RUBY LASER-This is the first laser developed by Maiman in 1960 and is the solid state laser. A solid laser can be made by introducing impurity atoms into a crystal (by doping method).

It consists of a pink ruby cylindrical rod whose ends are optically flat and parallel (figure 1.6).one end is fully silvered and the other is only partially silvered. The partially reflecting end can be used as a window for laser output. This works as **Resonant Cavity**.

Ruby rod is surrounded by a helical xenon flash tube, which provides light to raise chromium ions to upper energy levels.

In the xenon flash tube, each flash lasts several mili seconds and in each flash a few thousand Joules of energy is consumed. Only a small part of this energy is used in pumping Cr^{+++} ions while rest energy is wasted by heating up the apparatus.

For cooling the apparatus water circulation (liquid nitrogen) in a glass tube is provided.

In Ruby laser, Cr^{+++} ions are the active material. The solid state Ruby laser (pulse laser) is a three level laser system. A systematic diagram of construction and energy level diagram is shown in Figure (1.6) & Figure (1.7) respectively.

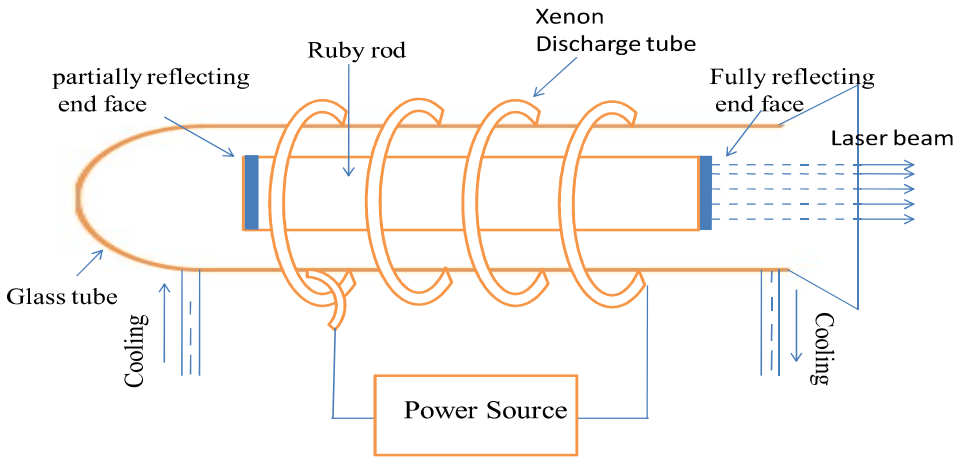


Fig. 1.6

Working-The ruby rod is a crystal of aluminium oxide (Al_2O_3) doped with 0.05% chromium oxide (Cr_2O_3), so that some of the Al^{+++} ions are replaced by Cr^{+++} ions. These "impurity" chromium ions give pink colors to the ruby and give rise to laser action. The crystal is in the form of cylindrical rod which is 2 to 20 cm in length and nearly 0.1 to 2.0 cm in diameter

A simplified energy- level diagram is shown in Figure 1.7. It consists of an upper short-lived energy level E_3 above its ground energy level E_1, the energy difference E_3-E_1 corresponds to a wavelength of about 5500 Å. There is an intermediate excited-state level E_2 which is metastable having a life time of 10^{-3} sec.

Normally, most of the chromium ions are in the ground state E_1.When a flash of light falls upon the ruby rod, the 5500 Å radiation photons are absorbed by the chromium ions which are pumped to the excited state E_3. The excited ions give up, by collision, part of their energy to the crystal lattice and decay to the metastable state E_2.The corresponding transition 2 is thus a radiation less transition. Since E_2 has a much longer life-time, the number of ions in this state goes on increasing while, due to pumping, the number in the ground state E_1 goes on decreasing. Thus, population inversion is established between the metastable state E_2 and the ground state E_1.

When an excited ion passes from the metastable state to the ground state, it emits a photon of wavelength 6943Å.This photon travels through the ruby rod and, if it is moving parallel to the axis of crystal, is reflected back and forth by the silvered ends until it stimulates an excited ion and causes it to emit a fresh photon, in phase with stimulating photon. This "stimulated" transition 4 is the laser transition. The process is repeated again and again because the photons repeatedly move along the crystal, being reflected from its ends. The photons thus multiply. When the photon beam becomes sufficiently intense, part of it emerges through the partially silvered end of the crystal.

Drawback in the three level lasers such as ruby-. The laser requires high pumping power because the laser transition terminates at the ground state and more than one half of the ground state atoms must be pumped up to the higher state to achieve population inversion.

The efficiency of ruby laser is very small. Only the green component of pumping light is utilized.

The laser output is not continuous. The output occurs in the form of pulses of microsecond duration.

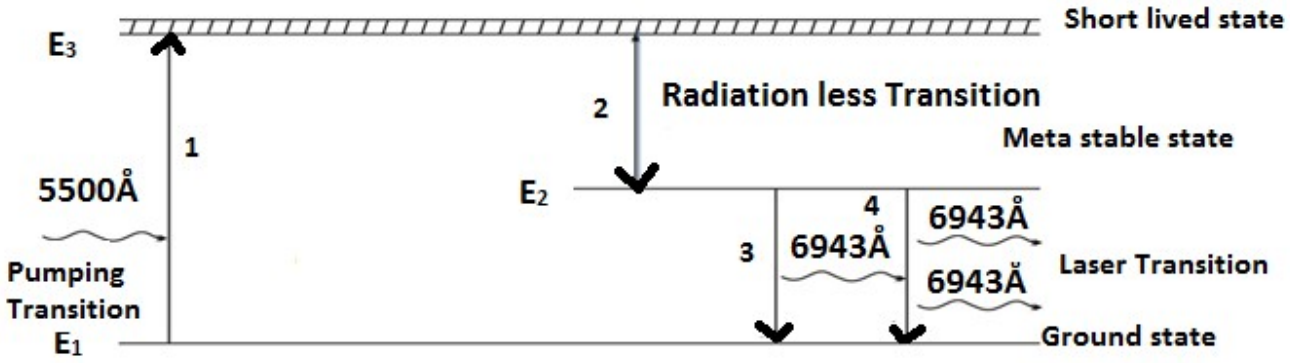


Figure 1.7

Characteristics of Ruby laser --

Type: Three level solid state laser

Active medium: Ruby rod is used as active medium

Pumping method: Optical pumping

Optical resonator: The two ends of Ruby rod which are polished with silver (one is fully silvered while the other is partially silvered) are used as optical resonatory.

Power output: 10^4- 10^6 watts.

Wavelength: The wavelength of output beam is 6943 Å.

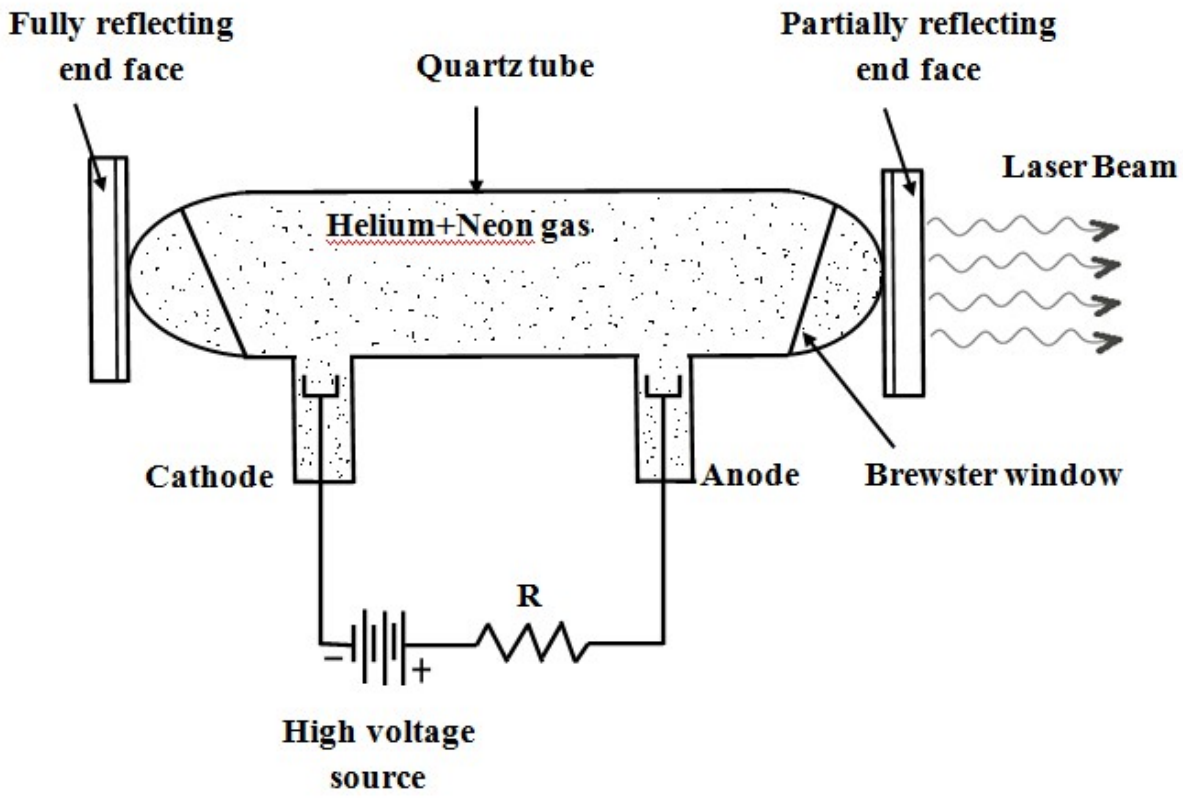
Nature of output: Pulsed beam of light.

Applications of ruby Laser

1. It is used in laboratory experiments.
2. It is used in soldering and wielding.
3. It is used to test the quality of the materials.
4. It is used in the treatment of detached ratina.
5. It is used in light detection and ranging (LIDAR).
6. It is used in the work of interferometry, holography.

Helium Neon Gas Laser—(Four Level Transition Laser)

In 1961 A. Javan, W. Bennett and D. Herriot reported a continuous He-Ne gas laser. It is the first gas laser which was operated successfully. To get continuous and intense beam of laser, gas lasers are used. The spectral lines in a gas laser are narrow and well defined as compared to solid in which absorption bands are broad. A simplified diagram showing basic features of a gas laser is shown in figure ().

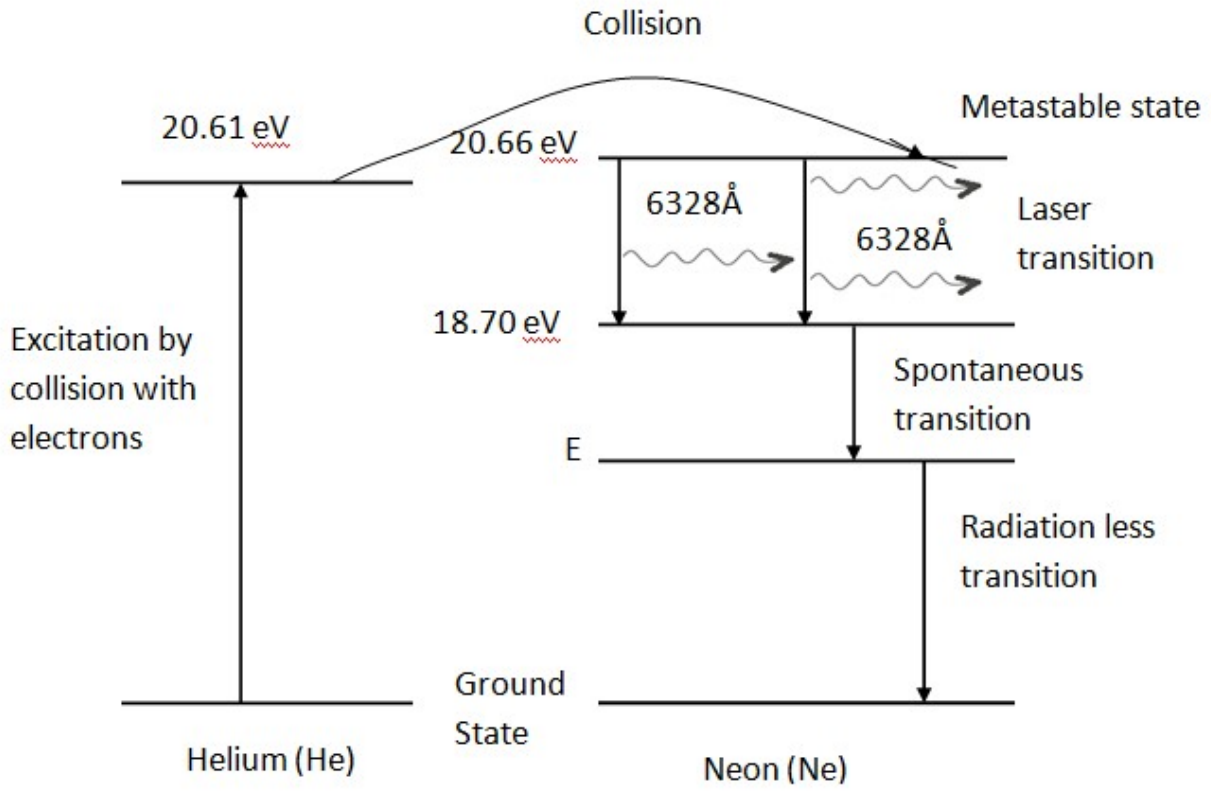


The resonant system is a long and thin optical cavity with mirrors at each ends. At one end, there is a perfect reflector while on another ends there is a partial reflector. Resonant system is also called a discharge tube.

He- Ne laser consists of a discharge (quartz) tube containing the helium and neon in the ration of 7 to 1 at a total pressure of about 1 torr (1 mm of Hg). The end faces of discharge tube are inclined at the polarizing angle so that the laser light is plane polarized. Such an arrangement is known as Brewster

window. A powerful generator (R. F. Generator) is used to produce a discharge in the gas. Actual lasing atoms are neon atoms while helium is used just for selective pumping of the upper laser level of neon.

He-Ne gas laser is a four level laser. The first few energy levels of He and Ne atoms are shown in fig ().



When an electric discharge passes through gas, the electrons in discharge tube collide with He and Ne atoms and excite or pump them to metastable state 20.61eV and 20.66 eV respectively above the ground state. Some of excited He atoms transfer their energy to unexcited Ne atoms by collisions. Thus lighter He atoms help in achieving population inversion in heavier Ne atoms.

When an excited Ne atoms drop down spontaneously from metastable state at 20.66 eV to lower energy state at 18.70 eV, it emits a photon (6328Å) in visible region. This photon travels through mixture of gas and if it is moving parallel to axis of tube, is reflected back and forth by reflector ends until it stimulates an excited Ne atom and causes it to emit a fresh 6328Å photon in phase with stimulating photon.

The photon emitted spontaneously which do not move parallel to axis of tube escape through sides of tube. The stimulated transition from 20.66 eV level to 18.70 eV level is the laser transition. The two

photons will knock out two more photons and the process is repeated again and again and photon thus multiplies. When this becomes sufficiently intense, a portion of it escapes through partially silvered end.

The Ne atoms drop down from 18.70 eV to lower metastable state E through spontaneous emission emitting incoherent light. From level E, Neon atoms are brought to ground state through collision with walls of tube. Hence final transition is radiation less.

Characteristics of He-Ne laser --

Type: Four level gas laser

Active medium: It uses a mixture of helium and neon gases as the active medium.

Pumping method: Electric discharge method.

Optical resonator: The two ends of Ruby rod which are polished with silver (one is fully silvered while the other is partially silvered) are used as optical resonatory.

Power output: 0.5 to 50 milliwatts.

Wavelength: The wavelength of output beam is 6328 Å.

Nature of output: continuous beam of light.

Applications of ruby Laser

1. It is used in laboratory experiments to produce interference and diffraction patterns.
2. It is used in optical communication without fibre for moderate distance.
3. It can be used to produce holograms i.e., 3 D photographs.
4. It is used in ophthalmology.

Significance of Pulse laser –As the flash lamp stop operating, the population of upper level decreases very rapidly and lasing action stops till the further operation of next flash. Hence Ruby laser is pulsed type of laser. During the period of operation of two flashes, laser output is oscillating. The output is called laser spiking.

Advantages of Gas laser (He-Ne) over solid state laser or Ruby laser-

In gas laser, light is produced as a continuous beam rather than ultra-short pulses as in Ruby laser. Gas laser beam is highly monochromatic and highly directional. This is because of fact that in gas

lasers the crystalline imperfection, thermal distortion and scattering are almost absent like Ruby laser. Gas laser are capable of operating continuously without any need of cooling. Therefore **He-Ne laser is superior than Ruby laser.**

Difference between Ruby laser and He-Ne laser—

	Ruby Laser	He-Ne Laser
1	It produces a pulsed laser beam.	It produces a continuous laser beam.
2	It is a three level laser system.	It is a four level laser system.
3	Optical pumping method is used for pumping.	Electric discharge method is used for pumping.
4	It has active medium in solid state.	It has active medium in gaseous state.
5	Cooling arrangement is required.	Cooling arrangement is not required.
6	It emits light of wavelength 6943 Å.	It emits light of wavelength 6328 Å.

Characteristic Of Laser Beam-The laser beam has the following main characteristics

1. High monochromaticity, high intensity, high degree of coherence and high directionality of laser radiation is of special significance in advanced research.

2. **Directionality**- A laser beam is very narrow and can travel to long distances without any spread while ordinary light source radiates light in all direction.

3. Output in a laser beam is many millions times more concentrated then the best search light available.

4. The laser gives out light in to a narrow beam and its energy is concentrated in a extremely small region.

5. Because of extremely high intensity of laser beam, it can produce temperature of the order of 10^4 $^{\circ}$c at a focused point.

6. Because of its narrow bandwidth, laser beams can be focused on a very small area of the order of 10^{-6} cm^2

7. Laser beam is extremely bright.

8. The laser beam is completely coherent spatially as well as temporally.

Applications And Uses Of Laser Radiations-

1. In **industrial** and technical fields the laser beam is used for drilling fine holes in diamonds, teeth, paper clips, hard sheets and even in human hairs.

Laser cutting technology is widely used in the fabrication of space craft. It has been observed that finger prints can be detected under laser light where the normal method of obtaining finger prints through dusting powder is ineffective.

2. In **medicine**, micro-surgery has become possible due to narrow angular spread of the laser beam. The laser beam can be focused on harmful components to destroy them without seriously damaging the neighbouring regions. It can be used in the treatment of kidney stone, tumour, in cutting and sealing the small blood vessel in brain operations.

3. Laser has an important application in **optical communication and holography**. Optic communication is a method of transmitting information from one place to another by sending highly intense laser light through an optical fiber

4. **Atmospheric Studies**-Laser remote sensing is frequently used for precise measurement of ozone in the atmosphere. Atmospheric optics uses lasers for the measurement of traces of pollutant gases, temp., water vapour concentration. Pictures of clouds, wind movement can be obtained with laser beam. The data so obtained helps in weather forecasting.

5. Radio astronomers have been able to amplify very faint radio signals from space with the uses of lasers. With the help of lasers it is possibly to hear the bursts of light and radiation waves from stars which emitted them over a millions of years ago.

6. **Photography-** We can get 3-D photography using laser, known as Holography.

7**. Military Applications**- Due to very high energy density, a laser beam can be used to destroy very big object like aircraft missiles in a few second by directing laser beam into target. So it is called 'Death ray or ray weapon'. In laser gun, highly convergent beam is focused on enemy targetsat a short range.