molecule when it is not excited. Only within the marked area inside the potential well of the excited state can a bound state exist, and it occurs for a specific distance between the atoms. This bound state is the high laser level, from it the molecule returns to the un-excited ground state.
The condition of population inversion is achieved at the moment that there is an excited state, since the population of the lower laser level is always zero.

Excitation of the Excimer laser

Obviously in equilibrium there are very few dimer molecules present in the ground state, since it is inherently unstable. Furthermore even when lasing commences the ground state population remains low because the ground state is inherently unstable. Once a molecule is in that state the atoms move rapidly apart and the molecule dissociates.

We cannot therefore get excitation directly from the ground state. Several possibilities exist using indirect excitation within the discharge. For example in ArF the following processes can take place:
1. We get electron attachment, as represented by the equation:

$$\mathbf{e+F_2 \rightarrow F^- + F}$$

2. The negative ions thus formed can then combine with positive ions that are present to give an excited molecule:

$$\mathbf{Ar^+ + F^- \rightarrow (ArF)^*}$$

In spite of this seemingly roundabout route such reactions can be very efficient in producing excited dimer molecules.

Gaseous discharges, electron beams and even photon beams have all been used for pumping, although commercial lasers rely on conventional gaseous discharge techniques. In the case of gas discharge the pumping rate is on the order of 1 GW of power per liter of gas. Thus,

excitation of the Excimer laser is done by passing strong electric pulses through the gas mixture. The excitation must be for a very short time and with a very high power, starting at about 100 KW/cm^3, and going to few Megawatts per cm^3.The electrons in the gas are accelerated as a result of the high voltage, and transfer their kinetic energy to the gas molecules by collision. The vigorous pumping which is needed to initiate the above reactions leads to the adoption of pulsed operation. Sometimes the gas in the discharge is pre–ionized using ultra–violet or X–ray excitation which helps to speed up the discharge in order to improve the efficiency of pumping.

The lifetime of the excited state is on the order of 10 ns. Thus the laser pulse is limited to tens of nano-seconds. Because of the high gain of the active medium of the Excimer laser, the laser can operate with no mirrors. Practically, the rear mirror is 100% reflecting, and in the front a transparent window is used. The very few percent of Fresnel reflection back from the window is enough to maintain lasing.

Because of the requirement for fast and strong pumping, it is common to use transverse discharge (at right angle to the laser axis). In transverse discharge, the distance between the electrodes is short, and there is a lot of space for the electrodes (along the laser axis).Care must be taken to choose the right materials inside the cavity, because of the high reactivity of the gases.

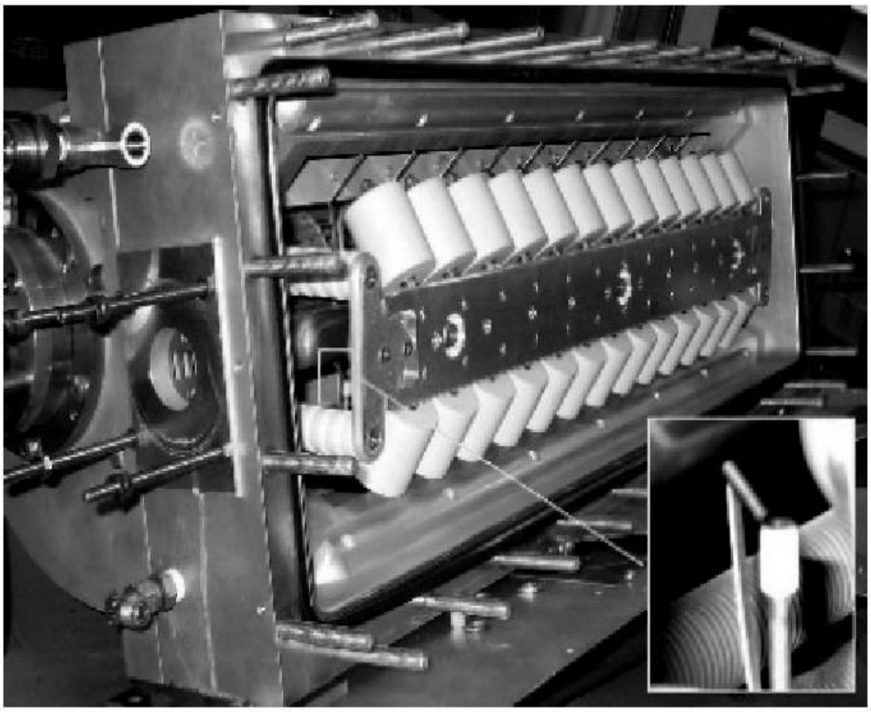

Figure 2.22: Excimer laser discharge channel with preionizer.

The heat removal from the discharge region is a major issue because of the very high input powers, so large blowers and water-cooled heat exchangers are needed.

Since the gases inside the Excimer laser are very toxic, then:

1.The laser must be sealed off after gas refill.
2. Quite often provision is made for changing the type of gas fill and thus altering the lasing wavelength.

3.Gas refill is necessary after using the laser for a few million pulses.

In any case regular replenishment of the gases is necessary to avoid degradation of the output. It is worth bearing in mind that some of these gases (particularly fluorine) can be quite hazardous.

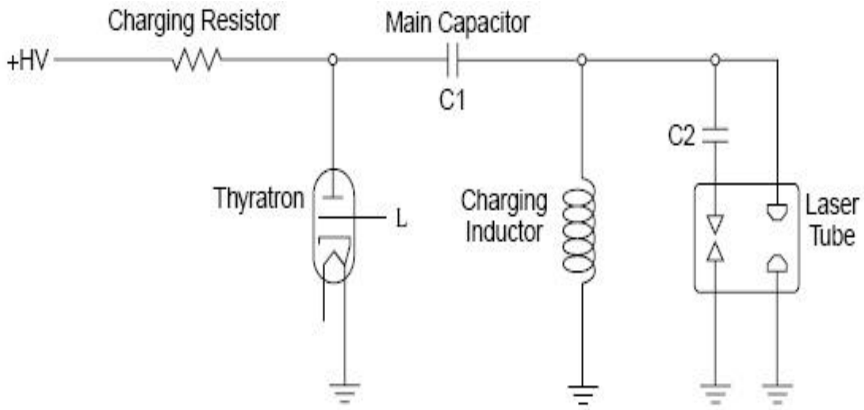

Figure 2.23: Excimer laser discharge circuitry.

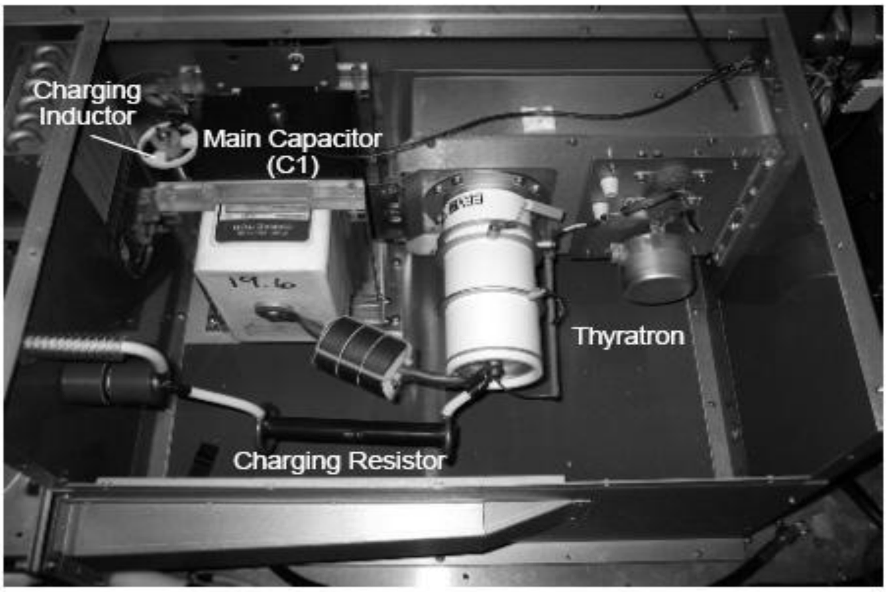

Figure 2.24: Excimer laser high-voltage section.

Properties of Excimer Lasers

- Excimer lasers emit in the Ultra-Violet (UV) spectrum: 120-500 nm.
- The radiation is emitted only in short pulses, E_p up to 100 W.
- The length of each pulse is between (10^{-12}-10^{-6} sec).
- The gas pressure inside the laser tube is high: 1-5 Atm.
- The efficiency of commercial Excimer lasers is up to a few percent (XeF and KrF, are quite efficient (up to 10–15%).

Modern Excimer lasers produce fast pulses with energy per pulse (E_p) of 0.1-1 J, pulse repetition rate (prr) of 300 Hz, and pulse width ($\Delta t_{1/2}$) of 10-30 ns. For example, if a certain Excimer laser produce a pulse with energy of 0.5 J and width of 20 ns then this pulse has a peak (maximum) power of 25 Mega Watt. This very high peak power means that every pulse of Excimer laser radiation contains a large number of photons and since the emitted wavelengths are very short, each individual photon carries a large amount of energy, which is enough to break the bond between molecules in the material that absorbed the radiation, so this laser radiation could be used to ablate target material without heating the surrounding material.

Applications of the Excimer Laser

- Photolithography- Material processing at a very high degree of accuracy (up to parts of microns).
- Cutting biological tissue without affecting the surrounding.
- Correcting vision disorders (Lasik surgery with ArF lasers: λ= 193 nm and E_p= 0.5 J) - Cutting very delicate layers from the outer surface of the cornea, thus reshaping it, to avoid the necessity for glasses.
- Marking on products - Since the short wavelength radiation from the Excimer laser is absorbed by every material, it is possible with a single laser to mark on all kinds of materials, such as plastics, glass, metal, etc.
- Material processing.
- Dye laser pumping.

The price of an Excimer laser is relatively high (tens of thousands of dollars), but it is used a lot because of its unique properties.

QUESTIONS

1. Discuss the following statement: Excimer laser is the laser in which the required conditions for lasing are achieved in exotic way.

2. What is the medium in an Excimer laser?

3. How is the operation of Excimer lasers differ from other gas lasers?

4. Why does the Excimer laser called Exiplex?

5. What is the composition of the gas mixture in Excimer laser?

6. Why does the population inversion easily achieved in Excimer laser?

7. What is the excitation mechanism used in Excimer laser to improve its efficiency?

8. Why the heat removal from the discharge is a major issue?

9. What are the properties of Excimer lasers?