., at A,

$$n_0 \sin\theta_0 = n_1 \sin\theta_1$$

$$\sin\theta_0 = \frac{n_1}{n_0}\sin\theta_1 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Applying Snell's law at B,

$$n_1 \sin(90-\theta_{1)} = n_2 \sin 90$$

$$n_1 \cos\theta_1 = n_2 \sin 90$$

$$\Rightarrow \cos\theta_1 = \frac{n_2}{n_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From expression (1) $\quad \sin\theta_0 = \frac{n_1}{n_0}\sqrt{1-\cos^2\theta_1}$

Substituting for $\cos\theta_1$ from (2)

$$\sin\theta_0 = \frac{n_1}{n_0}\sqrt{1-\frac{n_2^2}{n_1^2}}$$

$$\sin\theta_0 = \frac{n_1}{n_0}\sqrt{\frac{n_1^2-n_2^2}{n_1^2}}$$

$$\sin\theta_0 = \frac{\sqrt{n_1^2-n_2^2}}{n_0}$$

If n_0=1 i.e., surrounding medium if it is air

$$\sin\theta_0 = \sqrt{n_1^2-n_2^2}$$

$$\text{i.e., } N.A. = \sqrt{n_1^2-n_2^2}$$

Condition for propagation:

If θ_i is the angle of incidence of the incident ray, then the ray will be able to propagate,

$$\text{if } \theta_i < \theta_0$$

$$\Rightarrow if\ sin\,\theta_i < sin\,\theta_0$$

$$or\ sin\,\theta_i < \sqrt{n_1^2 - n_2^2}$$

$$i.e.,\ sin\,\theta_i < N.A.$$

Fractional index change(Δ)

The ratio of the difference in refractive index of core and cladding to the refractive index of core of an optical fiber. $i.e., \Delta = \frac{n_1 - n_2}{n_1}$

Refractive index profile:

The curve which represents the variation of refractive index when it moves radially outwards from the fiber axis is called refractive index profile.

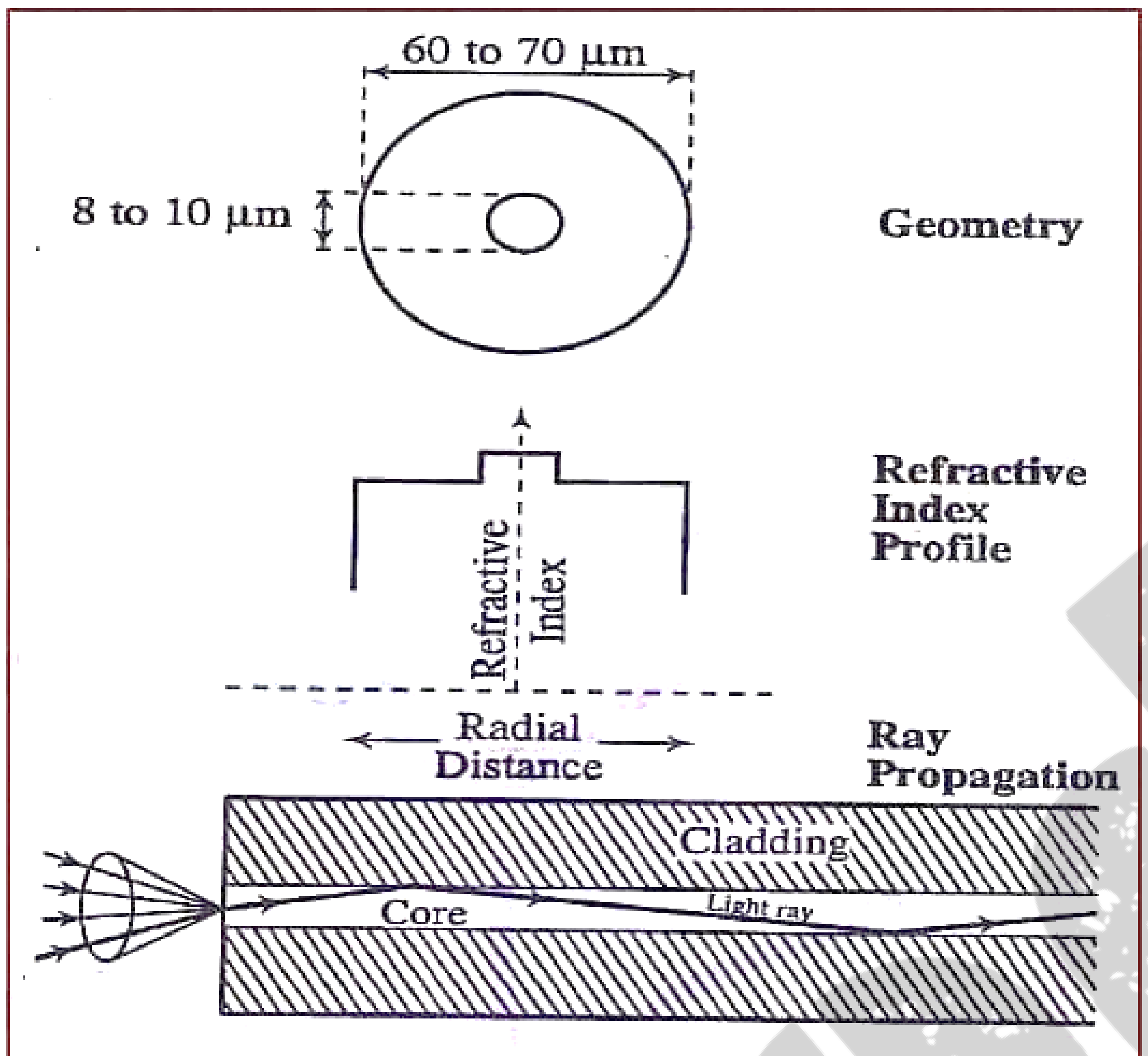
Types of optical fibers

Based on the refractive index profile and mode of propagation, there are three types of optical fibers,

1. Single mode fiber
2. Step index multimode fiber
3. Graded index multimode fiber

(i) Single mode fiber

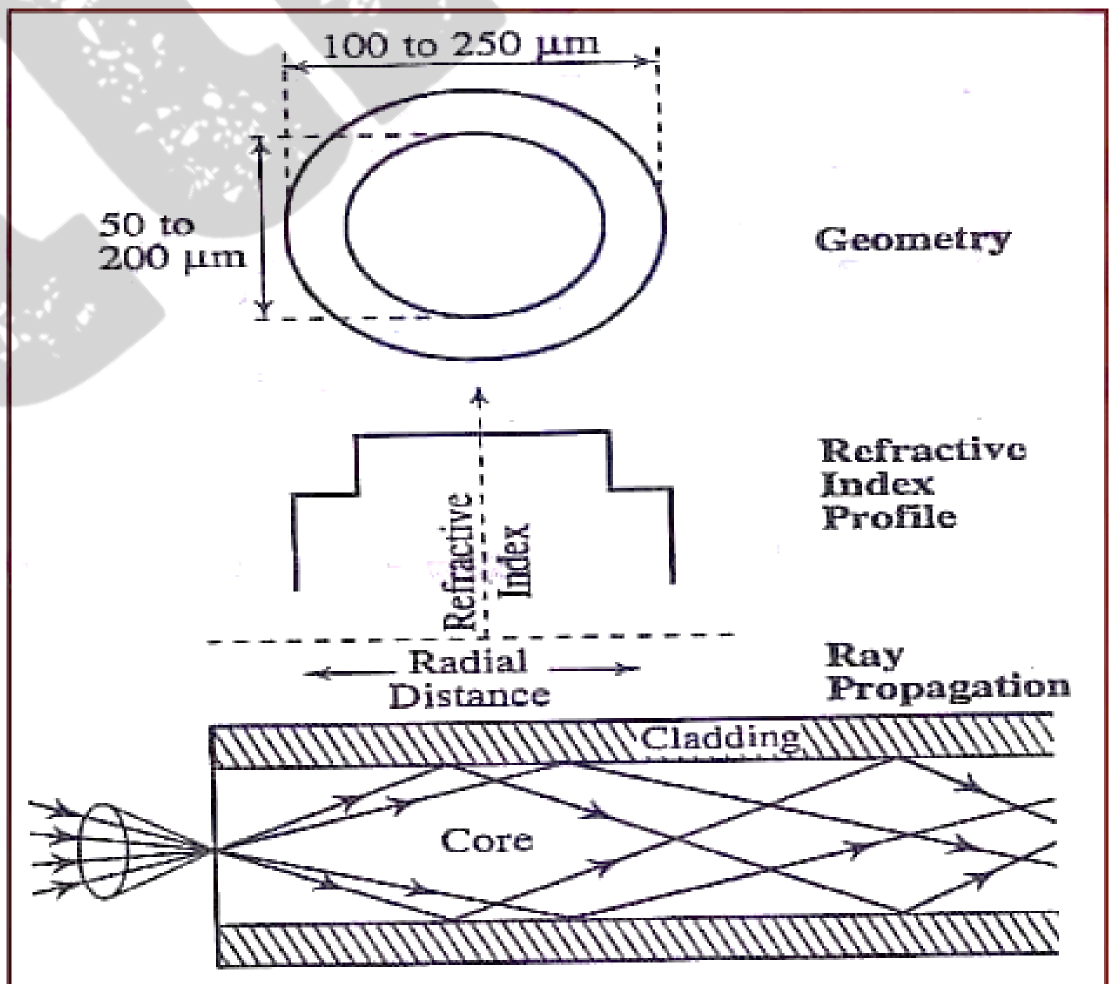
- Single mode fibers have a core material of uniform refractive index value.
- Cladding material also has a uniform refractive index but of lesser value than that of core.
- Thus its refractive index profile takes a shape of a step. The diameter of the core is about 8-10 μm and the diameter of the cladding is about 60-70 μm.



SINGLE MODE FIBER

- Because of its narrow core, it can guide just a single mode as shown in above figure.
- Single mode fibers are the extensively used ones ant they are less expensive. They need LASERs as the source of light.

(ii) <u>Step index multimode fiber</u>

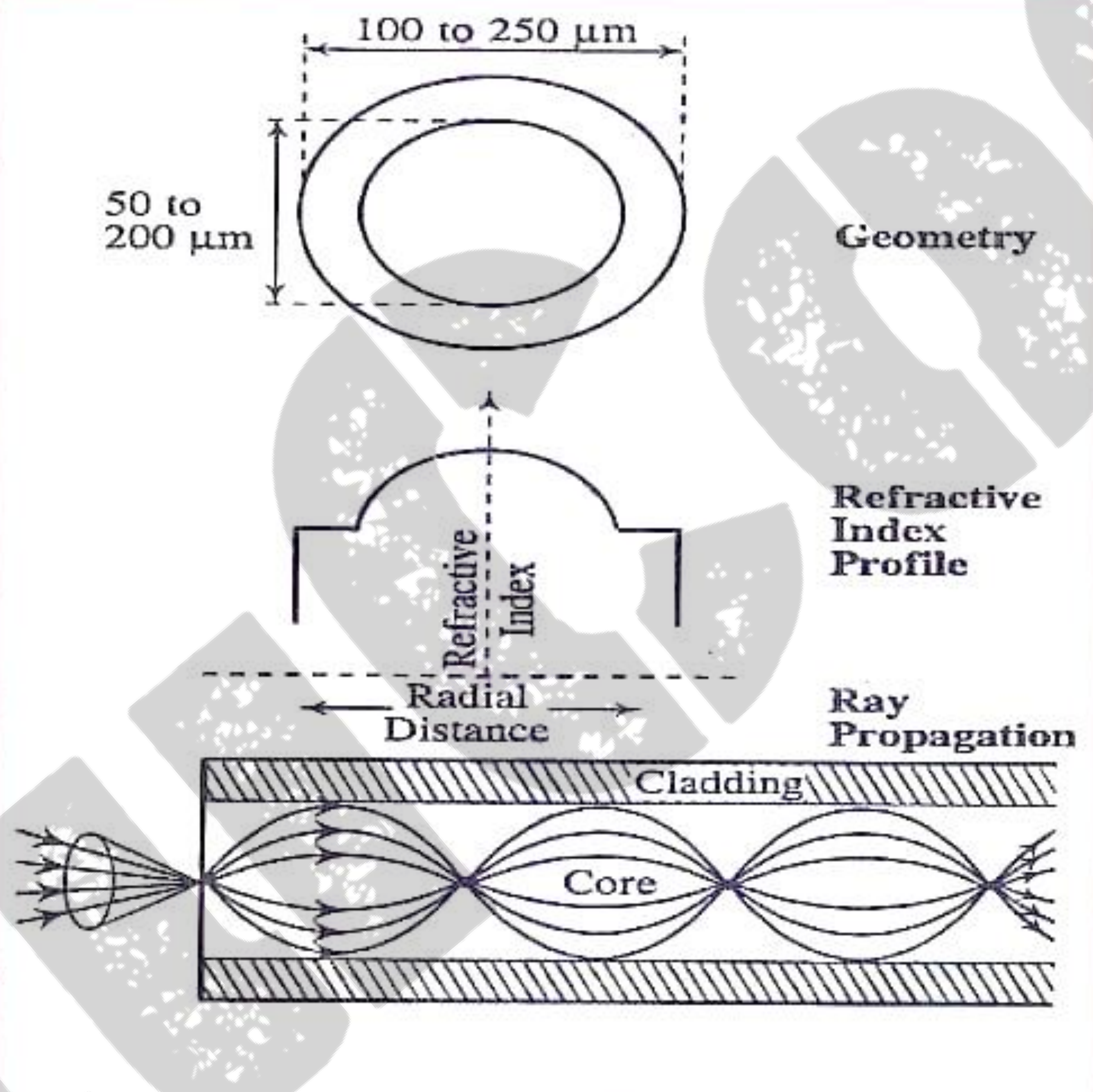


STEP - INDEX MULTIMODE FIBER

- A step index multimode fiber is very much similar to the single mode fiber except that its core is of large diameter. A typical fiber has a core diameter 50 to 200 μm and a cladding about 100 to 250μm outer diameter.

- Its refractive index profile is also similar to that of a single mode fiber but with a larger plane region for the core.
- Due to the large core diameter it can transmit a number of modes of wave propagation.
- The step index multimode fiber can accept either a LASER or an LED as source of light.
- It is the least expensive of all and its typical application is in data links which has lower bandwidth requirements.

(iii) Graded index multimode fiber



GRADED - INDEX MULTIMODE FIBER

- It is also called GRIN.
- The refractive index of core decreases in the radially outward direction from the axis of the fiber and becomes equal to that of cladding at the interface but the refractive index of the cladding remains uniform.
- Laser or LED is used as a source of light.
- It is the expensive of all. It is used in telephone trunk between central offices.

Signal attenuation in optical fibers

- Attenuation is the loss of optical power suffered by the optical signal as it propagates through a fiber also called as the fiber loss.
- There are three mechanisms through which attenuation takes place.

Attenuation co-efficient

- The attenuation of a fiber optic cable is expressed in decibels.

$$\text{i.e.,} \quad \alpha = -\frac{10}{L} log\left[\frac{P_{out}}{P_{in}}\right] \quad \frac{dB}{km}$$

- The main reasons for the loss in light intensity over the length of the cable is due to light absorption, scattering and due to bending losses.

Attenuation can be caused by three mechanisms.

(i) Absorption losses

- Absorption of photons by impurities like metal ions such as iron, chromium, cobalt and copper in the silica glass of which the fiber is made of.
- During signal propagation photons interact with electrons of impurity atoms and the electrons are excited to higher energy levels.
- Then the electrons give up their absorbed energy either in the form of heat or light energy.
- The re-emission of light energy will usually be in a different wavelength; hence it is referred as loss of energy.
- The other impurity such as hydroxyl (OH) ions which enters into the fiber at the time of fabrication causes significant absorption loss.
- The absorption of photons by fiber itself assuming that there are no impurities and in-homogeneities in it is called as *intrinsic absorption*.

(ii) Scattering losses

- Scattering of light waves occurs whenever a light wave travels through a medium having scattering objects whose dimensions are smaller than the wavelength of light.
- Similarly, when a light signal travels in the fiber, the photons may be scattered due to the sharp changes in refractive index values inside the core over distances and also due to the structural impurities present in the fiber material.
- This type of scattering is called as Rayleigh scattering. Scattering of

photons also takes place due to trapped gas bubbles which are not dissolved at the time of manufacturing.

- A scattered photon moves in random direction and leaves the fiber.

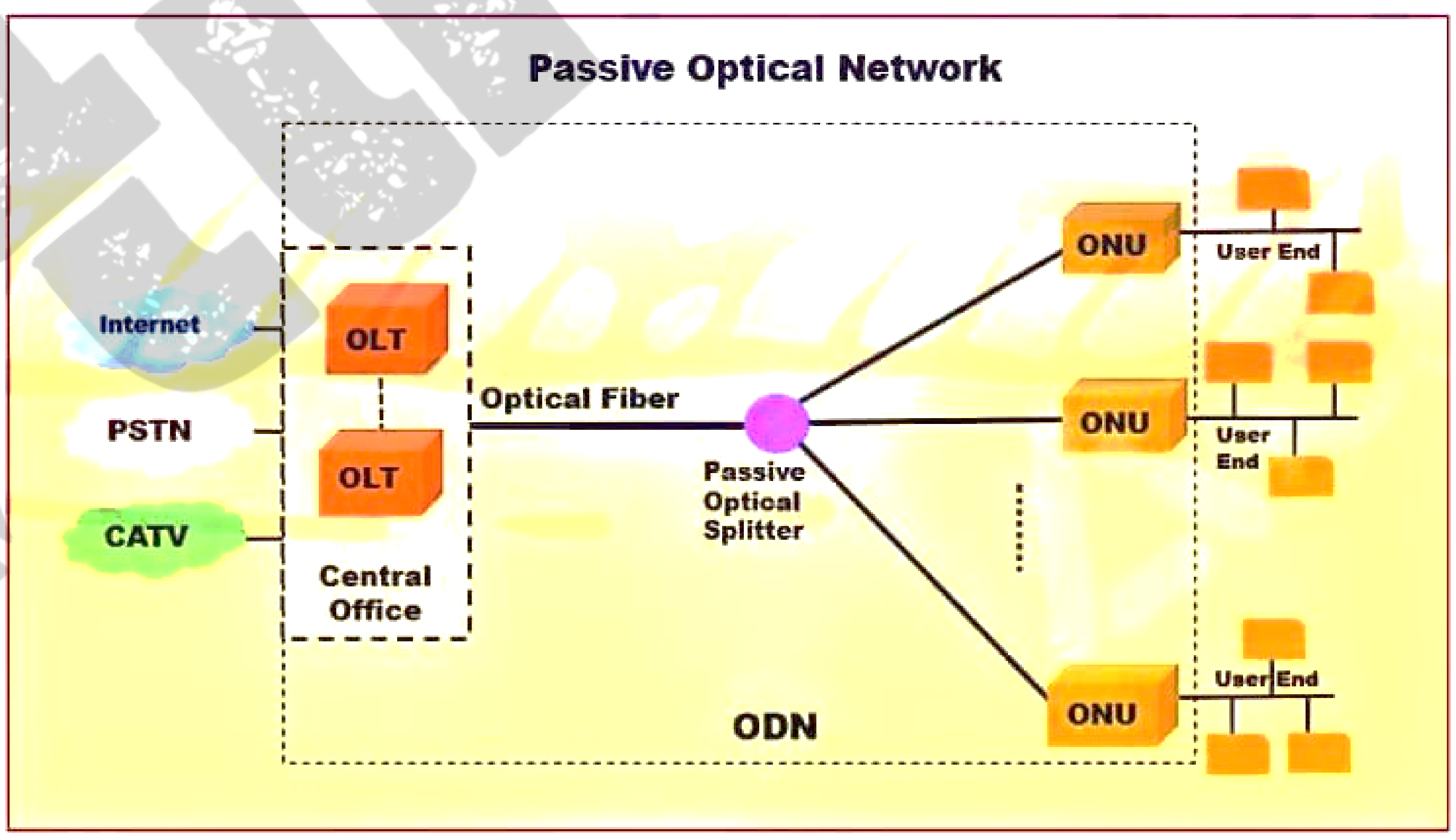
(iii) Radiation losses

Radiation losses occur due to macroscopic bends and microscopic bends.

- ***Macroscopic bending:*** All optical fibers are having critical radius of curvature provided by the manufacturer. If the fiber is bent below that specification of radius of curvature, the light ray incident on the core cladding interface will not satisfy the condition of total internal reflection. This causes loss of optical power.
- ***Microscopic bending:*** Microscopic bends are repetitive small scale fluctuations in the linearity of the fiber axis. They occur due to non-uniformities in the manufacturing and also lateral pressure built up on the fiber. They cause irregular reflections and some of them leak through the fiber. The defect due to non-uniformity (micro-bending) can be overcome by introducing optical fiber inside a good strengthen polyurethane jacket.

Applications of Optical fibers:

1. Optical fiber Networking:



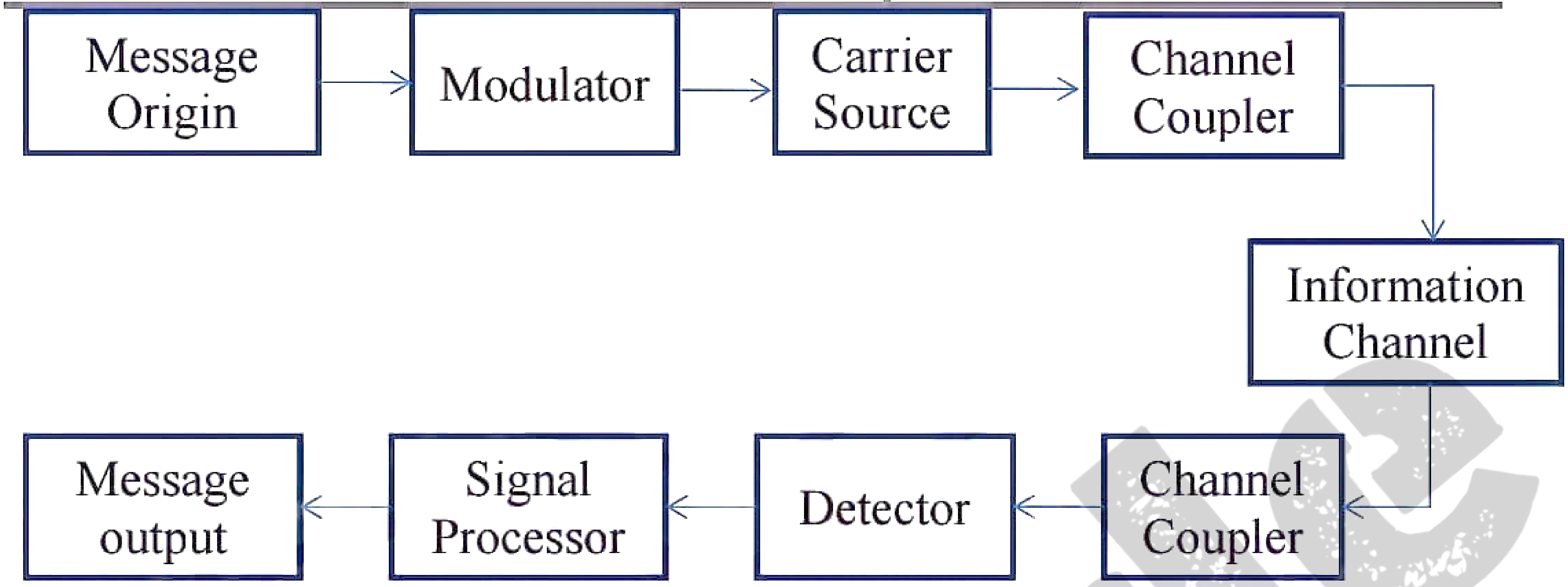
- The 'passive' part of the nomenclature refers to the fact that while the optical signal is traversing the network, there are no active electronic parts, and no power is needed.
- A typical PON is comprised of multiple ONUs *(optical network units)* and an OLTs *(optical line terminations)*. Generally, an OLT is located at the central office of the server provider, with as many as 32 ONUs situated close to the end users.
- A PON uses non-powered optical splitters to separate signals as they progress through the network, an optical splitter can take a single input and separate the signal to transmit to multiple users, sharing strands of fiber optics for different parts of network architecture.
- PONs only require power at the transmitting and receiving ends of the network and can serve up to 32 users with a single strand of fiber, they offer an option that's both cheaper to build and to maintain.

The advantages of PON

- Reduced operational costs
- Lower installation costs
- Reduced network energy costs
- A reduction in required network infrastructure
- No requirement for network switches

2. <u>Point to point optical fiber communication System</u>

Optical fiber communication system consists of transmitter, information channel and receiver. Transmitter converts an electrical signal into optical signal. Information channel carries the signal from transmitter to receiver. The receiver converts optical signal to electrical form. The block diagram of optical fiber communication system is shown in fig.



Message origin: It converts a non-electrical message into an electrical signal.

Modulator: It converts the electrical message into proper format and it helps to improve the signal onto the wave which is generated by the carrier source.

There are two types of format. They are Analog and digital. Analog signal is continuous and it doesn't make any change in the original format. But digital signal will be either in ON or OFF state.

Carrier source: It generates the waves on which the data is transmitted. These carrier waves are produced by the electrical oscillator. Light emitting diodes (LED) and laser diodes (LD) are the different sources.

Channel Coupler: (Input) The function of the channel coupler is to provide the information to information channel. It can be an antenna which transfers all the data.

Information channel: It is path between transmitter and receiver. There are two types of information channel. They are guided and unguided. Atmosphere is the good example for unguided information channel. Co-axial cable, two-wire line and rectangular wave guide are example for guided channel.

Channel Coupler: (Output) The output coupler guides the emerged light from the fiber on to the light detector.

Detector: The detector separates the information from the carrier wave. Here a photo-detector converts optical signal to electronic signal.

Signal processor: Signal processor amplifies the signals and filters the undesired frequencies.

Message output: The output message will be in two forms. Either person can see the information or hear the information. The electrical signal can be converted into sound wave or visual image by using CRO.

Advantages of optical fibers:

- Optical fibers are cheaper, small in size, light weight, mechanically strong and signal carrying capacity is high.
- They are immune to electromagnetic and RF interferences.
- The optical fibers have wider bandwidth so capable of carry more channels of information than electrical cables.
- It is compatible with electronic systems and tapping of signal is not possible.
- They have low loss per unit length (~2 dB/Km).
- It does not get affected by nuclear radiations, corrosion and moisture.
- No sparks are generated because the signal is optical signal.

Limitations:

- Optical fibers undergo expansion and contraction with temperature which upset little alignments that lead to loss in signal power.
- Because of some accidents or when fiber bent to circles of smaller radius, signal loss takes place or the fiber may break.
- Joining of two strands of a fiber (i.e., splicing) needs skill full work.
- High end maintenance is required.

QUESTION BANK: MODULE-1

1) Obtain an expression for the energy density in terms of Einstein's co-efficient.
2) Explain the conditions and requisites of laser system
3) Explain the construction and working of Semiconductor laser
4) Explain any two applications of laser in detail
5) Obtain an expression for Numerical aperture and hence write the condition for laser action
6) Explain the different types of optical fiber with neat diagrams
7) What is attenuation? Explain the different factors contribution g for the attenuation.
8) Explain 1) point to point communication using optical fiber and
   2) Fiber optic networking