time, yielding high power from the laser. The structure of a chemical laser is shown in figure 2.20.The gasses are injected into the laser through pipes with pinholes at their ends. The design of the pinholes is critical to avoid thermodynamic equilibrium of the gas. The gas flows rapidly out of the pinholes and creates a turbulent flow. This results in excited Hydrogen-halide molecule. The excited gas enters the laser optical cavity at right angle to the laser optical axis.

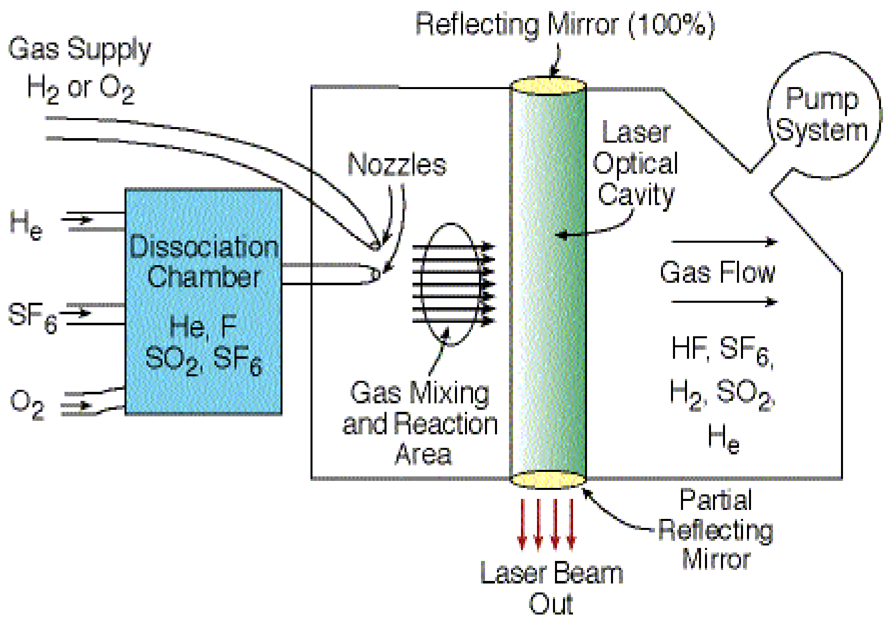

Figure 2.20: The Basic Structure of the Chemical Laser.

<u>Chemical Laser operation</u>

In a commercial chemical laser, high voltage of about 8,000 Volts is applied to the electrodes of the laser tube. Some lasers use Ultra-Violet (UV) radiation before the electric discharge to pre-ionize the gas and increase the efficiency of the chemical reaction. The chemical reaction between free Fluorine and Hydrogen releases a large amount of heat while creating the molecule HF^* which is in an excited state.

If we check the efficiency of the electrical input versus the laser output, we can get more than 100%, because of the chemical energy released by the reaction between the free Fluorine and Hydrogen. In commercial chemical lasers, the electrical efficiency is less than 1%, while the chemical efficiency is about 20%.

Chemical Laser Applications

Most of the applications of chemical laser are military applications, so the number of published articles in the open literature is limited.

Mid Infra-Red Advanced Chemical Laser (MIRACL)

It is designed to destroy enemy missiles in the air. It was the first megawatt-class; continuous wave, chemical laser built in the USA, and was operated first in 1980. Because of its unique properties, it will be described in details (that were published):

- This laser can emit a continuous power of up to 2 Megawatts, for a short time (Up to a maximum of 70 seconds).
- The clear aperture of the special telescope used to direct this laser is 1.5 meters, with computer automatic tracking of the target.
- The beam quality is good.
- The laser demonstrated reliable operation in more than 150 lasing tests, with over 3,000 seconds of lasing time during the last decade.

MIRACL laser operation is similar to a rocket engine in which a fuel (ethylene, C_2H_4) is burned with an oxidizer (Nitrogen Trifluoride, NF_3). Free, excited fluorine atoms are one of the combustion products. Only downstream from the combustor, deuterium and helium are injected into the exhaust. Deuterium combines with the excited fluorine to give excited deuterium fluoride (DF^*) molecules, while the helium stabilizes the reaction and controls the temperature.

Chemical Oxygen Iodine Laser (COIL)

Another chemical laser is based on the complicated reaction between Iodine and Oxygen. This laser was invented in the US Air-Force Weapons Laboratory in 1977.It is tested at Phillips Laboratory of the Air-Force as a potential weapon grade system.

Its main use is for destroying missiles in the air. COIL has been selected as the laser to be installed on the second generation airborne laser (ABL) aircraft, designed to intercept ballistic missiles in their boost stage.

This laser emits radiation at a wavelength of about 1.3 μm. This is the shortest wavelength achieved from chemical lasers. This wavelength is desirable for weapon applications, because of the high transmission of the atmosphere at this wavelength, and the availability of excellent grade, large size optics, required for high power laser system.

QUESTIONS

1. What is a chemical laser? Give an example of one and explain how it is different from another gas lasers.
2 .What are the advantages of chemical lasers? What are some of their disadvantages?
3. What is the role of He gas in HF chemical laser?
4. Draw , label, and describe the basic structure of the chemical laser.
5. What are the following abbreviations stand for: MIRACL, and COIL. From which one of these lasers, the shortest wavelength could be achieved ? Which one has good beam quality ?
6. What are the wavelength ranges emitted from HF and DF chemical lasers?

2.6.5 Excimer Laser

It is a laser in which the required conditions for lasing are achieved in exotic way, i.e., laser radiation is emitted from a molecule which only exists in an excited state for a very short time of less than 10 ns. An Excimer is a molecule which has a bound state (existence) only in an excited state. In the ground state this molecule does not exist, and the atoms are separated. The name Excimer comes from the combination of the two words: ***exited dimer***, which means that the molecule is composed of two atoms, and exists only in an excited state. (Some scientists consider this molecule to be a complex, and they call the laser "Exiplex"). Typical of excimer materials are the rare gas halides such as ArF, KrF and XeCl, …. Etc.

Atom & Atom --------------- Excited Diatomic Molecule

Noble gas Halogen

(Ar, Kr, Xe) (F,Cl,Br,I) (ArF,ArCl,KrF,KrCl,XeF,XeBr)

The composition of the gas mixture inside the tube of the Excimer laser is:

- Very little halogen (0.1-0.2%).
- Little noble gas (Argon, Krypton or Xenon).
- About 90% Neon or Helium.

The halogen atoms can come from:
-- halogen molecules such as: F_2, Cl_2, Br_2, or from
-- other molecules which contain halogens such as: HCl, NF_3. The advantage of using a compound and not a pure halogen is the strong chemical activity of the halogen molecule (especially Fluorine).

Historic Development of Eximer Lasers

The Excimer laser was invented in 1971 in the USSR by a group of scientists: Basov, Danilychev, and Popov. They showed stimulated emission at a wavelength of 172 nm from Xe_2 gas at low temperature, pumped by a beam of electrons. The first laser action in a noble gas with halogen (XeBr) was reported in 1975 by Searl and Hart. The common Excimer lasers are listed in the table, each with its characteristic wavelengths:

Excimer Laser	**Wavelengths [nm]**
ArCl	**175**
ArF	**193**
KrF	**248, (275)**
XeF	**351, 353, (460)**
KrCl	**222, (240)**
XeCl	**308, 351**
XeBr	**282, (300)**

A comparatively large number of Excimer lasers has been developed covering the wavelength range 120–500 nm. Some of these, especially XeF and KrF, are quite efficient (up to 10–15%). Peak powers of up to 1J with average powers of some 200 W can be obtained.

Energy Levels of Excimer Laser

A compound of a noble gas is a contradiction, since noble gases are inert (as their name implies). The atoms create a bound state only after a high energy input raises them to an ionized excited state.

If we draw a diagram of energy versus atomic separation for the ground state of a 'normal' molecule (see Fig. 2.18), we obtain a curve with an energy minimum occurring at the equilibrium separation of the molecule. Similar curves may be drawn for the excited states. For dimmers, however, although the excited states may have such minima the ground states do not. This situation is illustrated in Fig. 2.21. which shows a diagram of the energy levels of Excimer laser, as a function of the distance between the atoms in the molecule. R represents the noble gas atom and H represents the halogen.

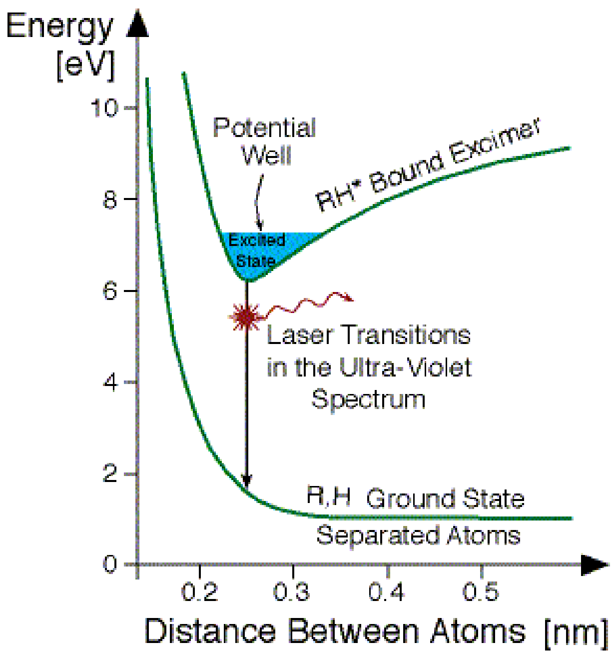

Figure 2.21:Energy levels in the Excimer Laser.

The valley (potential well) in the diagram of the excited state shows the existence of a momentary stable state. The fact that there is no potential well in the ground state shows that there is no bound state to the