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OPEN AND DISTANCE LEARNING(ODL) PROGRAMMES
(FOR THOSE WHO JOINED THE PROGRAMMES FROM THE ACADEMIC YEAR 2023–2024)

III YEAR

B.Sc. Physics

Course Material

Laser Physics

Prepared
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LASER PHYSICS

Unit –I: Fundamentals of LASER

Spontaneous emission – Stimulated emission – Meta stable state – Population inversion – Pumping – Laser Characteristics

Unit –II: Production of LASER

Helium – Neon Laser – Ruby Laser – CO_2 Laser – Semiconductor Laser

Unit –III: Industrial Applications of LASER

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Unit –IV: Lasers in Medicine

Lasers in Surgery – Lasers in ophthalmology – Lasers in cancer treatment

Unit –V: Lasers in Communication

Optic fibre communication – Total internal reflection – Block diagram of fibre optic communication system – Advantages of fibre optic communication.

Books for study:

1. N. Avadhanulu. *An introduction to LASERS*, S. Chand & Company, 2001.

Books for References:

1. William T. Silfvast, *Laser fundamentals*, University Press, Published in South Asia by Foundation books, New Delhi, 1998.
2. K. Thyagarajan and A.K. Ghatak, *LASER Theory and Application*, Mc Millan, India Ltd, 1984.

Unit –I: Fundamentals of LASER

Spontaneous emission – Stimulated emission – Meta stable state – Population inversion – Pumping – Laser Characteristics

LASER - Introduction:

Laser stands for 'Light Amplification by Stimulated Emission of Radiation'. It is a process by means of which we get a strong, intense, monochromatic, collimated, unidirectional and highly coherent beam of light.

It is a device which emits a powerful, monochromatic collimated beam of light. The emitted light waves are coherent in nature. The first laser, ruby laser was invented by Dr. T. H. Maiman in the year 1960. Since then, the development of lasers is extremely rapid. The laser action is being demonstrated in many solids, liquids, gases and semiconductor.

Einstein's coefficients:

Absorption: Suppose an atom is, in the lower energy level E_1. If a photon of energy $hv = (E_2 - E_1)$ is incident on the atom, it provides its energy to the atom and .disappears. Then we say that the atom absorbed an incident photon. As a result of absorption of adequate energy, the

atom jumps to the excited state E_2. The transition is called an absorption transition. It is also referred to as induced absorption. We may express the process as, $A + hv = A^*$, where A is an atom in the lower state and A^* is an excited atom.

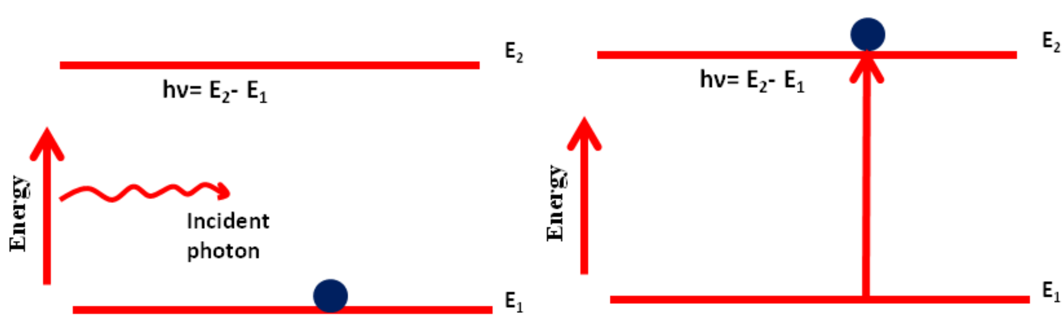


Fig. Schematic diagram of Processof absorption

The number of atoms per unit volume that undergo absorption transitions per second is called the rate of absorption transition. It is denoted by R_{abs}.

It is found that, $R_{abs} = B_{12}p(v)N_1$

Where, N1 is the population of atoms at E1, p(v)the energy density of the incident beam and B12 is the constant of proportionality. B_{12} is known as the Einstein coefficient for induced absorption. It indicates the probability of occurrence of an induced transition from level 1→2.

As a result of this induced absorption N_1 decreases and N_2 increases.

Spontaneous emission:

An atom cannot stay in the excited state for a longer time. In a time of about 10^{-8} s, the atom returns to the lower energy state by releasing a photon of energy hv, where $hv = (E_2 - E_1)$. The emission of photon occurs on its own and without any external impetus given to the excited atom. Emission of .a photon by an atom without any external impetus is called spontaneous emission. We may write the process as A* = A + hv.

The number of spontaneous transitions. Depends only on the number of atoms N_2 at the excited state E_2. Therefore, the rate of spontaneous transitions is given by $R_{sp} = A_{21}N_2$

Where, A_{21} is the proportionality constant and is called the Einstein coefficient for spontaneous emission. A_{21} represents the probability of a spontaneous transition from level 2—> 1.

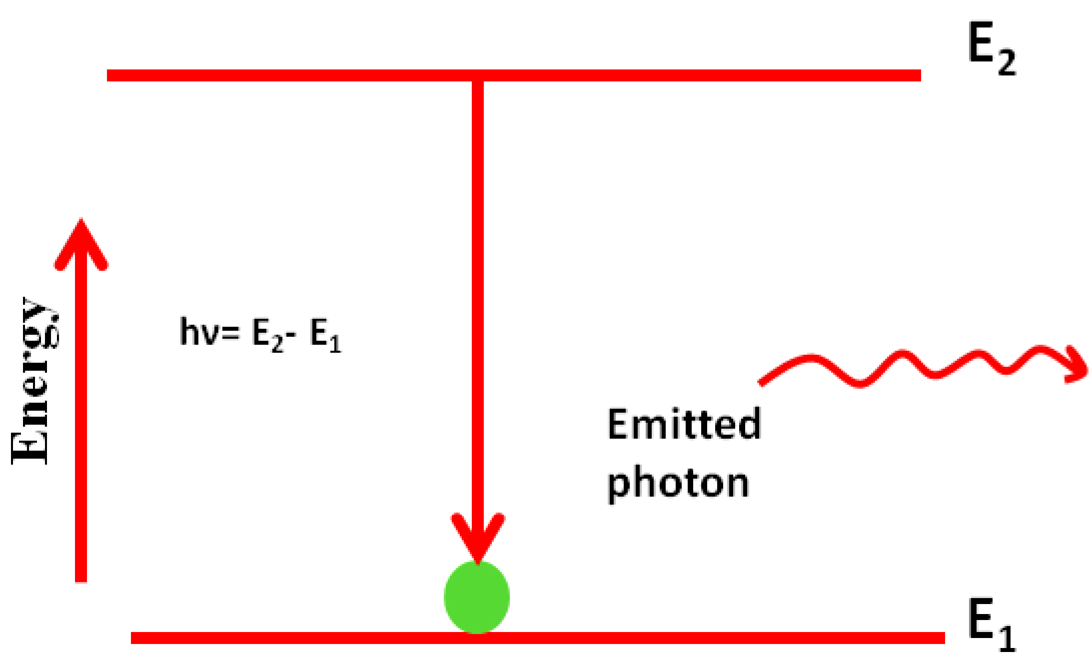


Fig: Schematic diagram of spontaneous emission

Stimulated emission:

An atom in the excited state need not "wait" for spontaneous emission of photon. Well before the atom can make a spontaneous transition, it may interact with a photon with energy hv = $E_2 - E_1$ and make a downward transition. The photon is said to **stimulate** or **induce** the excited atom to emit a photon of energy hv = $(E_2 - E_1)$. The passing photon does not disappear and in addition to it there is a second photon which is emitted by the excited atom (see Fig. 22.6). The phenomenon of forced photon emission by an excited atom due to the action o f an external agency is called **stimulated emission or induced emission.** The process may be expressed as

$$A^* + hv\ A + 2hv,$$

The rate of stimulated emission of photons is given by

$$R_{st}=B_{21}\rho(\nu)N_2$$

Where, B21 is the Einstein coefficient fo r stimulated emission and represents the probability for induced transition from level 2 → 1

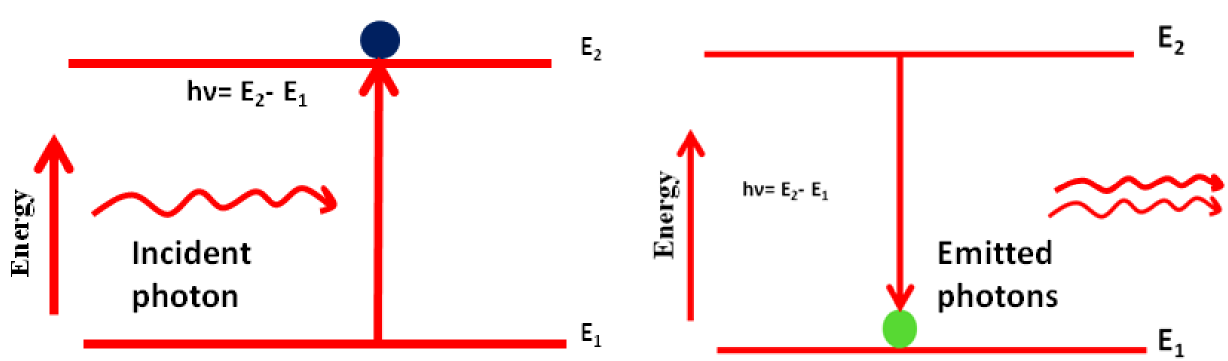


Fig: Schematic diagram of stimulated emission

Characteristics of stimulated emission

- The process of stimulated emission is controllable from outside.
- The photon induced in this process propagates in the same direction as that of stimulating photon.
- The induced photon has the same frequency, phase and polarization as that of the stimulating photon.
- The main advantage of this process is the multiplication of photons.
- All the waves generated in the medium are due to one initial wave and all the waves are in phase. Thus the waves are coherent and interfere constructively.
- The light emitted through the process of stimulated emission is of very high intensity and we say that the light is amplified.

Relation between Einstein's coefficients:

Under thermal equilibrium, the mean population (no. of atoms per unit volume) N_1 and N_2 in the lower and upper energy levels remain constant. This means that the number of transitions from E_2 to E_1 must be equal to the number of transitions from E_1 to E_2.

Thus the number of atoms absorbing photons per second per unit volume = The number of atoms emitting photons per second per unit volume

Now the number of atoms absorbing photons per second per unit volume = $B_{12}\rho(\nu)N_1$

Here ($\rho(\nu)$) is the energy density of the incident beam and B12 is known as the Einstein's coefficient for induced absorption.

The number of atoms emitting photons per second per unit volume = $A_{21}\, N_2 + B_{21}\, (\rho(\nu))\, N_2$

Here, A21 is known as the Einstein's coefficient for spontaneous emission and B_{21} is known as the Einstein's coefficient for stimulated emission.

At equilibrium, $B_{12}\, (\rho(\nu))\, N1 = A_{21}\, N_2 + B_{21}\, (\rho(\nu))\, N_2$

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

Dividing by $B_{12}\, N_2$

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

But, $\left(\frac{N_1}{N_2}\right) = \exp\left[\frac{-(E_2 - E_2)}{KT}\right]$

As $(E_2 - E_1) = h\nu$, Thus $\left(\frac{N_1}{N_2}\right) = \exp\left[\frac{-h\nu}{KT}\right]$ and $\left(\frac{N_1}{N_2}\right) = \exp\left[\frac{h\nu}{KT}\right]$

Therefore,

$$\rho(v) = \frac{\frac{A_{21}}{B_{12}}}{\exp\left[\frac{h\nu}{KT}\right] - \left(\frac{B_{21}}{B_{12}}\right)}$$

To maintain the thermal equilibrium the system must release energy in the form of electromagnetic radiation which is identical with Planck's radiation law

$$\rho(v) \frac{\frac{8\pi h v^3 \mu^3 h}{\omega^3}}{\exp\left[\frac{h\nu}{KT}\right]}$$

Here μ is the RI of the medium and c is the velocity of light in free space.

Comparing the equations, we have $A_{21} = \frac{8\pi h v^3 \mu^3 h}{c^3} B_{21}$ and $B_{12} = B_{21}$

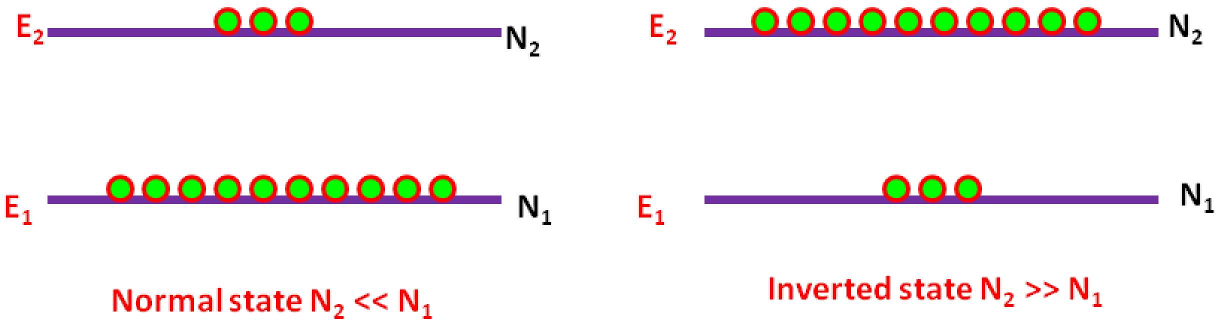
The above equations are called Einstein's relations. The coefficients A_{21}, B_{21} and B_{12} are known as Einstein's coefficients.

Population Inversion:

When the material is in thermal equilibrium condition, the population ratio is governed by the Boltzmann distribution law according to the following equation:

$$\left(\frac{N_1}{N_2}\right) = \exp\left[\frac{-(E_2 - E_2)}{KT}\right]$$

It means that the population N2 at the excited level E2 will be far smaller than the population N_1 at the level E_1. The condition in which there are more atoms in the lower energy level and relatively lesser number of atoms in the higher energy level is called **normal condition** or **thermal equilibrium.** Thus, under thermal equilibrium, N_1 N_2 .



To achieve a high percentage of stimulated emission, a majority of atoms should be at the higher energy level than at the lower level. If we can somehow increase the population in the excited level so that N_2 becomes more than that in the ground level, the condition is called population inversion. This is an non- equilibrium condition and can be achieved by pumping technique.

Metastable state:

An atom can be excited to a higher level by supplying energy to it. Normally, excited atoms have short lifetimes and release their energy in a matter of nanoseconds (10^{-9} s) through spontaneous emission. It means that atoms do not stay long enough at the excited state to be stimulated. As a result, even though the pumping agent continuously raises the atoms to the excited level, they undergo spontaneous transitions and rapidly return to the lower energy level. Population inversion cannot be established under such circumstances. In order to establish the condition of population inversion, the excited atoms are required to 'wait' at the upper energy level till a large number of atoms accumulate at that level. In other words, it is necessary that the excited state has a longer lifetime. A metastable state is such a state. Atoms excited to the metastable states remain excited for an appreciable time, which is of the order of 10^{-6} to 10^{-3} s.

Therefore, the metastable state allows accumulation of a large number of excited atoms at that level. The metastable state population can exceed the population at a lower level and establish the condition of population inversion in the lasing medium.

Pumping:

For achieving and maintaining the condition of population inversion, we have to raise continuously the atoms in the lower energy level to the upper energy level. It requires energy to be supplied to the system. **Pumping** is the process of supplying energy to the laser medium with a view to transfer it into the state of population inversion. There are a number of techniques for pumping a collection of atoms to an inverted state. Optical pumping, electrical discharge and direct conversion are some of the methods of pumping. In optical pumping, a light source such as a flash discharge tube is used to illuminate the active medium. This method is adopted in solid state lasers. In electrical discharge method, the electric field causes ionization of the medium and raises it to the excited state. In semiconductor diode lasers, a direct conversion of electrical energy into light energy takes place.

Three level pumping scheme:

A typical three-level pumping scheme is shown in Fig. The state E_1 is the ground level; E_3 is the pump level and E_2 is the metastable upper lasing level. When the medium is exposed to pump frequency radiation, a large number of atoms will be excited to E_3 level. However, they do not stay at that level but rapidly undergo downward transitions to the metastable level E_2 through non-radiative transitions. The atoms are trapped at this level as spontaneous transition from the level E_2 to the level E_1 is forbidden. The pumping continues and after a short time there will be a large accumulation of atoms at the level E_2. When more than half of the ground level atoms accumulate at E_2, the population inversion condition is achieved between the two levels E_1 and E_2. Now a chance photon can trigger stimulated emission.

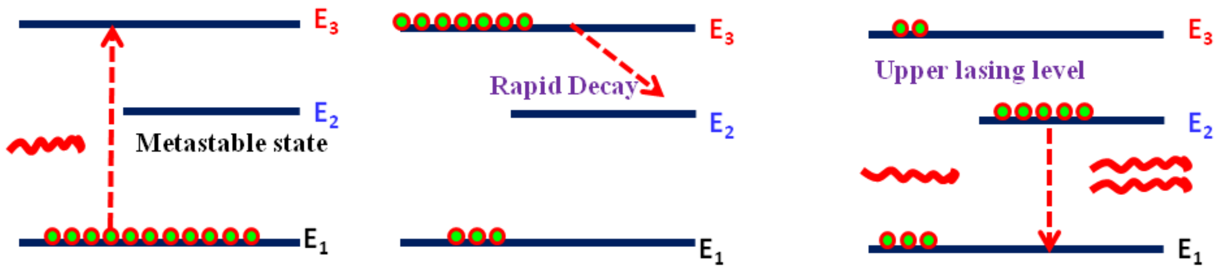


Fig. Schematic diagram of three level pumping scheme

Four level pumping scheme:

A typical four-level pumping scheme is shown in Fig. The level E_1 is the ground level, E_4 the pumping level, E_3 the metastable upper lasing level and E_2 the lower lasing level. E_2, E_3 and E_4 are the excited levels. When light of pump frequency νp is incident on the lasing medium, the active centers are readily excited from the ground level to the pumping level E_4. The atoms stay at the E_4 level for only about 10-8 s, and quickly drop down to the metastable level E_3. As spontaneous transitions from the level E_3 to level E_2 cannot take place, the atoms get trapped at the level E_3. The population at the level E_3 grows rapidly. The level E_2 is well above the ground level such that $(E_2 - E_1) > kT$. Therefore, at normal temperature atoms cannot jump to level E_2 from E_1on the strength of thermal energy. As a result, the level E_2 is virtually empty. Therefore, population inversion is attained between the levels E_3 and E_2. A chance photon of energy $h\nu = (E_3 - E_2)$ emitted spontaneously can start a chain of stimulated emissions, bringing the atoms to the lower laser level E_2. From the level E_2 the atoms subsequently undergo non-radiative transitions to the ground level E_1 and will be once again available for excitation.

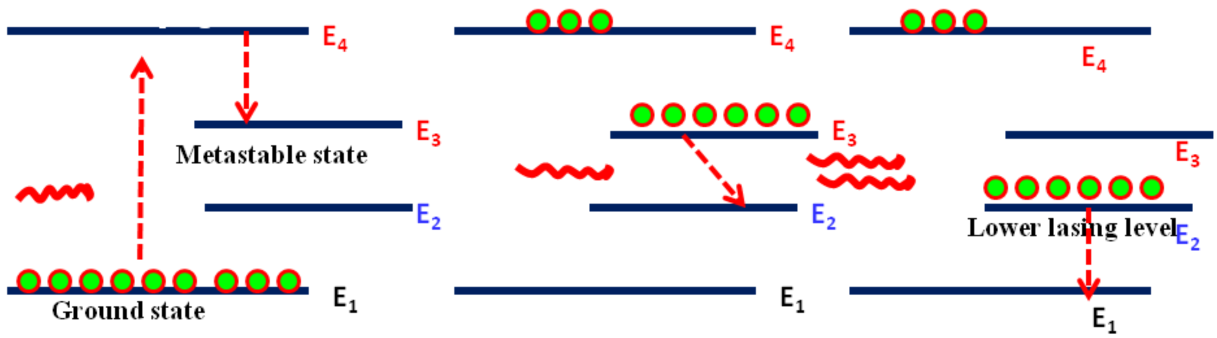


Fig. Schematic diagram of four level pumping scheme

Characteristics of Laser

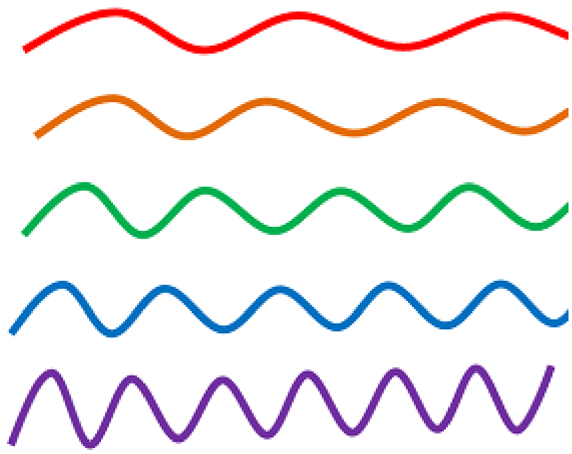
Laser light has four unique characteristics that differentiate it from ordinary light: these are

- Coherence
- Directionality
- Monochromatic
- High intensity

Coherence

The visible light is emitted when excited electrons (electrons in higher energy level) jumped into the lower energy level (ground state). The process of electrons moving from higher energy level to lower energy level or lower energy level to higher energy level is called electron transition.

In ordinary light sources (lamp, sodium lamp and torch light), the electron transition occurs naturally. In other words, electron transition in ordinary light sources is random in time. The photons emitted from ordinary light sources have different energies, frequencies, wavelengths, or colors. Hence, the light waves of ordinary light sources have many wavelengths. Therefore, photons emitted by an ordinary light source are out of phase.



Incoherent light

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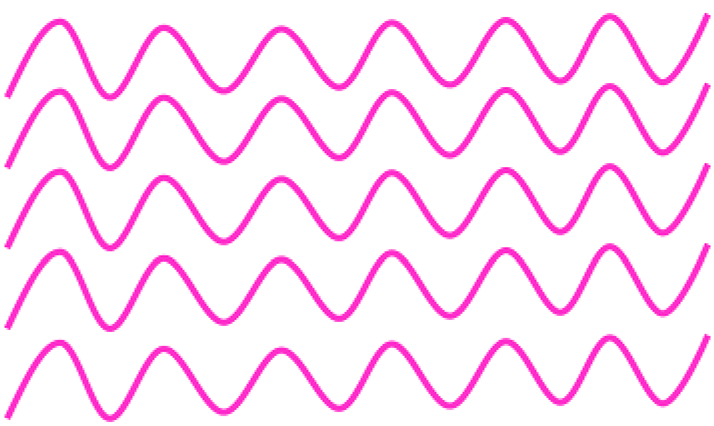
In laser, the electron transition occurs artificially. In other words, in laser, electron transition occurs in specific time. All the photons emitted in laser have the same energy, frequency, or wavelength. Hence, the light waves of laser light have single wavelength or color. Therefore, the wavelengths of the laser light are in phase in space and time. In laser, a technique called stimulated emission is used to produce light.



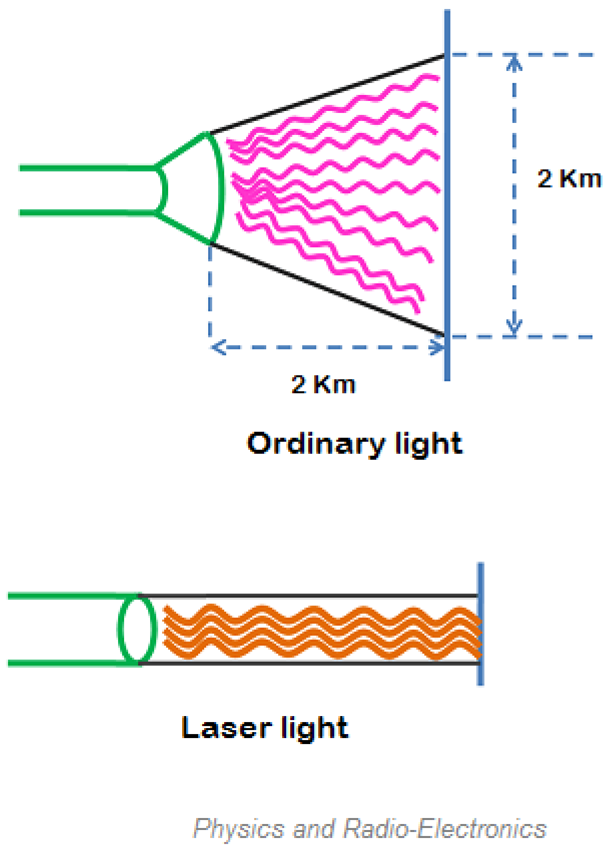
Coherent light waves

Thus, light generated by laser is highly coherent. Because of this coherence, a large amount of power can be concentrated in a narrow space.

Directionality

In conventional light sources (lamp, sodium lamp and torchlight), photons will travel in random direction. Therefore, these light sources emit light in all directions.

On the other hand, in laser, all photons will travel in same direction. Therefore, laser emits light only in one direction. This is called directionality of laser light. The width of a laser beam is extremely narrow. Hence, a laser beam can travel to long distances without spreading.



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

Monochromatic

Monochromatic light means a light containing a single color or wavelength. The photons emitted from ordinary light sources have different energies, frequencies, wavelengths, or colors. Hence, the light waves of ordinary light sources have many wavelengths or colors. Therefore, ordinary light is a mixture of waves having different frequencies or wavelengths.

On the other hand, in laser, all the emitted photons have the same energy, frequency, or wavelength. Hence, the light waves of laser have single wavelength or color. Therefore, laser light covers a very narrow range of frequencies or wavelengths.

High Intensity

The intensity of a wave is the energy per unit time flowing through a unit normal area. In an ordinary light source, the light spreads out uniformly in all directions.

A 100 Watt lamp filament from a distance of 30 cm, the power entering your eye is less than 1/1000 of a watt.

In laser, the light spreads in small region of space and in a small wavelength range. Hence, laser light has greater intensity when compared to the ordinary light.

If you look directly along the beam from a laser (caution: don't do it), then all the power in the laser would enter your eye. Thus, even a 1 Watt laser would appear many thousand times more intense than 100 Watt ordinary lamp.

Thus, these four properties of laser beam enable us to cut a huge block of steel by melting. They are also used for recording and reproducing large information on a compact disc (CD).

Unit –II: Production of LASER

Helium – Neon Laser – Ruby Laser – CO_2 Laser – Semiconductor Laser

Helium-Neon laser

Helium-Neon laser definition

Helium-Neon laser is a type of gas laser in which a mixture of helium and neon gas is used as a gain medium. Helium-Neon laser is also known as He-Ne laser.

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. The helium-neon lasers are most 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

At room temperature, a ruby laser will only emit short bursts of laser light, each laser pulse occurring after a flash of the pumping light. It would be better to have a laser that emits light continuously. Such a laser is called a continuous wave (CW) laser.

The helium-neon laser was the first continuous wave (CW) laser ever constructed. It was built in 1961 by Ali Javan, Bennett, and Herriott at Bell Telephone Laboratories.

Helium-neon lasers are the most widely used gas lasers. These lasers have many industrial and scientific uses and are often used in laboratory demonstrations of optics.

In He-Ne laser, the optical pumping method is not used instead an electrical pumping method is used. 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

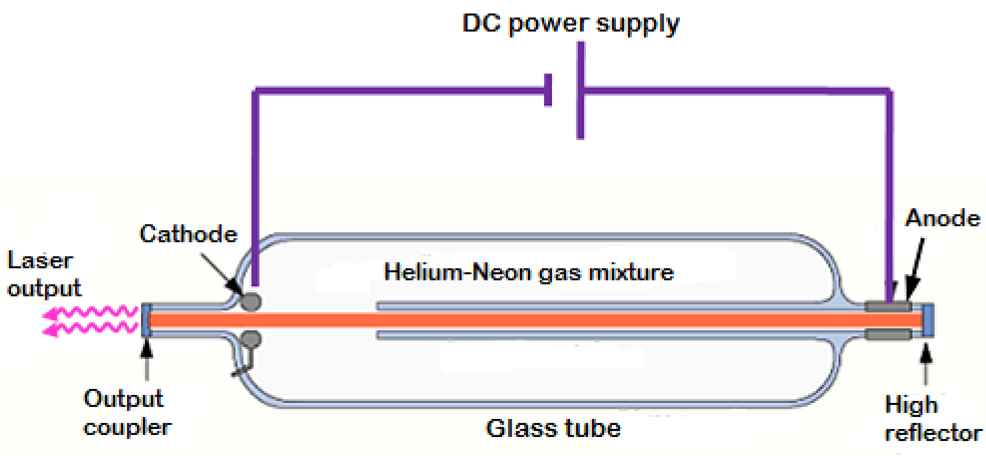
High voltage power supply or pump source

In order to produce the laser beam, it is essential to achieve population inversion. Population inversion is the process of achieving more electrons in the higher energy state as compared to the lower energy state.

In general, the lower energy state has more electrons than the higher energy state. However, after achieving population inversion, more electrons will remain in the higher energy state than the lower energy state.

In order to achieve population inversion, we need to supply energy to the gain medium or active medium. Different types of energy sources are used to supply energy to the gain medium.

In ruby lasers and Nd:YAG lasers, the light energy sources such as flashtubes or laser diodes are used as the pump source. However, in helium-neon lasers, light energy is not used as the pump source. 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.



Gain medium (discharge glass tube or glass envelope)

The gain medium of a helium-neon laser is made up of the mixture of helium and neon gas contained in a glass tube at low pressure. The partial pressure of helium is 1 mbar whereas that of neon is 0.1 mbar.

The gas mixture is mostly comprised of helium gas. Therefore, in order to achieve population inversion, we need to excite primarily the lower energy state electrons of the helium atoms.

In He-Ne laser, 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 power supply.

Resonating cavity

The glass tube (containing a mixture of helium and neon gas) is placed between two parallel mirrors. These two mirrors are silvered or optically coated.

Each mirror is silvered differently. The left side mirror is partially silvered and is known as output coupler whereas the right side mirror is fully silvered and is known as the high reflector or fully reflecting mirror.

The fully silvered mirror will completely reflect the light whereas the partially silvered mirror will reflect most part of the light but allows some part of the light to produce the laser beam.

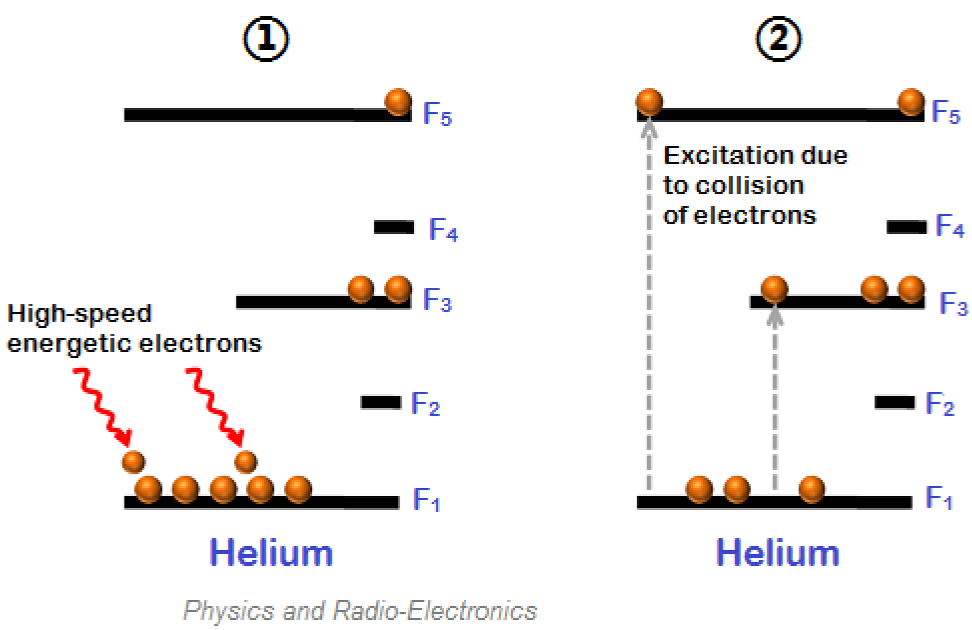
Working of helium-neon laser

In order to achieve population inversion, we need to supply energy to the gain medium. In helium-neon lasers, we use high voltage DC as the pump source. A high voltage DC produces energetic electrons that travel through the gas mixture.

The gas mixture in helium-neon laser is mostly comprised of helium atoms. Therefore, helium atoms observe most of the energy supplied by the high voltage DC.

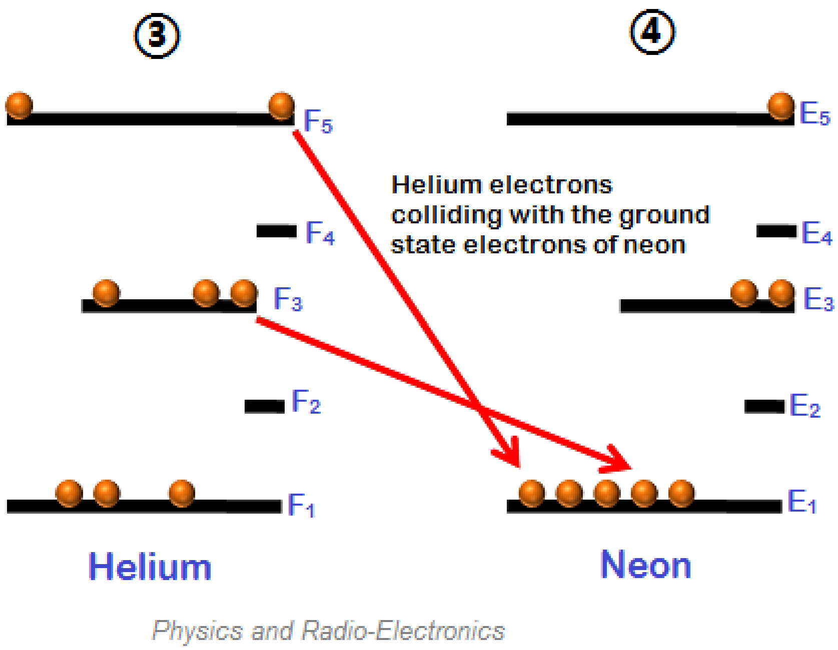
When the power is switched on, a high voltage of about 10 kV is applied across the gas mixture. This power is enough to excite the electrons in the gas mixture. The electrons produced in the process of discharge are accelerated between the electrodes (cathode and anode) through the gas mixture.

In the process of flowing through the gas, the energetic electrons transfer some of their energy to the helium atoms in the gas. As a result, the lower energy state electrons of the helium atoms gain enough energy and jumps into the excited states or metastable states. Let us assume that these metastable states are F_3 and F_5.

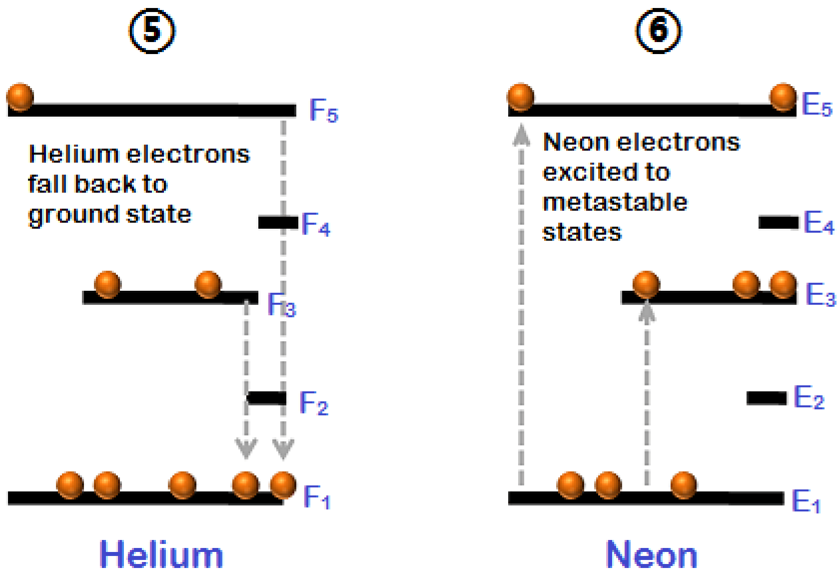


The meta stable state electrons of the helium atoms cannot return to ground state by spontaneous emission. However, they can return to ground state by transferring their energy to the lower energy state electrons of the neon atoms.

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 $F_3 = E_3$ and $F_5 = E_5$. E_3 and E_5 are excited states or metastable states of neon atoms.



Unlike the solid, a gas can move or flow between the electrodes. Hence, when the excited electrons of the helium atoms collide with the lower energy state electrons of the neon atoms, they transfer their energy to the neon atoms. As a result, 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 (E_3 and E_5) whereas the excited electrons of the helium atoms will fall into the ground state. Thus, helium atoms help neon atoms in achieving population inversion.



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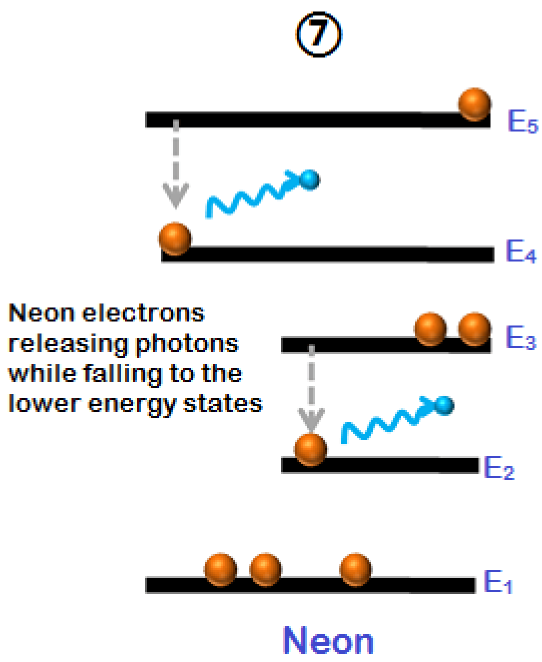
Likewise, millions of ground state electrons of neon atoms are excited to the metastable states. The metastable states have the longer lifetime. Therefore, a large number of electrons will remain in the metastable states and hence population inversion is achieved.

After some period, the metastable states electrons (E_3 and E_5) of the neon atoms will spontaneously fall into the next lower energy states (E_2 and E_4) by releasing photons or red light. This is called spontaneous emission.

The neon excited electrons continue on to the ground state through radiative and nonradiative transitions. It is important for the continuous wave (CW) operation.



The light or photons emitted from the neon atoms will moves back and forth between two mirrors until it stimulates other excited electrons of the neon atoms and causes them to emit light. Thus, optical gain is achieved. This process of photon emission is called stimulated emission of radiation.

The light or photons emitted due to stimulated emission will escape through the partially reflecting mirror or output coupler to produce laser light.

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.

Ruby Laser

Ruby laser definition

A ruby laser is a solid-state laser that uses the synthetic ruby crystal as its laser medium. Ruby laser is the first successful laser developed by Maiman in 1960.

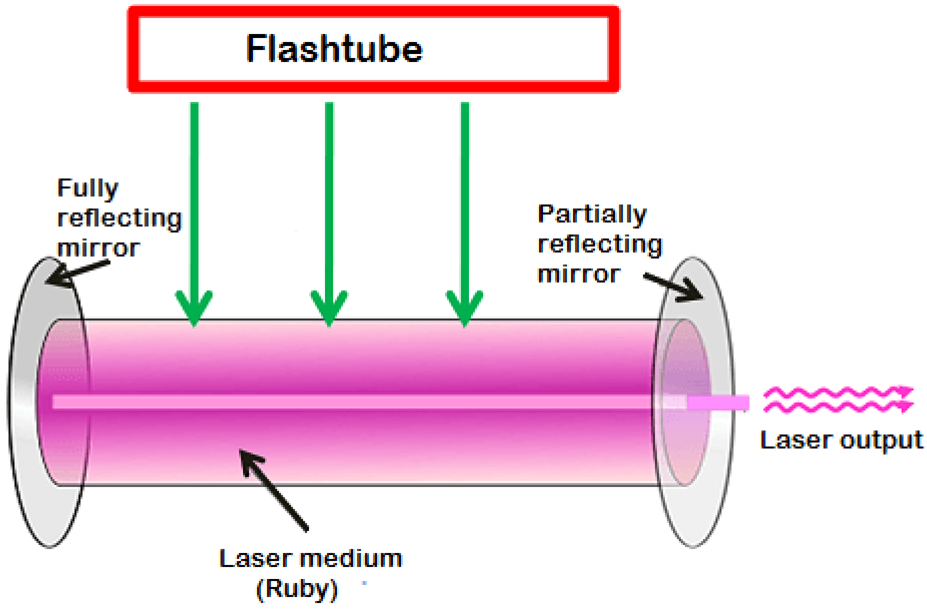
Ruby laser is one of the few solid-state lasers that produce visible light. It emits deep red light of wavelength 694.3 nm.

Construction of ruby laser

A ruby laser consists of three important elements: laser medium, the pump source, and the optical resonator.

Laser medium or gain medium in ruby laser

In a ruby laser, a single crystal of ruby ($Al_2O_3 : Cr^{3+}$) in the form of cylinder acts as a laser medium or active medium. The laser medium (ruby) in the ruby laser is made of the host of sapphire (Al_2O_3) which is doped with small amounts of chromium ions (Cr^{3+}). The ruby has good thermal properties.



Pump source or energy source in ruby laser

The pump source is the element of a ruby laser system that provides energy to the laser medium. In a ruby laser, population inversion is required to achieve laser emission. Population inversion is the process of achieving the greater population of higher energy state than the lower energy state. In order to achieve population inversion, we need to supply energy to the laser medium (ruby).

In a ruby laser, we use flashtube as the energy source or pump source. The flashtube supplies energy to the laser medium (ruby). When lower energy state electrons in the laser medium gain sufficient energy from the flashtube, they jump into the higher energy state or excited state.

Optical resonator

The ends of the cylindrical ruby rod are flat and parallel. The cylindrical ruby rod is placed between two mirrors. The optical coating is applied to both the mirrors. The process of depositing thin layers of metals on glass substrates to make mirror surfaces is called silvering. Each mirror is coated or silvered differently.

At one end of the rod, the mirror is fully silvered whereas, at another end, the mirror is partially silvered.

The fully silvered mirror will completely reflect the light whereas the partially silvered mirror will reflect most part of the light but allows a small portion of light through it to produce output laser light.

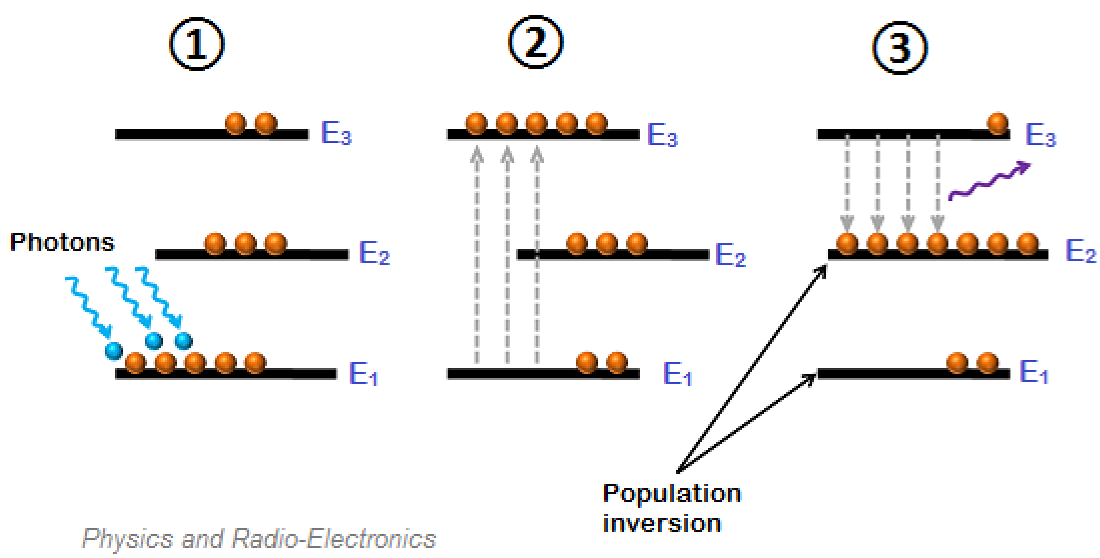
Working of ruby laser

The ruby laser is a three level solid-state laser. In a ruby laser, optical pumping technique is used to supply energy to the laser medium. Optical pumping is a technique in which light is used as energy source to raise electrons from lower energy level to the higher energy level.

Consider a ruby laser medium consisting of three energy levels E_1, E_2, E_3 with N number of electrons.

We assume that the energy levels will be $E_1 < E_2 < E_3$. The energy level E_1 is known as ground state or lower energy state, the energy level E_2 is known as metastable state, and the energy level E_3 is known as pump state.

Let us assume that initially most of the electrons are in the lower energy state (E_1) and only a tiny number of electrons are in the excited states (E_2 and E_3)



When light energy is supplied to the laser medium (ruby), the electrons in the lower energy state or ground state (E_1) gains enough energy and jumps into the pump state (E_3).

The lifetime of pump state E_3 is very small (10^{-8} sec) so the electrons in the pump state do not stay for long period. After a short period, they fall into the metastable state E_2 by releasing radiationless energy. The lifetime of metastable state E_2 is 10^{-3} sec which is much greater than the lifetime of pump state E_3. Therefore, the electrons reach E_2 much faster than they leave E_2. This results in an increase in the number of electrons in the metastable state E_2 and hence population inversion is achieved.

After some period, the electrons in the metastable state E_2 falls into the lower energy state E_1 by releasing energy in the form of photons. This is called spontaneous emission of radiation.

When the emitted photon interacts with the electron in the metastable state, it forcefully makes that electron fall into the ground state E_1. As a result, two photons are emitted. This is called stimulated emission of radiation.

When these emitted photons again interacted with the metastable state electrons, then 4 photons are produced. Because of this continuous interaction with the electrons, millions of photons are produced.

In an active medium (ruby), a process called spontaneous emission produces light. The light produced within the laser medium will bounce back and forth between the two mirrors. This stimulates other electrons to fall into the ground state by releasing light energy. This is called stimulated emission. Likewise, millions of electrons are stimulated to emit light. Thus, the light gain is achieved.

The amplified light escapes through the partially reflecting mirror to produce laser light.

CO_2 Laser

Molecular Gas Laser

In a molecular gas laser, laser action is achieved by transitions between vibrational and rotational levels of molecules. Its construction is simple and the output of this laser is continuous.

In CO_2 molecular gas laser, transition takes place between the vibrational states of Carbon dioxide molecules.

CO_2 Molecular gas laser

It was the first molecular gas laser developed by Indian born American scientist Prof. C.K.N. Pillai.

It is a four level laser and it operates at 10.6 μm in the far IR region. It is a very efficient laser.

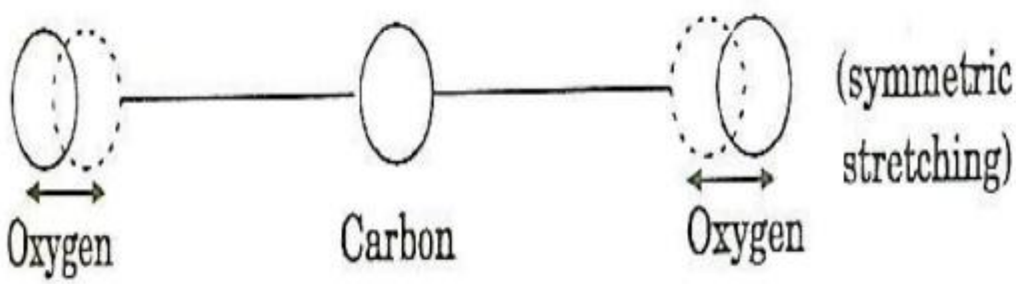
Energy States of CO_2 molecules

A carbon dioxide molecule has a carbon atom at the center with two oxygen atoms attached, one at both sides. Such a molecule exhibits three independent modes of vibrations. They are

a) Symmetric stretching mode
b) Bending mode
c) Asymmetric stretching mode

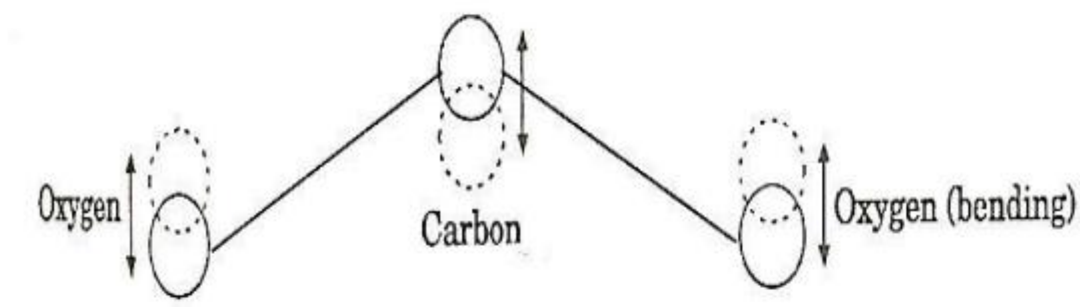
a. **Symmetric stretching mode**

In this mode of vibration, carbon atoms are at rest and both oxygen atoms vibrate simultaneously along the axis of the molecule departing or approaching the fixed carbon atoms.

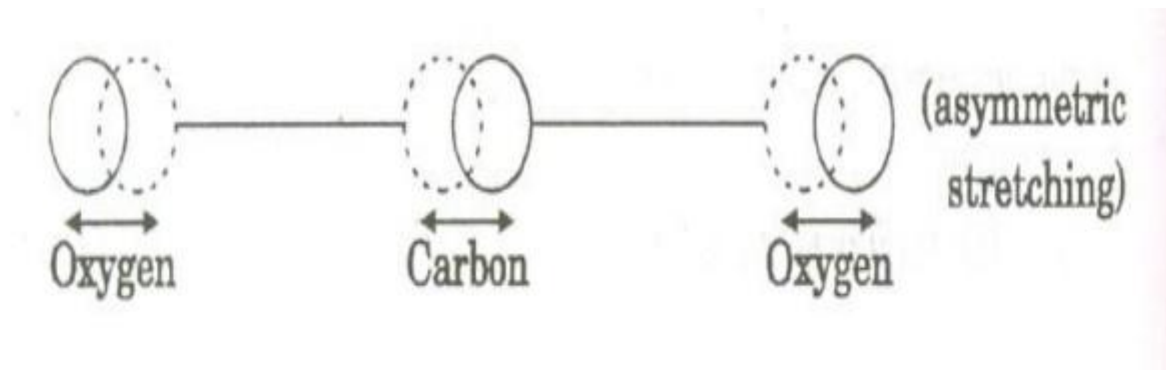


b. **Bending mode:**

In this mode of vibration, oxygen atoms and carbon atoms vibrate perpendicular to molecular axis.



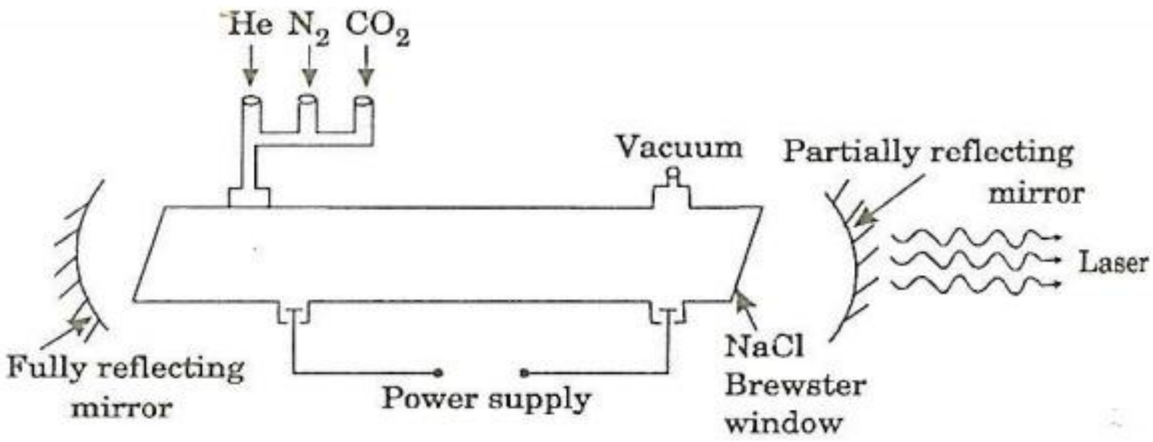
c. **Asymmetric stretching mode**:



In this mode of vibration, oxygen atoms and carbon atoms vibrate asymmetrically, i.e., oxygen atoms move in one direction while carbon atoms in the other direction.

Principle:

The active medium is a gas mixture of CO_2, N_2 and He. The laser transition takes place between the vibrational states of CO_2molecules.



Construction:

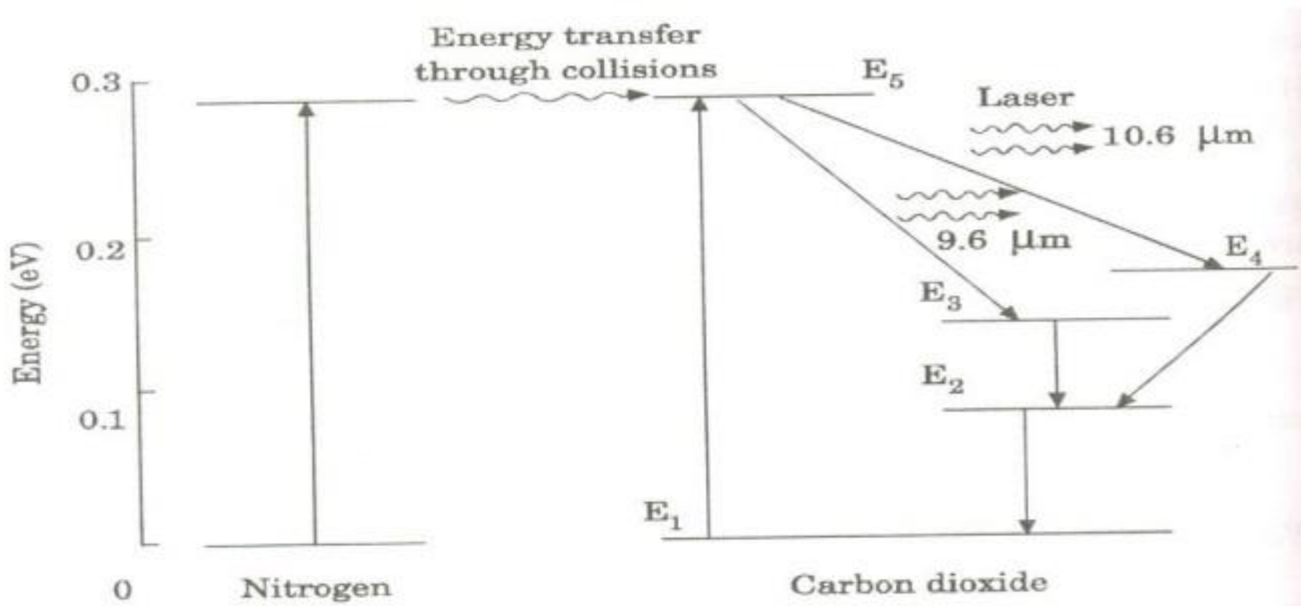
It consists of a quartz tube 5 m long and 2.5 cm in the diameter. This discharge tube is filled with gaseous mixture of CO2(active medium), helium and nitrogen with suitable partial pressures.

The terminals of the discharge tubes are connected to a D.C power supply. The ends of the discharge tube are fitted with NaCl Brewster windows so that the laser light generated will be polarized.

Two concave mirrors one fully reflecting and the other partially form an optical resonator.

Working:

Figure shows energy levels of nitrogen and carbon dioxide molecules.



When an electric discharge occurs in the gas, the electrons collide with nitrogen molecules and they are raised to excited states. This process is represented by the equation

$N_2 + e^* = N_2^* + e$

N_2 = Nitrogen molecule in ground state e^* = electron with kinetic energy

N_2^* = nitrogen molecule in excited state e= same electron with lesser energy

Now N_2 molecules in the excited state collide with CO_2 atoms in ground state and excite to higher electronic, vibrational and rotational levels.
This process is represented by the equation $N_2^* + CO_2 = CO_2^* + N_2$

N_2^* = Nitrogen molecule in excited state. CO_2 = Carbon dioxide atoms in ground state CO_2^* = Carbon dioxide atoms in excited state N_2 = Nitrogen molecule in ground state.

Since the excited level of nitrogen is very close to the E_5 level of CO_2 atom, population in E_5 level increases.

As soon as population inversion is reached, any of the spontaneously emitted photon will trigger laser action in the tube. There are two types of laser transition possible.

1. Transition E_5 to E_4:

This will produce a laser beam of wavelength 10.6μm

2. Transition E_5 to E_3

This transition will produce a laser beam of wavelength 9.6μm. Normally 10.6μm transition is more intense than 9.6μm transition. The power output from this laser is 10kW.

Characteristics:

1. Type: It is a molecular gas laser.
2. Active medium: A mixture of CO_2, N_2 and helium or water vapour is used as active medium
3. Pumping method: Electrical discharge method is used for Pumping action

4. Optical resonator: Two concave mirrors form a resonant cavity

5. Power output: The power output from this laser is about 10kW.

6. Nature of output: The nature of output may be continuous wave or pulsed wave.

7. Wavelength of output: The wavelength of output is 0.6μm and 10.6μm.

Advantages:

1. The construction of CO_2 laser is simple

2. The output of this laser is continuous.

3. It has high efficiency

4. It has very high output power.

5. The output power can be increased by extending the length of the gas tube.

Disadvantages:

1. The contamination of oxygen by carbon monoxide will have some effect on laser action

2. The operating temperature plays an important role in determining the output power of laser.

3. The corrosion may occur at the reflecting plates.

4. Accidental exposure may damage our eyes, since it is invisible (infra red region) to our eyes.

Applications:

1. High power CO_2 laser finds applications in material processing, welding, drilling, cutting soldering etc.
2. The low atmospheric attenuation (10.6μm makes CO_2 laser suitable for open air communication.
3. It is used for remote sensing

4. It is used for treatment of liver and lung diseases.

5. It is mostly used in neuro surgery and general surgery.

6. It is used to perform microsurgery and bloodless operations.

Semiconductor Laser

Definition:

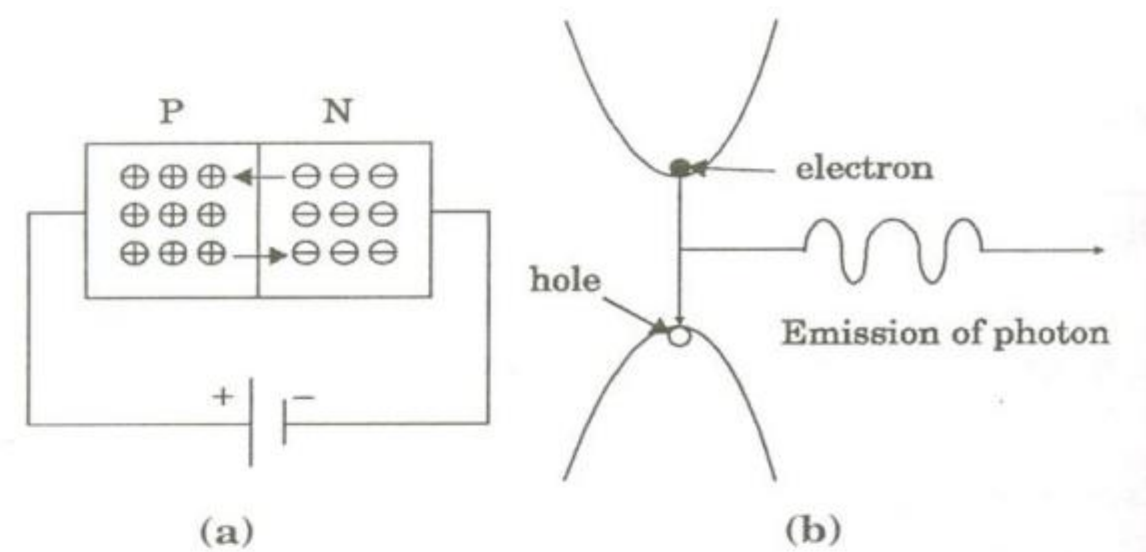
It is specifically fabricated p-n junction diode. This diode emits laser light when it is forward biased.

Principle:

When a p-n junction diode is forward biased, the electrons from n – region and the holes from the p- region cross the junction and recombine with each other.

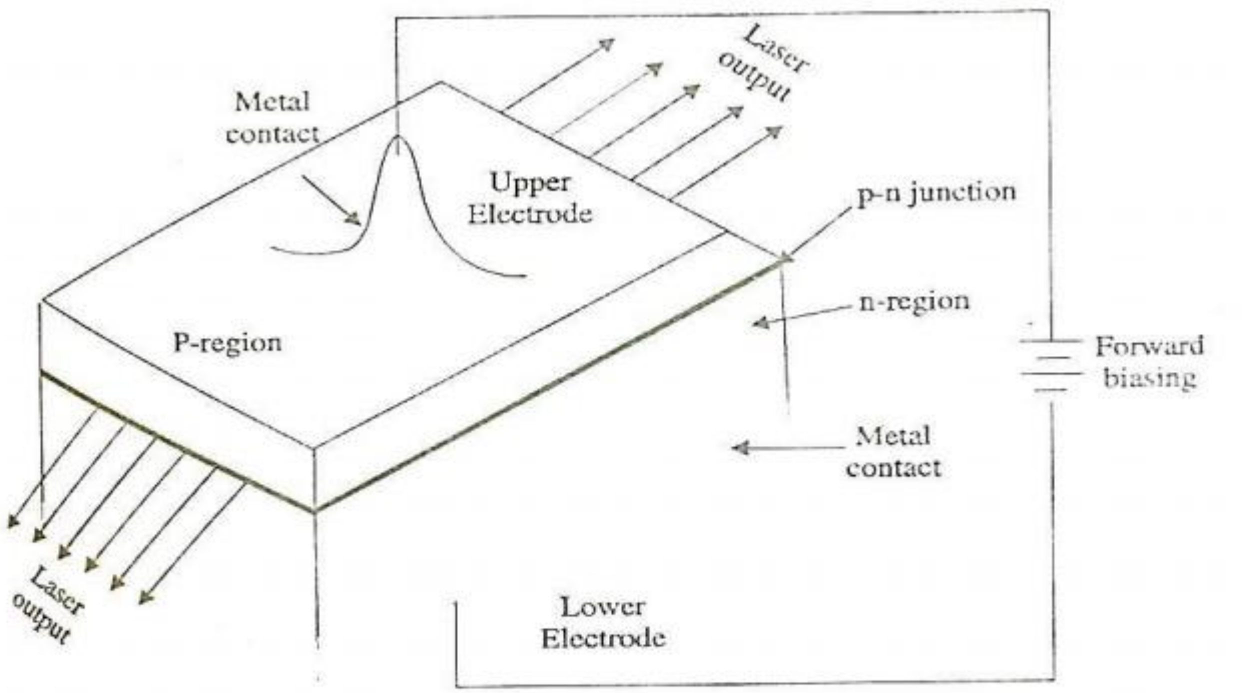
During the recombination process, the light radiation (photons) is released from a certain specified direct band gap semiconductors like Ga-As. This light radiation is known as recombination radiation.

The photon emitted during recombination stimulates other electrons and holes to recombine. As a result, stimulated emission takes place which produces laser.



Construction:

Figure shows the basic construction of semiconductor laser. The active medium is a p-n junction diode made from the single crystal of gallium arsenide. This crystal is cut in the form of a platter having thickness of 0.5μmm.



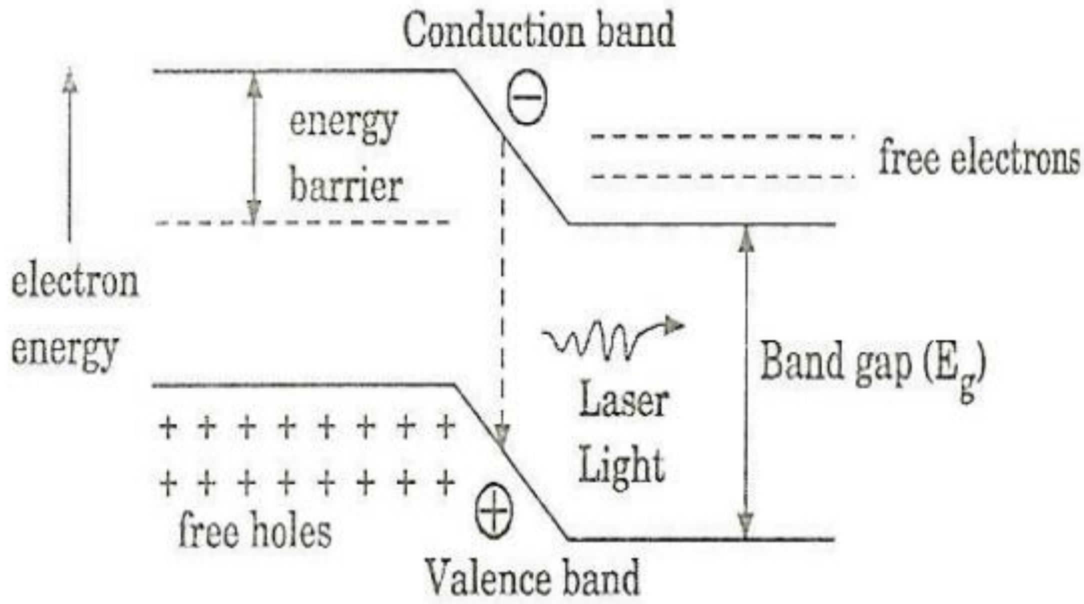
The platelet consists of two parts having an electron conductivity (n-type) and hole conductivity (p-type).

The photon emission is stimulated in a very thin layer of PN junction (in order of few microns). The electrical voltage is applied to the crystal through the electrode fixed on the upper surface.

The end faces of the junction diode are well polished and parallel to each other. They act as an optical resonator through which the emitted light comes out.

Working:

Figure shows the energy level diagram of semiconductor laser.



When the PN junction is forward biased with large applied voltage, the electrons and holes are injected into junction region in considerable concentration

The region around the junction contains a large amount of electrons in the conduction band and a large amount of holes in the valence band.

If the population density is high, a condition of population inversion is achieved. The electrons and holes recombine with each other and this recombination's produce radiation in the form of light.

When the forward – biased voltage is increased, more and more light photons are emitted and the light production instantly becomes stronger. These photons will trigger a chain of stimulated recombination resulting in the release of photons in phase.

The photons moving at the plane of the junction travels back and forth by reflection between two sides placed parallel and opposite to each other and grow in strength.

After gaining enough strength, it gives out the laser beam of wavelength 84000 A . The wavelength of laser light is given by

$$E_g = h\nu = h\frac{c}{\lambda}$$

$$\lambda = \frac{hc}{E_g}$$

Where Eg is the band gap energy in joule.

Characteristics:

1. **Type**: It is a solid state semiconductor laser.

2. **Active medium**: A PN junction diode made from single crystal of gallium arsenide is used as an active medium.
3. **Pumping method**: The direct conversion method is used for pumping action

4. **Power output:** The power output from this laser is 1mW.

5. **Nature of output:** The nature of output is continuous wave or pulsed output.

6. **Wavelength of Output:** gallium arsenide laser gives infrared radiation in the wavelength 8300 to 8500o A .

Advantages:

1. It is very small in dimension. The arrangement is simple and compact.
2. It exhibits high efficiency.

3. The laser output can be easily increased by controlling the junction current

4. It is operated with lesser power than ruby and CO_2 laser.

5. It requires very little auxiliary equipment

6. It can have a continuous wave output or pulsed output.

Disadvantages:

1. It is difficult to control the mode pattern and mode structure of laser.

2. The output is usually from 5 degree to 15 degree i.e., laser beam has large divergence.

3. The purity and monochromacity are power than other types of laser

4. Threshold current density is very large (400A/mm2).

5. It has poor coherence and poor stability.

Application:

1. It is widely used in fiber optic communication

2. It is used to heal the wounds by infrared radiation

3. It is also used as a pain killer

4. **It** is used in laser printers and CD writing and reading.

Unit –III: Industrial Applications of LASER

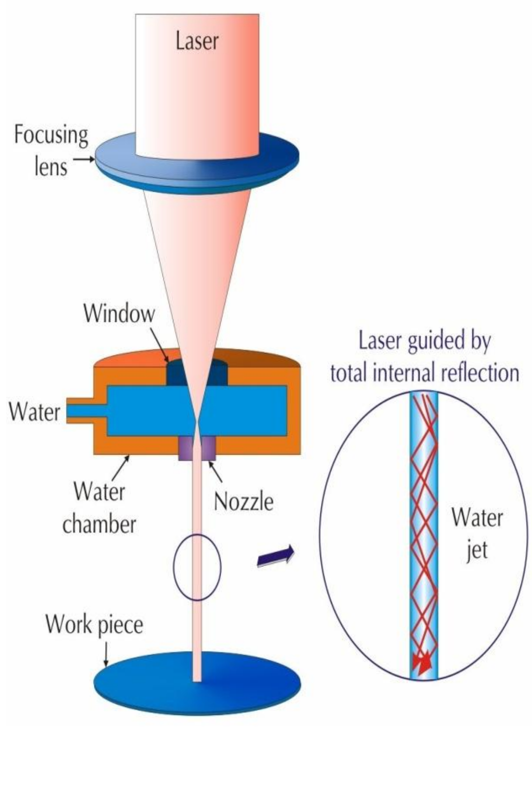
Laser cutting – Welding – Drilling – Hologram – Recording and reconstruction of hologram

Laser cutting and Welding

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications. Laser cutting works by directing the output of a high power laser, by computer, at the material to be cut. The material then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials.

Both gaseous CO_2 and solid-state Nd: YAG lasers are used for cutting, in addition to welding, drilling, surface treatment, and marking applications.

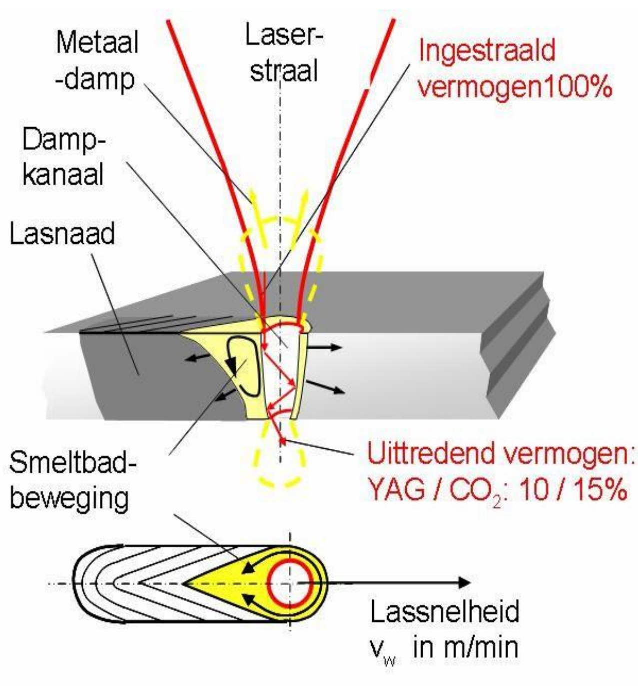
Laser cutters usually work much like a milling machine would for working a sheet in that the laser (equivalent to the mill) enters through the side of the sheet and cuts it through the axis of the beam. In order to be able to start cutting from somewhere else than the edge, a pierce is done before every cut. Piercing usually involves a high power pulsed laser beam which slowly (taking around 5-15 seconds for half-inch thick stainless steel, for example) makes a hole in the material.



Laser beam welding (LBW) is a welding technique used to join multiple pieces of metal through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. The process is frequently used in high volume applications, such as in the automotive industry.

A continuous or pulsed laser beam may be used depending upon the application. Milliseconds long pulses are used to weld thin materials such as razor blades while continuous laser systems are employed for deep welds.

LBW is a versatile process, capable of welding carbon steels, HSLA steels, stainless steel, aluminum, and titanium. Due to high cooling rates, cracking is a concern when welding high-carbon steels. The weld quality is high, similar to that of electron beam welding. The speed of welding is proportional to the amount of power supplied but also depends on the type and thickness of the work pieces. The high power capability of gas lasers make them especially suitable for high volume applications. LBW is particularly dominant in the automotive industry.



Some of the advantages of LBW in comparison to EBW are as follows: the laser beam can be transmitted through air rather than requiring a vacuum, the process is easily automated with robotic machinery, x-rays are not generated, and LBW result in higher quality welds.

Laser Drilling

One of the key disciplines of industrial laser material processing (or more specifically laser beam machining) is laser drilling. This means the generation of holes, which can have the following characteristics:

- Typically, one uses laser drilling for holes with *diameters* up to a few millimeters, but frequently for much smaller diameters below 100 μm, in extreme cases even for sub-micrometer holes (*micro-drilling*).
- They either go to a limited (and hopefully well-defined) depth (blind holes) or through the full thickness of some metal plates, for example.
- In some cases, a rather *high aspect ratio* (length divided by diameter) of e.g. 50 is possible. For example, holes with a 50 μm diameter can be made in hard metals to a depth of several millimeters.
- The holes are often perpendicular to the workpiece surface, but can also be made at variable angles.

A wide range of materials can be processed, including metals (even quite hard metals like stainless steel or titanium alloys), ceramics, glasses, semiconductors and other crystals. Frequently, no alternative drilling methods are available for such materials.

Applications and Limitations of Laser Drilling

Applications of laser drilling are very diverse. Some examples:

- Very small diameter holes, sometimes with a high aspect ratio, are required for certain machine parts, e.g. for injection nozzles as used for fuel injectors in combustion engines, and (with much smaller holes) for inkjet printers. This belongs to the area of laser micromachining.
- Large numbers of tiny holes are needed for some types of filter sieves.
- Larger holes are required for air cooling of turbine blades, for venting purposes, for instrumentation and various other purposes.

- In laser cutting processes, one often needs to start with the generation of an initial hole (piercing), from which the actual cutting process can continue.
- In electronic manufacturing, many small holes for contacting components on printed circuit boards need to be fabricated quickly. Microvias are realized in high-density interconnect (HDI) substrates. Similarly, silicon solar cells are often contacted on the backside with such methods, with contacts led through laser-made holes.
- For various purposes, one requires tiny holes, but often with a substantial depth, in glass, sapphire or ceramic materials. Such holes in hard and brittle materials would be difficult or impossible to achieve with conventional drilling methods.
- Polymer foils, metal foils and paper can be equipped with perforation holes at a very high speed, often with on-the-fly methods while the material is moved relative to the drilling laser beam.

Laser drilling is particularly suitable when very thin holes with large aspect ratio (ratio of length to diameter) need to be generated, which is hard with conventional mechanical methods. Also, it is often the only choice for fragile materials, which would break when applying mechanical processes.

On the other hand, there are various limitations:

- Particularly for larger holes, the processing speed is often less than desirable because of the need to remove a lot of material.
- There can be problems with a non-constant hole diameter (conicity) or an elliptical hole cross-section. That can be caused e.g. by non-ideal beam profiles, beam divergence or beam polarization; precisely cylindrical holes are needed for some applications. (Note, however, that some amount of conicity may even be desirable, for example for fuel injection nozzles.) Another common problem is the deposition of material around the hole. Laser drilling processes are often carefully optimized to avoid such imperfections to a large degree, which, however, may require more expensive laser sources (e.g. ultrafast lasers) and/or longer processing times.

Hologram – Recording and reconstruction of hologram

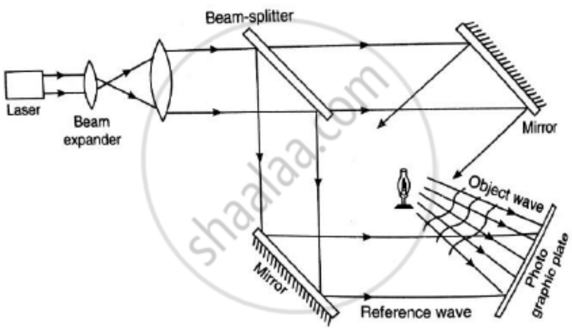
Holography technique to obtain 3D image of an object:

1. Holography is the science and practice of making holograms. Holography is actually a recording of interference pattern formed between two beams of coherent light coming from the same source.

2. In this process,both the amplitude and phase components of a light wave are recorded on a light sensitive medium such as a photographic plate. The recording is known as a hologram.

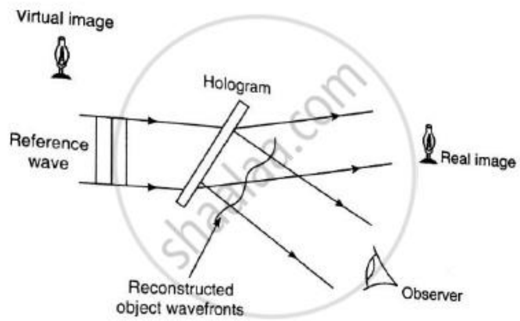
3. Holography requires an intense coherent light source.It became a practical proposition only after the invention of LASERS.

4. Holography is a two step process.In the first step,recording of hologram is done where the object is transformed into a photographic record and the second step is the reconstruction in which the hologram is transformed into image.



1.During the recording process we superimpose on the scattered wave emanating from the object,the another coherent wave(called as reference beam) of the same wavelength.

2.These 2 waves interfere in the plane of recording medium and produce interference fringes.This is the recording process of hologram.



1.The reproduction of the image from the hologram is known as reconstruction of the hologram.

2.In this process,a wave identical to reference beam is used.

3.When the hologram is illuminated by the reconstruction wave,2waves are produced.

4.One wave appears to diverge from the object and provides the virtual image of the object.

5.The second wave converges to form the real image of the object.

What is holography? Differentiate between holography and photography.

1. The advent of lasers has made the art of holography possible. Photography can be thought of as a new approach to the problem of generating images. An ordinary photography represents a two dimensional recording of three dimensional scene.
2. The emulsion of the photographic plate is sensitive to only intensity variations. In this process the phase information carried by the electromagnetic wave scattered from the object is lost. Since only the intensity pattern is recorded, the 3D character of the object is lost.
3. The principal behind holography is "During the recording process one superimposes on the scattered wave another coherent wave of same wavelength."
4. These two waves interfere in the plane of the recording medium and produce interference fringes. This is known s recording process. The interference fringes characteristic of light of object is formed. The recording medium records the intensity distribution in the interference pattern.
5. The interference pattern is recorded in it not only the amplitude distribution but also the phase of the electromagnetic waves scattered from the object. Since the recorded intensity pattern has both the amplitude and the phase recorded in it has been called "HOLOGRAM".
6. The hologram has little resemblance to the object. It has in it a coded form of a wavefront. The reproduction the image is known as reconstruction in which a wave identical to the one used as reference wave is used.
7. When hologram is illuminated by the reconstruction wave, two waves are produced. One wave appeared to diverge from the object and provides the virtual image of the object. The second wave converges to form a second image which is real.

Holography	**Photography**
1.The light from the object is scattered directly onto the recording medium in the recording of holography.	**1.**A lens is required in photography to record the image
2.A laser is required to record a hologram	**2.**A photograph can be recorded using normal light sources e.g.sunlight,etc.
3.In photography,only intensity is recorded so photography produces 2-D picture of the object.	**3.**In holography, both intensity as well as phase of light wave is recorded,thus holography gives 3-D picture of object.
4.5.There is a need of vibration less table for holography.	**4.**There is no need of vibration less table for photography.
5.When a hologram is cut in half, the whole scene can still be seen in each piece.	**5.**When a photograph is cut in half, each piece shows half of the scene.

Unit –IV: Lasers in Medicine

Lasers in Surgery – Lasers in ophthalmology – Lasers in cancer treatment

Lasers in Surgery:

What Is Laser Surgery?

Laser surgery is a type of surgery that uses special light beams instead of instruments for surgical procedures. LASER stands for "Light Amplification by the Stimulated Emission of Radiation." Lasers were first developed in 1960.

Newer laser modifications continue to have a large impact on medical and surgical practices. A large part of their impact has been seen in the treatment of various skin lesion and diseases.

What types of surgeries use lasers?

There are many indications for the use of lasers in surgery. The following are some of the more common indications:

- To remove tumors
- To help prevent blood loss by sealing small blood vessels
- To seal lymph vessels to help decrease swelling and decrease the spread of tumor cells
- To treat some skin conditions, including to remove or improve warts, moles, tattoos, birthmarks, scars, and wrinkles

How are lasers used during cancer surgery?

Laser surgery is a type of surgery that uses special light beams instead of instruments, such as scalpels, to perform surgical procedures. There are several different types of lasers, each with characteristics that perform specific functions during surgery. Laser light can be delivered either continuously or intermittently and can be used with fiber optics to treat areas of the body that are often difficult to access. The following are some of the different types of laser used for cancer treatment:

Carbon dioxide (CO_2) lasers: Carbon dioxide (CO_2) lasers can remove a very thin layer of tissue from the surface of the skin without removing deeper layers. The CO_2 laser may be used to remove skin cancers and some precancerous cells.

Neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers: Neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers can penetrate deeper into tissue and can cause blood to clot quickly. The laser light can be carried through optical fibers to reach less accessible internal parts of the body. For example, the Nd:YAG laser can be used to treat throat cancer.

Laser-induced interstitial thermotherapy (LITT): Laser-induced interstitial thermotherapy (LITT) uses lasers to heat certain areas of the body. The lasers are directed to areas between organs (interstitial areas) that are near a tumor. The heat from the laser increases the temperature of the tumor, thereby shrinking, damaging, or destroying the cancer cells.

Argon lasers: Argon lasers pass only through superficial layers of tissue such as skin. Photodynamic therapy (PDT) uses argon laser light to activate chemicals in the cancer cells.

Lasers in ophthalmology:

Lasers are an integral part of modern ophthalmology for both diagnosis and therapy due to their unique properties of being **monochromatic** (single wavelength), highly **collimated** (parallel rays), and **coherent** (waves in phase).

Fundamentals of Lasers

The acronym LASER stands for **Light Amplification by Stimulated Emission of Radiation**.

A laser system requires three main components:

- An **active medium** (gas, liquid, solid, or semiconductor) that produces the photons.
- An energy source (pump) to excite the atoms in the medium to a higher energy state.
- An optical cavity with mirrors to amplify the light through stimulated emission into an intense, focused beam that exits through a partially reflective mirror.

Laser-Tissue Interactions

The clinical effect of a laser depends on its wavelength, power density, and the target tissue's absorption characteristics (e.g., melanin, hemoglobin, xanthophyll). The primary mechanisms of interaction in ophthalmology are:

- **Photothermal (Photocoagulation/Photovaporisation):** Laser light is absorbed by tissue pigment and converted to heat, which denatures proteins and causes a burn or coagulation. This is the most common interaction.

- **Photodisruption (Photoionization):** High-energy, short-pulsed lasers create a plasma spark and a shockwave that mechanically cuts or disrupts tissue without significant thermal damage to surrounding areas.

- **Photoablation (Photodecomposition):** High-energy ultraviolet light breaks intramolecular bonds, allowing precise removal of tissue layer by layer without heat transfer.

- **Photochemical (Photoactivation):** Low-energy laser light activates a photosensitizing drug injected into the bloodstream, generating free radicals that damage target tissues, such as abnormal blood vessels.

Common Lasers Used in Ophthalmology

Laser Type	Wavelength	Mechanism	Common Indications
Argon	514 nm (Green)	Photocoagulation	Diabetic retinopathy (PRP), retinal tears, open-angle glaucoma (ALT)
Nd:YAG	1064 nm (Infrared)	Photodisruption	Posterior capsulotomy (after cataract surgery), peripheral iridotomy for glaucoma, laser vitreolysis
Frequency-ubled Nd:YAG	532 nm (Green)	Photocoagulation	Retinal photocoagulation (often via PASCAL laser system)
Excimer	193 nm (UV)	Photoablation	Refractive surgery (LASIK, PRK), phototherapeutic keratectomy (PTK)
Diode	810 nm (Infrared)	Photocoagulation	Panretinal photocoagulation (PRP), cyclophotocoagulation
Femtosecond	~1053 nm (Infrared)	Plasma-induced ablation/ Photodisruption	LASIK flap creation, femto-assisted cataract surgery, SMILE procedure

Diagnostic Uses

Laser technology is also crucial in diagnosis, in instruments such as:

- **Optical Coherence Tomography (OCT):** Provides high-resolution cross-sectional images of the retina and anterior segment to evaluate pathologies.
- **Confocal Scanning Laser Ophthalmoscopy (cSLO):** Used for optic nerve head evaluation and high-contrast retinal imaging.

Safety Considerations

Medical lasers are typically Class IV, posing significant eye and fire hazards.

- Only qualified physicians should operate laser devices.
- Appropriate laser safety goggles/filters must be used by the patient and all personnel in the treatment area.
- Reflective instruments should be avoided, and warning signs placed on the treatment room door.
- The patient's blink reflex is diminished under anesthesia, increasing risk, requiring extra caution.

Lasers in cancer treatment:

Laser treatment

A laser is a very thin, focused beam of light that heats and destroys tissue. Lasers can focus very accurately on tiny areas.

Doctors can use lasers:

- instead of blades (scalpels) for surgery
- to heat and destroy small areas of cancer or precancerous cells
- together with a light sensitive drug (photodynamic therapy)

There are different types of lasers depending upon the area they are treating.

What is laser treatment?

Laser treatment uses a narrow, thin beam of light. The laser removes or destroys abnormal or cancerous cells. Doctors might use laser therapy on its own. Or you have it with other treatments such as surgery, chemotherapy, or radiotherapy.

Using lasers for surgery

Surgeons can use lasers instead of scalpels during surgery. The lasers can cut through body tissue very precisely. An advantage of using a laser is that it seals off the blood vessels as it cuts. So there is very little bleeding.

Laser therapy to destroy abnormal or cancerous cells

Doctors can use laser beams to burn away abnormal or cancerous cells. This is called laser ablation. It can:

- destroy small areas of precancerous cells
- shrink or destroy cancers
- relieve some cancer symptoms such as bleeding or blockage

Combining laser with a light sensitive drug (photodynamic therapy)

Photodynamic therapy (PDT) combines a drug that makes cells sensitive to light with exposure to a type of light. The drug is called a photosensitiser or photosensitising agent.

Who can have laser treatment?

Laser therapy is a treatment for:

- abnormal cells that might become cancerous (precancerous cells) - including abnormal cells on the cervix, vulva or vagina
- abnormal cells on the surface of the skin of the penis, also called penile intraepithelial neoplasia (PeIN)
- basal cell skin cancer, combined with a light sensitive drug (photodynamic therapy)
- some advanced cancers inside the body - for example the food pipe (oesophagus), stomach or the windpipe (trachea)

For very early cancers, the laser cuts or burns away the cancerous tissue.

For more advanced cancers, laser therapy can shrink or destroy tumours. This can help to relieve blockages in the body.

Where you have laser treatment

You have laser therapy in hospital. You usually have treatment as a day case and go home on the same day.

You usually have the laser therapy in the outpatient department to treat:

- abnormal cells on the surface of the skin of the penis
- abnormal cells on your cervix, vulva or vagina

For other cancers, you might have treatment in the x-ray or endoscopy department.

How you have laser treatment

You can have laser treatment in different ways. How you have it depends on where the cancer or abnormal cells are in your body.

You might have laser treatment:

- directly to your skin - to treat penile intraepithelial neoplasia

- using a speculum to look inside the vagina - to treat abnormal cells on the cervix, vagina or vulva
- through a flexible tube (a scope) - to treat cancers inside your body such as lung or stomach cancer

Your doctor or specialist nurse will talk to you beforehand. They will tell you how you will have treatment and exactly what it involves.

Before you have laser treatment

You usually have treatment at the hospital as an outpatient.

Your appointment letter will tell you where to go and if you need to do anything to prepare.

You might have a local anaesthetic for treatment to your cervix, vulva or vagina. But some people have this treatment under a general anaesthetic.

For other cancers types you might have an injection to make you sleepy (sedation). Or you have a general anaesthetic which means you are asleep during the treatment.

Before some treatments you shouldn't eat or drink anything beforehand. Your appointment letter will tell you more about this.

Having laser therapy to treat abnormal cells on the cervix, vagina or vulva

You usually have this treatment as an outpatient in the gynaecology unit at the hospital.

You lie on a couch with your legs on padded supports. Your doctor puts a speculum into your vagina to hold it open. They then put local anaesthetic onto your cervix, vaginal wall or vulva. This numbs the area.

Your doctor points the laser beam at the abnormal areas. The laser burns away the abnormal area, so you may notice a slight burning smell during the treatment. This is nothing to worry about. It is just the laser working.

Afterwards, you may go to the day ward to rest for a few hours. You can go home after the nurse has checked that it is safe for you to do so.

Having laser treatment for penile cancer

You might have laser treatment for abnormal cells on the surface of the skin of the penis. You have this treatment under local or general anaesthetic.

The surgeon uses a powerful beam of light. This destroys the precancerous cells.

Having laser treatment for cancers inside your body (internal cancers)

Laser therapy can treat cancers in the:

- windpipe (trachea) or lung airway (bronchus)
- food pipe (oesophagus)
- stomach
- voice box (larynx)
- head and neck area, such as the tonsil, mouth, and nasal sinuses

To reach internal tumours doctors use a tube with a light at one end, and an eyepiece at the other end.

For lung or windpipe cancers, you have a bronchoscopy using a tube called a bronchoscope.

For cancers inside your food pipe or stomach you have an endoscopy using a tube called an endoscope.

Having a bronchoscopy

You usually have a general anaesthetic.

Your doctor uses a long, thin, flexible tube called a bronchoscope. They put this down your throat and into the airway. The doctor passes a small laser down the bronchoscope tube.

The doctor burns away as much of the tumour as possible with the laser. They then take out the bronchoscopy tube.

Having an endoscopy

You usually have medicine to make you sleepy. Or you might have a general anaesthetic which means you are asleep during the treatment.

Your doctor gently puts a long flexible tube called an endoscope into your mouth. It goes down into your food pipe. The tube has a light and a small camera on the end so your doctor can see inside your food pipe and stomach.

Relieving symptoms of a blockage (laser ablation)

The doctors position the end of the tube close to the tumour and direct the laser at it. This heats up the cancer cells and burns them away. This reduces the blockage or gets rid of it completely.

We have further information about laser treatment for stomach and oesophageal cancer. You can select the oesophageal or stomach cancer from the A-Z cancer type menu.

Removing early stage cancers (endoscopic resection)

The surgeons use the laser to cut away the areas of cancer. This type of laser therapy might be called endoscopic resection.

Side effects of laser treatment

The side effects of laser treatment depend on the area of your body that you're having treatment to. They also depend on whether the laser is for surgery or to destroy cancer cells.

Your doctor or specialist nurse will give you information about what to expect.

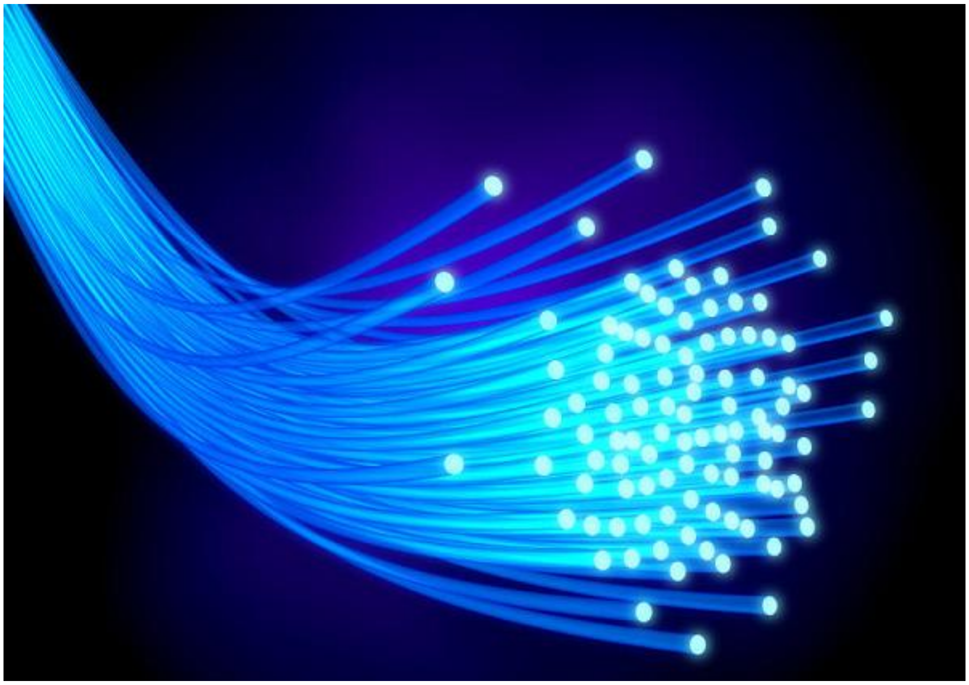
You can read more about side effects of laser therapy in the treatment section for your cancer type.

Unit –V: Lasers in Communication

Optic fibre communication – Total internal reflection – Block diagram of fibre optic communication system – Advantages of fibre optic communication.

Optic fibre communication:

An optical fiber can be understood as a dielectric waveguide, which operates at optical frequencies. The device or a tube, if bent or if terminated to radiate energy, is called a waveguide, in general. Following image depicts a bunch of fiber optic cables.



The electromagnetic energy travels through it in the form of light. The light propagation, along a waveguide can be described in terms of a set of guided electromagnetic waves, called as modes of the waveguide.

Working Principle

A fundamental optical parameter one should have an idea about, while studying fiber optics is **Refractive index**. By definition, the ratio of the speed of light in a vacuum to that in matter is the index of refraction ***n*** of the material. It is represented as –

the material. It is represented as –

$$n=c/v$$

Where,

c = the speed of light in free space = 3×10^8 *m/s*

v = the speed of light in di-electric or non-conducting material

Generally, for a travelling light ray, **reflection** takes place when $n_2 < n_1$. The bent of light ray at the interface is the result of difference in the speed of light in two materials that have different refractive indices. The relationship between these angles at the interface can be termed as **Snell's law**. It is represented as –

$$n1\sin\phi1 = n2\sin\phi2$$

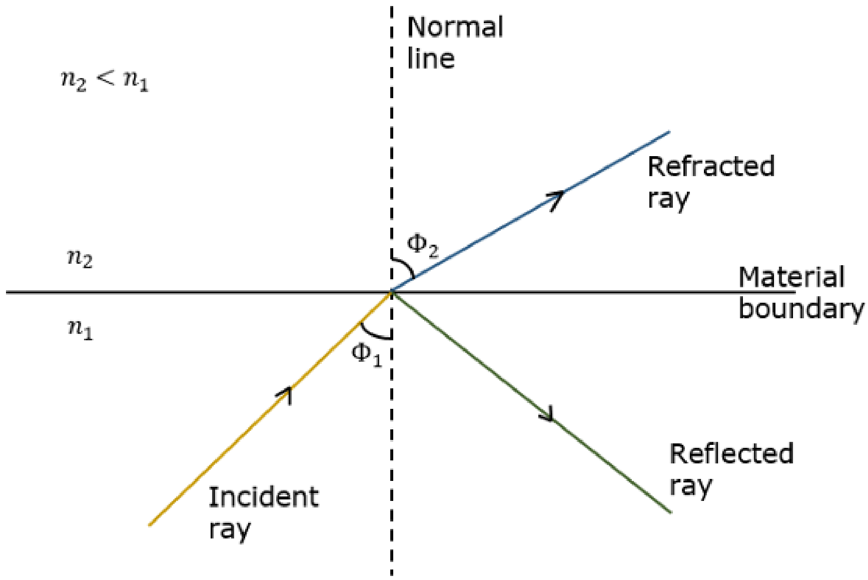
Where,

$\phi1$ is the angle of incidence

$\phi2$ is the refracted angle

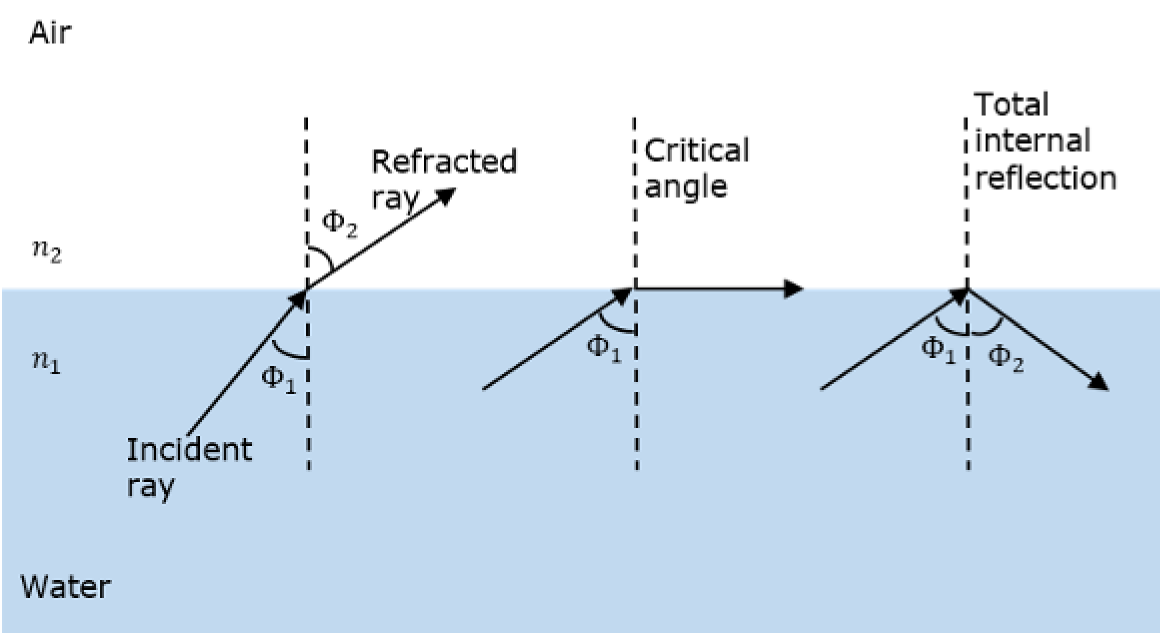
n_1 and n_2 are the refractive indices of two materials

For an optically dense material, if the reflection takes place within the same material, then such a phenomenon is called as **internal reflection**. The incident angle and refracted angle are shown in the following figure.



If the angle of incidence ϕ1 is much larger, then the refracted angle ϕ2 at a point becomes Π/2. Further refraction is not possible beyond this point. Hence, such a point is called as **Critical angle** ϕc. When the incident angle ϕ1 is greater than the critical angle, the condition for **total internal reflection** is satisfied.

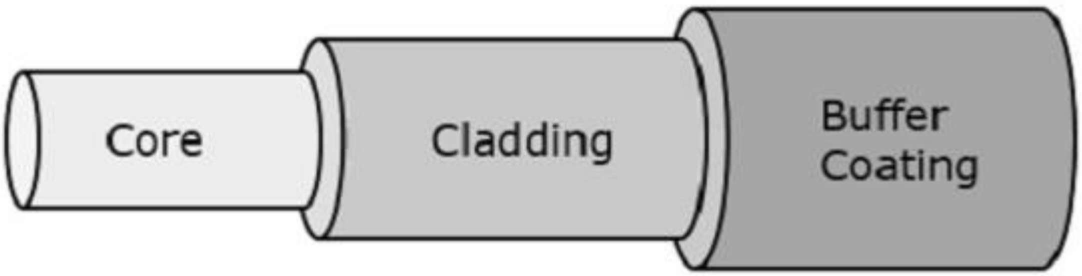
The following figure shows these terms clearly.



A light ray, if passed into a glass, at such condition, it is totally reflected back into the glass with no light escaping from the surface of the glass.

Parts of a Fiber

The most commonly used optical fiber is **single solid di-electric cylinder** of radius **a** and index of refraction n_1. The following figure explains the parts of an optical fiber.



Parts of an Optical fiber

This cylinder is known as the **Core** of the fiber. A solid di-electric material surrounds the core, which is called as **Cladding**. Cladding has a refractive index n_2 which is less than n_1.

Cladding helps in –

- Reducing scattering losses.
- Adds mechanical strength to the fiber.
- Protects the core from absorbing unwanted surface contaminants.

Types of Optical Fibers

Depending upon the material composition of the core, there are two types of fibers used commonly. They are −

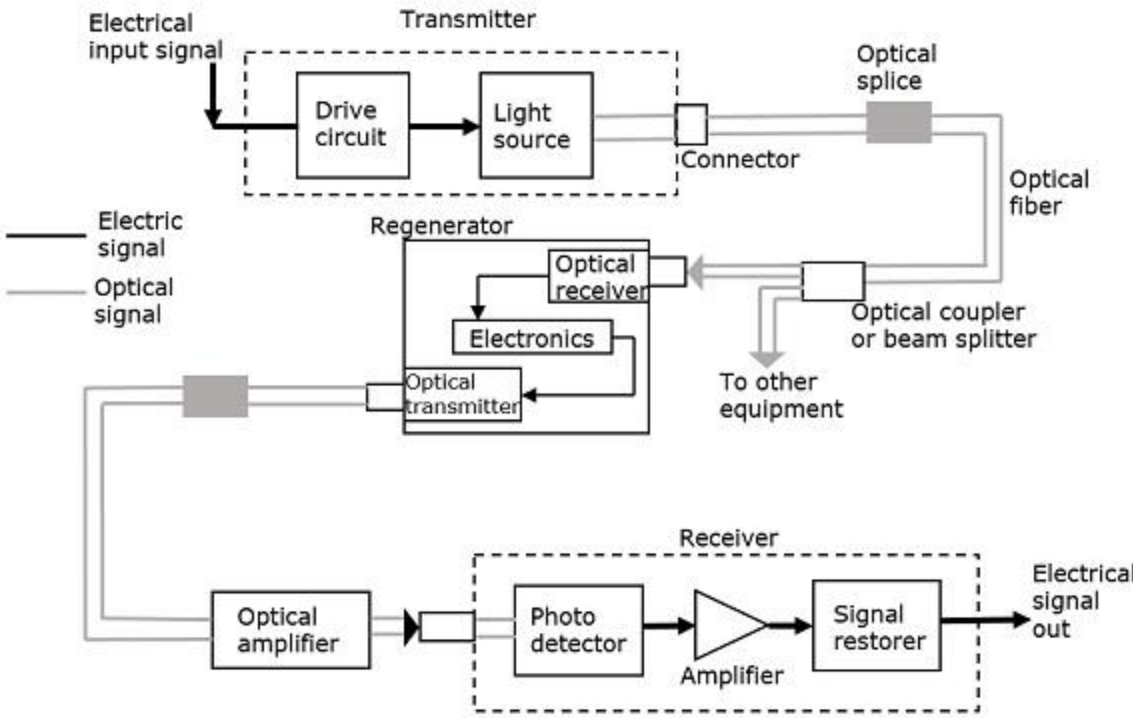
- **Step-index fiber** − The refractive index of the core is uniform throughout and undergoes an abrupt change (or step) at the cladding boundary.
- **Graded-index fiber** − The core refractive index is made to vary as a function of the radial distance from the center of the fiber.

Both of these are further divided into −

- **Single-mode fiber** − These are excited with laser.
- **Multi-mode fiber** − These are excited with LED.

Optical Fiber Communications

The communication system of fiber optics is well understood by studying the parts and sections of it. The major elements of an optical fiber communication system are shown in the following figure.



The basic components are light signal transmitter, the optical fiber, and the photo detecting receiver. The additional elements such as fiber and cable splicers and connectors, regenerators, beam splitters, and optical amplifiers are employed to improve the performance of the communication system.

Functional Advantages

The functional advantages of optical fibers are –

- The transmission bandwidth of the fiber optic cables is higher than the metal cables.
- The amount of data transmission is higher in fiber optic cables.
- The power loss is very low and hence helpful in long-distance transmissions.
- Fiber optic cables provide high security and cannot be tapped.
- Fiber optic cables are the most secure way for data transmission.
- Fiber optic cables are immune to electromagnetic interference.
- These are not affected by electrical noise.

Physical Advantages

The physical advantages of fiber optic cables are –

- The capacity of these cables is much higher than copper wire cables.
- Though the capacity is higher, the size of the cable doesnt increase like it does in copper wire cabling system.
- The space occupied by these cables is much less.
- The weight of these FOC cables is much lighter than the copper ones.
- Since these cables are di-electric, no spark hazards are present.
- These cables are more corrosion resistant than copper cables, as they are bent easily and are flexible.
- The raw material for the manufacture of fiber optic cables is glass, which is cheaper than copper.
- Fiber optic cables last longer than copper cables.

Disadvantages

Although fiber optics offer many advantages, they have the following drawbacks –

- Though fiber optic cables last longer, the installation cost is high.
- The number of repeaters is to be increased with distance.
- They are fragile if not enclosed in a plastic sheath. Hence, more protection is needed than copper ones.

Applications of Fiber Optics

The optical fibers have many applications. Some of them are as follows –

- Used in telephone systems
- Used in sub-marine cable networks
- Used in data link for computer networks, CATV Systems
- Used in CCTV surveillance cameras
- Used for connecting fire, police, and other emergency services.
- Used in hospitals, schools, and traffic management systems.
- They have many industrial uses and also used for in heavy duty constructions.