2.6.2 Carbon-Monoxide (CO) Laser

This laser is very similar to the CO_2 laser, except for the active gas - CO. The spectrum output of these lasers is: 5-6 μm. One of the problems with this laser is the gas CO which is poisonous.

QUESTIOS

1. What is the spectrum output of CO laser?
2. What is the important problem with CO laser?

2.6.3 Nitrogen (N2) Laser

The Nitrogen laser was first developed in 1963 and has been sold as a commercial product since 1972.

Laser Action

The active medium in Nitrogen lasers is Nitrogen gas at pressures of 20 torr up to 1 atm. In some Nitrogen lasers the gas flows in the tube, while others have a sealed tube. The Nitrogen laser is based on vibronic transitions (involving both electronic and vibrational levels) between energy levels of the nitrogen molecule and give rise to an output in the ultra violet at 337 nm, and is electrically excited. The energy level diagram of the Nitrogen laser is shown in figure 2.18. The N_2 laser is a three–level laser system. Interestingly the levels between which lasing action takes place would appear to have entirely the wrong relative lifetime. Remember in an ideal situation the lifetime of the upper level should be long whilst that of the lower level should be short. In Nitrogen the reverse is true (the lifetime of the upper laser energy level is about 40 nsec, while the lifetime of the lower laser level is longer: 10 msec). Obviously we cannot hope for CW operation in these circumstances. Nitrogen laser is a pulsed laser. It is impossible to operate a Nitrogen laser such that it emits radiation continuously. The lifetime of the upper laser level becomes shorter as the operating pressure increases, and it is equal to 18 ns at 60 torr while it reaches only 2.5 ns at one atmosphere. In general, the upper laser level lifetime ($\boldsymbol{\tau}$) as related to the pressure can be given as:

$$\tau(ns) = \frac{1}{1+P(torr)/58}$$

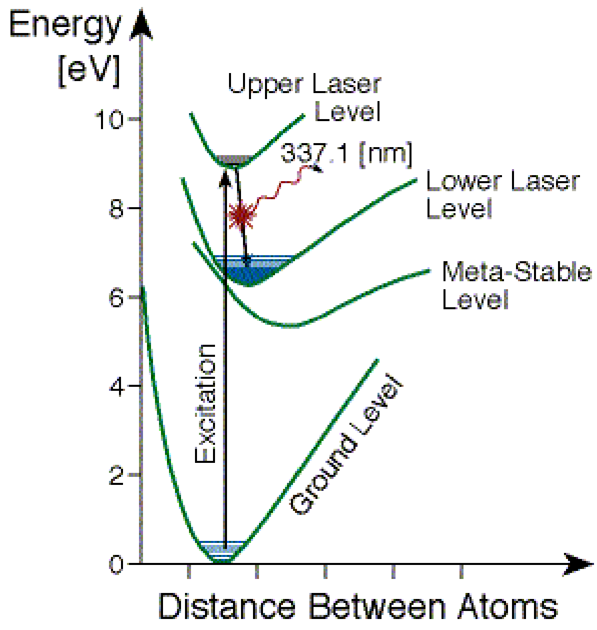

Figure 2.18: Energy level diagram of Nitrogen laser.

Pulsed Operation of Nitrogen Laser

Nitrogen gas excitation is performed by a short pulse (about 10 ns) of high voltage (20-40 KVolts). This high voltage pulse creates electric discharge in the gas, which causes momentary population inversion. A short (ns) laser pulse is emitted, and the gas returns to the ground state.

The pulse widths are, however, very narrow since as soon as lasing begins the population of the terminal state increases rapidly and after a few nanoseconds population inversion is reduced to a level where lasing cannot be supported. Such a laser is termed self–terminating. Pumping is not trivial since it has to take place in a time which is less than the pulse width.

Configuration of N_2 laser

Usually a configuration similar to the TEA CO2 laser is adopted. A capacitor is rapidly discharged between electrodes placed transversely to the laser axis, and the gas may be cooled by flowing it through a heat exchanger. Interestingly very high gains(50 dB/m) are possible, so much so that only one mirror need be used but in practice, a total (100%) reflecting mirror is used on one side of the laser, and the laser radiation is emitted through a window on the other side. Such high gain operation is termed superradiant. Pulse energies are up to a few mill joules and, because of their very short duration, the peak powers can be in the region of megawatts.

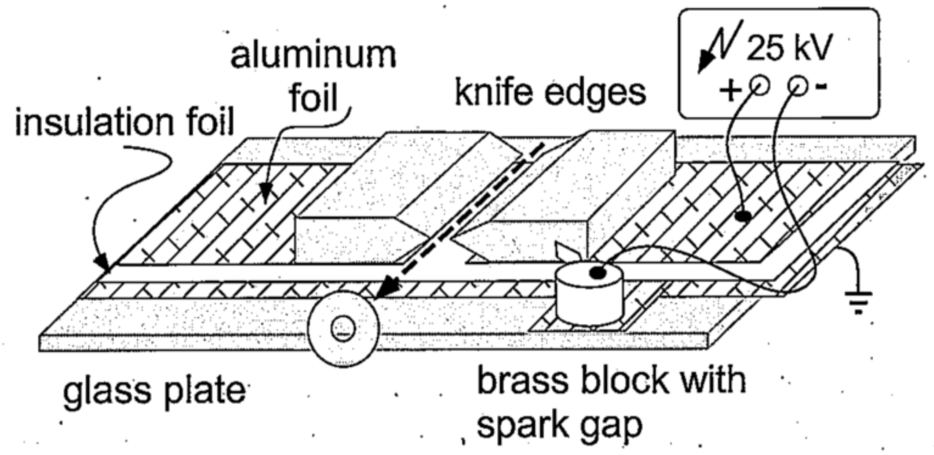

Figure 2.19. Home-built Air laser.

Properties of Nitrogen laser

- Nitrogen lasers emit radiation in the Ultra-Violet (UV) region of the electromagnetic spectrum, at a wavelength of 337.1 nm.
- Very simple and cheap laser.
- Pulse with very high peak power - up to few Mega-Watts.
- Pulse frequency - up to 1,000 Hz - limited by heating effects.
- Pulse length is of the order of 10 nsec.
- Energy per pulse - a few milli-Joule.
- Average energy - up to a few hundred milli-Watts.
- Total efficiency - about 0.1 %.

QUESTIONS

1. Explain why the data on lifetime of energy levels limits the laser action to pulsed operation.
2. Can a laser be operated just with air ?
3. Why the pumping in N_2 laser is not trivial?
4. Why the N_2 laser pulse width is very short?
5.Why the N_2 laser is termed self-terminating?

6.Give only five properties of N_2 laser.

2.6.4 Chemical Laser

The first chemical laser, which was operated in the pulsed mode, was developed in 1965 by J. V. V. Kasper, and G. C. Pimental. The lasing action of the chemical laser is usually based on vibrational transitions of diatomic molecule.

In chemical laser little or no electrical power is needed, where the pump energy comes from a chemical reaction between two atoms(the energy released is used to produce population inversion and hence lasing action, For example a kilogram of high explosive will yield about 8 MJ).

A popular reaction for such purposes is that which can take place between hydrogen and fluorine. If both are present only in their molecular form then no reaction takes place; however, if by some means single atoms of either species can be generated, then the following two reactions initiate a 'chain reaction' during which all the hydrogen and fluorine can recombine

$$\mathbf{F + H_2 \rightarrow HF + H(+energy)}$$
$$\mathbf{H + F_2 \rightarrow HF + F(+energy)}$$

The HF molecules thus formed are in vibrationally excited states and population inversion may be obtained between these states and the ground state. Lasing action at a variety of wavelengths from 2.5 to 3.4 μm has been observed.

The Material in a Chemical Laser

Most chemical lasers are based on Hydrogen halides:

HF

The most well known member of this family is Hydrogen Fluoride (HF).
The emitted radiation is in the Infra-Red (IR), with a few lines in the spectrum range: 2.6 - 3.0 μm.

DF

When Hydrogen is replaced by its heavier isotope - Deuterium, another member of the family: Deuterium Fluoride (DF) is created and emits in the spectrum range: 3.5 - 4.2 μm. Other halides such as

Hydrogen Chloride (HCl) and Hydrogen Bromide (HBr) have demonstrated lasing in the lab, but are not common. Because Fluorine and Hydrogen are very reactive gasses, Hydrocarbons are used as a Hydrogen source, and Fluorine compounds such as SF_6 or NF_3 are used as a source for Fluorine.

Fluorine extraction is done by electrical discharge which separates the SF_6 molecule into Fluorine and Sulfur. In commercial chemical lasers, Oxygen is added to the reaction chamber, to react with the Sulfur to create SO_2 molecules. Helium gas is added as a dilution gas(stabilize the reaction and controls the temperature). and sometimes other gasses as well. The total pressure inside a chemical laser is low (a few torr).

Advantages of Chemical Lasers

- The source of energy is conveniently stored.
- Very high output power.

The atmosphere is more transparent to the emitted spectrum out of DF lasers than for HF lasers, so the DF laser is more developed, although its efficiency is lower, and the price of the Deuterium isotope is higher.

Disadvantages of Chemical Lasers

- Fluorine is a very reactive gas.
- Hydrogen gas can explode easily.

Construction Technology and Laser Structure

The chemical laser is a member of the family of Gas Dynamic Lasers. Gas dynamic lasers are based on rapid expansion of hot, high pressure gas, through nozzles into a near vacuum. This rapid expansion reduces the gas temperature.

As a result, since the transfer of the molecules to the ground state takes more than the time of rapid expansion, we get at low temperature many molecules at excited levels, thus, "population inversion". The gas usually flow through the nozzles in a transverse flow (perpendicular to the optical axis of the laser), so many nozzles can operate at the same