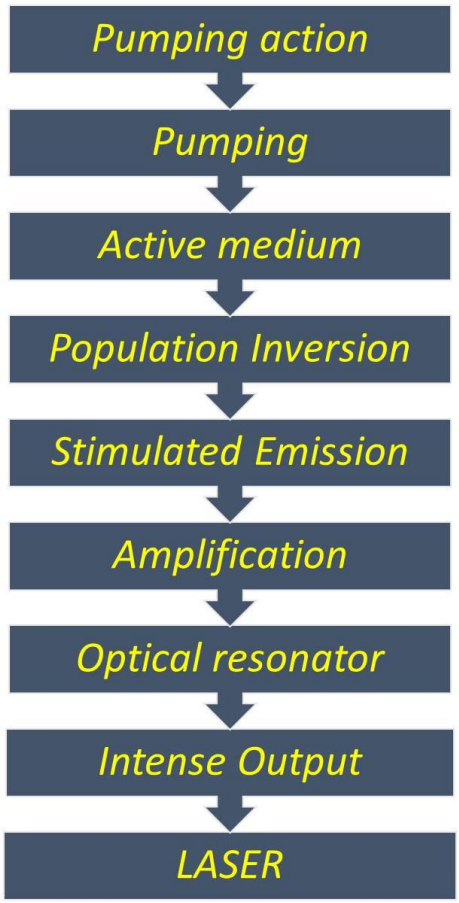
Differences between ordinary light and Laser beam:

Ordinary Light	Laser beam
1. In ordinary light the angular spread is more.	1. In laser beam the angular spread is less.
2. They are not directional.	2. They are highly directional.
3. It is less intense	3. It is highly intense
4. It is not a coherent beam and is not in phase.	4. It is a coherent beam and is in phase
5. The radiation are polychromatic	5. The radiations are monochromatic
6. Example: Sun light, Mercury vapor lamp	6. He-Ne Laser, CO_2 laser

Flow chart of Laser action:

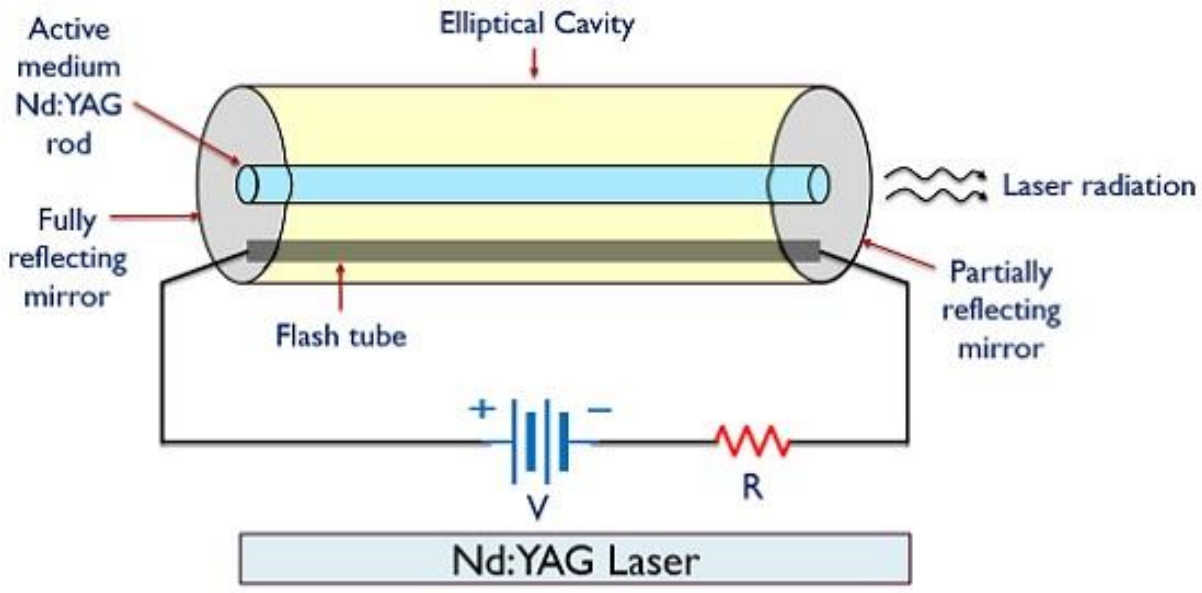


Nd:YAG Laser:

Nd: YAG laser is a neodymium based laser. Nd stands for Neodymium (rare earth element) and YAG stands for Yttrium Aluminium Garnet (Y_3 Al_5 O_{12}). It is a four level solid state laser.

Principle: The active medium Nd: YAG rod is optically pumped by Krypton flash tubes. The Neodymium ions (Nd^{3+}) are raised to excited levels. During the transition from metastable state to ground state, a laser beam of wavelength 1.064 µm is emitted.

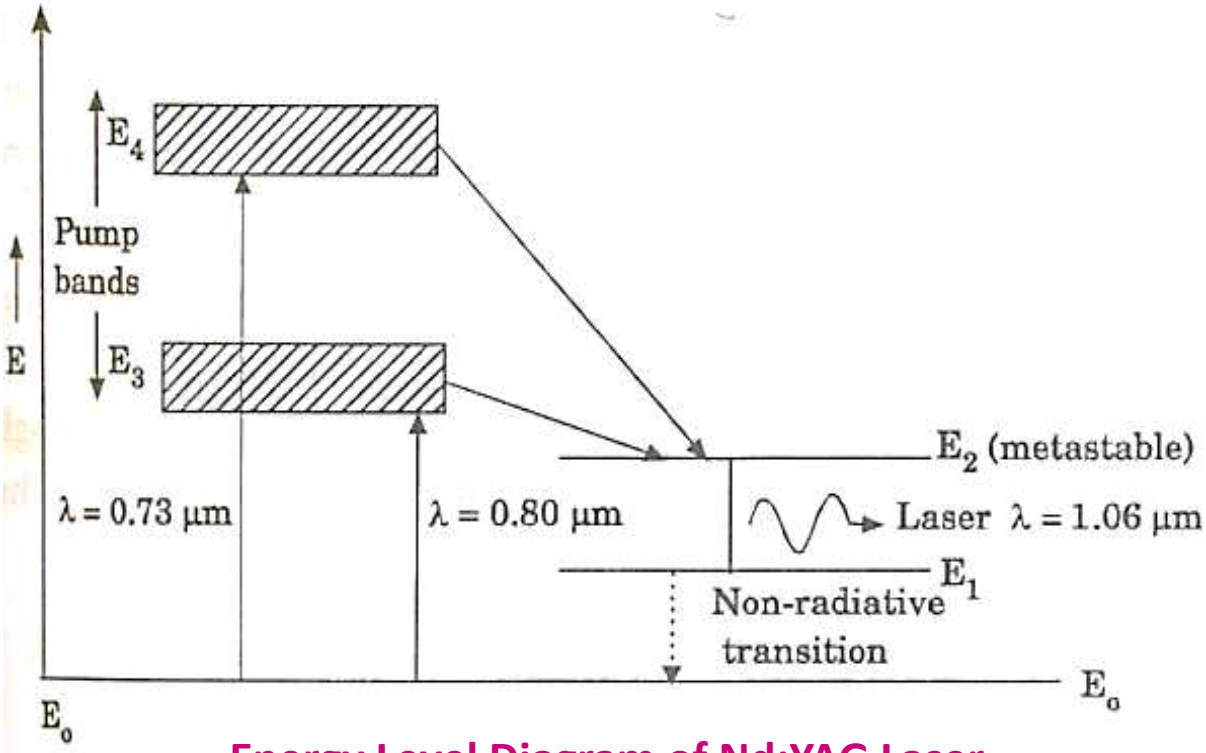
Construction: A small amount of Yttrium ions (Y^{3+}) is replaced by Neodymium (Nd^{3+}) in the active element of Nd: YAG crystal. This active element is cut into a cylindrical rod. The ends of the cylindrical rod are highly polished and they are made optically flat and parallel. This cylindrical rod (laser rod) and a pumping source (flash tube) are placed inside a highly (reflecting) elliptical reflector cavity. The optical resonator is formed by using two external reflecting mirrors. One mirror (M1) is 100% reflecting while the other mirror (M2) is partially reflecting.



Working:

- When the krypton flash lamp is switched on, by the absorption of radiation of wavelength 0.73 µm and 0.8 µm, the Neodymium (Nd^{3+}) atoms are raised from E_0 to upper levels E_3 and E_4 (Pump bands).
- The Neodymium ions atoms make a transition from these energy levels E_2 by non-radiative transition. E_2 is a metastable state.
- The Neodymium ions are collected in the level E_2 and the population inversion is achieved between E_2 and E_1.
- An ion makes a spontaneous transition from E_2 to E_1, emitting a photon of energy hv. This emitted photon will trigger a chain of stimulated photons between E_2 and E_1.

- The photons thus generated travel back and forth between two mirrors and grow in strength. After some time, the photon number multiplies more rapidly.
- After enough strength is attained (condition for laser is satisfied), an intense laser light of wavelength 1.06 µm is emitted through the partial reflector. It corresponds to the transition from E_2 to E_1.



Energy Level Diagram of Nd:YAG Laser

Characteristics:

- ✓ Type: It is a four level solid state laser.
- ✓ Active medium: The active medium is Nd: YAG laser.
- ✓ Pumping method: Optical pumping is employed for pumping action.
- ✓ Pumping source: Xenon or Krypton flash tube
- ✓ Optical resonator: Two ends of Nd: YAG rod is polished with silver (one end is fully silvered and the other is partially silvered) are used as optical resonator.
- ✓ Power output: The power output is approximately 70 watt.
- ✓ Nature of output: Output is pulsed or continuous beam of light.
- ✓ Wavelength of the output: The wavelength of the output beam is 1.06µm (infra-red)

Advantages:

- 👍 It has high energy output.
- 👍 It has very high repetition rate operation

- It is much easy to achieve population inversion

Disadvantages:

- The electron energy level structure of Nd^{3+} in YAG is complicated.

Applications of Nd: YAG Laser

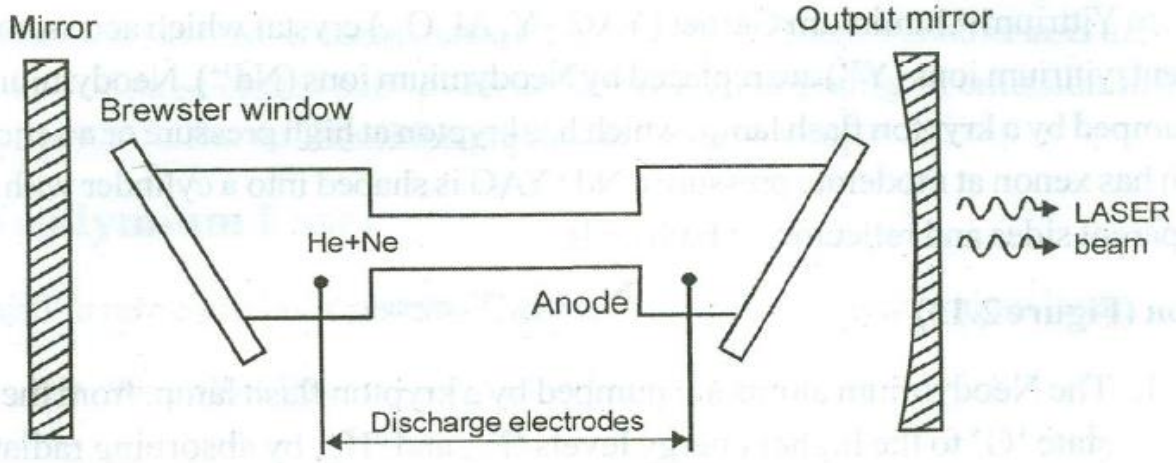
- ✓ It finds many applications in range finders and illuminators.
- ✓ It is widely used in engineering applications such as resistor, trimming scribing, micro machining operations as well as welding, drilling etc.
- ✓ It finds many medical applications such as endoscopy, urology, neurosurgery, ENT, gynecology, dermatology, dental surgery and general surgery.

He-Ne Laser:

The first successful demonstration of a gas laser was done by Ali Javan in 1961. He-Ne is an atomic laser which employs four-level pumping scheme.

Principle: It is a type of gas laser where helium and neon gases are used as an active medium. Commonly, this laser emits at 632.8 nm (usually red). However, it has two other lasing outputs as well at 1.152 µm and 3.392 µm, these two wavelengths can also be generated if desired. These lasers can produce the maximum power of 50 watts.

Construction: The He-Ne laser consists of a long and narrow discharge tube having length about 50 cm and diameter 1.5 cm. The tube is filled with the mixture of He and Ne in the ratio 10:1 respectively.

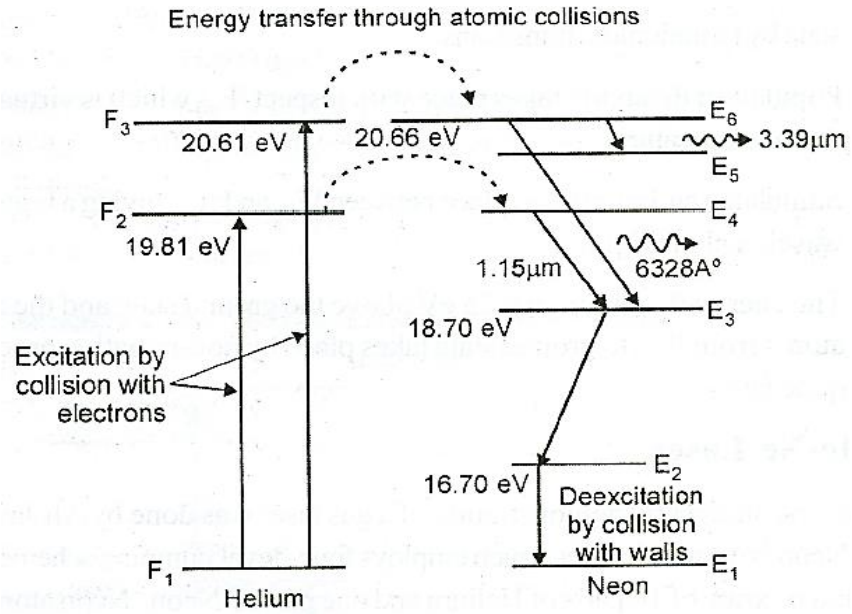


Schematic diagram of He-Ne laser

So majority atoms are Helium and minority atoms are Neon. Ne atoms act as active centers. Two mirrors M1 and M2 are mounted at the ends of the tube. The mirror M1 is completely silvered while the other M2 is partially silvered. The electrodes are connected to high voltage supply. The end windows of the tube are set at Brewster's angle to get polarized light at the output.

Working:

- When the power is switched on, a high voltage of 10 kV is applied across the gas. It is sufficient to ionize the gas.
- The electrons and ions produced in the process of discharge are accelerated towards the anode and cathode respectively.
- The 'He' atoms are more readily excitable than the neon atoms because they are lighter. Electrons excite He atoms to upper levels F_2 and F_3 which lie at 19.81 eV and 20.61 eV. These two levels are metastable levels and the excited He atoms cannot return to the ground state.



Energy Level Diagram of He-Ne Laser

- Here radiative transition is not possible. He atoms can return to the ground state by transferring their energy to neon atoms through collisions. As the energy exchange is continuous, the population inversion of Ne atoms in the excited states increases more and more.
- This energy transfer is called resonant transfer of energy. Since, the neon energy levels namely E_6 and E_4 nearly coincide with F_3 and F_2 levels of

helium atom. Therefore, the resonant transfer of energy can occur readily.

- When an excited Ne atom passes from E_6 to E_5 and E_4 to E_3 spontaneously and emits a photon. This photon travels parallel to the axis of the tube and it reflected back and initiates stimulated photons.
- These photons undergo multiple reflections between the mirrors, after getting sufficient intensity, a part of laser beam escapes through partially silvered mirror M2.
- In reality the neon energy levels E_6, E_5, E_4, E_3 and E_2 are not single but a group of lines. Consequently several laser possible transitions are possible. They are

  ✓ $E_6 \rightarrow E_5$ transition: this transition generates a laser beam of wavelength 33,900 Å lies in infrared region
  ✓ $E_6 \rightarrow E_3$ transition: this transition generates a laser beam of wavelength 6328 Å lies in visible red region.
  ✓ $E_4 \rightarrow E_3$ transition: this transition generates a laser beam of wavelength 11,500 Å lies in infrared region.

- The He-Ne laser is made to oscillate at 6328 Å and by placing some optical absorbers in the path of light which absorb 33,900 Å and 11,500 Å wavelengths, releases 6328 Å only.

Advantages:

Some of the major advantages of Helium Neon lasers are

- its low cost,
- less complicated construction,
- high coherence.

Applications of Helium - Neon Laser

- ✓ The Narrow red beam of He-Ne laser is used in supermarkets to read bar codes.
- ✓ The He- Ne Laser is used in Holography in producing the 3D images of objects.
- ✓ He-Ne lasers have many industrial and scientific uses, and are often used in laboratory demonstrations of optics.

Molecular Gas laser:

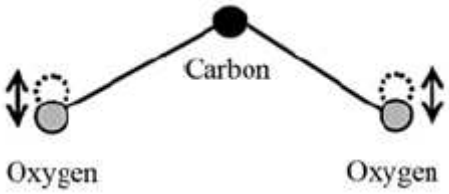
In a molecular gas laser, laser action is achieved by transitions between vibrational and rotational levels of molecules. Its construction is simple and the output of this laser is continuous. In CO_2 molecular gas laser, transition takes place between the vibrational states of Carbon dioxide molecules.

CO_2 Molecular gas Laser:

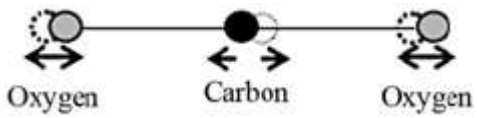
It was the first molecular gas laser developed by Indian born American scientist Prof.C.K.N.Pillai. It is a four level laser and it operates at 10.6 μm in the far IR region. It is a very efficient laser. Energy states of CO_2 molecules. A carbon dioxide molecule has a carbon atom at the center with two 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.

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.

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



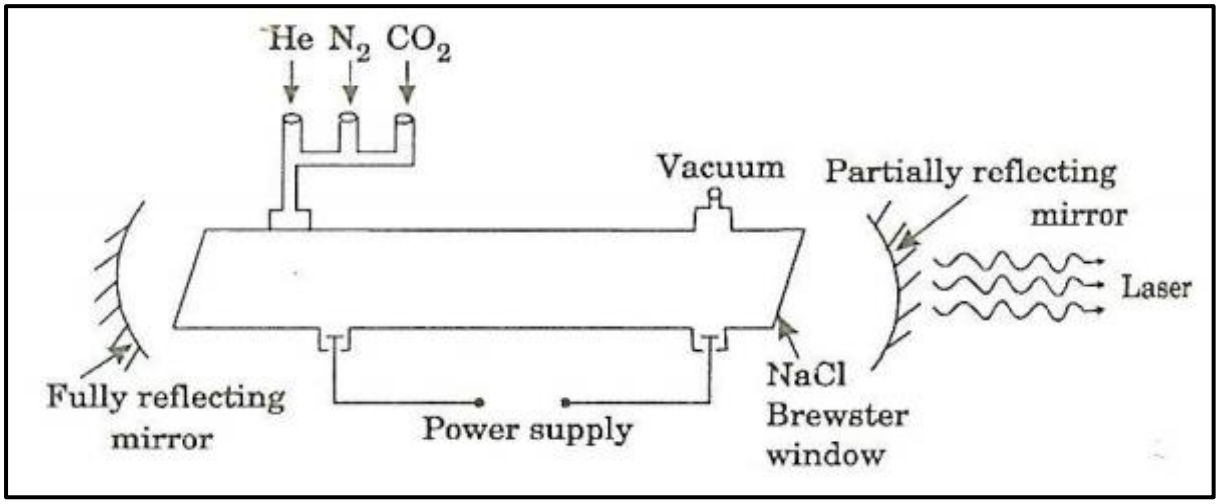
Asymmetric stretching mode: In this mode of vibration, oxygen atoms and carbon atoms vibrate asymmetrically, i.e., oxygen atoms move in one direction while carbon atoms in the other direction.



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_2 molecules.

Construction: The discharge tube is filled with a mixture of carbondioxide, nitrogen and helium gases in 1:4:5 proportions. 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 CO_2 (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.



Schematic Diagram of CO_2 Laser

Working:

- 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

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

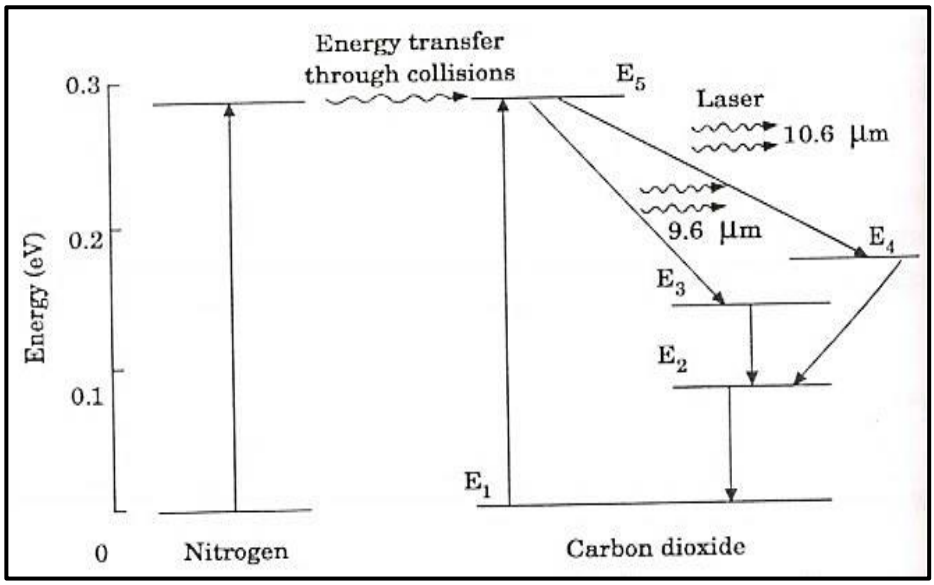
N_2 = Nitrogen molecule in ground state; e^* = electron with kinetic energy; N_2^* = nitrogen molecule in excited state; e = same electron with lesser energy.

- 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.



Energy level Diagram of CO_2 Laser

- $E_5 \longrightarrow E_4$ transition: This will produce a laser beam of wavelength 10.6μm
- $E_5 \longrightarrow E_3$ transition: 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:

- ✓ Type: It is a molecular gas laser.
- ✓ Active medium: A mixture of CO_2 , N_2 and helium or water vapour is used as active medium
- ✓ Pumping method: Electrical discharge method – pumping action
- ✓ Optical resonator: Two concave mirrors form a resonant cavity
- ✓ Power output: The power output from this laser is about 10kW.
- ✓ Nature of output: The nature of output may be continuous wave or pulsed wave.
- ✓ 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

APPLICATIONS OF LASER:

In Medicine:

1. Lasers are used to stitch wounds
2. Lasers are used to instantly weld injured muscles, tendons and ligaments without the use of heat.
3. Lasers are used for the elimination of moles and tumors developing on the skin tissue.
4. Lasers are used in ophthalmology for attach a detached retina.
5. Lasers are used in ear, nose and throat surgery

6. Lasers are used in gynecology for fertility microsurgery and fallopian tube reconstruction.

In Science and Research:

1. To study the nature of chemical bonds
2. To break the molecules where one want to break
3. To modify the surfaces
4. To deposit metallic films and introduce departs in semiconductor substrates.
5. To deposit metal structures about 50 microns wide and also lasers are used in counting of atoms, isotope separation, plasma production, thermo nuclear fusion

In Industry/Engineering:

1. For drilling of small holes and welding of small melt parts.
2. For cutting different types of materials. Especially this technology is used in fabrication of space craft.
3. Lasers are used as light sources for telephoto pictures, particularly used in high speed photography.
4. *LIDAR*: Laser beam can be used for detection and ranging like RADAR. The only difference is it uses light instead of radio waves. Hence it is called light detection and ranging.
5. Lasers are used to for detection and analysis of finger prints.
6. To transmit memory blanks from one computer to another
7. Laser is used in computer printers
8. Large amount of data can be stored in CD-ROM
9. It is used to read the data from CD-ROM