LASER

Ruby LASER:

The first laser was indeed a solid-state laser: Ruby emitting at 694.3 nm. Ruby consists of the naturally formed crystal of aluminum oxide (Al2O3) called corundum. In that crystal some of Al^{3+} ions are replaced by Cr^{3+} ions. It's the chromium ions that give Ruby the pinkish color, i.e. its flourescence, which is related to the laser transisitons, see the level structure in Figure 1. Ruby is a three level laser.

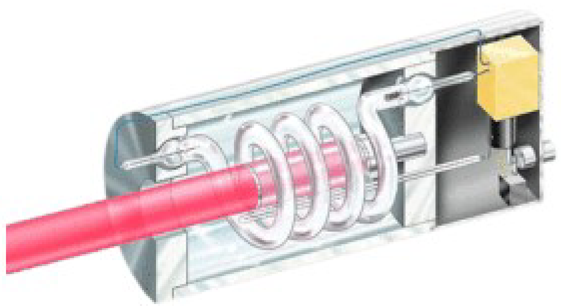
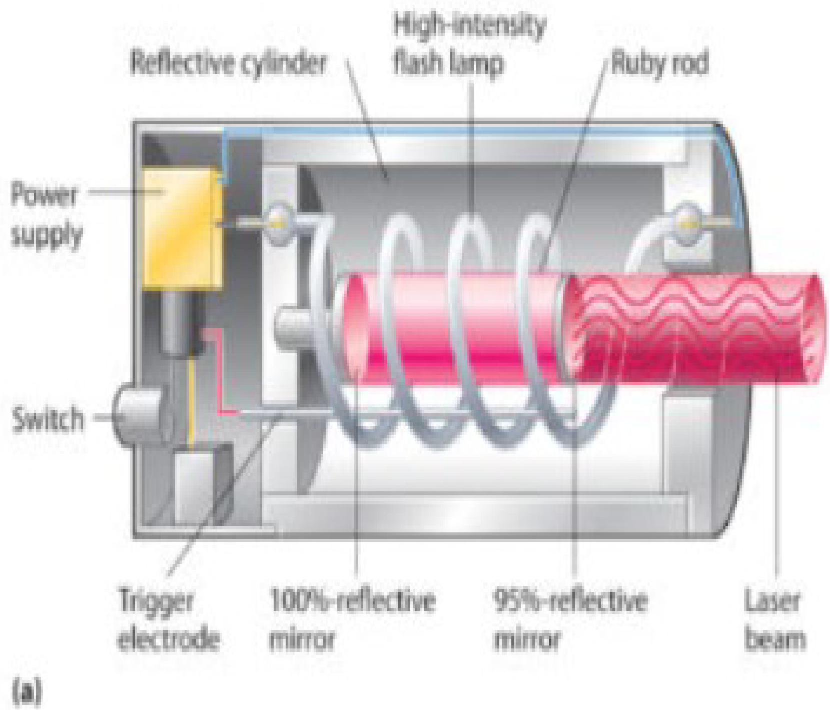


Figure 1

Construction of Ruby Laser:

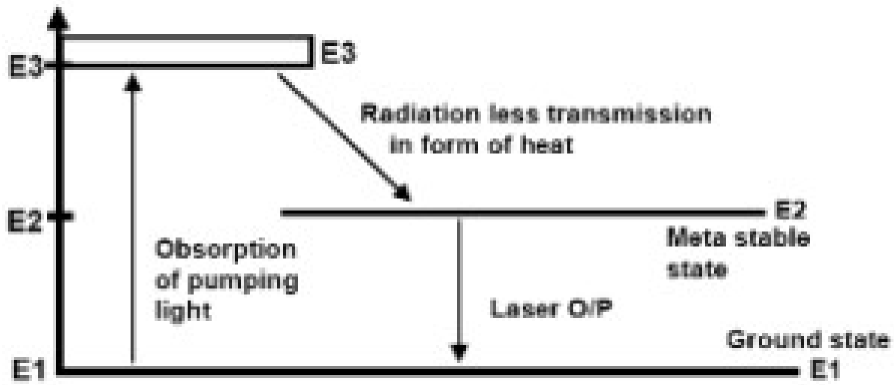
The ruby laser consists of a ruby rod which is made of chromium doped ruby material. At the opposite ends of this rod there are two silver polished mirrors. Whose one is fully polished and other is partially polished. A spring is attached to the rod with fully polished end for adjustment of wave length of the laser light. Around the ruby rod a flash light is kept for the pump input. The whole assembly is kept in the glass tube. Around the neck of the glass tube the R.F source and switching control is designed in order to switch on and off the flash light for desired intervals.



Operation of Ruby Laser:

When we switch on the circuit the R.F operates. As a result the flash of light is obtained around the ruby rod. This flash causes the electrons within ruby rod to move from lower energy band towards higher energy band. The population inversion takes place at high energy band and electrons starts back to travel towards the lower energy band. During this movement the electron emits the laser light.
This emitted light travels between the two mirrors where cross reflection takes place of this light. The stimulated laser light now escapes from partially polished mirror in shape of laser beam. The spring attached with the fully polished mirror is used to adjust the wave length equal to $\lambda/2$ of laser light for optimum laser beam. The switching control of the R.F source is used to switch on and off the flash light so that excessive heat should not be generated due to very high frequency of the movement of the electron.

Energy Level Diagram for Ruby Laser:



The above three level energy diagram show that in ruby lasers the absorption occurs in a rather broad range in the green part of the spectrum. This makes raise the electrons from ground state E1 to the band of level E3 higher than E2. At E3, these excited levels are highly unstable and so the electrons decays rapidly to the level of E2. This transition occurs with energy difference (E3 – E2) given up as heat (radiation less transmission). The level E2 is very important for stimulated emission process and is known as Meta stable state. Electrons in this level have an average life time of about 5 ms before they fall to ground state. After this the population inversion can be established between E2 and E1.

The population inversion is obtained by optical pumping of the ruby rod with a flash lamp. A common type of the flash lamp is a glass tube wrapped around the ruby rod and filled with xenon gas. When the flash lamp intensity becomes large enough to create population inversion, then stimulated emission from the Meta stable level to the ground level occurs which result in the laser output. Once the population inversion begins, the Meta stable level is depopulated very quickly. Thus the laser output consists of an intense spike lasting from a few Nano sec to µ sec. after stimulated emission spike, population inversion builds up again and a 2 spike results. This process continues as long as the flash lamp intensity is enough to create the population inversion.

He-Ne LASER:

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. 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 lasers, 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

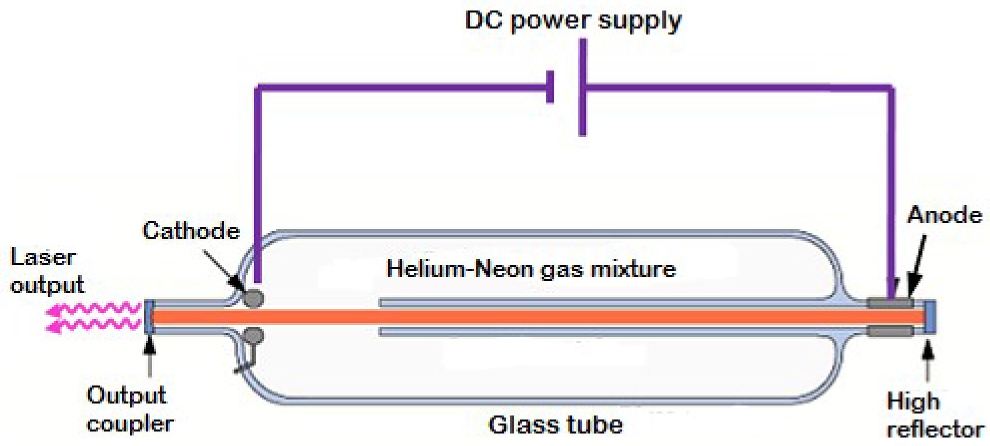
High voltage power supply or pump source

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.

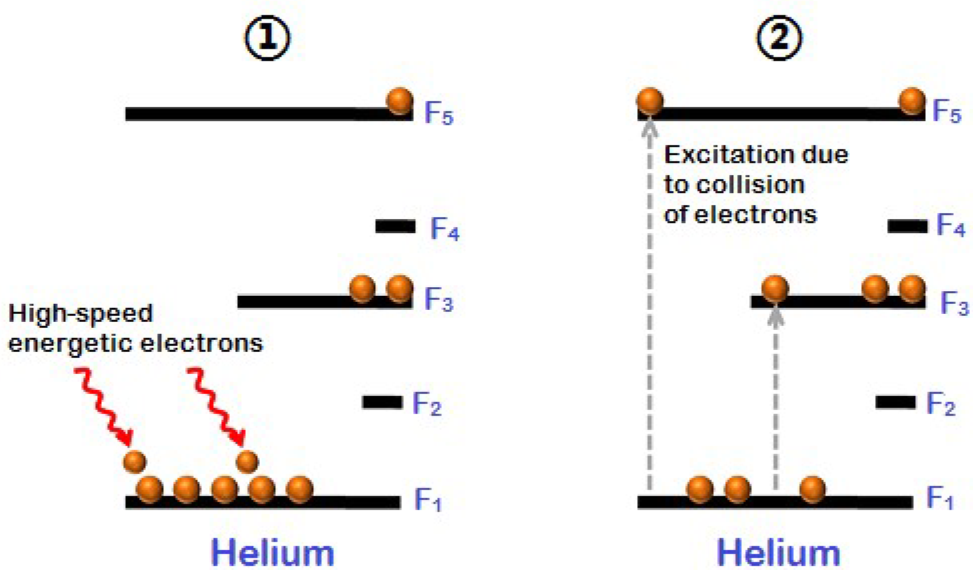
Working of helium-neon laser

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.

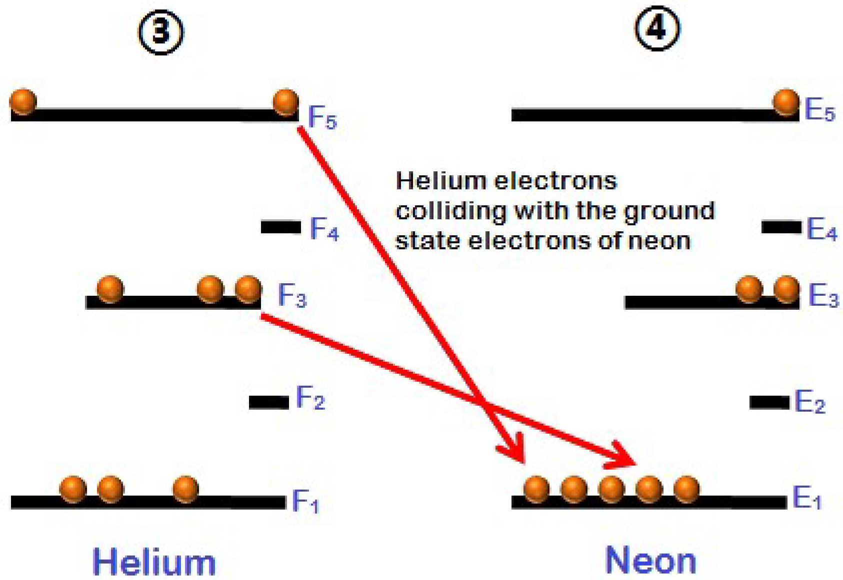
When the power is switched on, a high voltage of about 10 kV is applied across the gas mixture. This power is enough to excite the electrons in the gas mixture. The electrons produced in the process of discharge are accelerated between the electrodes (cathode and anode) through the gas mixture.

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.

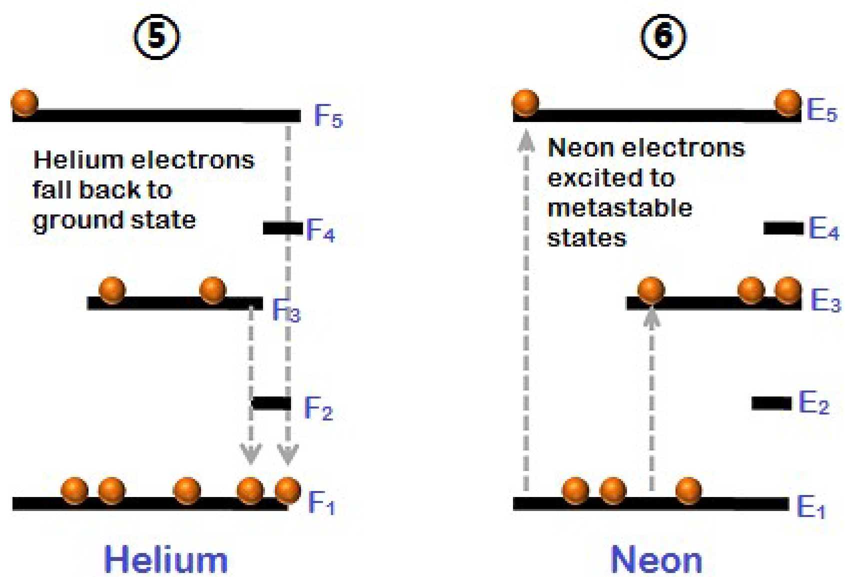


The metastable state electrons of the helium atoms cannot return to ground state by spontaneous emission. However, they can return to ground state by transferring their energy to the lower energy state electrons of the neon atoms.

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.



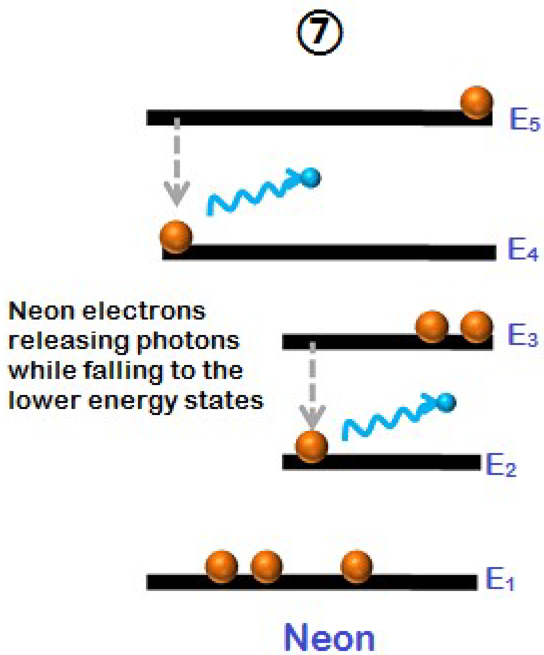
Unlike the solid, a gas can move or flow between the electrodes. Hence, when the excited electrons of the helium atoms collide with the lower energy state electrons of the neon atoms, they transfer their energy to the neon atoms. As a result, the lower energy state electrons of the neon atoms gain enough 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.



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.