CONTENTS

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LASER INTRODUCTION:-

Before going into how LASER (Light Amplification by Stimulated Emission of Radiation) works, let's first take a look at how light works.

WHAT IS LIGHT?

- **Light is a kind of energy released by an atom. Light is made up of very small particles called photons.**
- **Atoms are the basic units of matter. Each atom consists of a nucleus and a set of electrons orbiting the nucleus.**
- **Nucleus is formed as a result of strong nuclear force between the protons and neutrons. Protons have positive charge so they are referred as positively charged particles. Neutrons do not have charge so they are referred as neutral particles.**
- **Neutrons do not have charge so the overall charge of the nucleus is positive.**
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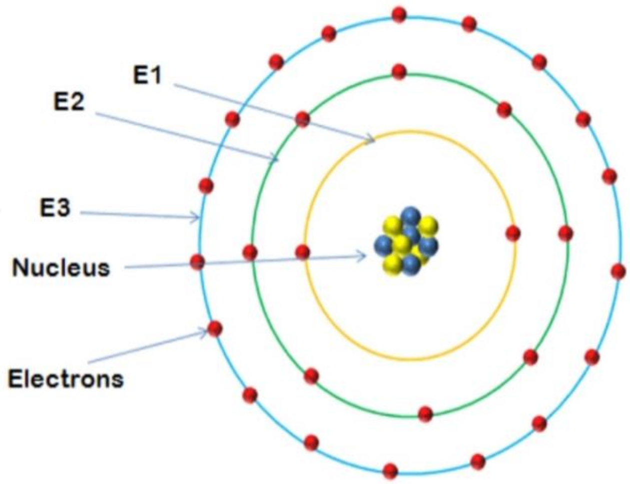


  particles.
- **Electrons have negative charge so they are referred as negatively charged particles. Electrons always orbit the nucleus because of the electrostatic force of attraction present between them. Electrons revolve around the nucleus in different orbits or shells. Each orbit has a unique energy level.**

- **The electrons orbiting at a larger distance from the nucleus have higher energy level whereas the electrons orbiting at a smaller distance from the nucleus have lower energy level.**

- **The electrons in the lower energy level need some extra energy to jump from lower energy level to the higher energy level. This extra energy can be supplied from various types of energy sources such as heat, electric field or light.**

- **Light shows properties of both waves and particles so it can behave simultaneously as a particle or a wave. Einstein believed that light is a particle or photon and the flow of photons is a wave.**

Light is obtained from various sources like candles, lamps and sun-rays.

- **Candles and lamps are called as the man made light sources and sun-rays is called natural light source.**

- **The first reliable artificial light source (incandescent light bulb) was invented in 1879 by Thomas Edison. In incandescent light bulb, electric current flows through a filament inside the bulb.**
- **When sufficient electric current is passed through the filament, it gets heated up and emits visible light. Thus, visible light is emitted from the incandescent light bulb.**

WHAT IS LASER?

- **The word LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. Laser is a device that amplifies or increases the intensity of light and produces highly directional light.**

- **Laser not only amplifies or increases the intensity of light but also generates the light. Laser emits light through a process called stimulated emission of radiation which amplifies or increases the intensity of light. Some lasers generate visible light but others generate ultraviolet or infrared rays which are invisible.**
- **In general, when electron jumps from a higher energy level to a lower energy level, it emits light or photon. The energy of the emitted photon is equal to the energy difference between the energy levels. The loss of electron energy is attributed to the entire atom. Therefore, it can be thought that the atom is moving from a higher energy state to a lower energy state.**

- **Laser light is different from the conventional light. Laser light has extra-ordinary properties which are not present in the ordinary light sources like sun and incandescent lamp.**
- **The conventional light sources such as electric bulb or tube light does not emit highly directional and coherent light whereas lasers produce highly directional, monochromatic, coherent and polarized light beam.**

- **In conventional light sources, excited electrons emit light at different times and in different directions so there is no phase relation between the emitted photons.**
- **On the other hand, the photons emitted by the electrons of laser are in same phase and move in the same direction.**

- **Einstein gave the theoretical basis for the development of laser in 1917, when he predicted the possibility of stimulated emission. In 1954, C.H. Townes and his co-workers put Einstein's prediction for practical realization.**

- **They developed a microwave amplifier based on stimulated emission of radiation. It was called as MASER (Microwave Amplification by Stimulated Emission of Radiation. Maser operates on principles similar to laser but generates microwaves rather than light radiation.**

- **In 1958, C.H. Townes and A. Schawlow extended the principle of masers to light. In 1960, T.H. Maiman built the first laser device.**

MECHANISM

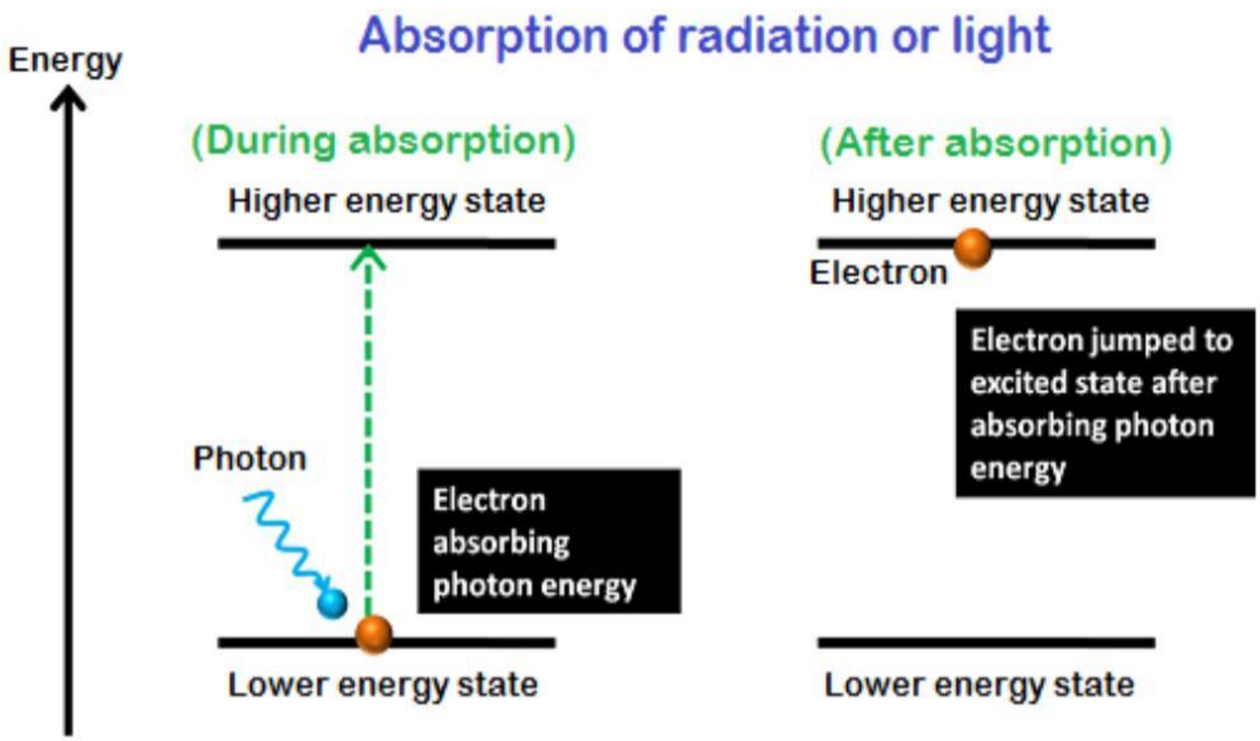
- **In lasers, photons are interacted in three ways with the atoms:**

- *Absorption of radiation*
- *Spontaneous emission*
- *Stimulated emission*

Absorption of radiation:-

- **Absorption of radiation is the process by which electrons in the ground state absorbs energy from photons to jump into the higher energy level.**

- **The electrons orbiting very close to the nucleus are at the lower energy level or lower energy state whereas the electrons orbiting farther away from the nucleus are at the higher energy level.**
- **The electrons in the lower energy level need some extra energy to jump into the higher energy level. This extra energy is provided from various energy sources such as heat, electric field, or light.**
- **Let us consider two energy levels (E1 and E2) of electrons. E1 is the ground state or lower energy state of electrons and E2 is the excited state or higher energy state of electrons. The electrons in the ground state are called lower energy electrons or ground state electrons whereas the electrons in the excited state are called higher energy electrons or excited electrons.**



- **In general, the electrons in the lower energy state can't jump into the higher energy state. They need sufficient energy in order jump into the higher energy state.**

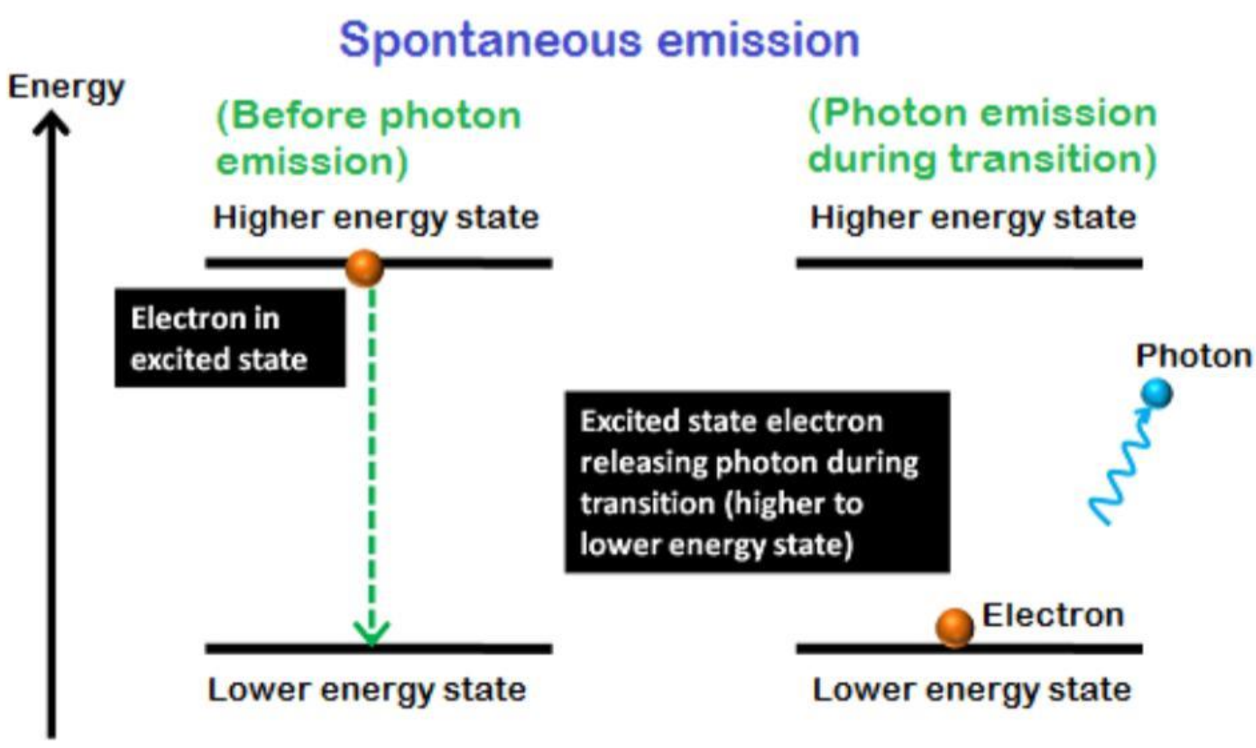
- **When photons or light energy equal to the energy difference of the two energy levels (E2 – E1) is incident on the atom, the ground state electrons gains sufficient energy and jumps from ground state (E1) to the excited state (E2).**

- **The absorption of radiation or light occurs only if the energy of incident photon exactly matches the energy difference of the two energy levels (E2 – E1).**

Spontaneous emission:-

- **Spontaneous emission is the process by which electrons in the excited state return to the ground state by emitting photons.**

- **The electrons in the excited state can stay only for a short period. The time up to which an excited electron can stay at higher energy state (E2) is known as the lifetime of excited electrons. The lifetime of electrons in excited state is 10-8 second.**



- **Thus, after the short lifetime of the excited electrons, they return to the lower energy state or ground state by releasing energy in the form of photons.**

- **In spontaneous emission, the electrons move naturally or spontaneously from one state (higher energy state) to another state (lower energy state) so the emission of photons also occurs naturally. Therefore, we have no control over when an excited electron is going to lose energy in the form of light.**
- **The photons emitted in spontaneous emission process constitute ordinary incoherent light. Incoherent light is a beam of photons with frequent and random changes of phase between them. In other words, the photons emitted in the spontaneous emission process do not flow exactly in the same direction of incident photons.**

Stimulated emission:-

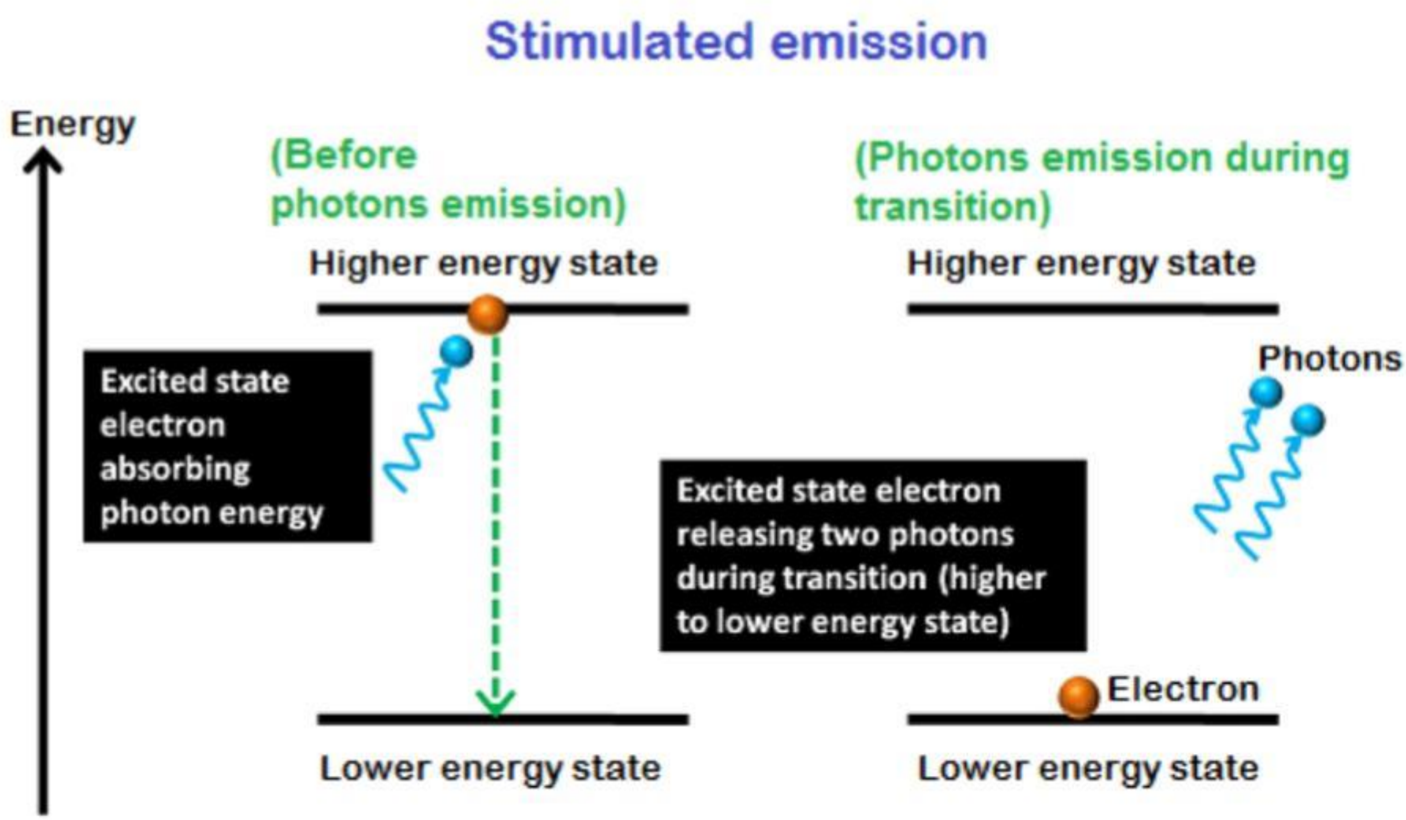
- **Stimulated emission is the process by which incident photon interacts with the excited electron and forces it to return to the ground state.**

- **In stimulated emission, the light energy is supplied directly to the excited electron instead of supplying light energy to the ground state electrons.**

- **Unlike the spontaneous emission, the stimulated emission is not a natural process it is an artificial process.**

- In spontaneous emission, the electrons in the excited state will remain there until its lifetime is over. After completing their lifetime, they return to the ground state by releasing energy in the form of light.

- However, in stimulated emission, the electrons in the excited state need not wait for completion of their lifetime. An alternative technique is used to forcefully return the excited electron to ground state before completion of their lifetime. This technique is known as the stimulated emission.



- **When incident photon interacts with the excited electron, it forces the excited electron to return to the ground state. This excited electron release energy in the form of light while falling to the ground state.**
- **In stimulated emission, two photons are emitted (one additional photon is emitted), one is due to the incident photon and another one is due to the energy release of excited electron. Thus, two photons are emitted.**

- **The stimulated emission process is very fast compared to the spontaneous emission process.**

- **All the emitted photons in stimulated emission have the same energy, same frequency and are in phase. Therefore, all photons in the stimulated emission travel in the same direction.**

- **The number of photons emitted in the stimulated emission depends on the number of electrons in the higher energy level or excited state and the incident light intensity.**

- **It can be written as:**
- **Number of emitted photons α Number of electrons in the excited state + incident light intensity.**

Common components of all LASER :-

1.Active Medium:-

- **The active medium may be solid crystals such as ruby or Nd:YAG, iquid dyes, gases ike Co2 or Helium/Neon, or semiconductors such as Gas. Active mediums contain atoms whose electrons may be excited to a metastable energy level by an energy source.**

2.Excltatlon Mechanlsm:-

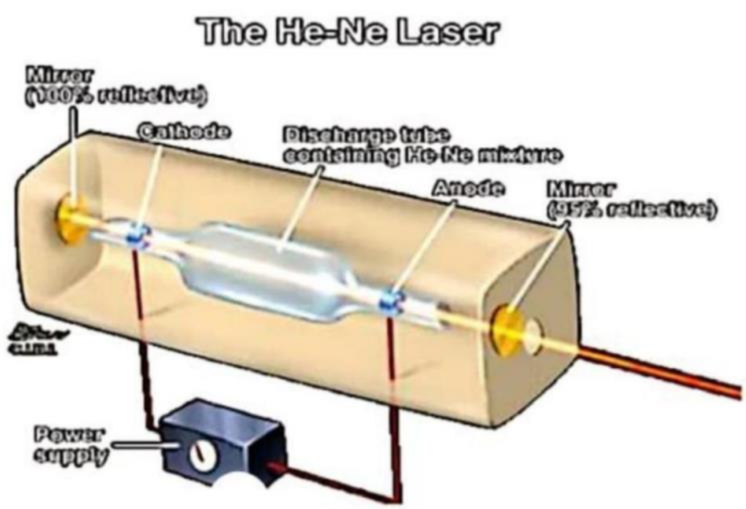
- **Excitation mechanisms pump energy into the acivemedíum by one or more of three**
- **Basic methods; optical, electrical or chemical.**

3.Hlgh Relectance Mirror :-

- **A miror which reflects about**

4.Partially Transmissive Mirror:-

- **A mirror which reflects less than 100% of the laser light and transmits the Remainder**



Steps involving Lasing action

- 1. Energy is applied to a medium raising electrons to an unstable energy level.
- 2. These atoms spontaneously decay to a relatively long-lived, lower energy, metastable state.
- 3. A population inversion is achieved when the majority of atoms have reached
- this metastable state.
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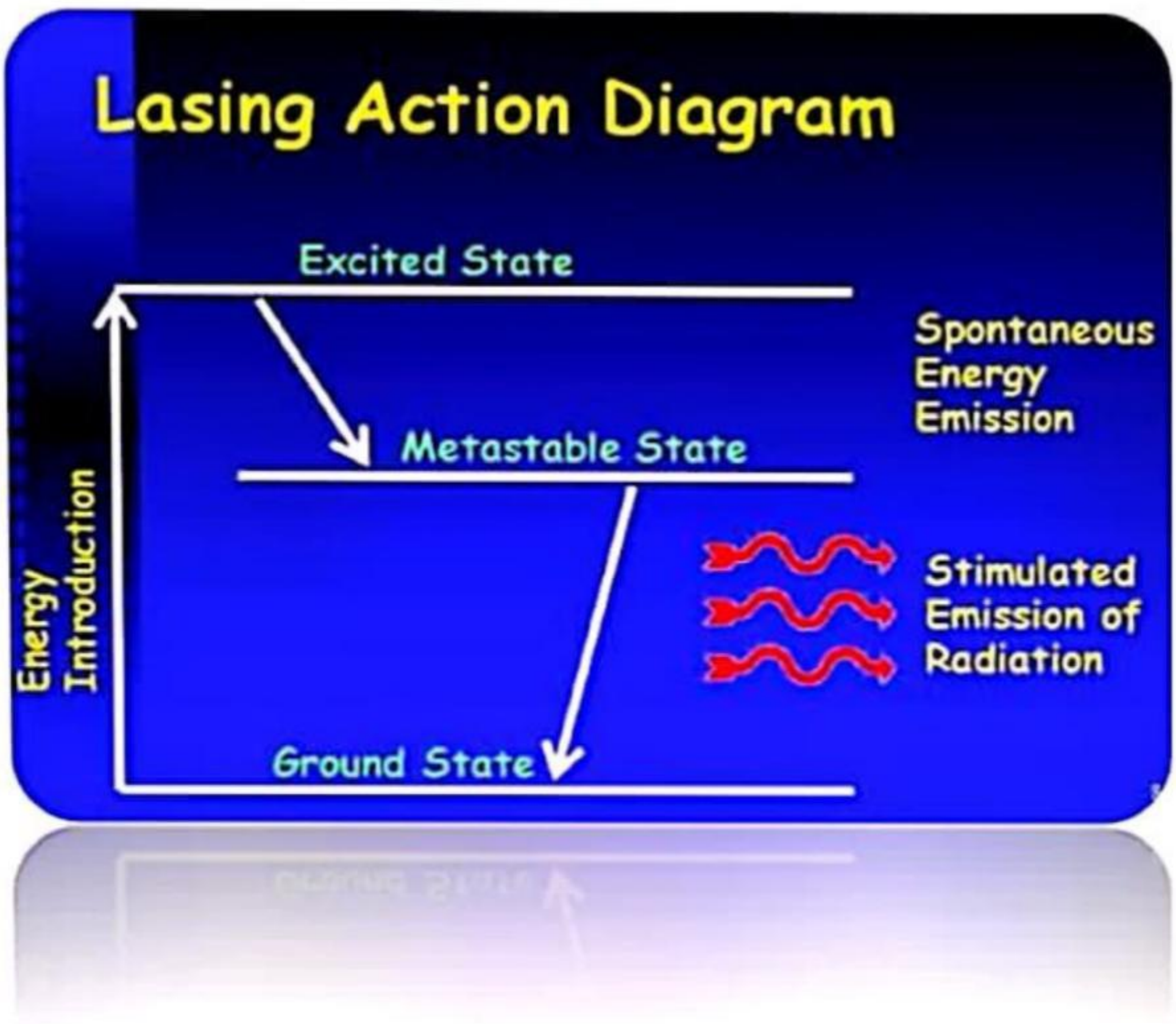
- **7. The partially reflective mirror allows the transmission of a small amount of coherent radiation that we observe as the "beam".**
- **8. Laser radiation will continue as long as energy is applied to the lasing medium.**

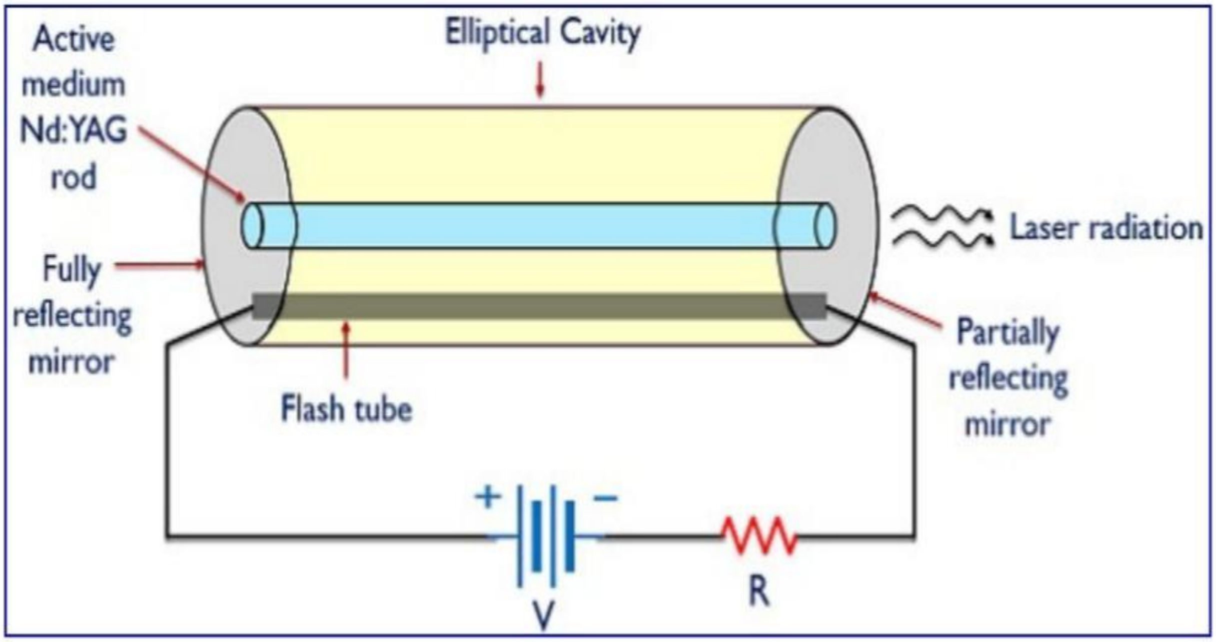


TYPES OF LASER:-

- **Based on the type of active medium, Laser systems are broadly classified into the following Categories.**

S.No	TYPES OF LASER	EXAMPLES
01	Solid State laser Ruby Laser	Nd:YAG laser
02	Gas Laser He- Ne Laser	CO2 Laser, Argon – ion laser
03	Liquid Laser	SeOCL2 Laser, Europium Chelate Laser
04	Dye Laser	Rhodamine 6G laser, Coumarin dye laser
05	Semiconductor Laser	GaAs laser, GaAsP laser

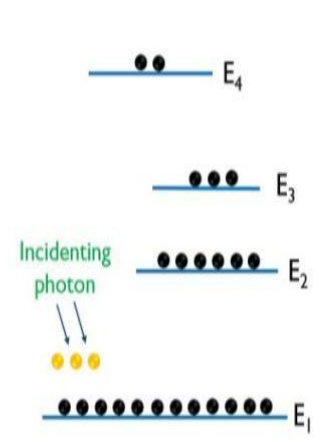
- **Solid state Laser – NdYAG LASER**
- **It is a solid state and 4 level system as it consists of 4 energy levels. Nd ion is rare earth**
- **Metal and it is doped with solid state host.Due to doping, yttrium ions get replaced.**
- **Nd3+ ions. Also, the doping concentration is around 0.725% by weight.**



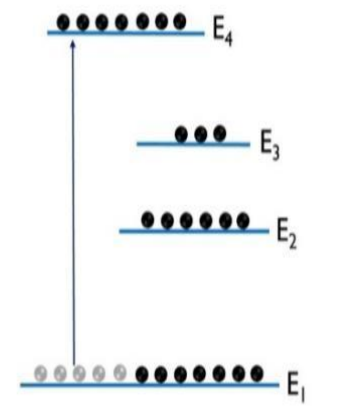
Construction of Nd:YAG laser

- **Active medium: when the external energy source is provided then the electrons from Lower energy state moves to higher energy state thereby causing lasing action**
- **External Energy source: optical pumping, xenon or krypton flash tube is taken**
- **Nd:YAG rod and the flash tube are placed inside an elliptical cavity**
- **Optical resonator: two ends of the Nd:YAG rod is coated with silver. – to achieve Maximum light reflection.**
- **Other end is partially coated in order to provide a path for the light ray from an external Source to reach the active medium.**
- **E1 is the lowest energy state while E4 is the highest energy level, electrons present in the Energy state E1 gains energy and moves to energy state E4.E4 is an unstable state.**

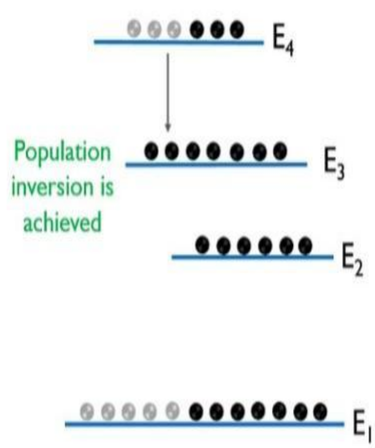
- **Electrons that were excited to this state by the application external pumping will not stay At this state for much longer duration and comes to lower energy state E3 very fastly but Without radiating any photon.**
- **E3 is the metastable state and exhibits longer lifespan. Thereby attaining population Inversion.**
- **Lifetime of the electrons at the metastable state gets exhausted then these electrons by Releasing photons come to lower energy state E2.**
- **E2 also exhibit shorter lifespan like E4. Thus, electrons present in E2 state will come to E1**



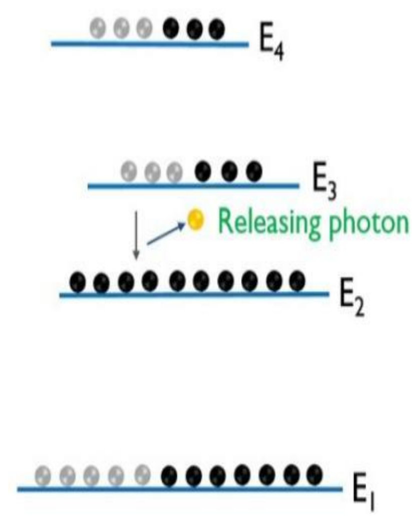
When external pumping is provided to the active medium of the Nd:YAG laser.



Due to external pumping electron in lowest energy state gains energy and move to highest unstable energy state.



Once carrier lifespan is exhausted at unstable state, electrons come to metastable state and population inversion is achieved.



The electrons on coming to E_2 state emits energy in the form of photon.

Electrons by gaining single photon of energy releases the energy of 2 photons. Also, as the System is equipped with optical resonators so, more number of photons will get generated as the Pumped energy will get reflected inside the active medium.

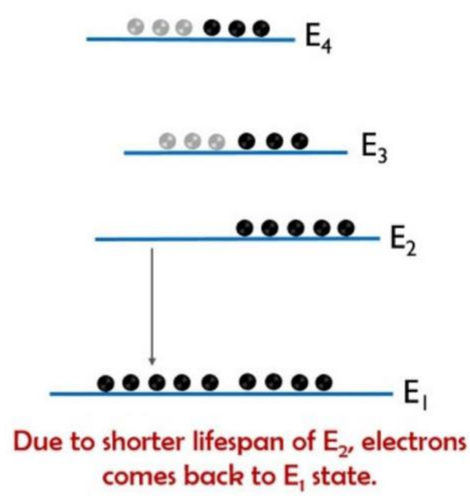
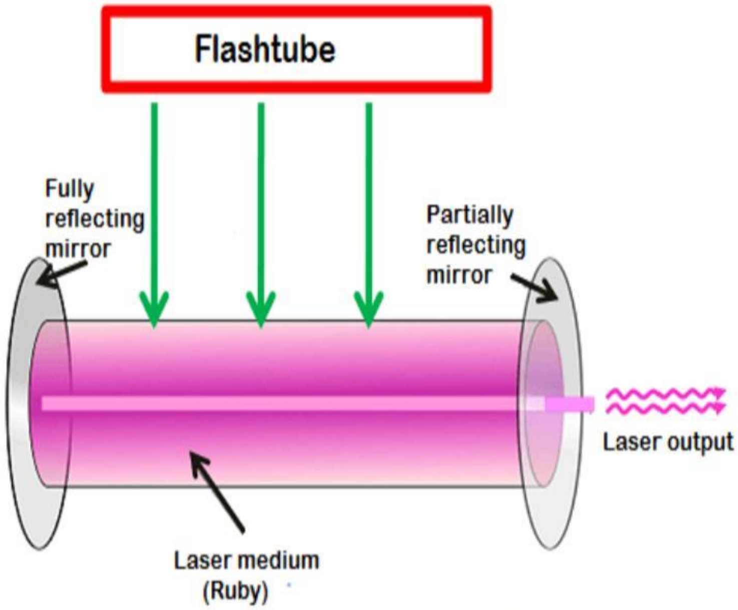


Fig. 2.2

- **Several electrons on stimulation produce photons thereby generating a coherent laser beam of**
- **1.064 µm.**
- **Applications of Nd:YAG Laser**
- **Military applications to find the desired target.**
- **Application in medical field for the surgical purpose.**
- **Used in welding and cutting of steel and**
- **Used in communication system**

Solid State Laser – Ruby Laser



Construction of Ruby laser:-

- **Ruby is a crystal of aluminium oxide (Al2O3) in which some of the aluminium ions (Al3+) Are replaced by chromium ions (Cr3+). This is done by doping small amounts of Chromium oxide**
- **Pink or red color depending upon the concentration of chromium ions**
- **Al2O3 does not participate in the laser action. It only acts as the host.**
- **Length of ruby crystal is usually 2 cm to 30 cm and diameter 0.5 cm to 2 cm.**

High temperature is produced during the operation of the laser, the rod is surrounded by liquid Nitrogen to cool

Active medium or active center: Chromium ions act as active centers in ruby crystal. So it is the Chromium ions that produce the laser

Pumping source: A helical flash lamp filled with xenon is used as a pumping source. The ruby Crystal is placed inside a xenon flash lamp. Thus, optical pumping is used to achieve population Inversion in ruby laser.

Optical resonator system: The ends of ruby crystal are polished, grounded and made flat. The One of the ends is completely silvered while the other one is partially silvered to get the output. Thus the two polished ends act as optical resonator system.

Working

- ✓ **Ruby is a three level laser system.**
- ✓ **There are three levels E1, E2 and (E3 & E4). E1 is the ground level, E2 is the metastable Level, E3 and E4 are the bands. E3 & E4 are considered as only one level because they are Very closed to each other.**
- ✓ **Pumping: The ruby crystal is placed inside a xenon flash lamp**
- ✓ **A part of this energy is absorbed by chromium ions in the ground state.**
- ✓ **Optical pumping raises the chromium ions to energy levels inside the bands E3 and E4.This process is called stimulated absorption.**

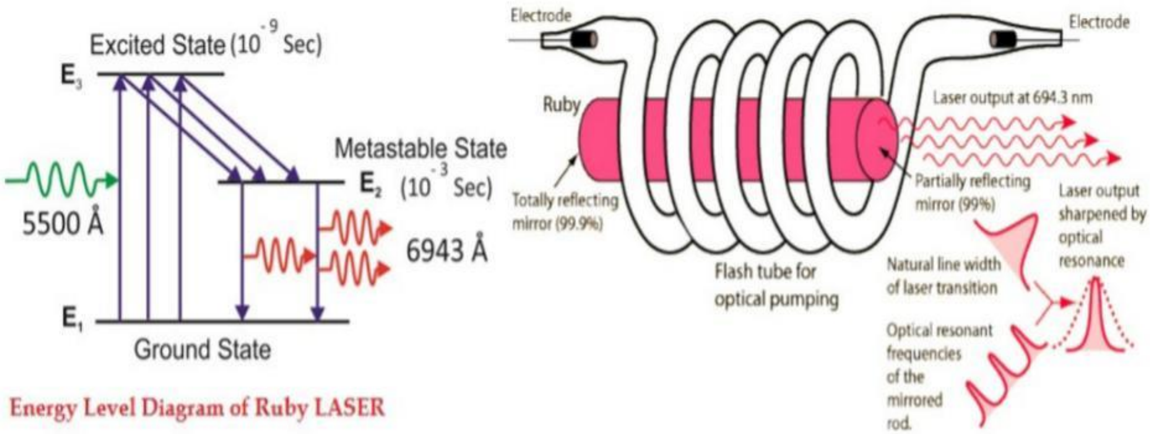


Fig. 2.4

Achievement of population inversion:-

- **Cr3+ ions in the excited state loose a part of their energy**
- **The transition from excited states to metastable state is non-radiative transition or in other Words there is no emission of photons.**
- **The number of chromium ions goes on increasing in E2 state, while due to pumping.**
- **As a result, the number of chromium ions become more in excited state(metastable state) As compared to ground state E1.**
- **Hence, the population inversion is achieved between states E2 and E1.**

- ✓ **Photon travels through the ruby rod and if it is moving in a direction parallel to the axis Of the crystal, then it is reflected to and fro by the silvered ends of the ruby rod until it Stimulates the other excited ions and cause it to emit a fresh photon in phase with the Stimulating photon.**

- ✓ **Emitted photons will knock out more photons by stimulating the chromium ions and their Total number sufficiently increases.**

Output Measurement

- ✓ **In the energy level diagram, E2 is the upper laser level and E1 is the lower laser level Because laser beam is achieved in between these levels. Thus, the ruby laser fits into the Definition of three level laser system.**

- ✓ **Output: The output wavelength of ruby laser is 6943 Å and output power is 10 raise to Power 4 to 10 raise to power 6 watts and it is in the form of pulses.**

Type	Solid state laser; Three- level laser system
Active medium	Ruby rod (Cr: Al_2O_3)
Active centre	Cr^{3+} ion
Pumping method	Optical pumping
Pumping source	Helical flash lamp of filled with Xenon
Optical resonator	The ends of the ruby rod are kept in between two optically coated mirrors, silvered differently.
Output power	Low
Nature of the output	Pulsed (Spiked)
Wavelength emitted	693.4 nm

APPLICATIONS

1. Ruby laser has very high output power of the order of 104-106 Watts. It Has wavelength of 6943 Angstroms.
2. 2.Ruby lasers are used in industrial cutting and welding.
3. They are used for hair removal and tattoo
4. Holography, NDT, Decoration, Display and toys

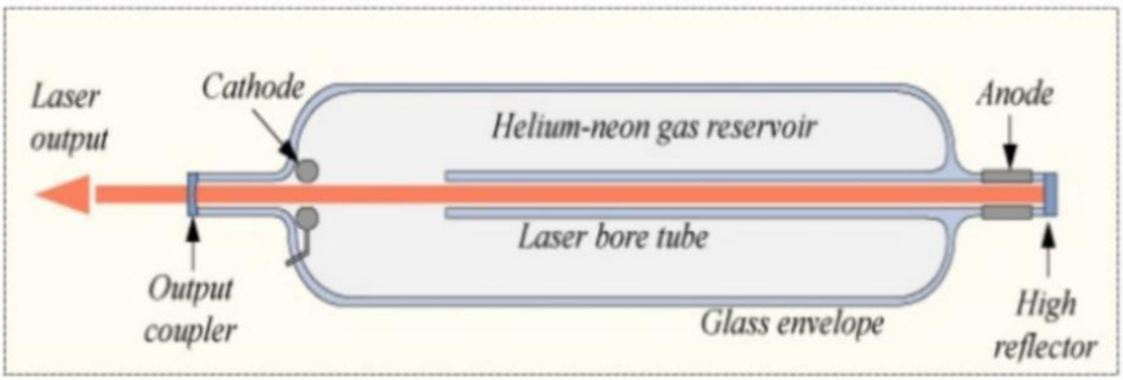
GAS LASER

A gas laser is a type of laser in which a mixture of gas is used as the active medium or laser Medium. Gas lasers are the most widely used lasers.

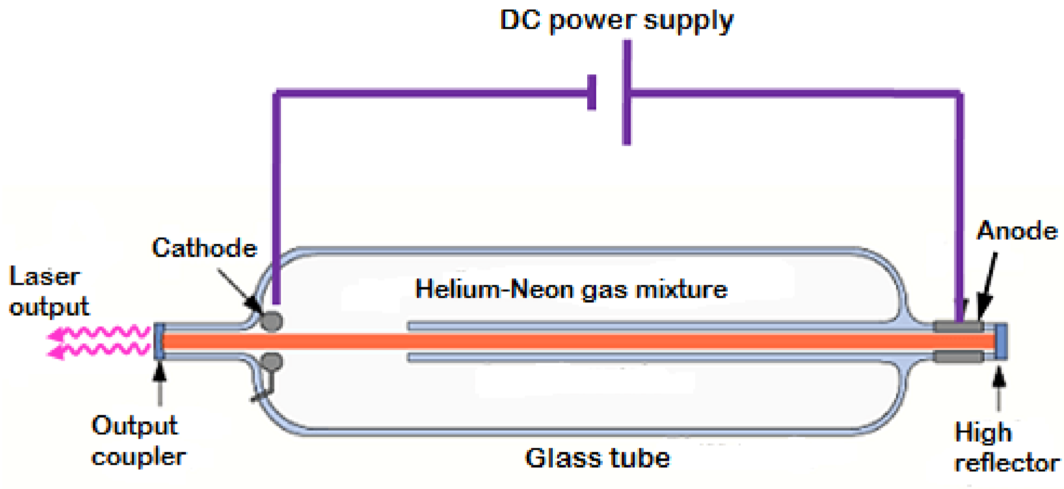
Gas lasers range from the low power helium-neon lasers to the very high power carbon Dioxide lasers. Commonly used in college laboratories whereas the carbon dioxide lasers are Used in industrial applications.

The main advantage of gas lasers (eg: He-Ne lasers) over solid state lasers is that they are Less prone to damage by overheating so they can be run continuously.

Helium-neon laser

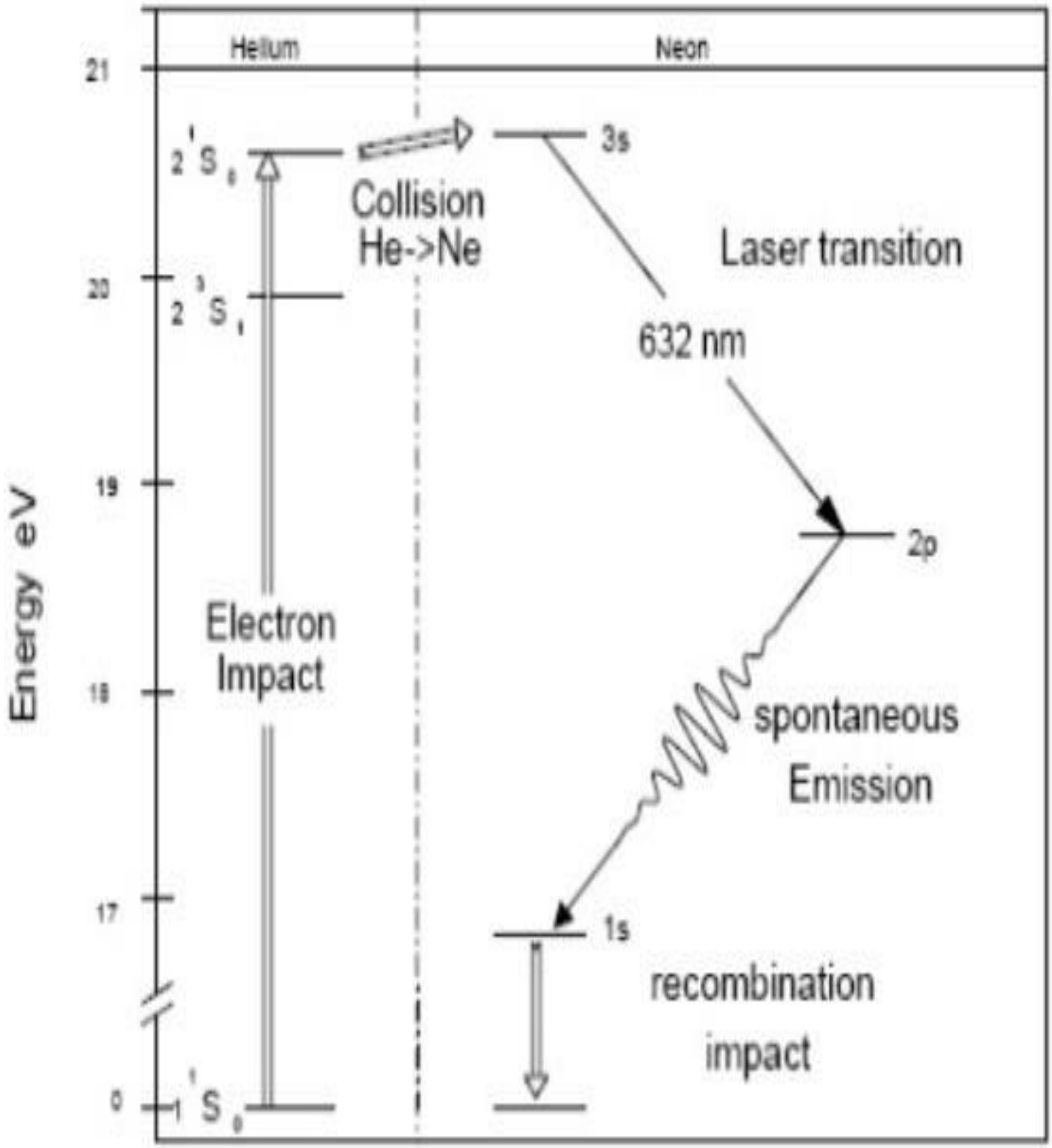


- **The helium-neon laser was the first continuous wave (CW) laser ever constructed**
- **The excitation of electrons in the He-Ne gas active medium is achieved by passing an Electric current through the gas.**
- **The helium-neon laser operates at a wavelength of 632.8 nanometers (nm), in the red Portion of the visible spectrum.**



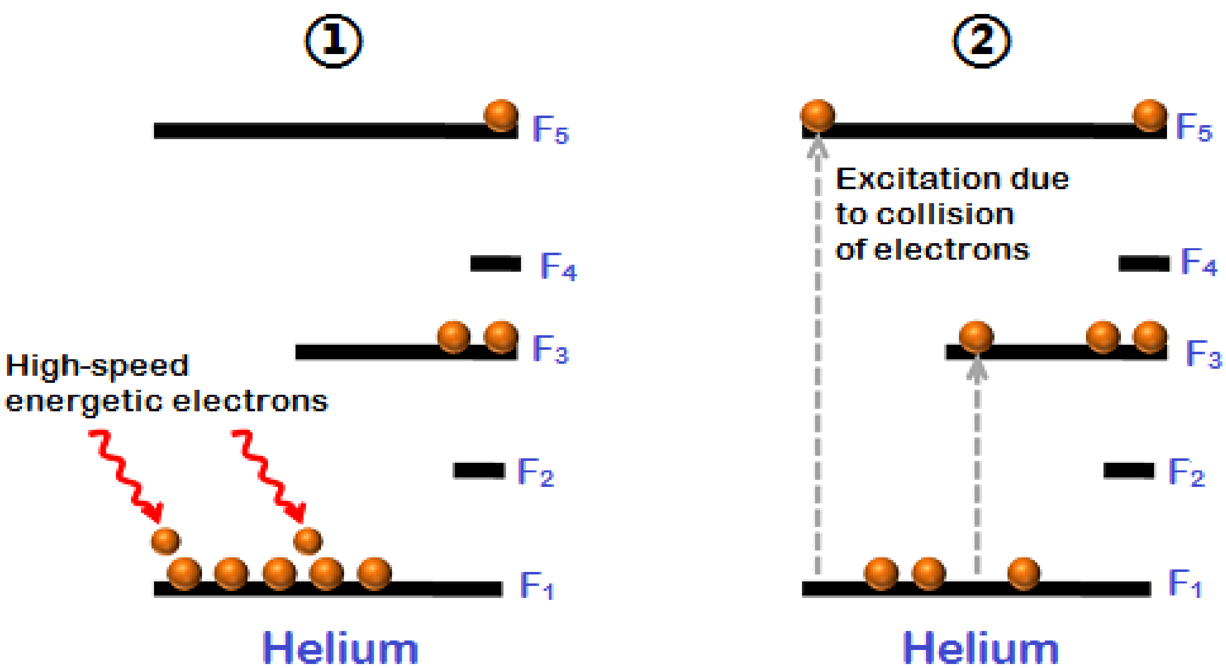
Helium-neon laser construction:-

- **The helium-neon laser consists of three essential components:**
- **Pump source (high voltage power supply)**
- **Gain medium (laser glass tube or discharge glass tube)**
- **Resonating cavity**
- **High voltage power supply to achieve population inversion, we need to supply energy to the gain medium or active medium**
- **In helium-neon lasers, a high voltage DC power supply is used as the pump source. A High voltage DC supplies electric current through the gas mixture of helium and neon.**


Helium
Neon
21
20
19
18
17
0
Energy eV
Collision
He->Ne
3s
Laser transition
632 nm
2p
Electron
Impact
spontaneous
Emission
1s
recombination
impact

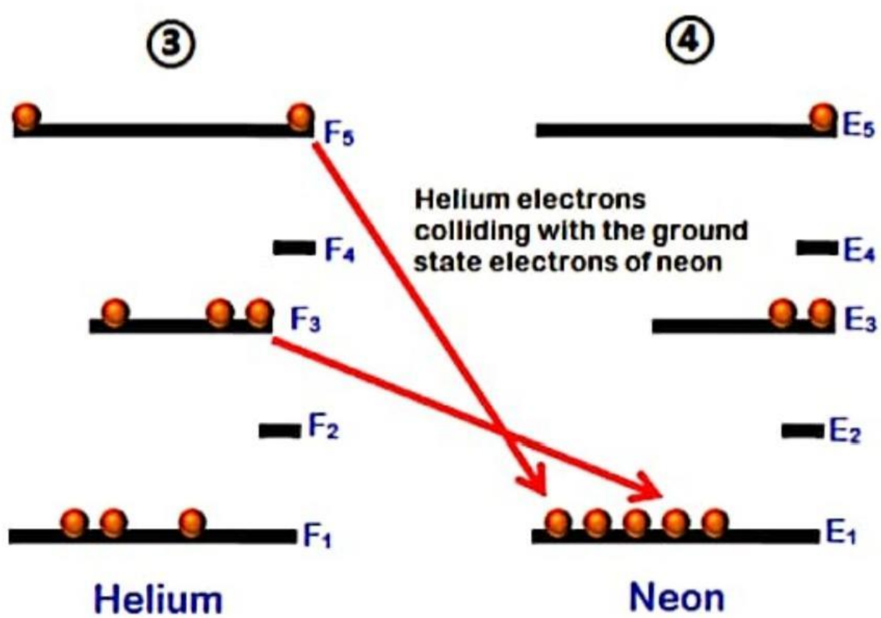
Gain medium:-

- ✓ The partial pressure of helium is 1 mbar whereas that of neon is 0.1 mbar.
- ✓ to excite primarily the lower energy state electrons of the helium atoms.
- ✓ neon atoms are the active centers and have energy levels suitable for laser transitions While helium atoms help in exciting neon atoms.
- ✓ Electrodes (anode and cathode) are provided in the glass tube to send the electric current Through the gas mixture. These electrodes are connected to a DC

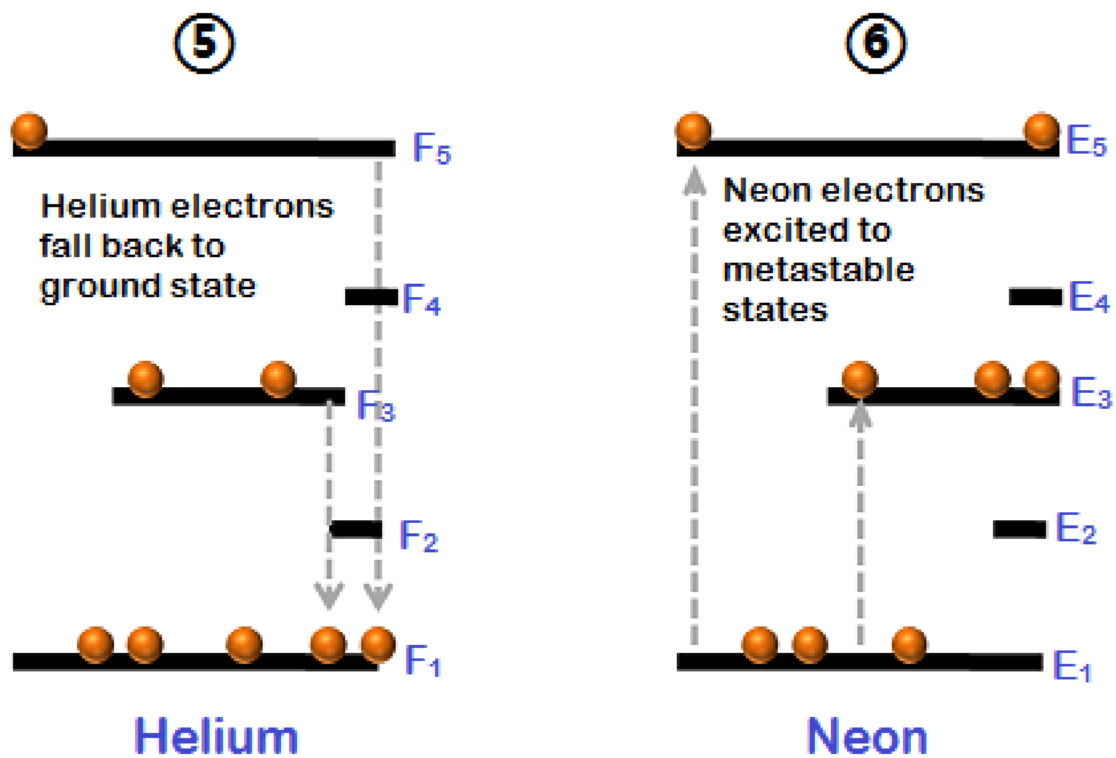


The power is switched on, a high voltage of about 10 kV is applied It is enough to excite the Electrons and are accelerated

- **Electrons transfer some of their energy to the helium atoms, jumps into the excited states**
- **Assume that these metastable states are F3 and F5**
- **Metastable state electrons of the helium atoms, return to ground state by transferring their Energy to the lower energy state electrons of the neon atoms.**
- **The energy levels of some of the excited states of the neon atoms are identical to the Energy levels of metastable states of the helium atoms.**
- **Let us assume that these identical energy states are F3 = E3 and F5 = E5. E3 and E5 are Excited states or metastable states of neon atoms.**

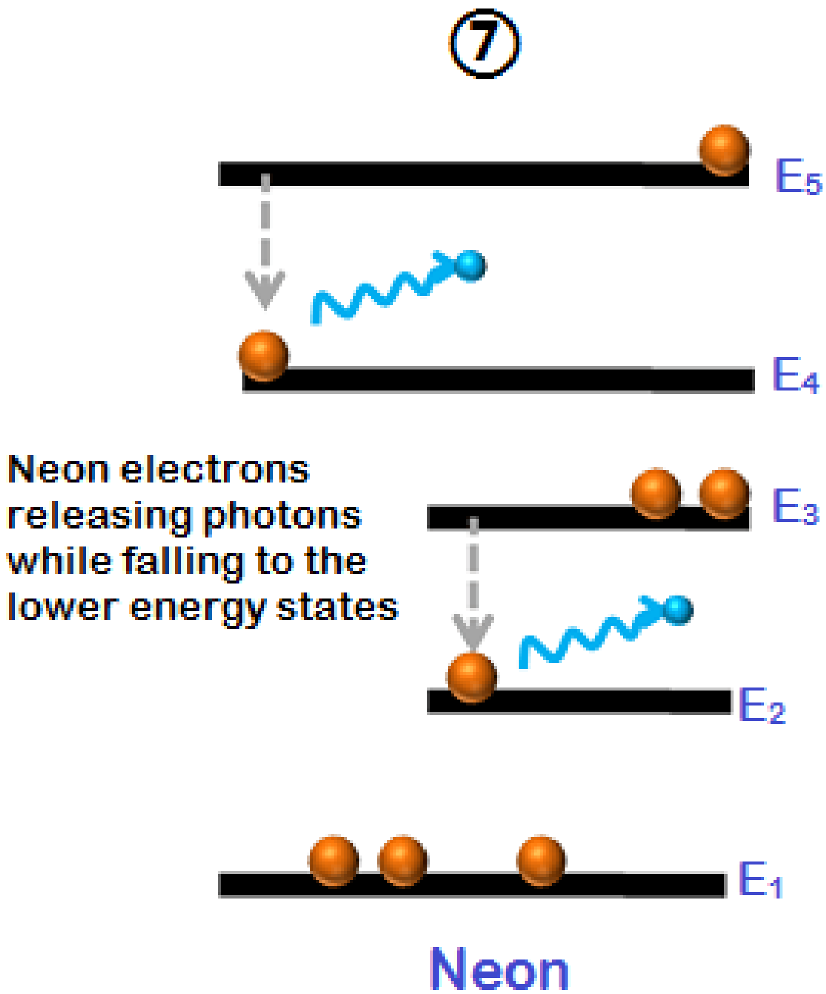


The lower energy state electrons of the neon atoms gain enough energy from the helium atoms And jumps into the higher energy states or metastable states (E3 and E5) whereas the excited Electrons of the helium atoms will fall into the ground state. Thus, helium atoms help neon atoms In achieving population inversion.



- Millions of ground state electrons of neon atoms are excited to the metastable states Having longer lifetime
- Electrons (E3 and E5) of the neon atoms will spontaneously fall into the next lower energy States (E2 and E4) by releasing photons or red light.
- Neon excited electrons continue on to the ground state through radiative and non radiative Transitions.

- Photons emitted from the neon atoms will moves back and forth between two mirrors Until it stimulates other electrons
- Optical gain is achieved due to stimulated emission



Photons emitted will escape through the partially reflecting mirror or output coupler to produce Laser.

Advantages of helium-neon laser

- **Helium-neon laser emits laser light in the visible portion of the spectrum.**

- **High stability**
- **Low cost**
- **Operates without damage at higher temperatures**

Disadvantages of helium-neon laser

- **Low efficiency**
- **Low gain**
- **Helium-neon lasers are limited to low power tasks**
- **Applications of helium-neon lasers**
- **Helium-neon lasers are used in industries.**
- **Helium-neon lasers are used in scientific instruments.**
- **Helium-neon lasers are used in the college laboratories**

APPLICATIONS OF LASER

Introduction:-

Lasers deliver coherent, monochromatic, well-controlled, and precisely directed light beams. A priori, therefore, lasers would seem tobe poor choices for general-purpose illumination, however, they are ideal for concentrating light in space, time, or particular wavelengths. Lasers have been regularly used to measure, cut, drill, weld, read, write, send messages, solve crimes, burn plaque out of arteries, and perform delicate eye operations.

Laser	Wavelength (µm)	Peak power (watts)	Pulse repetition rate (pulses per second)	Typical use
Nd:YAG (repetitively pulsed)	1.06	10^6	10	Drilling metals, scribing silicon wafers
Nd:YAG (repetitively Q-switched)	1.06	10^5	5000	Trimming resistors
Nd:YAG (continuous)	1.06	up to 5400	—	Cutting metals
CO_2 (repetitively pulsed)	10.6	10^5	100	Hole drilling in alumina circuit boards
CO_2 (TEA)	10.6	10^6	100	Marking components
CO_2 (continuous)	10.6	up to 20,000	—	Cutting metals, plastics, cloth
Copper vapor	0.512, 0.578	3×10^5	6500	Drilling metals
Excimer	0.193, 0.248	10^6–10^7	100	Drilling plastics, ceramics
Ruby	0.694	10^6	low (<1)	Drilling gemstones
Nd:glass	1.06	10^6	low (<1)	Drilling hard metals

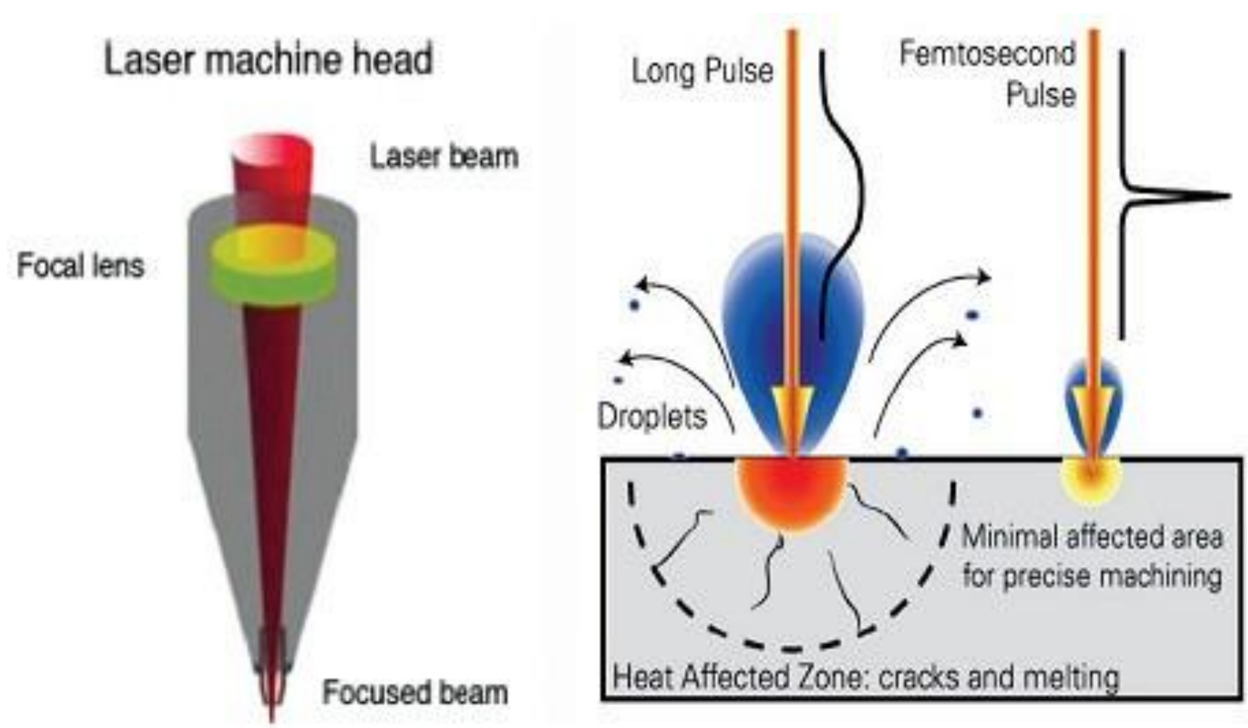
Over and over again the laser has proved to be an extremely practical tool. Nevertheless, lasers Have also proved their usefulness in non-practical applications, especially in the realm of art andEntertainment. Lasers are involved in almost all aspects of these fields, from "light shows" to Compact Discs (CDs) and Digital Video Discs (DVDs), to

special effects in the movies. Some Other commonplace application of lasers are as Laser pointers, barcode scanners, laser printers, etc.

Still, much of the important modern day celebrated applications lie in the fiber-optic Communication, laser machining and fabrication, trace element detection, laser metrology and Medical imaging.

Laser Machining and cutting

Laser energy can be focused in space and concentrated in time so that it heats, burns away, or Vaporizes many materials. Although the total energy in a laser beam may be small, the Concentrated power on small spots or during short intervals can be enormous. Although lasers Cost much more than mechanical drills or blades, their different properties allow them to perform Otherwise difficult tasks.



A laser beam does not deform flexible materials as a mechanical drill would, so it can drill holes In materials such as soft rubber nipples for baby bottles. Likewise, laser beams can drill or cut Into extremely hard materials without dulling bits or blades. Laser machining is not dependent on The material hardness but on the optical properties of the laser and the optical and thermo-Physical properties of the material. For example, lasers have drilled holes in diamond dies used For drawing wire.Several recent research have shown that laser cutting is best achieved with Ultrafast lasers (Fig. 2), as the material only ablates and does not get a chance to melt under such Ultrafast time scale interactions.

Laser cutting

In the simplest terms, a CNC laser cutter uses a coherent beam of light to cut material, most often Sheet metal, but also wood, diamond, glass, plastics and silicon. In the beginning, the beam was Directed through a lens via mirrors, but these days fiber optics are much more common. The lens Focuses the beam at the work zone to burn, melt or vaporize the material. Exactly which Process(es) the material undergoes depends on the type of laser cutting involved. Broadly speaking, laser cutting can be divided into two types: laser fusion cutting and ablative Laser cutting. Laser fusion cutting involves melting material in a column and using a high-Pressure stream of gas to shear the molten material away, leaving an open cut kerf. In contrast, Ablative laser cutting removes material layer by layer using a pulsed laser—it's like chiseling, Only with light and on a microscopic scale. This generally means evaporating the material, rather Than melting it. Two other key factors distinguish laser fusion cutting from ablative laser cutting.

First, ablative laser cutting can be used to make partial cuts in a material, whereas laser fusion Cutting can only be used to cut all the way through it. This is due to fusion cutting operating with Lasers either in continuous waves or with significantly longer pulses than ablative cutting (micro-Or milliseconds vs. nanoseconds), which causes a molten pool to penetrate the entire depth of the Metal. This molten material must be sheared away via gas stream, otherwise it can stay in the Kerf and weld back cut edges upon cooling.

The second and more significant factor that distinguishes these two types of laser cutting is Speed. "With sheet metal cutting—which makes up the bulk of the cutting industry. At the Current state of laser technology, laser fusion cutting is much faster for those setups. Ablative Cutting takes more time, for now.

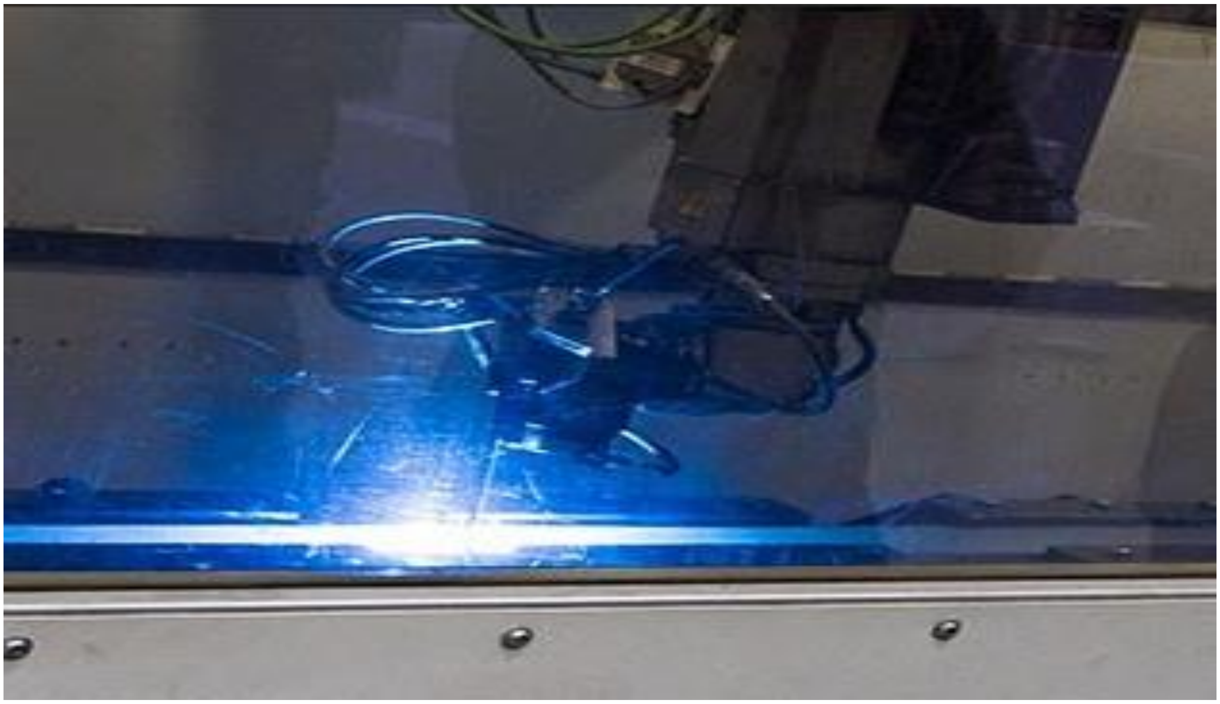
Fiber Lasers vs CO_2:-

- **The two most common types of laser cutting machines are fiber laser and CO_2.**
- **CO_2 lasers use an electromagnetically stimulated gas—typically, a mixture of carbon dioxide, Nitrogen and sometimes hydrogen, xenon or helium—as their active laser medium. In contrast,Fiber lasers—which are a type of solid-state laser—use an optical fiber doped with rare-earth Elements, such as erbium, ytterbium, neodymium or dysprosium. As indicated by Houldcroft's Experiments, the industry began with CO_2, and that technology dominated until only recently. "Potentially, CO_2 lasers will be replaced completely. If so, this would happen mid-term while the Fiber laser technology further evolves. Currently, CO_2 lasers still have some specific advantages, e.g., better edge quality in thick material and smaller burrs.**
- **CNC laser cutters are used on a wide range of materials in a variety of industries. Since cutting Sheet metal is the most common application, it's worth focusing on the particularities involved. For instance, reflectance and surface thickness are two of the most important factors to consider. Laser cutting uses high-pressure gas—5-25 bars for nitrogen cutting—so you need the parts to Either be supported by their own weight, which works if they're thicker than 2-3 mm and Relatively large in size, but for the parts that are thin and small, to resist the force of the gas Stream, small sections need to remain uncut," Sarrafi said. "These micro-joints are very small, 0.2-0.4 mm wide, so they're easy to break in post processing, but sometimes they're necessary to Connect the parts to the frame so the parts don't fly away**

Laser welding

- **Laser welding is used more frequently in industrial processes because it has wider application Than traditional welding as less heat is created because the beam is so focused. This means that Heat transfer to the workpiece is much less and the metallurgical structure is less affected and the Quality of the weld is much higher than with traditional forms of welding.**
- **Laser welding is a much more accurate manufactoring process and welds can be as small as one Hundredths of a millimetre. Small pulses of heat are used to create the weld which leads to a Higher quality finish which is stronger providing a better depth to width ratio. Depending on the Power of the laser, welding penetration up to 15 millimetre of steel or stainless steel can be Achieved.**

- **Another distinct advantage of laser welding over other methods is that lasers can weld a greater Variety of metals such as high strength stainless steel, titanium, aluminium, carbon steel as well As precious metals like gold and silver.**
- **With laser welding, welds are much more accurate and finish is superior as is strength. The Manufactoring process is therefore excellent for fine components and it can be used in areas Where there is limited access. Lasers enable precision and quality where required for fine component.**



Summary of Laser Welding Advantages

- Aesthetically better weld finishes
- More suited to high value items such as jewellery
- Great for inaccessible places
- Ideal for solenoids and machined components
- Perfect for medical devices where weld quality is vital for hygiene and precision
- Better weld quality for a variety of metals and metal depths
- No concerns for weld weaknesses due to minimal distortion
- Work pieces can be handled almost immediately because heat transference is low
- Overall improved productivity

The benefits of laser welding for modern processes over traditional welding are many. Laser Welding overall has a much wider application

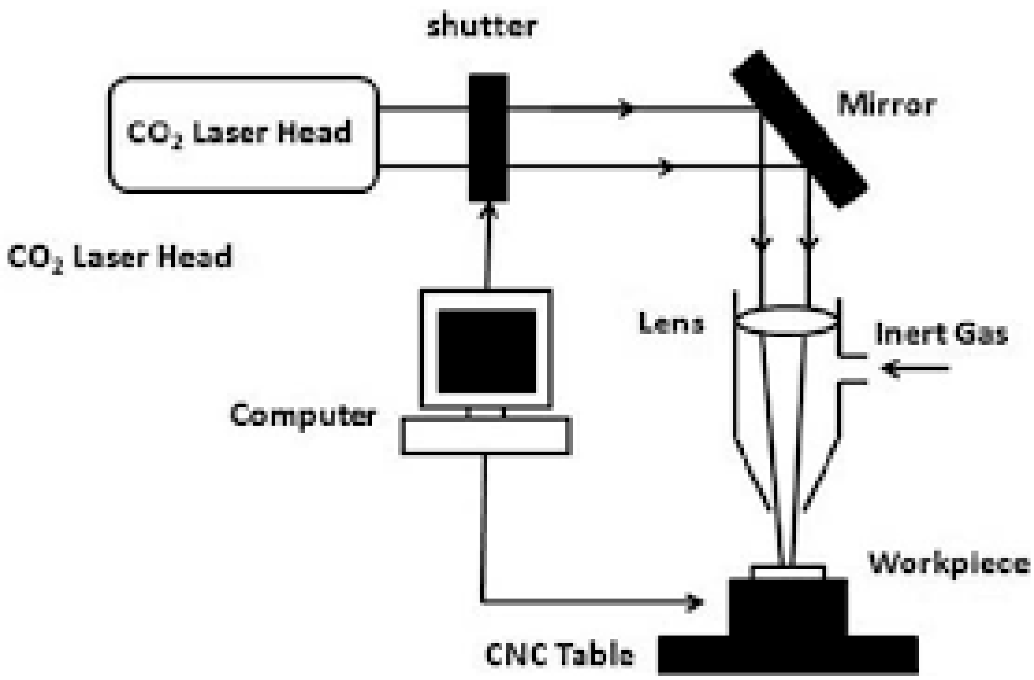
and an ability to weld a greater number of metals To a much higher quality which is vital where precision engineering is required.

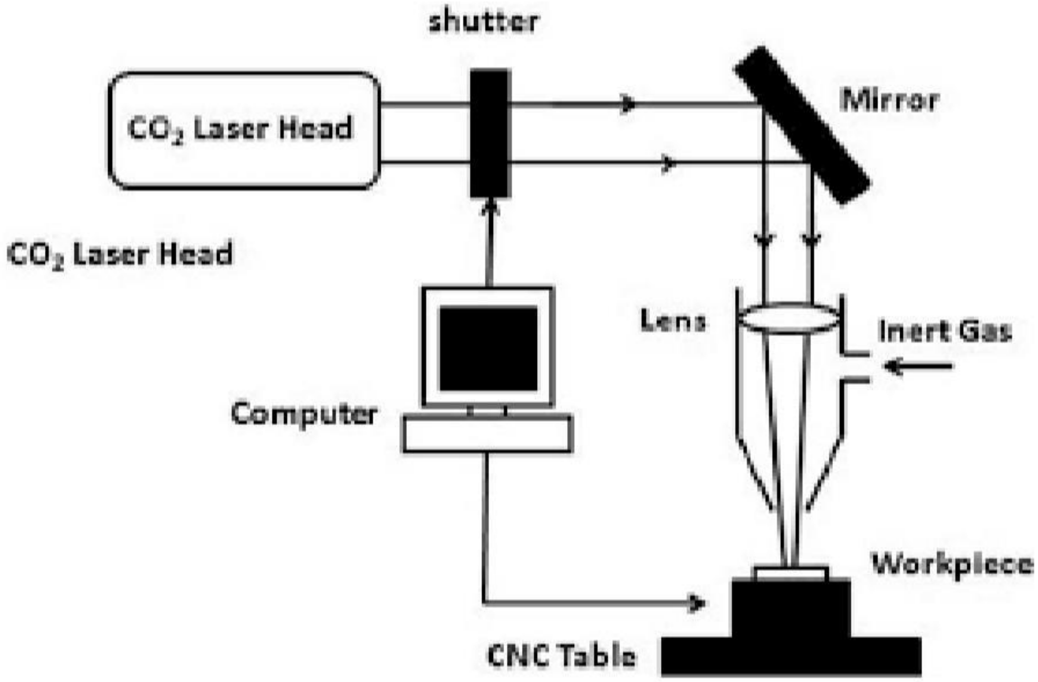
Laser – Hole drilling:-

We will describe the physical processes that occur in the interaction of high-power laser Radiation with surfaces. An understanding of these processes is important for understanding Thecapabilities and limitations of laser vaporization. We will emphasize metallic targets, but Muchof what is said applies to other absorbing surfaces as well.

Lasers used—The Nd:YAG laser has often been used for drilling holes in metals. It can deliver irradiance of 106–109 watts/cm2 to a target surface. For most metals, it offers lower Reflectivity than the CO2 laser, so that less light energy is lost by reflection. It also offers high Processing speed. The CO2 laser, with a wavelength 10 times larger than the Nd:YAG laser, has Less importance in drilling of metals, because the beam cannot be focused to as small a spot, and Because the absorption is not so high as for the Nd:YAG laser. But for many nonmetals, like Alumina, the absorption is much higher for the CO2 laser than for the Nd:YAG laser. Thus, CO2 Lasers have an important role in the drilling of materials like ceramics and plastic. The copper Vapor laser, with a high pulse repetition rate, has also found a role in the drilling of metals. Excimer lasers offer material removal with relatively little heating of the surrounding material, Because the chemical bonds in the target can be broken by shorter, ultraviolet wavelengths of the Excimer laser. The material is removed without significant thermal conduction of heat into the Interior of the work

piece. Thus, excimer lasers may be used for hole drilling in materials that are Sensitive to heat, like plastics.





Depth of holes—When high-power laser radiation is absorbed by a target, the surface is heated By the incoming laser light. The surface temperature goes quickly through the melting point and Reaches the vaporization temperature (boiling point). Material begins to vaporize and a hole is Produced in the surface. When a pulsed laser beam with duration around 1 millisecond interacts With a surface, the process of material involves conventional heating, melting, and vaporization. The time scale is 10 Optics and Photonics Series, Photonics-Enabled Technologies: Manufacturing long enough so that vaporized material can flow away from the point of the Interaction. Vaporization occurs at a continually retreating surface

.

	Absorbed laser irradiance (watts/cm^2)		
Metal	**10^5**	**10^6**	**10^7**
Lead	118 μs	1.18 μs	12 ns
Zinc	128 μs	1.28 μs	13 ns
Magnesium	245 μs	2.45 μs	24.5 ns
Nickel	1.84 ms	184 μs	184 ns
Iron	1.86 ms	186 μs	186 ns
Aluminum	2.67 ms	26.7 μs	267 ns
Molybedenum	5.56 ms	55.6 μs	556 ns
Copper	8.26 ms	82.6 μs	826 ns
Tungsten	10.46 ms	104.6 μs	1.05 μs

Advantages

Hole drilling with lasers offers many advantages over competing techniques.

1. ***There is no contact of external materials with the workpiece, and hence, no contamination.***
2. ***Hard, brittle materials that are difficult to drill with conventional techniques are often easily Drilled with lasers.***
3. ***The heat-affected zones around the holes can be very small.***
4. ***It is possible to produce very small holes in thin materials.***
5. ***Laser drilling is compatible with automation, so that it is possible to produce large numbers of Holes and complex patterns of holes in a completely automated process.***

6. ***There is no wear of expensive tool bits, so that in some cases, laser drilling offers an economic Advantage.***
7. ***Holes can be drilled with high throughput rate, so that the cost is low.***

Limitations

Laser hole drilling, of course, will not completely replace conventional hole drilling. There are a Number of limitations for laser hole drilling.

1. **Laser energy is relatively expensive and may not compete economically with other processes For specific applications.**
2. **The holes drilled by lasers tend to have limited depth. One might think that one could use a CO2 laser and allow it to dwell on a spot for a long time. But the heat then spreads over a 1arger volume and much of the advantage in using lasers is lost.**
3. **There may be a recondensation of vaporized material around the entrance to the hole, which Forms a crater-like lip. The lip can be removed fairly easily, but this adds one more step to the Laser-drilling process.**
4. **Laser Imaging and Holography Holography is a much broader field than most people have perceived. Recording and displaying Truly three-dimensional images are only small parts of it. Holographic optical elements (HOE)Can perform the functions of mirrors, lenses, gratings, or combinations of them, and they are Used in myriad technical devices. Holographic interferometry measures microscopic Displacements on the surface of an object and small changes in index of refraction of transparent Objects like plasma and heat waves. The coherence of laser light is crucial for interferometry and holography, which depend on Interactions between light waves to make extremely precise measurements and to record threeDimensional image (Fig. 4). Later, when lasLight**

illuminates that pattern from the same angle as the reference beam, it is scattered to Reconstruct an identical wave front of light, which appears to the viewer as a three-dimensional Image of the object. Holograms now can be mass-produced by an embossing process, as used on Credit cards, and do not have to be viewed in laser light.

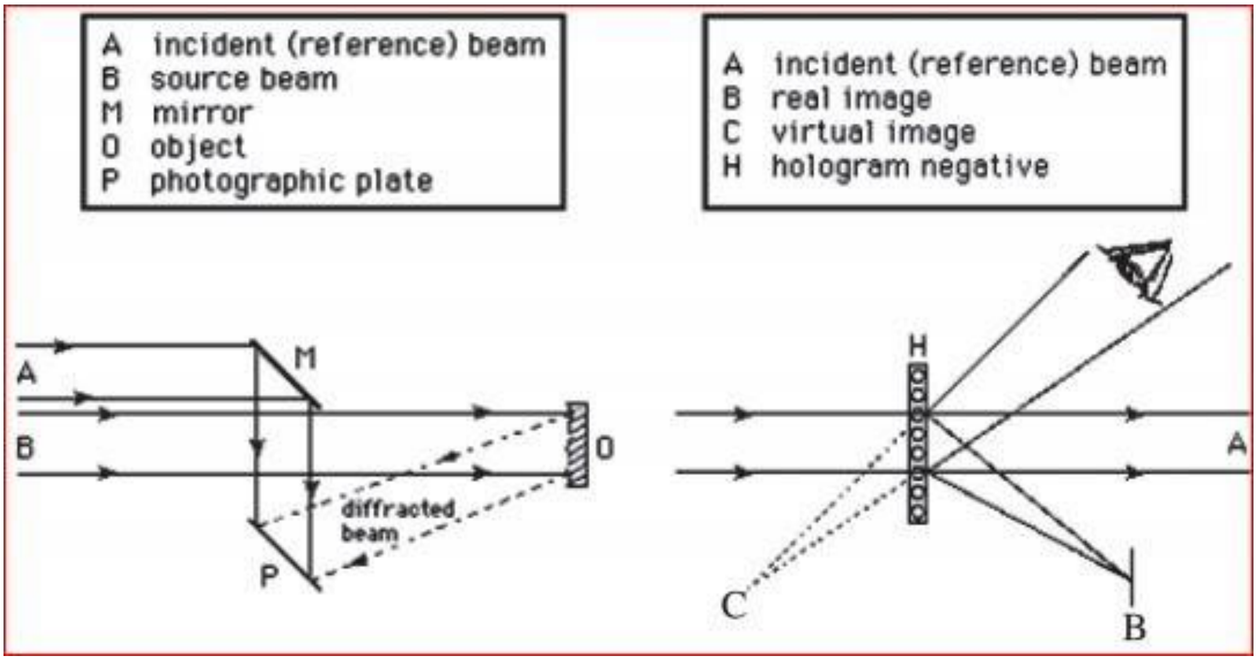


Fig. 2.1 Schematic of Holography process where the laser beam is split into three components. First two beams are needed to create the hologram which is viewed with the help of the third.

TYPES OF HOLOGRAMS

A hologram is a recording in a two- or three-dimensional medium of the interference pattern Formed when a point source of light (the reference beam) of fixed wavelength encounters light of The same fixed wavelength arriving from an object (the object beam). When the hologram is Illuminated by the reference beam alone, the diffraction pattern recreates the wave fronts of light From the original object.

Thus, the viewer sees an image indistinguishable from the original Object.

- ***The reflection hologram***
- ***Transmission holograms***
- ***Hybrid holograms***

Recording and reconstruction of holograms

Recording of hologram. The recording of hologram is based on the phenomenon of Interference. It requires a laser source, a plane mirror or beam splitter, an object and a Photographic plate. A laser beam from the laser source is incident on a plane mirror or beam Splitter. As the name suggests, the function of the beam splitter is to split the laser beam. One Part of splitted beam, after reflection from the beam splitter, strikes on the photographic plate. This beam is called reference beam. While other part of splitted beam (transmitted from beamSplitter) strikes on the photographic plate after suffering reflection from the various points of Object. This beam is called object beam. Each and every part of the hologram receives light from various points of the object. Thus, even If hologram is broken into parts, each part is capable of reconstructing the whole object.

Reconstruction of image.

In the reconstruction process, the hologram is illuminated by laser beam and this beam is called Reconstruction beam. This beam is identical to reference beam used in construction of hologram. The hologram acts a diffraction grating. This reconstruction beam will undergo phenomenon of Diffraction during passage through the hologram. The reconstruction beam after passing through The hologram produces a real as well as virtual image of the object.. If the observer moves Round the virtual image then other sides of the

object which were not noticed earlier would be Observed. Therefore, the virtual image exhibits all the true three dimensional characteristics. The Real image can be recorded on a photographic plate.

Applications of holography

The three-dimensional images produced by holograms have been used in various fields, Such as technical, educational also in advertising, artistic display etc.

Holographic diffraction gratings: The interference of two plane wavefronts of laser Beams on the surface of holographic plate produces holographic diffraction grating. The Lines in this grating are more uniform than in case of conventional grating.

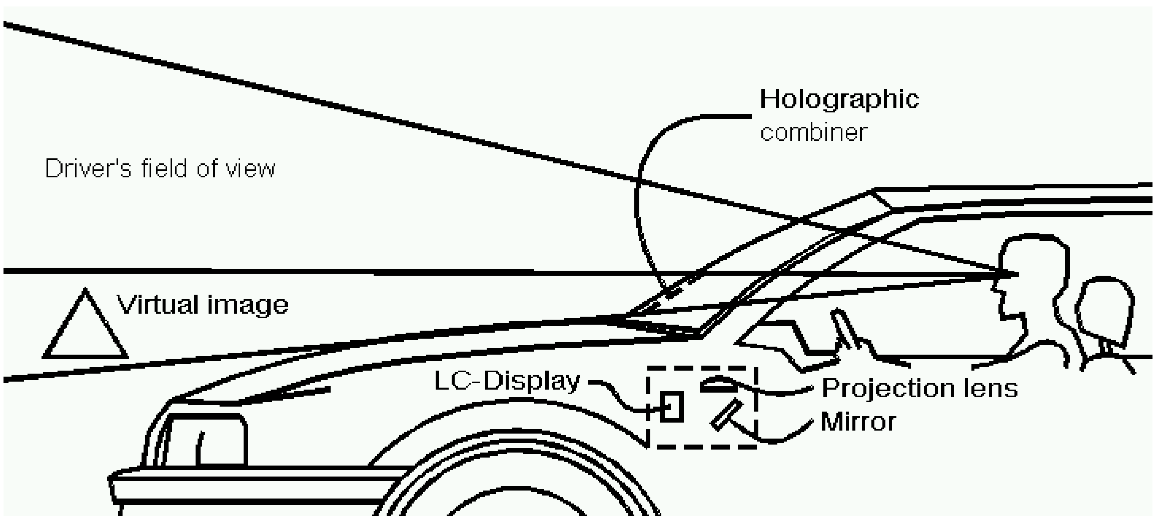
Hologram is a reliable object for data storage, because even a small broken piece of Hologram contains complete data or information about the object with reduced clarity.

The information-holding capacity of a hologram is very high because many objects can Be recorded in a single hologram, by slightly changing …

Some current applications that use holographic technology are:

- **Holographic interferometry is used by researchers and industry designers to test and design Many things, from tires and engines to prosthetic limbs and artificial bones and joints.**
- **Supermarket and department store scanners use a holographic lens system that directs laserLight onto the bar codes of the merchandise.**

• Holographic optical elements (HOE's) are used for navigation by airplane pilots. A Holographic image of the cockpit instruments appears to float in front of the windshield. This Allows the pilot to keep his eyes on the runway or the sky while reading the instruments. This Feature is available on some models of automobiles.



Medical doctors can use three-dimensional holographic CAT scans to make measurements Without invasive surgery. This technique is also used in medical education.

• Holograms are used in advertisements and consumer packaging of products to attract potential Buyers.

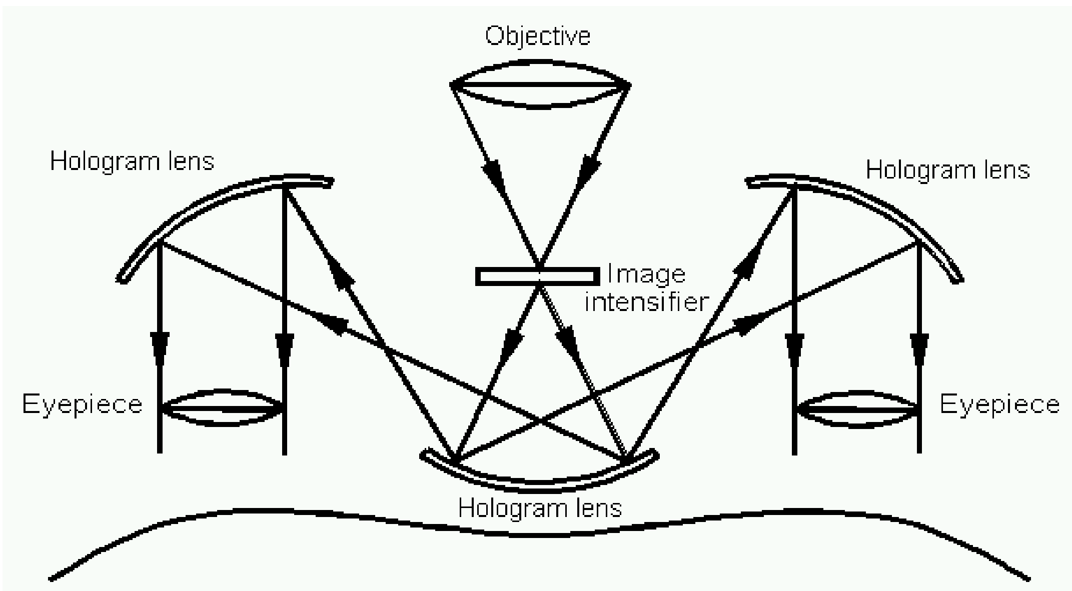
• Holograms have been used on covers of magazine publications. One of the most memorable Sports Illustrated covers was the December 23, 1992 issue featuring Michael Jordan. Holograms Have also been used on sports trading cards.

• The use of holograms on credit cards and debit cards provide added security to minimize Counterfeiting.

• Holography has been use by artists to create pulsed holographic portraits as well as other Works of art.

Future applications of holography include:

• Future colour liquid crystal displays (LCD's) will be brighter and whiter as a result of Holographic technology. Scientists at Polaroid Corp. have developed a holographic reflector that Will reflect ambient



light to produce a whiter background.

• Holographic night vision goggles

Many researchers believe that holographic televisions will become available within 10 years at A cost of approximately $5000. Holographic motion picture technology has been previously Attempted and was successful in the 1970s. The future of holographic motion pictures may Become a reality within the next few years.Holographic memory is a new optical storage method that can store 1 terabyte (= 1000 GB) of Data in a crystal approximately the size of a sugar cube. In comparison, current methods of Storage include CD's that hold 650 to 700 MB, DVD's that store 4.7 GB, and computer hard Drives that hold up to 120 GB.

• Optical computers will be capable of delivering trillions of bits of information faster than the Latest computers.

MEDICAL ENDOSCOPE – FIBER OPTIC: CONSTRUCTION AND WORKING

Optical fibers are very much useful in medical field. Using low quality, large diameter and short Length silica fibers we can design a fiber optic endoscope or fibroscope.

MEDICAL ENDOSCOPE

Optical fibers are very much useful in medical field. Using low quality, large diameter and short Length silica fibers we can design a fiber optic endoscope or fibroscope. A medical endoscope is A tubular optical instrument, used to inspect or view the internal parts of human body which are Not visible to the naked eye. The photograph of the internal parts can also be taken using this Endoscope.

Construction

Figure shows the structure of endoscope. It has two fibers viz., 1. Outer fiber(f0) The inner fiber (fi).Optical fibers are very much useful in medical field. Using low quality, large diameter and short Length silica fibers we can design a fiber optic endoscope or fibroscope. A medical endoscope is A tubular optical instrument, used to inspect or view the internal parts of human body which are Not visible to the naked eye. The photograph of the internal parts can also be taken using this Endoscope.

WORKING

Light from the source is passed through the outer fiber (f0). The light is illuminated on the Internal part of the body. The reflected light from the object is brought to focus using the Telescope to the inner fiber (fi). Here each fiber picks up a part of the picture from the body.

Hence the picture will be collected bit by bit and is transmitted in an order by the array of fibers. As a result, the whole picture is reproduced at the other end of the receiving fiber as shown in the

Figure. The output is properly amplified and can be viewed through the eye piece at the receiving End. The cross sectional view is as shown in the figure.

INTRODUCTION TO FIBER OPTICS

The development of lasers and optical fiber has brought about a revolution in the field Of communication systems. Experiments on the propagation of information – carrying light Waves through an open atmosphere were conducted. The atmospheric conditions like rain, fog Etc. affected the efficiency of communication through light waves.

Optical fiber

The optical fiber is a wave guide. It is made up of transparent dielectrics (SiO_2), (glass or Plastics).

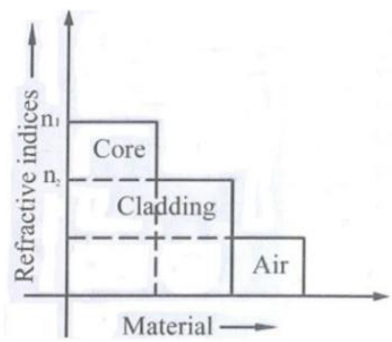
STRUCTURE OF OPTICAL FIBER

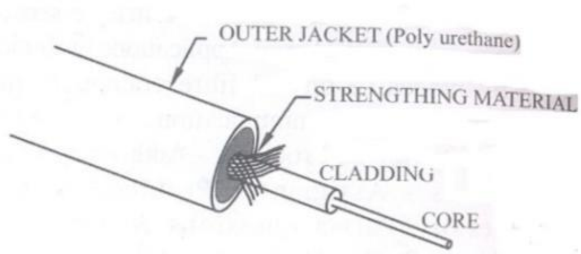
Fiber Construction

It consists of an inner cylinder made of glass or plastic called core. The core has high Refractive index n1. This core is surrounded by

cylindrical shell of glass or plastic called Cladding. The cladding has low refractive index n2. This cladding is covered by a jacket which is

Made of polyurethane. It protects the layer from moisture and abrasion.





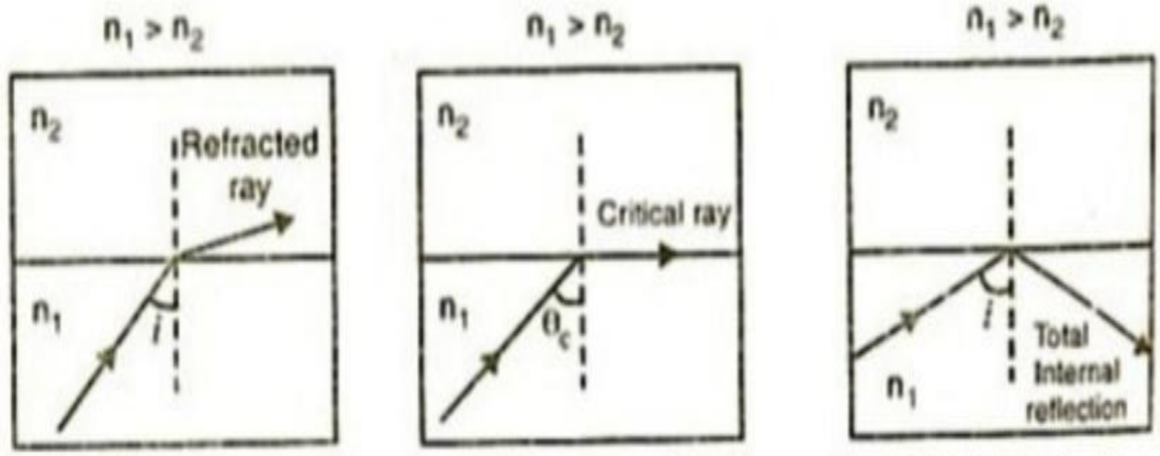
Principle of propagation of light in an optical fiber

The light launched inside the core at one end of the fiber propagates to the other end due To total internal reflection at the core and cladding interface.

Total internal reflection at the fiber wall can occur only if two conditions are satisfied.

1. The refractive index of the core material n1 must be higher than that of the cladding n2 Surrounding it (n1> n2).
2. At the core – cladding interface, the angle of incidence (between the ray and normal to The interface) must be greater than the critical angle
    a) When, it is refracted into rarer medium

b) When , it traverses along the interface so that angle of Refraction is 90 degree
c) When , it is totally reflected back into the denser Medium itself.



(a) When $i < \theta_c$ (b) When $i = \theta_c$ (c) When $i > \theta_c$

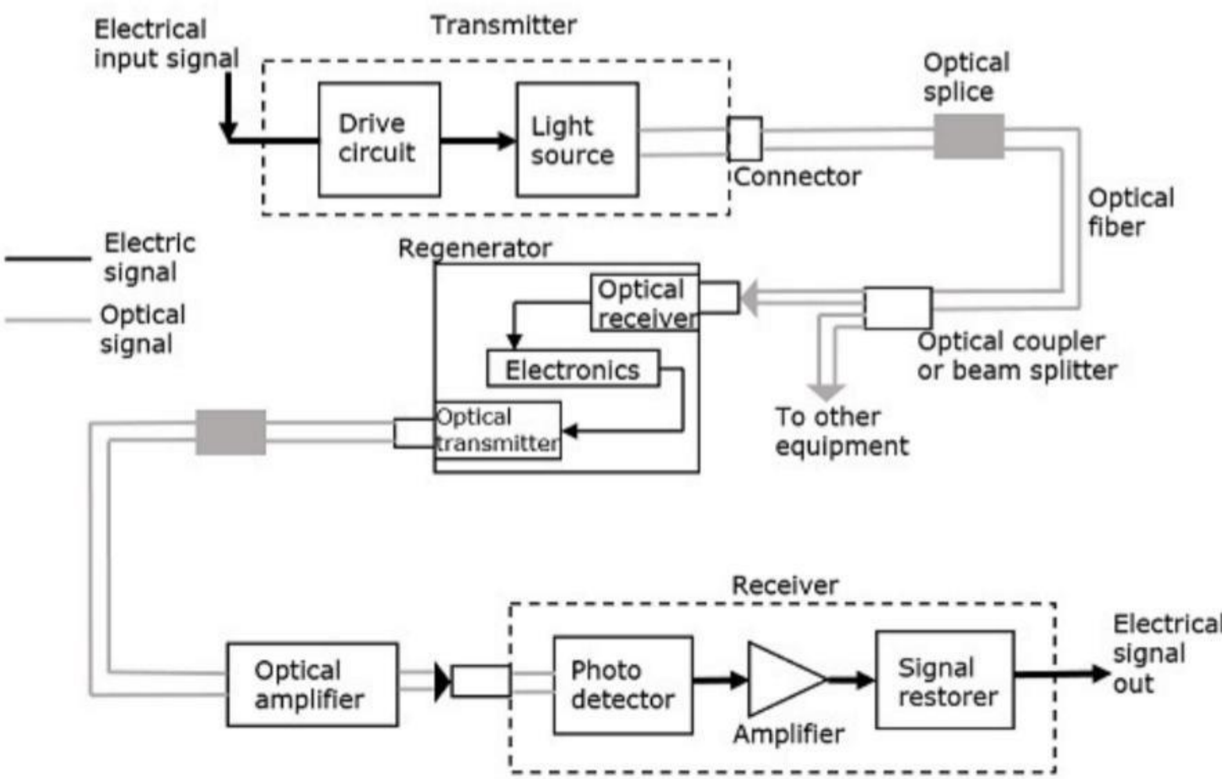
When , then by Snell's law,

$$n_1 Sin\theta_c = n_2 \; Sin\; 90^0$$

$$Sin\theta_c = \frac{n_2}{n_1}\; Sin\; 90^0$$

FIBER OPTIC COMMUNICATION

Source and Detectors for fiber Optic communication



Transmitter:

•The transmitter first converts the input voltage to current value which is used to drive the Light source. Thus it interfaces the input circuit and the light source.

• The light source is normally an infrared LED or LASER device which is driven by the Current value from the V to I convertor. It emits light which is proportional to the drive Current. Thus light which is proportional to the input voltage value is generated and given As input to fiber.

• A source to fiber interface is used for coupling the light source to the fiber optic cable. The light emitted from the source is inserted into the fiber such that maximum light Emitted from it is coupled to the fiber.

Optical Splice:

• For creating long haul communication link, it is necessary to join one fiber to other fibers Permanently. For this purpose, optical splicing techniques are used to join different Fibers.

Optical Coupler/ Beam splitter:

• Optical couplers are used to couple the light output from the fiber end to the device which Can be receiver or regenerator.

• Beam splitters are used to split the light beam which can be given to other equipment.

Regenerator/ Repeater:

• After an optical signal is launched in to a fiber, it will become progressively attenuated

And distorted with increasing distance because of scattering, absorption and dispersion Mechanisms in the glass material.

• Therefore repeaters are placed in between to reconstruct the original signal and again Retransmit it.

• The signal is processed in electronics domain and hence optical to electrical conversion And electrical to optical conversions are performed in the repeater.

Optical Amplifier:

• After an optical signal has travelled a certain distance along a fiber, it becomes greatly Weakened due to power loss along the fiber.

• Therefore, when setting up an optical link, engineers formulate a power loss budget and Add amplifiers or repeaters when the path loss exceeds the available power margin.

• The periodically placed amplifiers merely give the optical signal a power boost, whereasA repeater attempts to restore the signal to its original shape.

Receiver:

• At the destination of an optical fiber transmission line there is a coupling device (connector) which couples the light signal to the detector.

• Inside the receiver is a photodiode that detects the weakened and distorted optical signalEmerging from the end of an optical fiber and converts it to an electrical signal. (Referred To as photo current).

• I to V convertor produce an output voltage proportional to the current generated by theLight detector. Thus, we obtain output value which was given to the system as data input.

Advantages:

• Good information carrying capacity, which depends on bandwidth of the cable and fiber Optical cable have much greater bandwidth.

• Lower loss as there is less signal attenuation over long distances.

• Fiber optical cable has lightweight and small size as compared to electrical cable.

• Optical cable does not cause interface because they do not carry the signals, which cause Interference.

• Fiber optical cables cannot be tapped as easily as electrical cables.

• Fiber optical cables do not carry electricity. Therefore, there is no shock hazard.

• Fiber Optical cables are stronger than electrical cables.

• Materials required for fiber optical cables are easily available.

• They are simple in construction

Disadvantages:

1. **Interfacing Costs: To be practical and useful, they must be connected to standard electronic Facilities, which often require expensive interfaces.**
2. **Strength: Optical fibers by themselves have a significantly lower tensile strength than coaxial Cable. This can be improved by coating the fiber with a protective jacket of PVC.**

3. Remote electrical power: Occasionally it is necessary to provide electrical power to remote Interface or regenerating equipment. This cannot be accomplished with the optical cable, so Additional metallic cables must be included in the cable assembly.

4. Optical fiber cables are more susceptible to losses introduced by bending the Cable: Bending the cable causes irregularities in the cable dimensions, resulting in a loss of Signal power.

5. **Specialized tools, equipment and training: Optical fiber cables require special tools to splice And repair cables and special test equipment to make routine measurements. Sometimes it is Difficult to locate faults in optical cables because there is no electrical continuity.**

CONCLUSION :-

Through this experiment we have seen how we can transfer thae light beams from one point to the other even through a curved path.This is also the only principle behind the fibre optics technology in which laser beams are used to transfer the data from one system to other through a wire having reflective coating at the interior.

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