LASER

3.2 He-Ne Laser and Hologram

3

CHAPTER OUTLINE

3.3–1 He - Ne laser (Principle only)

3.3–2 Holograms and its uses

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What is LASER

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. The LASER action was first proposed by Einstein. But, the term LASER is also, used for a device that generates an intense beam of coherent monochromatic electromagnetic light by stimulated emission of photons from excited atoms or molecules.

HISTORY OF LASER

1917: *On the Quantum theory of radiation* – Einstein's paper.

• 1954: MASER by Townes *et al*.

• Means of Acquiring Support for Expensive Research

• 1958: Townes (1964) and Schawlow (1981) conceive basic ideas for a laser.

• 1960: LASER coined by Gould.

• 1960: First laser (Ruby) by Maiman.

• 1961: First HeNe laser, then rapid invention of most lasers …

• 1977: Gordon Gould awarded the patent for the laser.

In 1958, Charles H. Townes and Arthur L. Schawlow showed that the effect of stimulated emission can be amplified to produce a practical source of light, which is coherent and can travel long distances without appreciable spread of the beam width. Such a light source is called LASER, an acronym for Light Amplification by Stimulated Emission of Radiation.

The He-Ne 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.

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. But, 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.

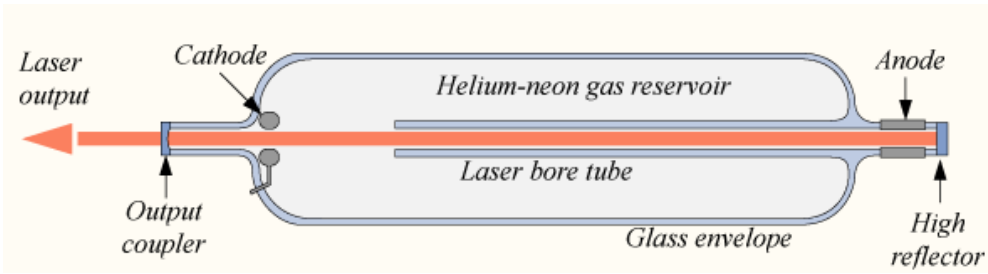
Helium-Neon laser

A laser can be named by its lasing medium. Among various lasing or active medium like solid (crystals, glasses), liquid (dyes or organic solvents), gas (Helium, CO_2) or semiconductors gas lasers are the most widely used. The main advantage of gas lasers (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 also, known as He-Ne laser, is the most widely used gas lasers in which a mixture of Helium and Neon gas is used as a gain medium. The excitation of electrons in the He-Ne gas active medium is achieved by passing an electric current through the gas. Optical pumping method is not used. He-Ne lasers are most commonly used in laboratory demonstrations of optics and scientific uses whereas the carbon dioxide lasers are used in industrial applications.

He-Ne laser operates at a wavelength of 632.8 nanometers (nm), in the red portion of the visible spectrum.

Construction of He-Ne laser



He-Ne laser consists of three essential components:

a. **Pump source (high voltage power supply)**
b. **Gain medium (laser glass tube or discharge glass tube)**
c. **Resonating cavity**

High voltage power supply or pump source

In order to achieve population inversion, different types of energy sources are used to supply energy to the gain medium. In He-Ne lasers, high DC voltage is used as the pump source. A high voltage DC produces energetic electrons that travel through the He-Ne gas mixture.

Gain medium (discharge glass tube or glass envelope)

The gain medium of a He-Ne laser is made up of the mixture of Helium and Neon gas contained in a glass tube at low pressure in the ratio of 4:1. 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, the lower energy state electrons of the Helium atom is primarily needed to excite. Neon atoms are the active centers and have energy levels suitable for laser transitions while Helium atoms help in exciting Neon atoms. By chance, Helium and Neon have nearly identical metastable states, located at 20.61 eV and 20.66 eV respectively.

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 differently.

Right side mirror is fully silvered whereas the left side mirror is partially, silvered known as output coupler. The partially silvered mirror will reflect major part of the light to produce the laser beam.

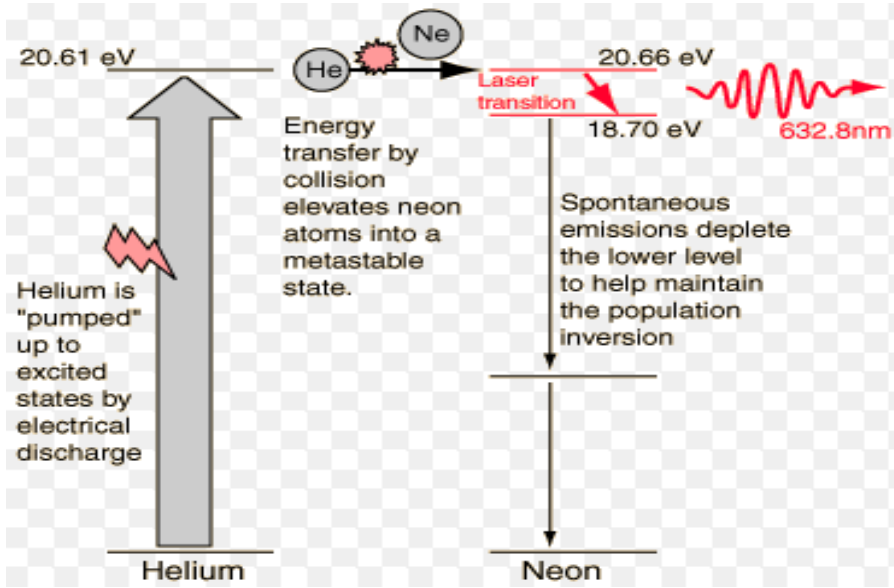
Working function of He-Ne laser

When the high voltage of about 10 kV DC is applied across the gas mixture, it produces highly energetic electrons that travel through the gas mixture. These electrons produced in the process of discharge are accelerated between the electrodes (cathode and anode) through the gas mixture.

These energetic electrons transfer some of their energy to the Helium atoms. As a result, electrons at the lower energy state of the Helium atoms gain enough energy and jump into the excited states or metastable state 20.61 ev.

The electrons of this metastable state of Helium atoms cannot return to the ground state by spontaneous emission. But, they can return to ground state by transferring their energy to the lower energy electrons of the Neon

atoms. Thus, the excited Helium atoms collide with the Neon atoms, each transferring its own 20.61ev energy to the Neon atom at its ground state along with 0.05 ev of kinetic energy from the moving atom. As a result, the electrons in Neon atoms are raised to the 20.66 ev energy state and in this way, population inversion is achieved.



This process is given by the reaction equation:

$$He^* + Ne \rightarrow He + Ne^* + \Delta E$$

Where (*) represent an excited state, and ΔE is the small energy difference between the energy states of the two atoms, of the order of 0.05 ev.

In this way, a population inversion is sustained in the Neon gas relative to an energy level of 20.66 eV. Spontaneous emission from Neon atoms initiates laser action and simulated emission causes electrons in the Neon to drop from 20.66 eV to the 18.70 eV level and red laser light of wavelength 632.8 nm corresponding to 1.96 ev energy is generated.

The light or photons emitted from the Neon atoms will move back and forth between two mirrors inside the cavity and overlap constructively to make highly amplified coherent monochromatic Laser beam of light. This laser beam will escape through the partially reflecting mirror or output coupler.

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

Hologram

In conventional photography, a negative is made first and using it a positive print is produced later. The positive print is only a 2D record of light intensity received from 3D object. Only intensity of light recorded but information of phase can't be imitated but lost.

Dennis Gabor (1900-1979), a Hungarian - born brilliant Physicist, invented a new technique in the early 1950s where intensity and phase both are recorded. This technique is called holography.

Hologram is a light wave interference pattern recorded on photographic film or other suitable surface that can produce a 3-dimensional image when illuminated properly.

This is based on the **coherency** of LASER radiation. A laser beam is split into two beams. The reference beam is spread by a lens or curved mirror and aimed directly at the film plate. The object beam is spread and aimed at the object. The object reflects some of the light on the holographic film-plate. The two beams interact forming an interference pattern on the film. This is the hologram based on holography.

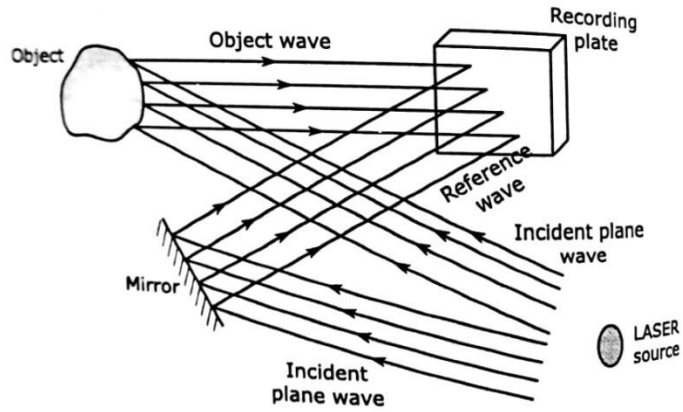
Hologram cannot be copied by photo copier because 3-dimensional images cannot be copied on 2-dimensional plate that easily. So now a day, it is widely used in credit card, ID card, Logo and bar code of bills for protecting against the counterfeiting. Hologram makes 3- dimensional images, so it is used in Art. For construction of image and reconstruction, Laser light is needed because it is made of coherent light of same wavelength and phase.

Holography is done in two stages:

1. Construction of image (freezing) or Hologram making

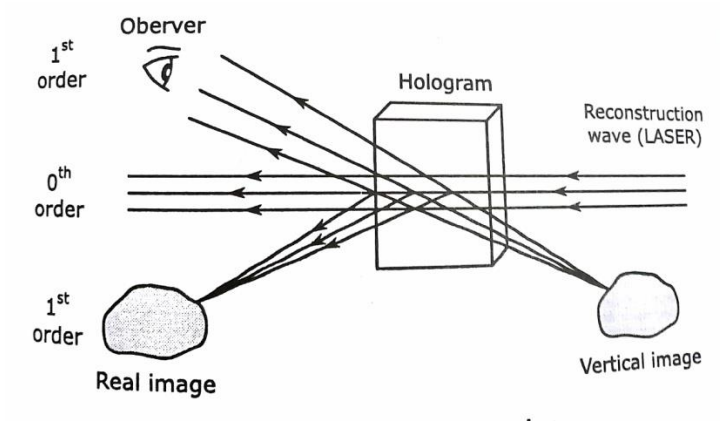
A weak but broad beam of laser light split into two beams by means of beam splitter. One beams directly go to the photographic film called as reference beam and second beam illuminates the object called as object beam. The light scattered by the object moves towards the photographic plate and interferes with the reference beam. The photographic plate carrying complex interference pattern of the object is called hologram.

The object is stored in the hologram in the form of interference pattern. Whenever required the object can be viewed by illuminating the hologram as shown in the figure below.



2. Reconstruction (unfreezing):

A laser beam identical to the reference beam is used for reconstruction of the object. This read out bream illuminates the hologram at the same angle as the reference beam. The hologram acts as a diffraction grating and secondary waves from hologram interferes constructively in certain directions and destructively in other directions. They form a real image in front of the hologram and a virtual image behind the hologram at the original site of the object. An observer sees light waves diverging from the virtual image. An image of the object appears where the object once stood and the image is identical to what our eyes would have perceived in all its details of the object.



Application:

- Hologram is reliable medium for data storage
- Hologram is used in concerts for authentication
- Holograms are used in exhibitions to avoid possible theft.