GAS & DYE LASERS

Gas Lasers

Most widely used lasers and most varied.

- Low power (He-Ne) to High power (CO_2) lasers
- Operates with rarified gases as active medium excited by electric discharge.
  - **Neutral atom lasers**
    - Helium- Neon Laser
  - **Ion Lasers**
    - Argon Laser
    - Krypton Ion Laser
    - Helium-Cadmium Laser
    - Copper-Vapour Laser
    - Gold-Vapour Laser

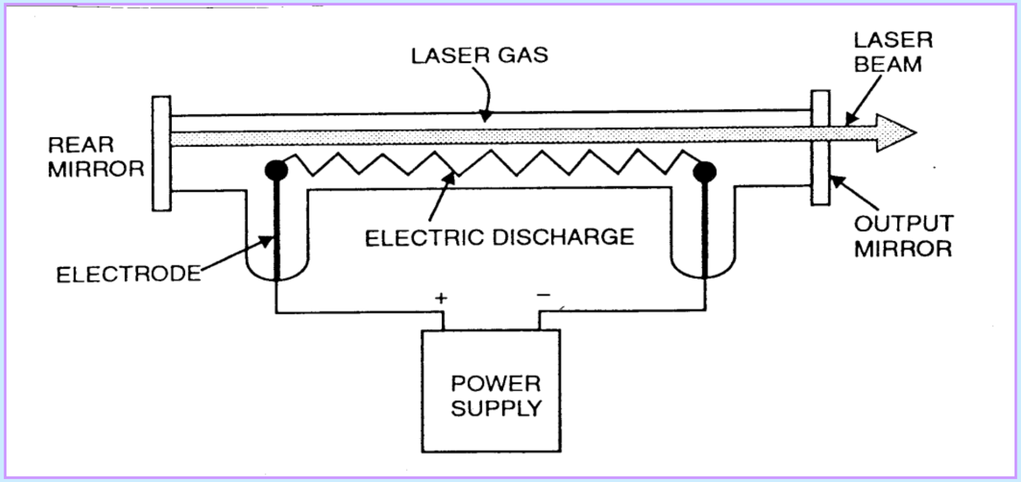
- **Molecular Lasers**
  - Carbon Dioxide Laser
- **Excimer Lasers**
  - Excited rare gas dimmers; Ar_2^*, Kr_2^*, Xe_2^*, . . .
  - Rare gas Oxides; ArO^*, KrO^*, XeO^*, . . .
  - Rare gas atom in combination with halide atom; ArF^*, KrF^*, $XeCl^*$. . .
- **Chemical Lasers**
  - HF Laser

Schematic of Gas Lasers

- **In gases**, energy levels of atoms involved in lasing action are well defined and narrow; ***broad pump bands do not exist***
- To excite gaseous atoms; pump sources with sharp wavelengths are required
  ⇒ ***Optical pumping not suitable for gas lasers***.
- Finding an appropriate optical source for pumping – **A problem ?**

❖ **Most common method**; Passing electric discharge through the gas medium.

- Gas contained in a tube with cavity mirrors.
- A high DC voltage ionizes the gas for conduction.
- Electrons in the discharge transfer energy to atoms in the gas by collisions.



Schematic arrangement of a gas laser

- **For optimum operation, in practice, laser medium contains a mixture of two gases (A&B) at low pressure**
  - Atoms of kind A are initially excited by electron impact
  - Transfer their energy to atoms of kind B, which are actual active centres.

- **Cavity mirrors can be either inside the gas container or outside**
  - If inside, the output light is generally unpolarized
  - For outside case, mirrors placed at Brewster angle $\Rightarrow$ Polarized light

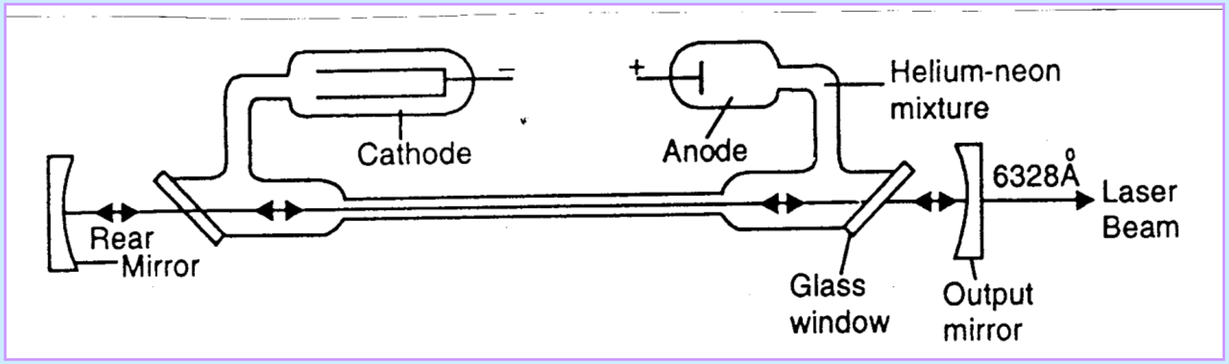
- **Gas lasers; vary widely in characteristics;**
  - Output wavelength from UV to Far IR region
  - Operates in pulsed mode and some in CW modes
  - Ouptut power, less than a mW to over 10 kW

☞ **First gas laser: He-Ne in 1961 at Bell Telephone Labs, USA**

He-Ne Laser

❖ ***First gas laser ever developed*** **;** Still one of the most widely used lasers.

- **He-Ne**: An atomic laser employs **Four-level pumping scheme**.
  - Active Medium; a mixture of 10 parts of He to 1 parts of Ne
  - **Ne-atoms; *active centres***- have energy levels suitable for laser transitions
  - **He-atoms help efficient excitation** of Ne-atoms

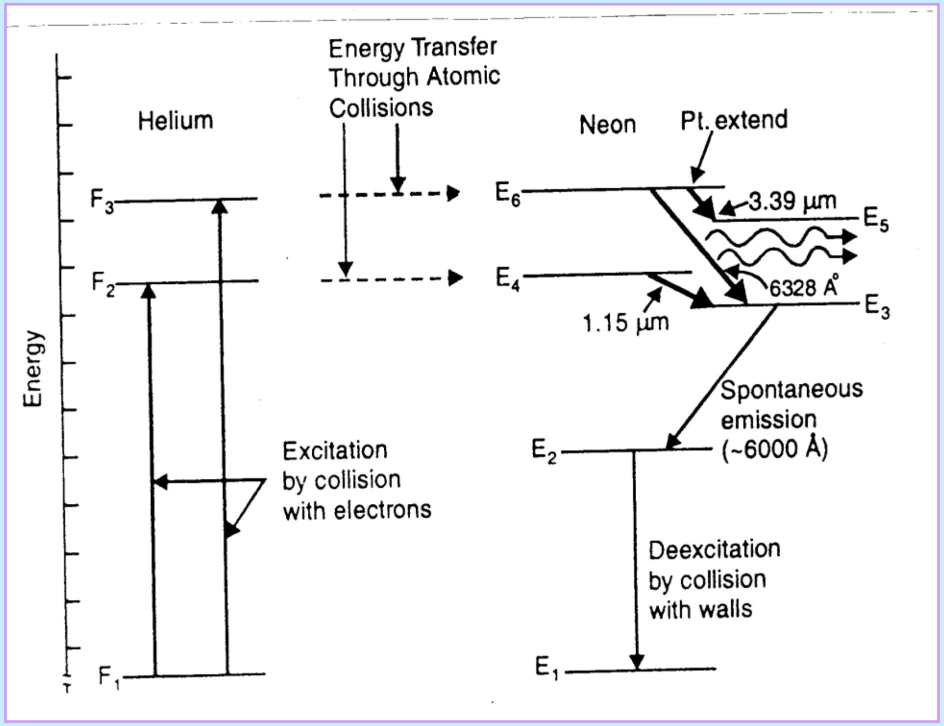


Schematic of a He-Ne laser with external mirrors

- Discharge tube of about 30cm long, 1.5 cm in diameter, filled with a mixture of He & Ne gases in 10:1 ratio.
- Electrodes connected to HV (~10kV) to produce discharge in gas.

- HV of 10kV applied across the gas- ***ionizes the gas***
- Electrons & ions accelerated towards anode and cathode
  - Electrons being smaller in mass acquire higher velocity

- Electrons transfer K.E. to He atoms through inelastic collisions.
- He atoms excited to levels F_2 & F_3 – ***metastable levels***
- Transfer energy to Ne-atom through collisions
  - ***Resonant transfer of energy***
- Possible in He-Ne atoms



Energy levels of He and Ne atoms and transitions between the levels.

❖ Ne-atoms being heavy, could not be pumped up efficiently without He-atoms.

- Role of He-atoms is to excite Ne-atoms and cause P.I.
  - Probability to transfer energy from He-Ne is more ; 10 He per 1 Ne atoms.
  - Reverse probability i.e. Ne-He is extremely small

- E_4 & E_6 levels in Ne ; **Metastable States** $\Rightarrow$ Accumulation of atoms
- Population inversion between
  - E_6 and E_5, E_3 levels
  - E_4 and E_3 levels
- Lasing takes place and light is produced corresponding to

$$\left.\begin{array}{l} \bullet\ E_6 \rightarrow E_5 \\ \bullet\ E_6 \rightarrow E_3 \end{array}\right\} \quad \text{and} \quad E_4 \rightarrow E_3$$

- ❖ $E_6 \rightarrow E_3$ transitions; laser beam of red colour at 632.8 nm (6328 A^o)
- ❖ $E_4 \rightarrow E_3$ transitions; laser beam at wavelength of 1150 nm (11500A^o)
- ❖ $E_6 \rightarrow E_5$ transitions; laser beam in IR region at 3390 nm (33900A^o)

☞ In reality, several laser transitions ≈**150 possible**, however, only three are dominant transitions.

- ***Ne-atoms in level E_3 decays rapidly to E_2 (a metastable state) $\rightarrow$ Accumulation may take place unless removed by some means***

  - $E_2 \rightarrow E_1$ transition induced by collisions with walls of discharge tube.
  - Discharge tube made as narrow as possible to enhance probability of atomic collisions with walls.

- **E_2 level is more likely to be populated by the electric discharge itself**

  - An increase in population at E_2 causes decrease in P.I. $\Rightarrow$ **Lasing ceases**.
  - Current in discharge tube maintained at low level

  $\Rightarrow$ Reason for not getting high power He-Ne lasers

- **Major applications as Red light at 632.8 nm**

  - Resonator mirrors coated with multi-layer dielectric coatings.

- **He-Ne laser**: Simple, less expansive, practical, high quality beam

Applications: Laboratories, Interferometry, Laser Printing, Bar Code Reader, Scanners, Surface Testing, Surveying, Alignment etc.

Ion Gas Lasers

- **He, Ne, Ar, Xe and Kr** $\rightarrow$ Rare/noble gases have electronic state capable of laser transitions.
- Except for Ne, noble gases difficult to pump and hence not of practical interest
- However, if first ionized by electron collisions $\Rightarrow$ **Easy to pump**

❖ **Argon laser**

❖ **Krypton lasers**

❖ **He-Cd laser**

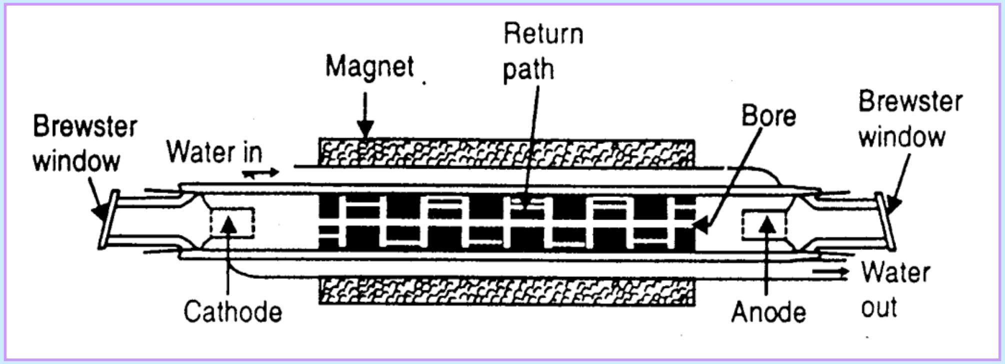
❖ **Copper vapour laser**

❖ **Gold vapour laser**

Argon Gas Laser

- **Four level laser;** Operates in Visible region over wavelength, **350 - 520 nm**
- **Most powerful CW laser** operating in visible region (powers ≈100W)
- Extensively used in laser light shows
- Provides approx **25 Visible and 10 UV** wavelengths

- Active medium; Ar gas
- Active centres; ionized Ar-atoms
- A narrow water cooled ceramic tube for arc discharge

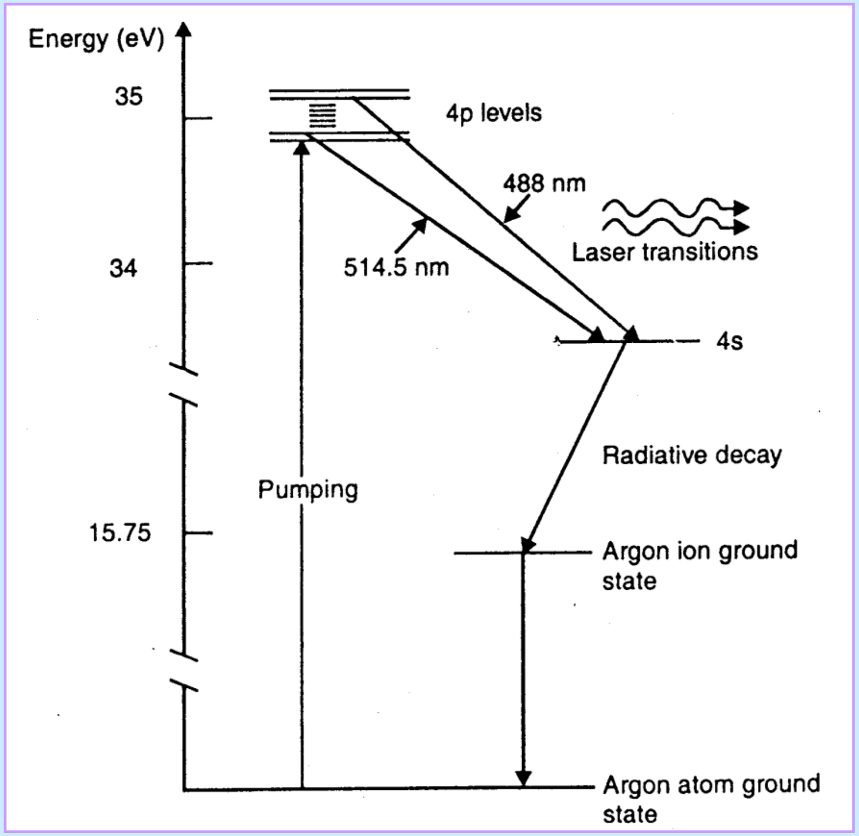


Schematic of a typical ion laser tube

- Anode and cathode space communicate through a return path which ensures free circulation of gas.
- A magnet surrounds the discharge tube to restrict the discharge area and increase the concentration of ions along the axis of tube.

- Initial HV ionizes the gas to conduct current
- Electrons transfer energy to Ar-atoms, ionize them and raises the ions to a group of high energy levels.

- Different process populate the metastable state (4p level)
- Three possible are:
  - ✓ Electron collision with Ar^+ ions in ground state
  - ✓ Collision with ions in metastable state
  - ✓ Radiative transitions from higher states.
- **Conditions for P.I. satisfied between 4p and 4s levels.**



Energy level scheme for an Argon atom

❖ **Transitions can occur between many pairs of upper and lower lasing levels**

⇒ Many laser wavelengths emitted

- Most important and more common are: **488 nm (Blue)** and **515 nm (Green)**
- Ar^+ ions quickly drop from lower laser level to ground state of the ion by emitting UV-light at 740A^o.
    - ***Available for further action as UV light***
- Any desired wavelength can be selected through the cavity optics (using small prisms or gratings)

- During operation, positive ions collected at cathode; neutralized and slowly diffuse back into discharge $\Rightarrow$ leads to pressure gradient
- A return path is provided between anode and cathode to equalize the pressure

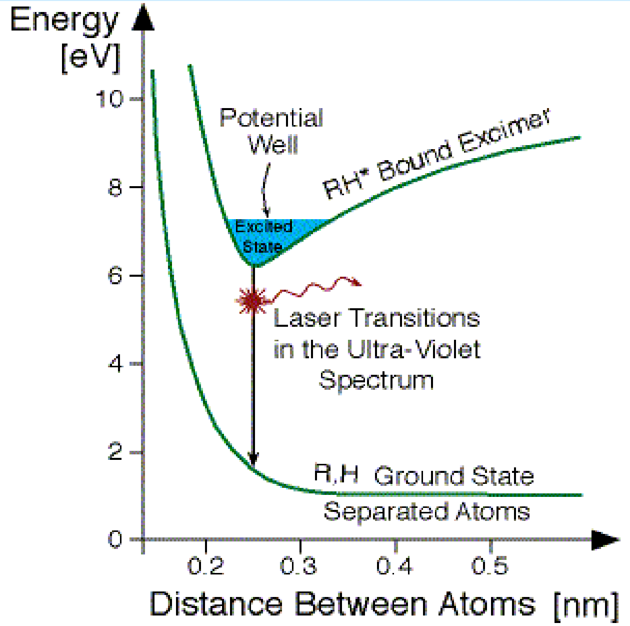
❖ **Laser needs active cooling**

❑ **Argon lasers used extensively in Eye Surgery;** For treatment of Diabetic retinopathy, Retinal detachment, Glaucoma and Macular degeneration

Excimer Lasers

- ❖ **An Interesting & Important class of molecular lasers**
- ❖ First demonstrated in mid 1970s; **Most powerful UV laser**

- **Active Medium**; Diatomic molecules that can be bound into a single system when they are in excited state only.
- These diatomic molecules exist only as monomers in the ground state $\Rightarrow$ ***repel one another in atomic distances.***
- An excitation modify the state of atoms and there appears an attractive force with other atoms.



Internal energy of a rare gas halide molecule in excited and ground state

- ➢ Such molecules which exist only in excited state

  $\Rightarrow$ **Excited state dimers** or **Excimers**

- ➢ Atoms of inert gases can be bound to molecules by imparting energy to them.

❖ **Excimer State; *A metastsble state***

- When atoms are bound together in the excited state $\Rightarrow$ *can occupy several vibrational levels in the potential well.*

- Excited by passing a short, intense electric discharge through a mixture of desired gases
- Electrons in discharge transfer energy to the lasing gas causing formation of excited molecules.
- Molecules remain excited for $\approx$ 10ns $\Rightarrow$ drop to ground state and dissociate.
  - ULL- electronic excited states
  - LLL- electronic ground state
- P.I. occur as soon as atoms bound to form molecules in excited state
  - Once molecule drop to lower laser level, it separates out into atoms

    $\Rightarrow$ lower laser level is always vacant.

- **Excimer Lasers**: High gain, No cavity mirrors required; one fully reflective mirror used in rear & unsilvered transparent window used as output mirror.

▪ Examples of active medium for Excimers

- An excited rare gas dimers; Ar_2^*, Kr_2^*, Xe_2^*,
- A rare gas oxides; ArO^*, KrO^*, XeO^*,
- A rare gas atoms in combination with a halide; ArF^*, KrF^*, $XeCl^*$,

Excimer Lasers

Type	Wavelength (A^o)
Ar_2^*	1260
$ArCl^*$	1750
ArF^*	1930
$KrCl^*$	2220
KrF^*	2490
$XeCl^*$	3080
XeF^*	3500

Major Applications:

- Mainly used in **refractive vision correction** of Eye (LASIK, PRK)
- Manufacturing of semiconductor devices, Photolithography
- Material processing,
- Pumping of dye lasers.

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