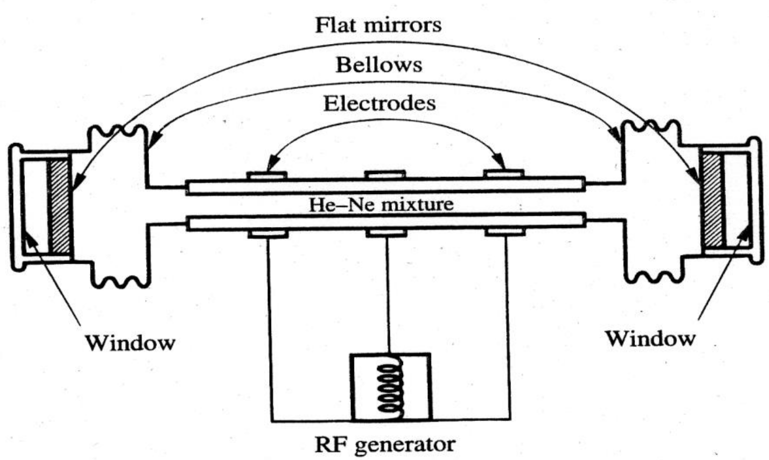
Helium-neon Laser

- The **Helium-Neon** laser was the first **continuous laser**
- It was invented by **Ali Javan** et. al. in **1961**.
- Is an atomic laser employs **four level pumping** scheme.
- Its usual **operation wavelength** is **632.8 nm**, in the **red** portion of the visible spectrum.
- It operates in **Continuous Working (CW)** mode.
- Active medium is a mixture of **10 parts** of **Helium** and **one part** of **Neon**.
- Ne atoms are **active centers** and have energy levels suitable for laser transitions while, He atoms **help** in **efficient excitation** of Ne atoms.

Construction of He-Ne laser

- The setup consists of a discharge tube of **length 35 cm** and bore **diameter of 1 cm**.
- The medium - **mixture** of helium and neon gases, in a **5:1** to **20:1** ratio, contained at low pressure (an average **50 Pa per cm** of **cavity length**) in a glass envelope.
- The energy or pump source of the laser is provided by an electrical discharge of few kilo volts through an anode and cathode at each end of the glass tube. A current of 5 to 100 mA is typical for CW operation.

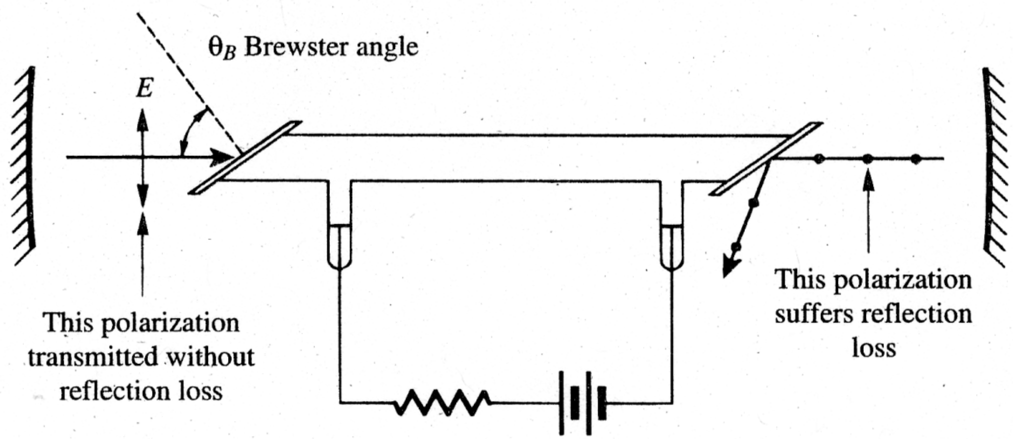


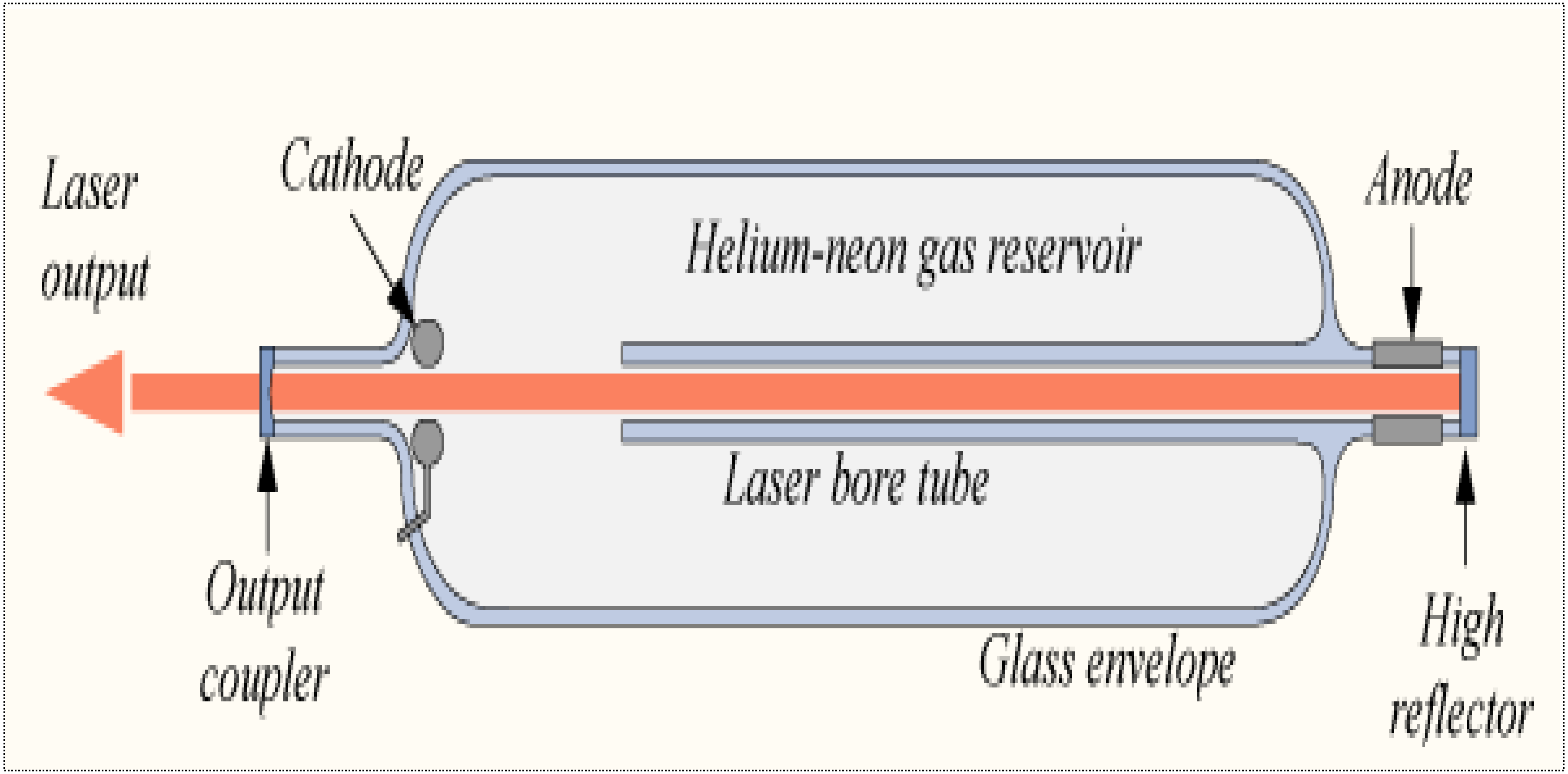
Schematic arrangement of the first gas laser.

Helium-Neon Lasers

- The optical cavity of the laser typically consists of a plane, high-reflecting mirror at one end of the laser tube, and a concave output coupler mirror of approximately 1% transmission at the other end.
- Since the cavity window is outside the tube, Brewsters windows may be used at the ends of tube to minimize reflection loss.
- HeNe lasers are normally small, with cavity lengths of around 15 cm up to 0.5 m, and optical output powers ranging from 1 mW to 100 mW.

Typical schematic design of a modern laser.

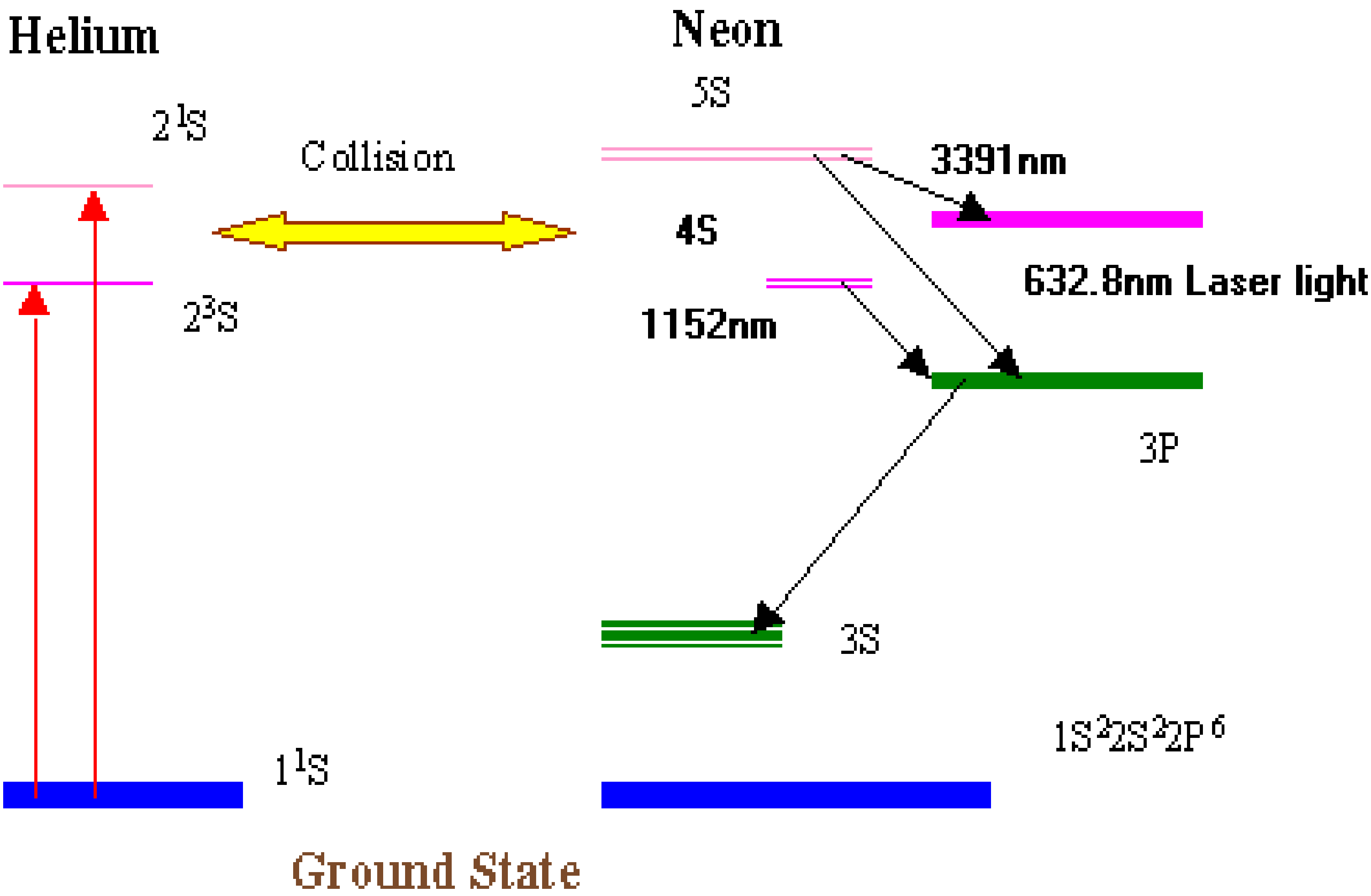




Laser output
Cathode
Helium-neon gas reservoir
Anode
Laser bore tube
Output coupler
Glass envelope
High reflector

Working of He-Ne laser

- When **voltage** is applied to the **electrodes** it **ionizes** the **gas**, the **electrons** and **ions** thus **produced** are accelerated towards anode and cathode respectively.
- Electrons acquire higher velocity due to its smaller mass when compared to the others. They **transfer K.E to He atoms** through **inelastic atom-atom collision**.
- **He atoms** are readily **excited by electrons** impact because of its **fairly light mass**.
- Thus He atoms are excited to **F_2 and F_3 states** which lie at **19.81 and 20.61 eV** respectively.
- These are **meta stable states** and these atoms **cannot return** to **ground state** by spontaneous emission.
- These atoms **returns to ground state** by **transferring energy to Ne atom** in the state which has identical energy. Such transfer is called **resonant transfer of energy.**
- Ne energy levels **E_6 and E_4 nearly coincide with F_3 and F_2** so resonant transfer can occur.
- This energy exchange process occurs with high probability only because of the accidental near equality of the two excitation energies of the two levels in these atoms. Thus, the purpose of population inversion is fulfilled.



Helium
Neon
2^1S
5S
Collision
3391nm
4S
632.8nm Laser light
2^3S
1152nm
3P
3S
$1S^22S^22P^6$
1^1S
Ground State

- When Ne atom in the **E_6 level** and **E_4 level** emits a photon parallel to the axis of the tube
- In reality neon energy levels E_6, E_5, E_4,E_3,E_2 are not single but a **group of lines**. Consequently several laser transitions are possible.
- Three main laser transitions are
  - **E_6 to E_3** – generates laser beam of **red** color at **6328Å**
  - **E_4 to E_3** – IR beam at wavelength of **1.15 mm**
  - **E_6 to E_5** – light in Far IR region at **3.39 mm**
- Level E_2 is a metastable state, the neon atoms tend to accumulate at this level, if they are not removed the population in the ground state continuously decreases restricting lasing action.
- E_2 to E_1 transition can be induced by collision with the walls of the discharge tube.

Applications of He-Ne laser

- The Narrow red beam of He-Ne laser is used in supermarkets to read bar codes.
- The He- Ne Laser is used in Holography in producing the 3D images of objects.
- He-Ne lasers have many industrial and scientific uses, and are often used in laboratory demonstrations of optics.

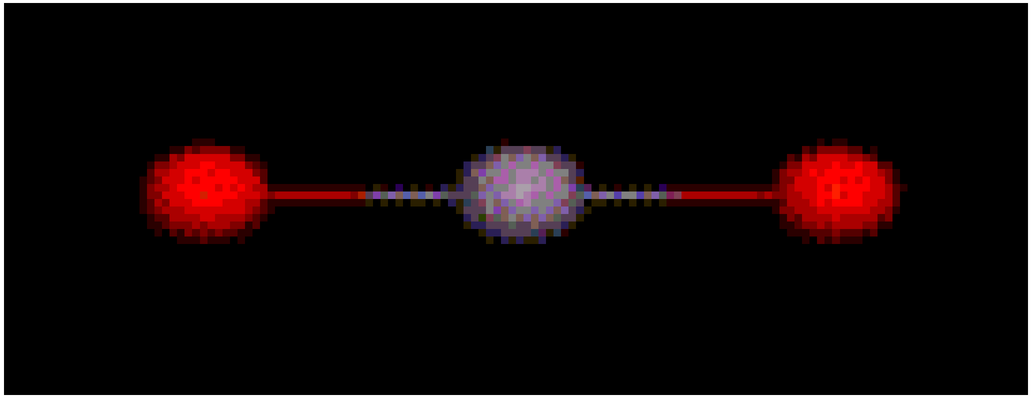
CO_2 Laser

Carbon-di-oxide laser

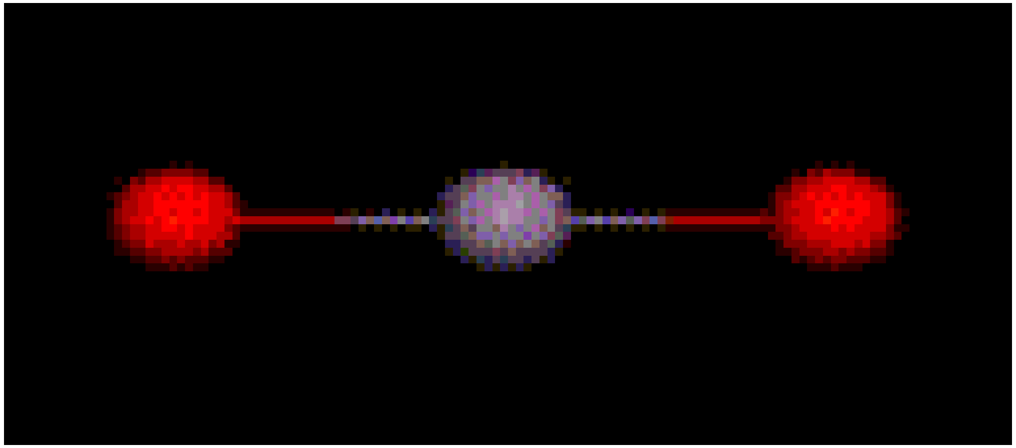
- CO_2 laser was one of the earliest gas laser to be developed in BELL Labs in 1964 by **Indian born CKN Patel**.
- It is a **molecular gas laser**
- o/p of these lasers are more **powerful**
- In CO_2 laser the transition occurring between **different vibrational states** are responsible for laser effect
- CO_2 molecule has a central carbon and two Oxygen one at either ends
- Such a molecule can vibrate in **three different modes of vibration**, and in each mode of vibration the center of gravity remains fixed
  - Three modes are

1. Sym. Stretching mode
2. Bending mode
3. Assym. Stretching mode.

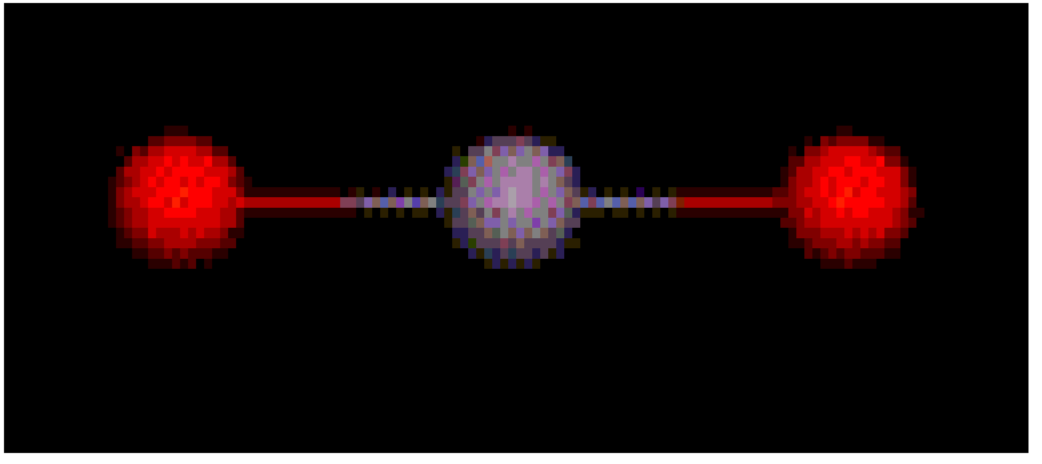
- Symmetric stretching mode
  - Carbon atom fixed in its position and each oxygen atom can vibrate along the axis of the molecule simultaneously departing or approaching the fixed carbon atom.
  - The frequency corresponding to this mode of vibration is called symmetric stretching frequency



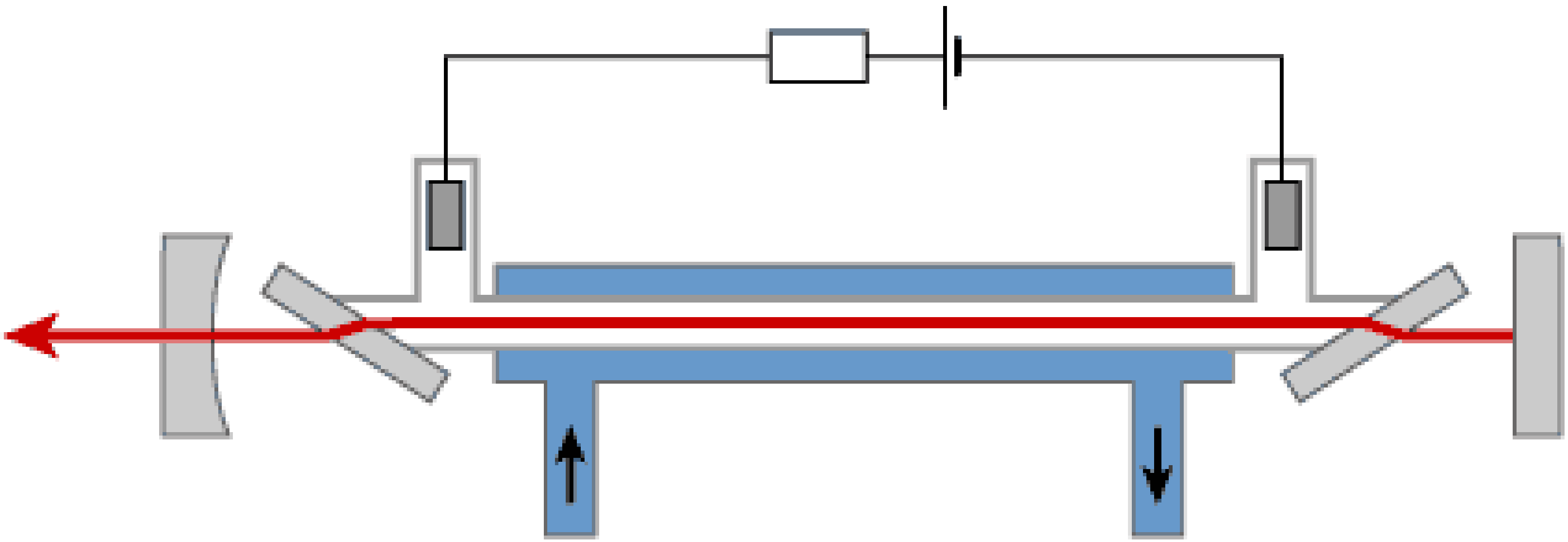
- Bending mode
  - Oxygen atom and carbon atom may vibrate at right angles to the line passing through the centre of gravity.
  - The frequency corresponding to this mode of vibration is called as bending frequency



- Asymmetric stretching mode
    - The two oxygen atom and the carbon atom at the centre vibrates asymmetrically or they vibrate in an opposite directions with respect to its mean position.
    - The corresponding frequency is called asymmetric stretching frequency.



- The experimental setup is as shown



- Consist of discharge tube made of fused Quartz of **2.5 cm** in **diameter** and **5 m long**.
- Special feature of the CO_2 laser is the o/p is **dependent** on the **diameter** of the discharge tube.
- Active medium consists of He, N_2 and CO_2, **Brewster's windows** at the ends,
- Near confocal silicon mirror coated with aluminium formed at the resonant cavity

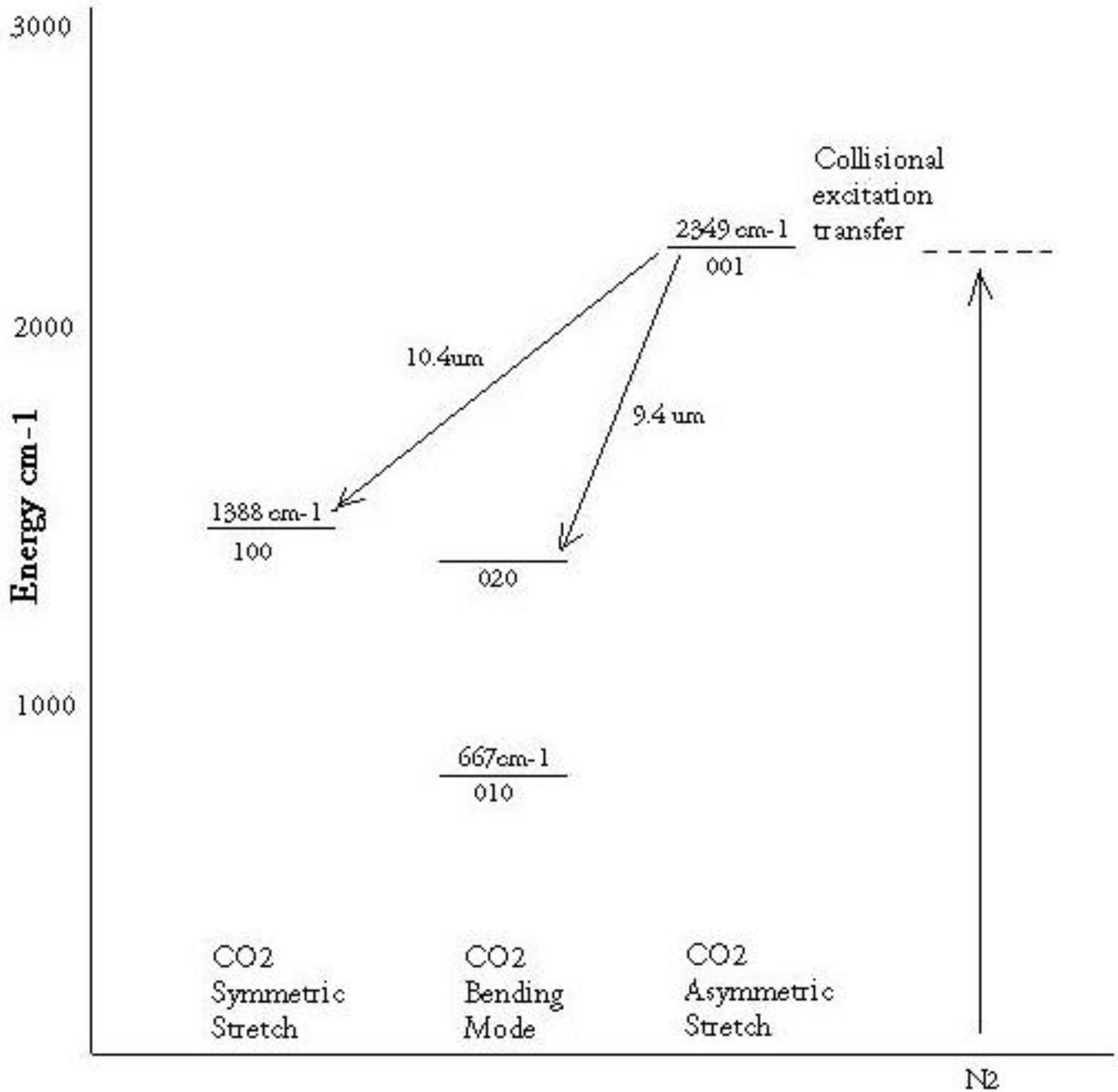
- Working
  - In CO_2 lasers **N_2 plays** the **similar role** of **He** in He-Ne laser
  - **N_2 goes to excited state by collision with electrons**

$$N_2 + e \rightarrow N_2^* + e$$

  - **The excited N_2 transfers energy to CO_2 and CO_2 gets excited**

$$N_2 + CO_2 \rightarrow CO_2^* + N_2$$

  - The lowest vibrational level of N_2 has nearly as much energy as the asymmetric stretching mode of CO_2 molecule and so the excited N_2 readily transfer energy to CO_2 in resonant collisions.
- Merits and demerits
  - Has very high o/p power
  - o/p power can be increased by increasing the length of the gas tube


3000
2000
1000
Energy cm-1
Collisional excitation transfer
2349 cm-1
001
10.4um
9.4 um
1388 cm-1
100
020
667cm-1
010
CO2 Symmetric Stretch
CO2 Bending Mode
CO2 Asymmetric Stretch
N2