UV GAS LASERS

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Introduction

- The most important ultraviolet lasers are the nitrogen laser and the excimer laser.
- Both lasers are molecular lasers in which the lasing species is a diatomic molecule.
- In the case of the nitrogen laser, the active lasing species is nitrogen molecule; in an excimer laser, the active lasing species is a transient molecule consisting of a halogen and an inert gas (such as argon or krypton).

Nitrogen Laser

Nitrogen Laser Development

- First developed in 1963 by H.G. Heard.
- He succeeded in producing 10 W pulses of UV light.
- Within four years nitrogen laser producing peak powers in the MW range was developed.
- Development continued and TEA (Transverse Electrical discharge at Atmospheric pressure) nitrogen lasers capable of producing MW powers appeared.
- TEA laser was an important milestone in UV laser development that led directly to the more powerful excimer laser.

Lasing Medium

- Each energy level of N_2 is Actually a series of vibrational levels dependent on internuclear separation.

- When a nitrogen molecule is excited by direct collision with electrons in the discharge, it enters the ULL.

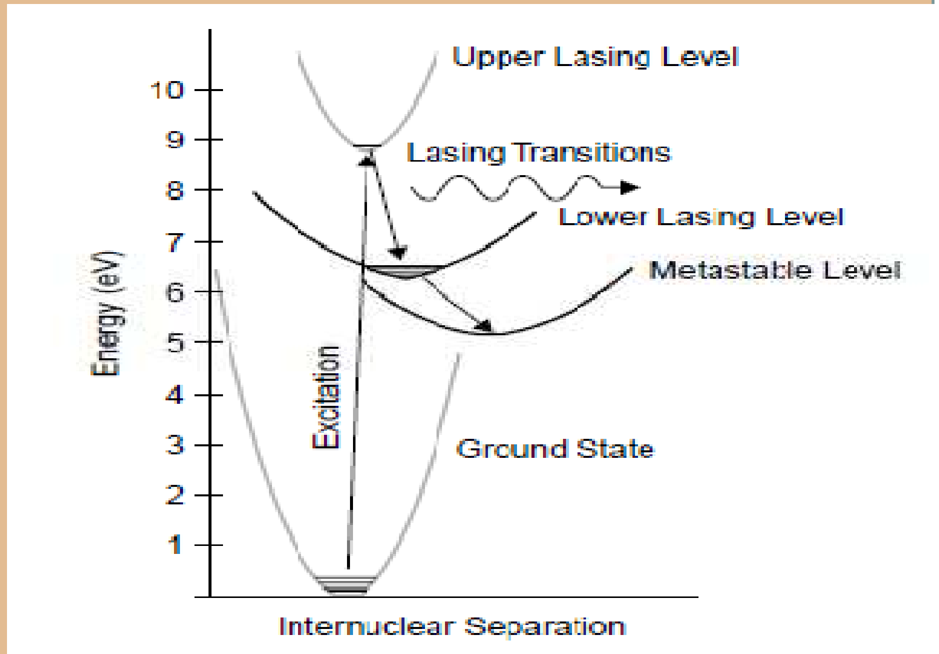

Fig: Molecular Nitrogen Laser Energy Levels

- From the ULL, N_2 falls to the LLL, emitting a photon of UV

Lasing Medium(Contd.)

- From the LLL, N_2 molecule falls to a metastable state and finally, to the ground state.

- Transitions in a normal N_2 laser are in the 0-0 band, in which both ULL and LLL are the same lowest vibrational state (v=0).

- Transitions in the 0-1 band is also possible, where the ULL is the lowest vibrational state (v=0), but LLL is the v=1 vibrational state.

Lasing Medium(Contd.)

- The ULL has a lifetime that is pressure dependent according to

$$t = \frac{36}{1 + \frac{p}{58}}$$

- The lifetime of ULL is much shorter than the lifetime of LLL, so CW laser is impossible, but pulsed laser is possible.

Gain and Optics of N_2 laser

- Gain for a nitrogen laser is on the order of 40 to 50 dB/m or more, depending on the specific laser. The highest gain reported for a nitrogen laser was 75 dB/m.
- A single high gain reflector and a output coupler are frequently installed in a nitrogen laser tube.
- The coating of the high reflector is made of Al to reflect UV, and windows on the laser tube is made of quartz or some other material that is transparent to UV radiation.

N_2 Laser Structure

- The basic requirement for a practical nitrogen laser is to supply a massive electrical current to excite the gas.
- To achieve this, most nitrogen lasers use an electrical configuration called *Blumlein configuration.*
- Since ULL lifetime is short , a short discharge time is necessary.

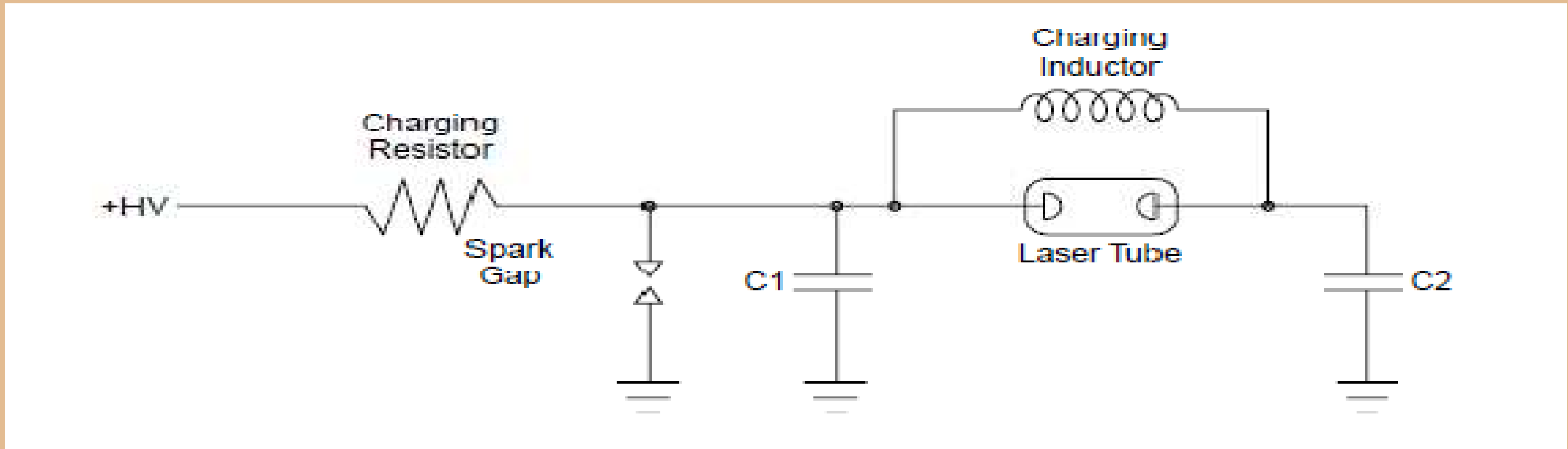

Figure : Electrical schematic of a Blumlein laser

N_2 Laser Structure(Contd.)

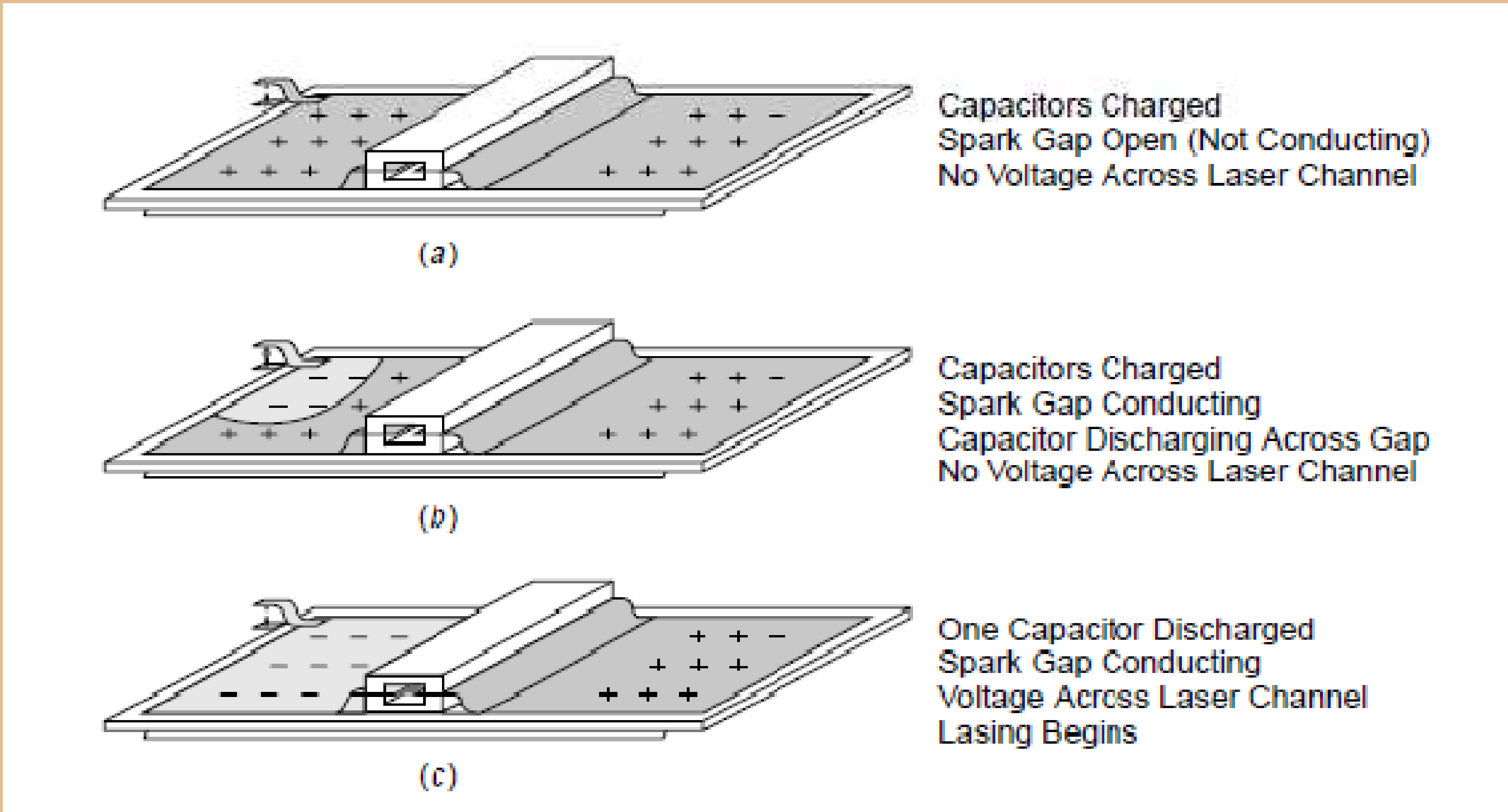

Fig: Nitrogen laser discharge sequence

N_2 Laser Structure(Contd.)

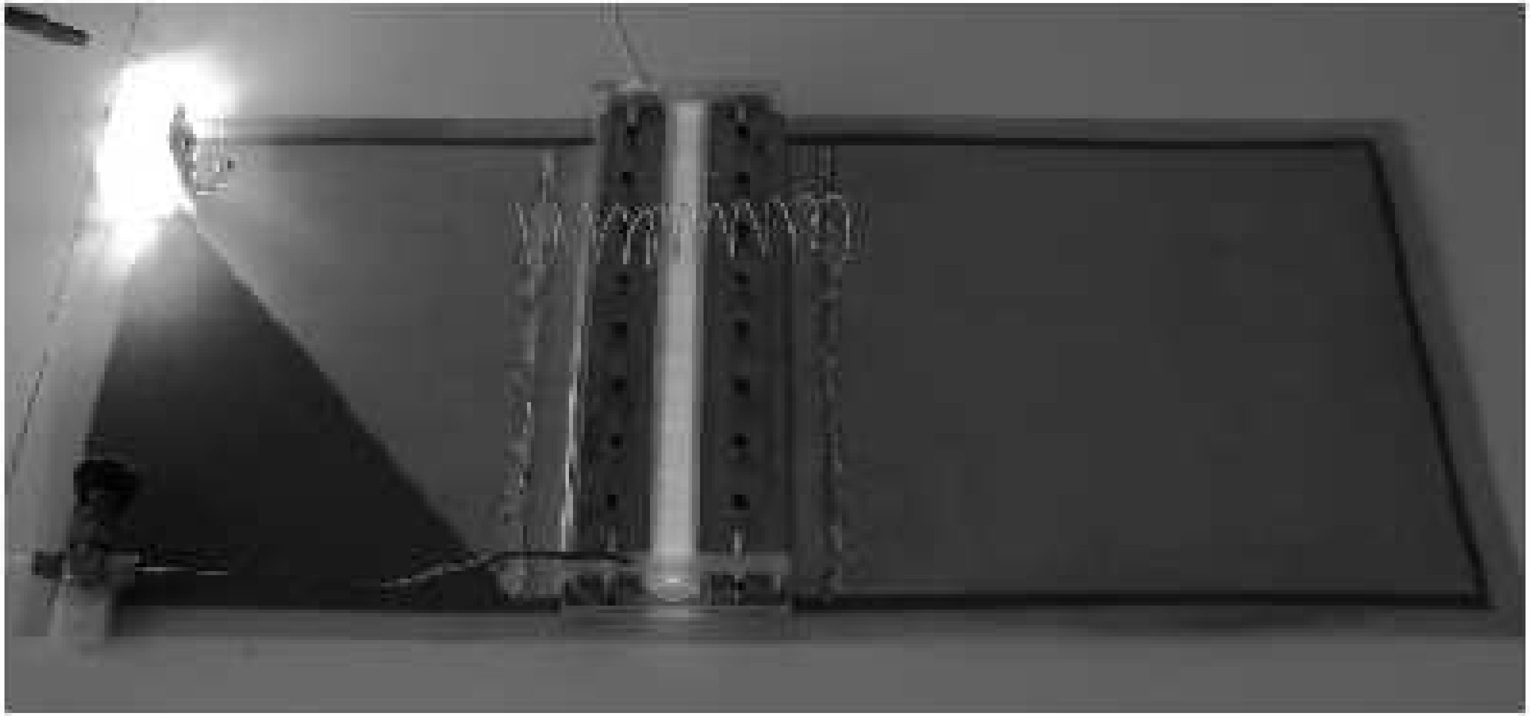

Fig: A practical nitrogen laser

N_2 Laser Structure (Contd.)

- Like low pressure N_2 laser, most TEA N_2 laser use *Blumlein configuration.*
- But the lifetime of the ULL is about 2.5 ns. So the requirement s for fast discharge are more in a TEA laser.
- So the inductance in the discharge path is constructed to an absolute minimum and dielectrics for capacitors are kept very thin.

N_2 Laser Structure (Contd.)

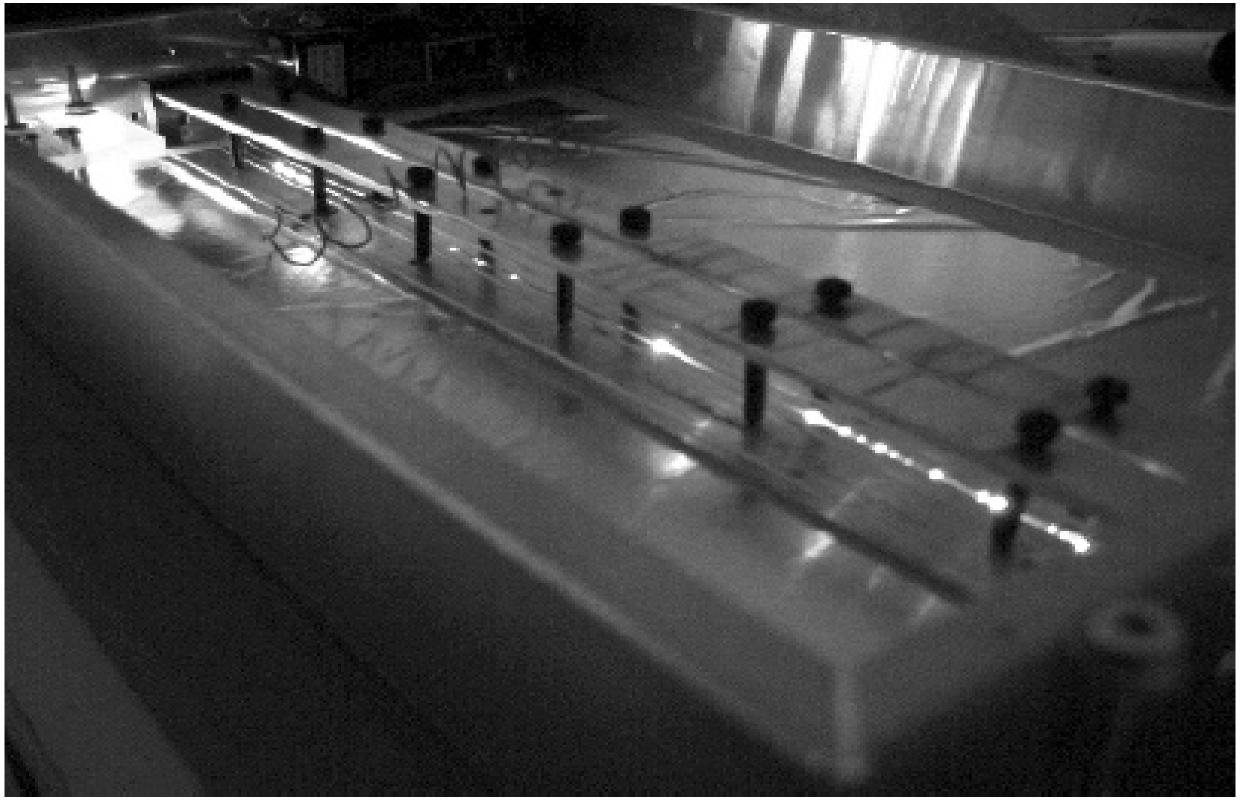

Fig: A practical TEA nitrogen laser

N_2 Laser Structure (Contd.)

To increase the efficiency of TEA laser , measures must be taken

- To even out the discharge;
- dilution of the nitrogen gas with helium;
- use of an electrode structure consisting of multiple points;
- preionization of the discharge channel with a high-voltage corona or ultraviolet radiation before the main laser discharge ensues.

N_2 Laser Structure (Contd.)

- In some large lasers, thyratrons are used instead of spark gaps.
- Thyratrons are switching devices that use mercury vapor or hydrogen gas and feature incredibly fast rise times, many times faster than spark gaps.
- As well as faster switching times, thyratrons also allow triggering on command, an important feature when laser is used in a laboratory experiment requiring synchronization and precise timing.

Output Characteristics of N_2 Laser

- Output consists of highly amplified emission.
- Collimation is poor and divergence is quite large compared to other types of lasers.
- Coherence length is also poor, since the spectral width of the laser output is quite large.

Applications

- Excellent pump sources for pumping dye lasers.
- Useful for exciting fluorescence in substances.
- Used for small microcutting procedures on individual biological cells or for trimming thin films for semiconductor industry.
- Low-cost source of intense UV light.

Excimer Laser

Introduction to Excimer Lasers

- Excimer lasers are much larger and produce more power outputs than nitrogen lasers.
- Like the nitrogen laser, a fast, high-current discharge is required to produce the excimer molecule.
- Excimer lasers are more complex since they operate at high pressure and one of the active gases is highly toxic.

Lasing Medium

- When unbound, the enegy of the system is the lower energy level of the laser.

- The upper energy state is formed when the inert atom and halogen form an excimer molecule.

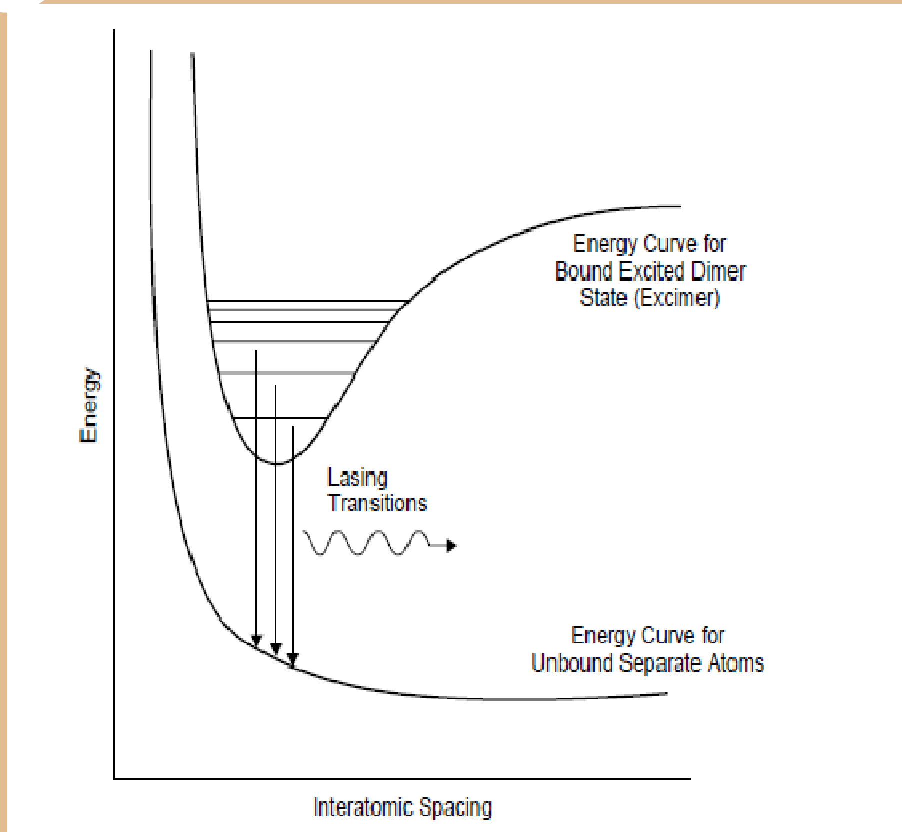

Fig: Excimer energy levels

Lasing Medium(Contd.)

- The most powerful excimer laser is KrF, but the popular excimer laser is XeCl.
- Shortcomings of KrF laser include the output wavelength is absorbed readily by air, and the extremely corrosive nature of fluorine.
- ArF laser produces a wavelength so short that it produces ozone gas from atmospheric oxygen as it passes through air.
- XeCl has a longer wavelength, allowing better transmission in air and the use of considerably cheaper optics. The gas mixture also has a much longer useful lifetime.

Lasing Medium(Contd.)

Laser Species	Wavelength (nm)	Relative Power Output
ArF	193	0.5
KrF	249	1.0
XeCl	308	0.7
XeF	350	0.6

Table: Wavelength and relative power output of various excimer species.

Lasing Medium(Contd.)

- The useful lifetime of lasing gases may be extended by using a cryogenic gas processor.

Fig: Cryogenic gas processor.

Gain and Optics

- The gain of excimer lasers is very high.
- A stable resonator is employed to produce highest pulse energies and uniform energy distribution.
- Output couplers are made primarily of MgF.

Excimer Laser Structure

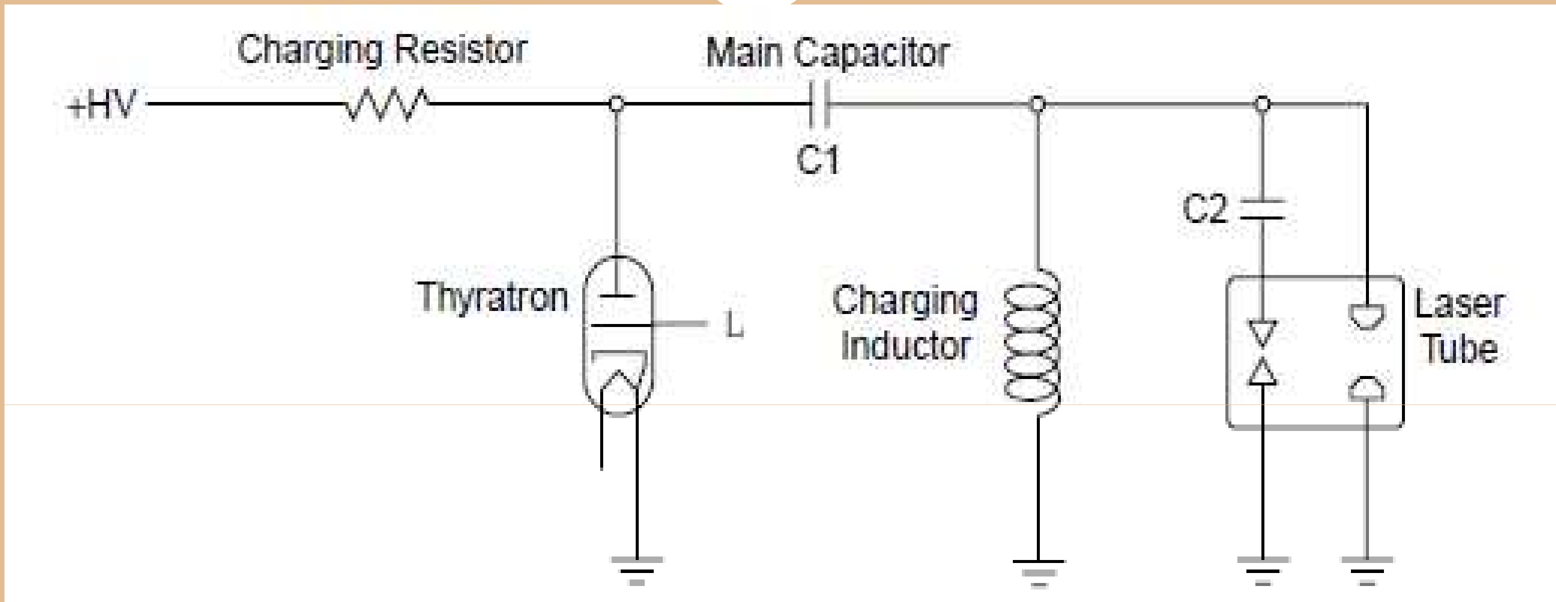

Fig: Excimer laser discharge circuit.

- The lifetime of ULL is more than that of nitrogen laser, so the requirements for a low inductance and fast electrical discharge path are relaxed.

Excimer Laser Structure(Contd.)

- Discharge does not occur immediately since the pressure of the laser tube is high and gas is not ionized.
- Ionization is performed by current flowing through capacitor C2 and using preionization spark gaps.
- UV radiation produced from the spark gaps ionizes gas, which then conducts the discharge current, producing a laser pulse.

Excimer Laser Structure(Contd.)

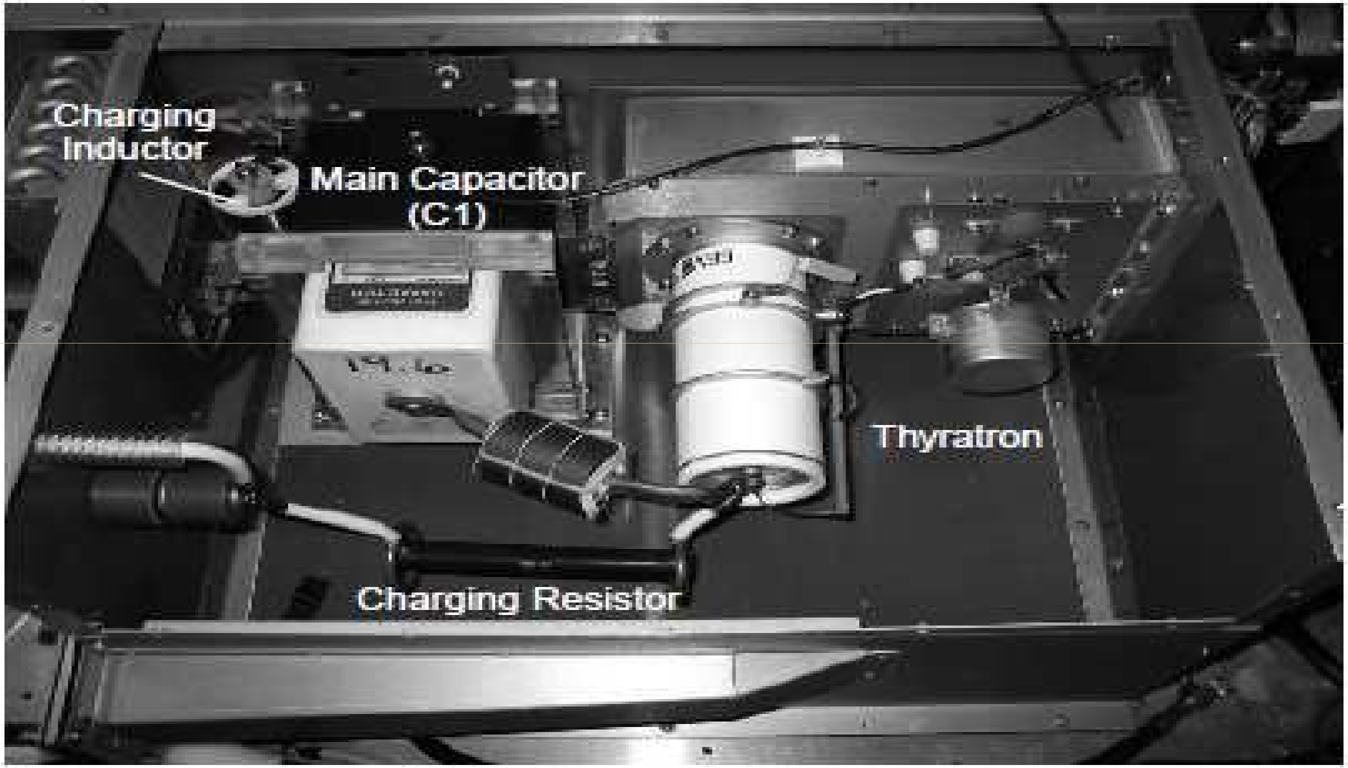

Fig: Excimer laser high-voltage section.

Excimer Laser Structure(Contd.)

- Since the input energy to the laser tube is several kWs, a large amount of heat must be extracted from the lasing gas.

- This is done by using a large squirrel-case blower and water-cooled heat exchanger tubes.

Excimer Laser Structure(Contd.)

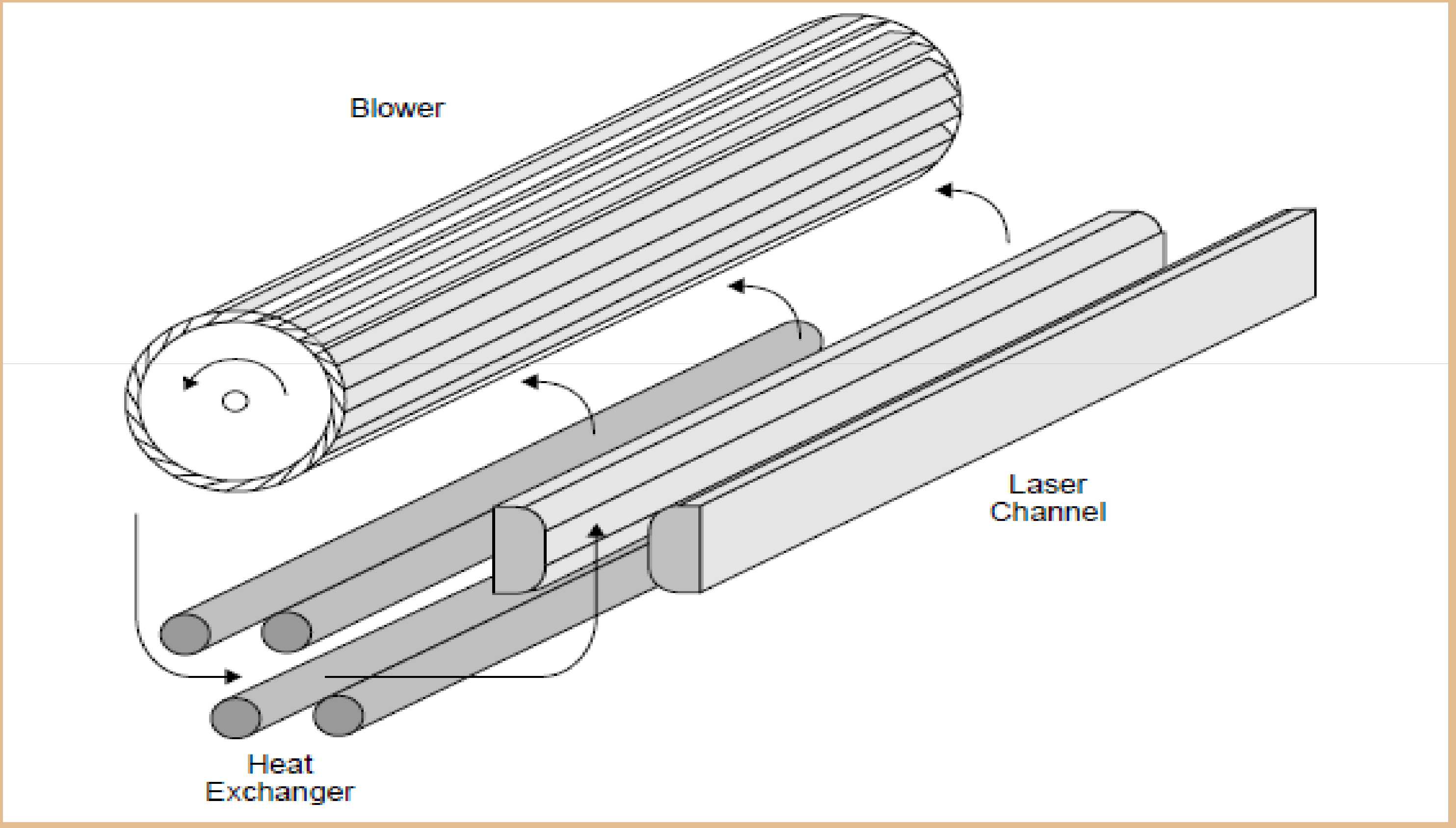

Fig: Excimer laser heat removal mechanism and gas flow.

Applications

- Used in lasik surgery.
- Used as a UV source in photolithography.
- Used for glass marking applications .
- ArF(and sometimes KrF) is used to manufacture fiber Bragg grating for optical fiber communications.
- Used in cutting and material processing applications, drilling inkjet printer nozzle holes, and marking wires.

Thank You