Al-Mustaqbal University

College of Engineering & Technology

Biomedical Engineering Department

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Lecture No.:-6

Lecture Title: [Gas Laser]

Gas laser

Most elements can be made to lase when they are in the gas state. Also, many molecules (composed of a few atoms each) have been demonstrated to lase. A gas laser is a laser in which an electric current is discharged through a gas to produce coherent light. The gas laser was the first continuous laser and the first laser to operate on the principle of converting electrical energy to a laser light output. The first invented gas laser was Helium–neon laser (HeNe) in 1960. It produced a coherent light beam in the infrared region of the spectrum at 1.15 µm one year after the first laser (Ruby) was demonstrated. In a gas laser, the laser active medium is a gas at a low pressure (A few milli torr).

The main reasons for using low pressure are:

• To enable an electric discharge in a long path, while the electrodes are at both ends of a long tube.

• To obtain narrow spectral width not expanded by collisions between atoms.

Excitation of a gas laser

Two main excitation techniques are used for gas lasers:

• Electrical Discharge.

• Optical Pumping.

Excitation of Gas Laser by Electrical Discharge

Applying high voltage to electrodes at both sides of the tube containing the gas causes electrical breakdown through the gas. Electrons are ejected from the cathode, accelerated toward the anode, and collide with the gas molecules along the way. During the collision, the mechanical kinetic energy of the electrons is transferred to the gas molecules and excites them.

Gas lasers are usually excited by an electric discharge. Also, a gas laser can be excited by an optical source with very narrow bandwidth (laser), which fits the narrow absorption spectral lines of the gas. This method is used for pumping Far Infra-Red (FIR) gas lasers by a CO2 laser.

Groups of Gas Lasers

Gas lasers are divided into three groups:

1. Atoms: The laser active medium is composed of neutral gas atoms such as Helium-Neon and Copper Vapor.
2. Ions: The laser active medium is composed of ionized gas such as Argon ion gas or Helium-Cadmium gas.
3. Molecules: The laser active medium is composed of gas molecules, like Carbon Dioxide (CO_2), Nitrogen (N_2), Excimer laser, Chemical lasers (HF), Far Infra-Red (FIR) laser.

Gas laser Characteristics:

- The active gas is used with other gases in a mixture.
- The extra gas(es) help increase the excitation efficiency.
- Maximum gain is achieved when the tube diameter is very small.

Gas lasers usually operate in the continuous mode

Helium-Neon (He-Ne) Laser

A helium–neon laser or HeNe laser, is a type of gas laser whose gain medium consists of a mixture of helium and neon (5:1) inside of a small bore capillary tube, usually excited by a DC electrical discharge. The best-known and most widely used HeNe laser operates at a wavelength of 632.8 nm, in the red part of the visible spectrum.

- The active medium is a noble gas Neon (Ne).
- Is a 4 level laser.
- Two meta-stable energy levels act as upper laser levels.
- Have two lower laser levels, so quite a few wavelengths can come out of the transitions between these levels.

The important wavelengths are:

$\lambda 1=632.8$ nm, $\lambda 2 = 1152$ nm, $\lambda 3 = 3391.3$ nm

- **Construction and operation**

Figure (1) shows the structure of a typical mass-produced helium–neon laser. The discharge passing between electrodes at opposite ends of the tube is concentrated in a narrow bore, one to a few millimeters in diameter. This raises laser excitation efficiency and helps maintain good beam quality. The bulk of the tube volume is a gas reservoir containing extra helium and neon. Gas pressure within the tube is typically a few tenths of a percent of atmospheric pressure.

Mirrors are bonded directly to mass-produced helium–neon tubes by a high-temperature process that produces what is called a "hard seal," which slows the helium leakage that otherwise might limit laser lifetime. The mirrors must have low loss because of the laser's low gain. The rear cavity mirror is totally reflective. The output mirror transmits only a few percent of the intracavity power to produce the laser beam. One or both mirrors have concave curvature to focus the beam within the laser cavity, which is important for good beam quality. The output power of helium–neon lasers depends on tube length, gas pressure, and diameter of the discharge bore.

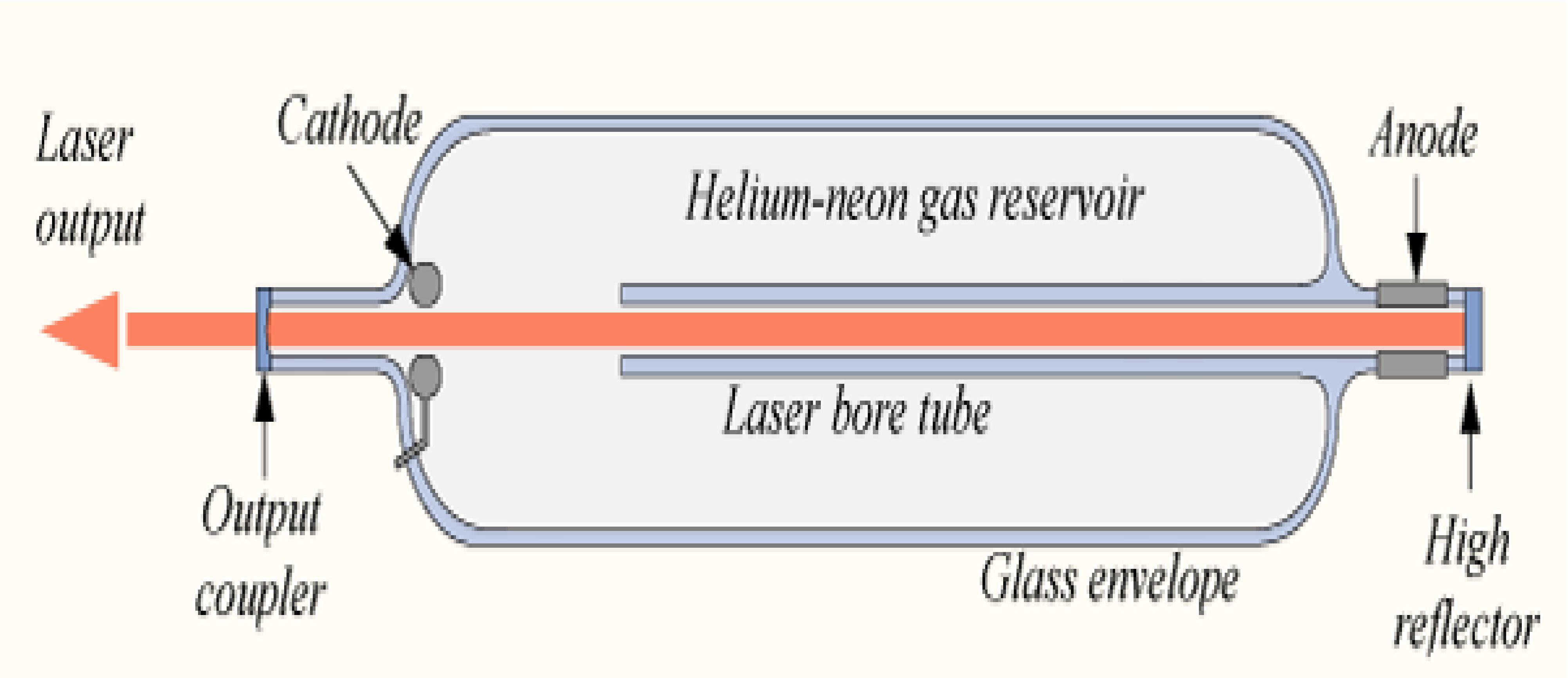

Figure (1): Schematic diagram of HeNe Laser

- ## Lasing Mechanism

Helium–neon lasers can emit on several transitions among the energy levels shown in Figure (2). Electrons passing through a mixture of five parts helium and one part neon excite both species to high energy states, with the more abundant helium atoms collecting most of the energy. Excited helium atoms readily transfer that energy to neon atoms when the two collide, raising the neon atoms to the 5s and 4s energy levels. The 5s and 4s energy levels of neon are metastable, so atoms stay in those states for a comparatively long time, producing a population inversion.

The transitions shown in Figure (2) are the strongest and most useful of the several possible transitions in helium–neon mixtures. Note that some transitions descend from the 5s level and others from the 4s level. The first helium–neon laser operated at 1153 nm in the infrared, but the demand for visible beams made the 632.8 nm red line the standard for helium–neon. He–Ne lasers emitting on the 543-nm green line are also available. Once neon atoms drop to the lower laser level, they quickly drop through a series of lower energy levels to the ground state. Energy transfer from helium atoms can then raise them again to the upper laser level. The overall gain of the helium–neon laser is very low, so care is needed to minimize laser cavity losses.

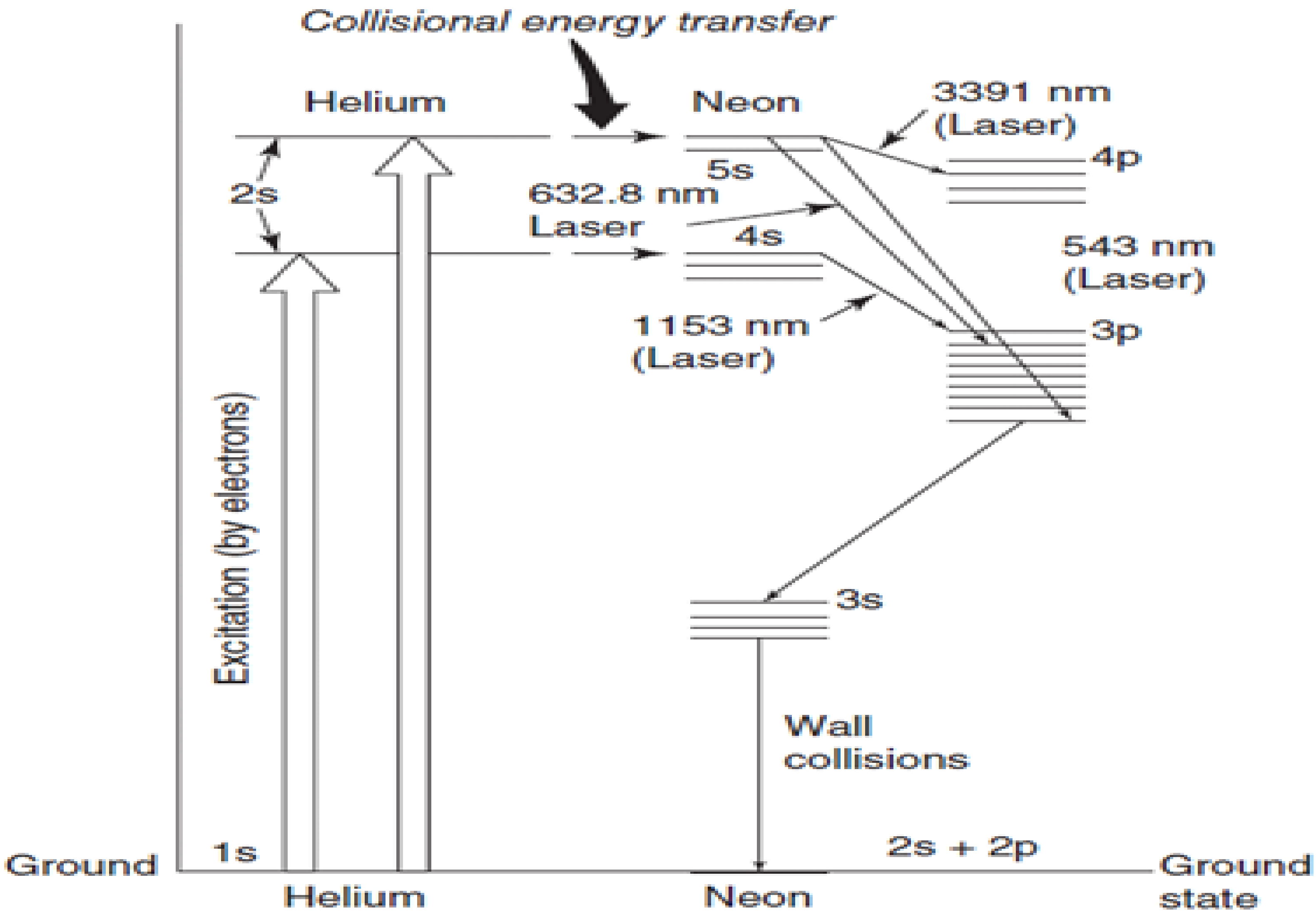

Figure (2): Energy levels of HeNe laser

- Applications

Red HeNe lasers have many industrial and scientific uses. They are widely used in laboratory demonstrations in the field of optics because of their relatively low cost and ease of operation compared to other visible lasers producing beams of similar quality in terms of spatial coherence (a single-mode Gaussian beam) and long coherence length.