CHAPTER TWO

GAS LASERS

2.1 An Overview

As laser gain media, gases offer an interesting contrast to solids. Because of the difference in densities the population inversions that can be achieved in gases are much less than in solids. (A Nd:YAG rod contains some 6 x 10^{25}Nd atoms m^{-3}, whereas a He-Ne laser only has 10^{21} Ne atoms m^{-3}). In consequence we would expect high-power gas lasers to be relatively large. On the other hand gases are much more homogeneous than solids and may be readily circulated for cooling (heat removal) and replenishment purposes. A huge advantage of gases is their ability to mix in different ratios and at different pressures to form highly homogeneous media. A relatively low density of gas medium demonstrates narrow and well-defined spectral emission lines, which makes them stable sources of optical radiation (in output power and frequency). Because of all the above advantages we can ask: Why are gas lasers so interesting?

– Gas lasers can be easily scaled in length, area , and volume without a significant increase in the cost of the device.

– In many lasers, recycling of the gas sufficiently increases their lifetime.

– Long lifetime has been achieved for gas laser devices because of well-developed high vacuum technologies.

– The other advantage is the possibility of using isotopes to shift the spectrum of laser radiation.

– The well-developed technique of gas discharges allows exciting gas media in reasonable, easily formable, laser cavities.

– Gas lasers are widely available in almost all powers (milliwatts to megawatts) and wavelengths from far infrared (FIR) radiation to X-ray and can be operated in pulsed and continuous modes.

Since the atoms in gases exhibit very narrow absorption lines it is impractical in most cases to use optical pumping. Instead atoms are almost always excited within a gas discharge.

A schematic gas laser is shown in Fig. 2.1. The gas, at fairly low pressure, is contained within a glass discharge tube with anode and cathode at either end. If the cavity mirrors are outside the tube, then Brewster windows may be used at the ends of the tube to minimize

reflection losses (this, of course, will result in a plane polarized output.

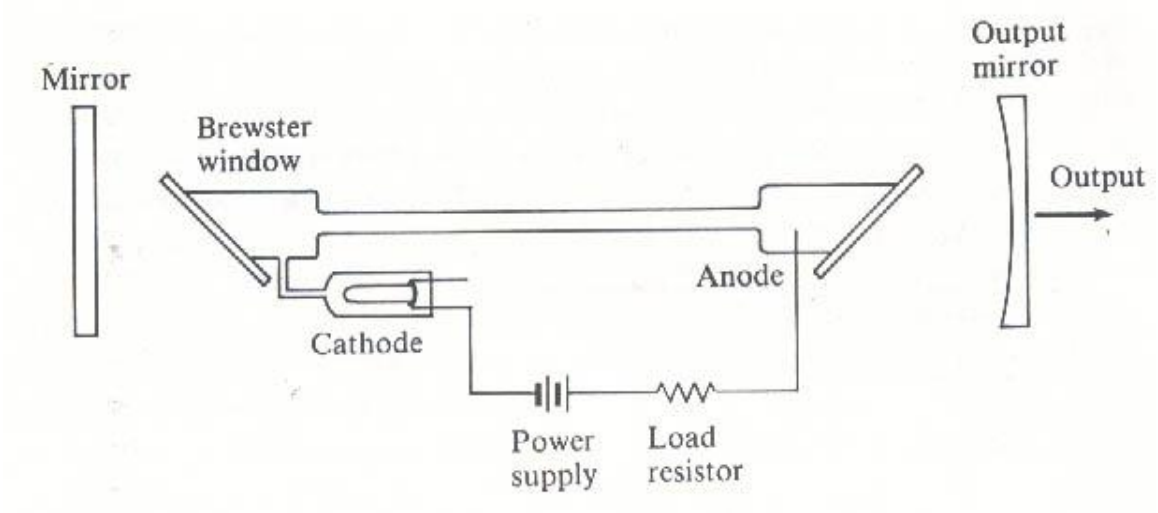

Figure 2.1:Schematic construction of a low-power gas laser such as the helium-neon laser.

Voltages of a few kilovolts applied across the tube then initiate a gas discharge. The load resistor serves to limit the current once the discharge has been initiated. The gas may need to be pre-ionized, as in the flashtube, by the application of a high-voltage pulse either to one of the electrodes or to a short length of wire wrapped round the tube. In such a discharge both free electrons and ions will be present as well as neutral atoms.

In a gas laser, the laser active medium is a gas at a low pressure of a few milli-torr (A few types of gas lasers use gas at high pressure). The main reasons for using low pressure are:

1. To enable an electric discharge in a long path, while the electrodes are at both ends of a long tube.
2. To obtain narrow spectral width not expanded by collisions between atoms.

The first gas laser was operated in 1961; one year after the first laser (Ruby) was demonstrated. The first gas laser was a Helium-Neon laser, operating at a wavelength of 1152.27 nm (Near Infra-Red).

2.2 Excitation of a gas laser

Two main excitation techniques are used for gas lasers:

- Electrical Discharge

- Optical Pumping

The excitation of gas lasers is either:

- a one - step process, or

- a two – step process (in many instances , like in He-Ne & CO_2 lasers).

2.2.1 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. (This same method of energy transfer is used in common fluorescent lights).

2.2.2 Excitation of Gas Laser by Optical Pumping

Exciting a laser medium by optical pumping, requires that the absorption spectrum of the medium will be similar to the emission spectrum of the pumping source, so that a big amount of the radiation will be absorbed. Conventional light sources (Arc-lamps & Flash-lamps) used for optical pumping have broad emission spectrum, so only a small part of the light is used in the excitation process. Because gas atoms absorb only a small portion of the spectrum, optical pumping is not generally an efficient method for gas lasers.

When we want to excite a gas laser by optical pumping; we need to find an optical source with very narrow bandwidth, which fits the narrow absorption spectral lines of the gas. A good source for optical pumping of a gas laser is another laser. This method is used for pumping Far-Infra-Red (FIR) gas lasers by a CO_2 laser.

2.3 Groups of Gas Lasers

For convenience, gas lasers are divided into three groups depending on whether the lasing transitions take place between the energy levels of atoms, ions or molecules :

Atoms - The laser active medium is composed of *neutral* gas atoms such as Helium-Neon and Copper Vapor.

Ions - The laser active medium is composed of ionized gas such as Argon ion gas or Helium-Cadmium gas.

Molecules - The laser active medium is composed of gas molecules, like Carbon Dioxide (CO_2), Nitrogen (N_2), Excimer laser, Chemical lasers (HF, DF), Far Infra-Red (FIR) laser.

QUESTIONS

1. Why gases, as laser gain media, offer an interesting contrast to solids?
2. What would you expect from the following: An Nd:YAG rod contains some $6x10^{25}$Nd atoms m^{-3}, while the He-Ne laser only has 10^{21} Ne atoms m^{-3}.
3. Why gas lasers are so interesting?
4. Why it is impractical in most cases to use optical pumping in gas lasers?
5. Discuss a gas laser with a schematic diagram.
6. Why the laser active medium in gas lasers is a gas at fairly low pressure.
7. Brewster windows may be used at the ends of gas laser tube. Why are they used? Are they always used?
8. How are typical gas lasers pumped (excited).
9. Why gas lasers are conveniently divided into three main categories (groups)? What are they?

2.4 Neutral Gas Lasers (Atoms)

The active medium in these lasers is a noble gas in its neutral state, or a metal vapor. The active gas is used with other gases in a mixture. The extra gas help increase the excitation efficiency. Maximum gain is achieved when the tube diameter is very small. Gas lasers usually operate in the continuous mode.

2.4.1 Noble Gas Laser

As the name implies, the active medium in this laser is a gas in its