Lecture-04

Nd:YAG & CO_2 Lasers

Types of Laser

- Gas Laser: He-Ne, Argon ion and CO_2
- Solid state Laser : Ruby, Nd:YAG, Nd:glass
- Semiconductor Laser
- Tunable dye Laser

Nd:YAG Laser

NEODYMIUM : YTTRIUM ALUMINIUM GARNET LASER

Nd: YAG Laser

- It is a solid state four level laser
- The **neodymium** (Nd^{+3}) ion is a rare earth metallic ion.
- Nd-YAG laser consists of Nd^{+3} ions doped (as impurity) in YAG crystal.
- The maximum concentration of Nd^{+3} ions in $Y_3Al_5O_{12}$ (**Yttrium aluminium garnet**) is about 1 to 1.5% (The increase concentration results in decrease of lifetime of metastable state.)

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- The YAG crystal is transparent and colorless. When doped with approximately 1% Nd, the crystal takes on a light blue color.

- Nd^{+3} ions occupy Yttrium ion sites & provide lasing transitions
- Role of YAG: (a) Nd^{+3} ions subjected to crystal field of host crystal YAG leads to splitting of energy levels of Nd^{+3} ions.

  (b) Transition probabilities of various energy levels of Nd^{+3} ions are modified so that some transitions which are forbidden in free ion become allowed.

Construction :

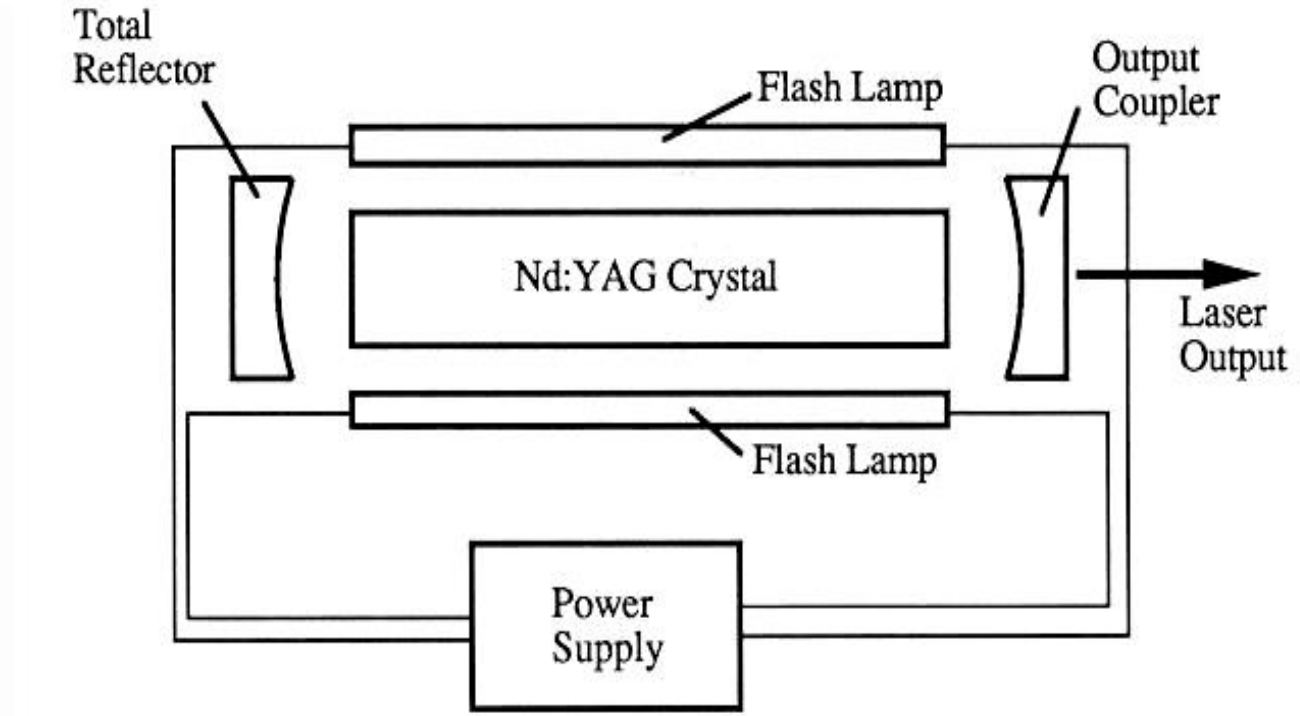
- Essential parts of laser:-

(i) Yttrium aluminium garnet in which 1.5% of neodymium ions are doped as impurities. Nd^{+3} is the lasing ion.

(ii) Two end mirrors M_1 & M_2

(iii) Excitation is achieved by krypton or xenon **flash lamps**

Generally, a cooling system is required for operation of ND:YAG lasers. With an efficiency of about 3%, a typical ND:YAG produces thirty times as much waste heat as laser output; this heat must be removed in order to ensure proper laser operation.



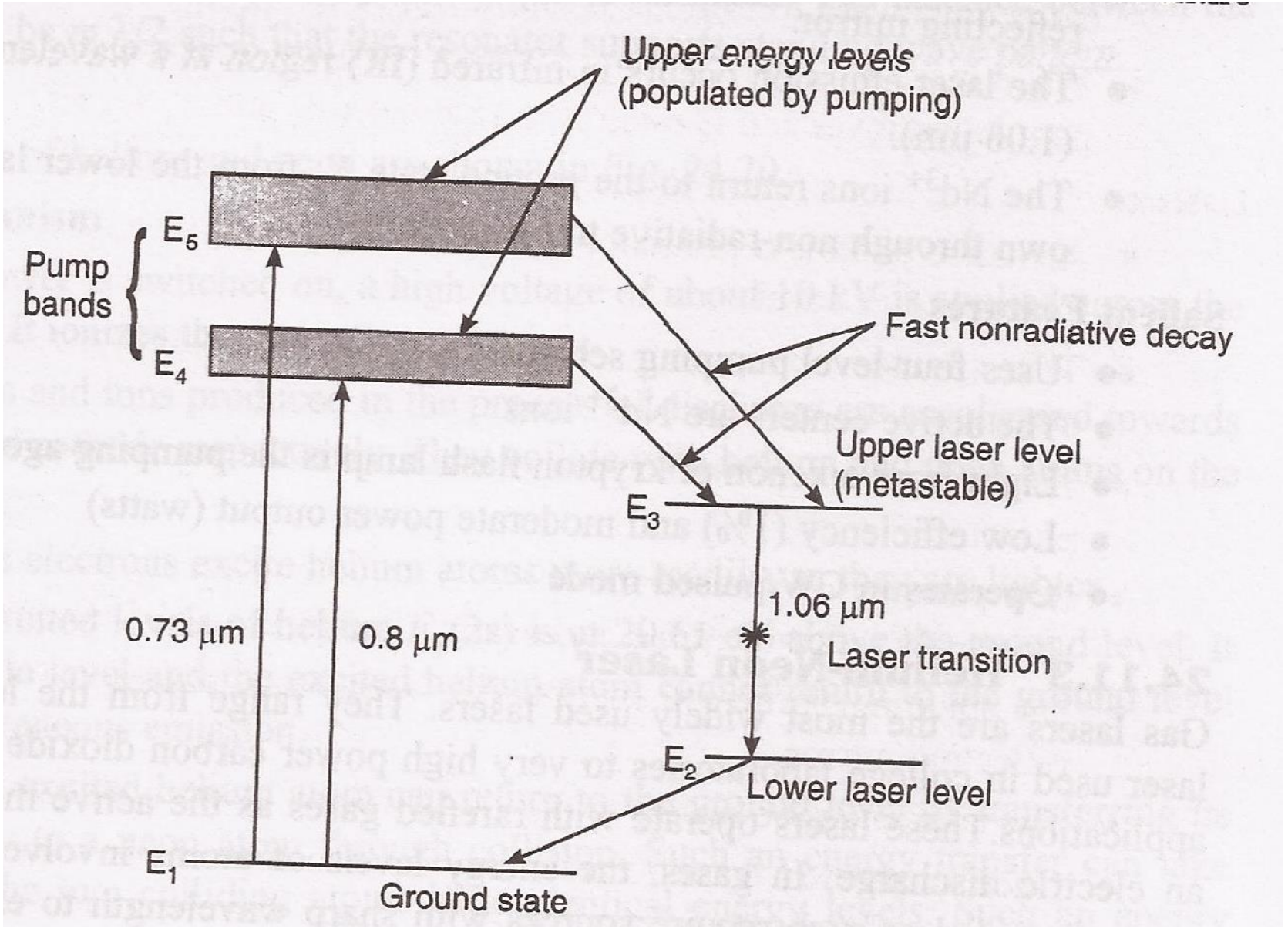
Nd : YAG laser rod has a length of about 10 cm with a diameter 12mm. It is kept at one foci of an elliptical glass tube.

Krypton flash lamp , the optical source is placed at the other foci of the glass tube. It is provided with necessary power supply arrangement.

Mirrors M_1 (total reflector)& M_2(output coupler) act as a resonant cavity to produce stimulated and amplification process.

WORKING:

- When flash lamp is energised it gives out radiations
- Nd^{+3} ions get excited to higher energy levels by absorbing 0.73 µm and 0.80µm from the input radiations.(white light)
- Nd^{+3} ions can stay for a duration of about 10^{-8} sec.
- These ions undergo non-radiative transitions to reach the metastable state E_3.
- Laser output of wavelength 1.06 µm is obtained from E_3 to E_2 transition.



Energy Levels of Neodymium ions in a crystal

Applications

- Material processing, such as drilling,, cutting and welding steel and super alloys.
- Medical applications(hair removal, and treatment of minor vascular defects).
- For soft tissue surgeries in the oral cavity
- In manufacturing as a means for engraving, etching, or marking a variety of metals and plastics.
- the most common laser used in laser designators and laser rangefinders.

CARBON DIOXIDE LASER

(CO_2 Laser)

Features of CO_2 Laser

- Carbon Dioxide laser is a four-level **molecular gas** laser (operates on a set of vibrational-rotational transitions).
- Emit in the Infra Red (IR) Spectrum (λ= 9-11 μm)
- CO_2 Laser operates with an efficiency of up to 30 %.
- This laser is powerful enough to cut many substances and also destroy many others.
- As a continuous wave (CW) laser, this laser beam is the most powerful in production.
- Very simple to operate, and the gasses are non-toxic

- **Pumping Method**: Electrical excitation, Collisional transfer.

Structure of CO_2

- CO_2 molecule is an in-line arrangement of two oxygen atoms and the carbon atom . The atoms can vibrate in different modes, rotate about various axes in addition to electronic motions.
- Each electronic level splits into **vibrational sublevels**, each **vibrational level is subdivided into rotational sublevels**.
- The carbon dioxide molecule can vibrate in a combination of the three modes of state of vibration **: Symmetric stretch**, the **Bending**, and the **Asymmetric Stretch** modes
- This can be described by **three integers (*mnq*)***; the three integers correspond, respectively, to the degree of excitation (amount of energy)* in the symmetric stretch (m), in bending (n), and asymmetric stretch modes(q), respectively.

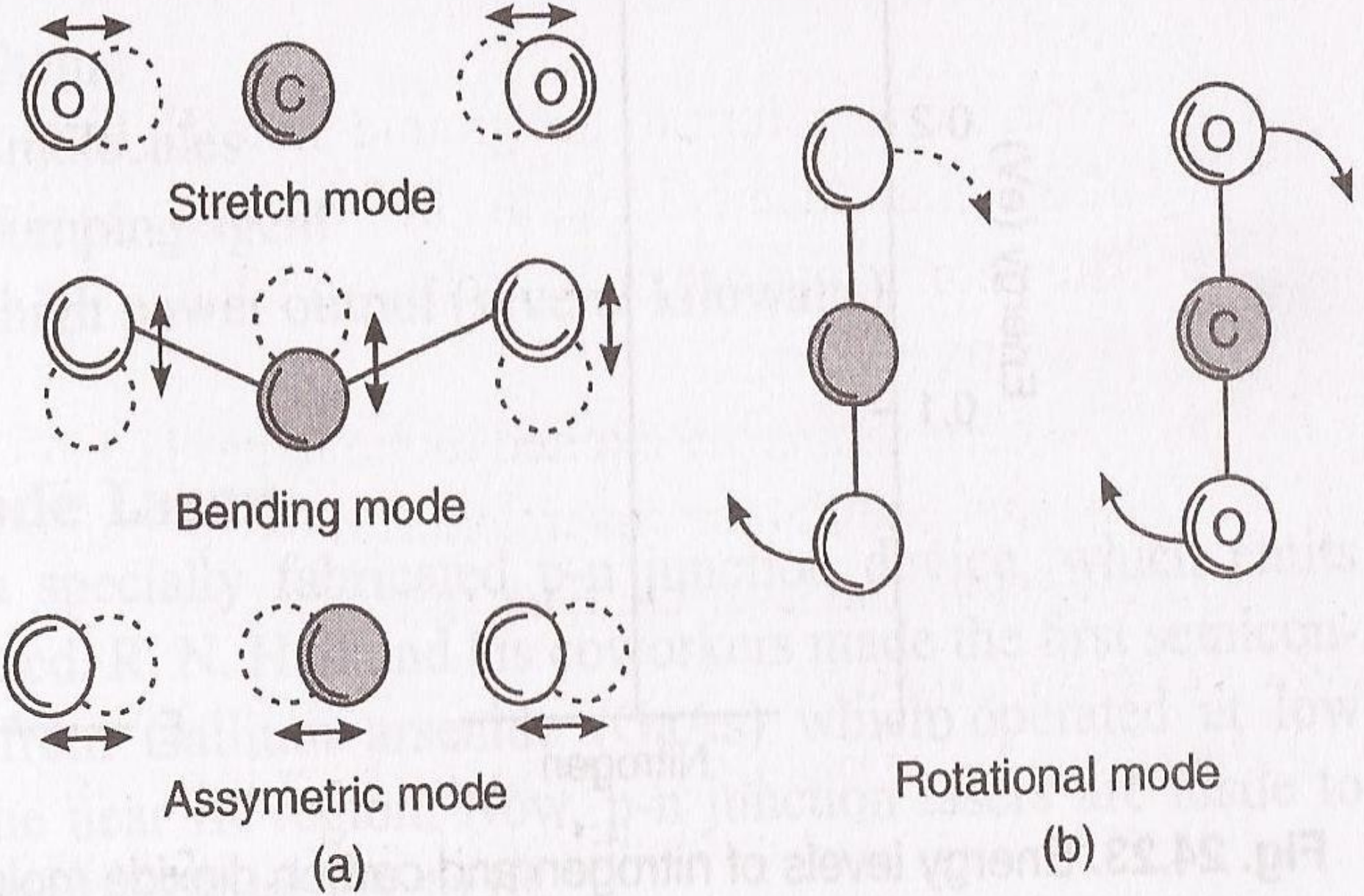
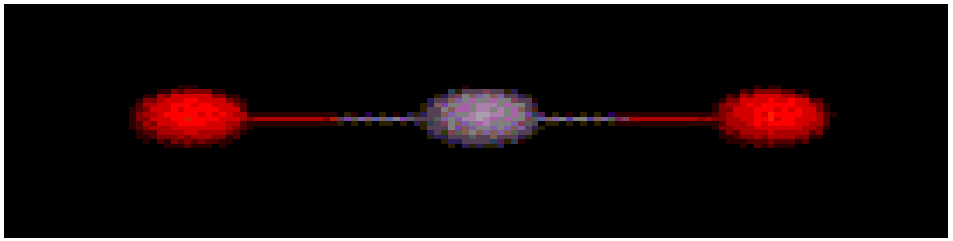
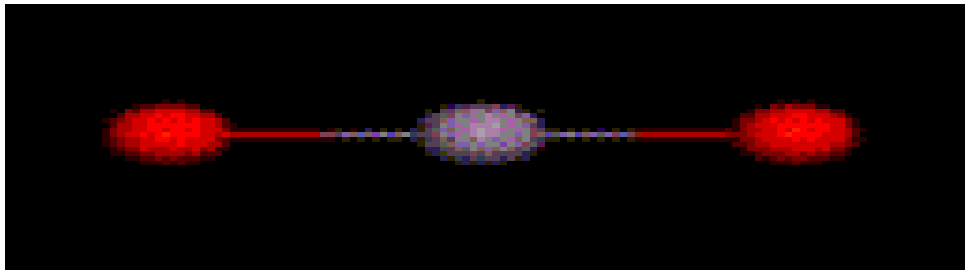
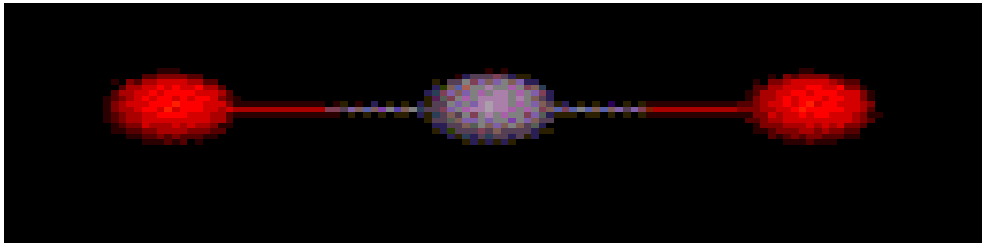


Fig. 2 . Vibrational modes of a CO_2 molecule

Symmetric Stretch, Bending and Asymmetric Stretch



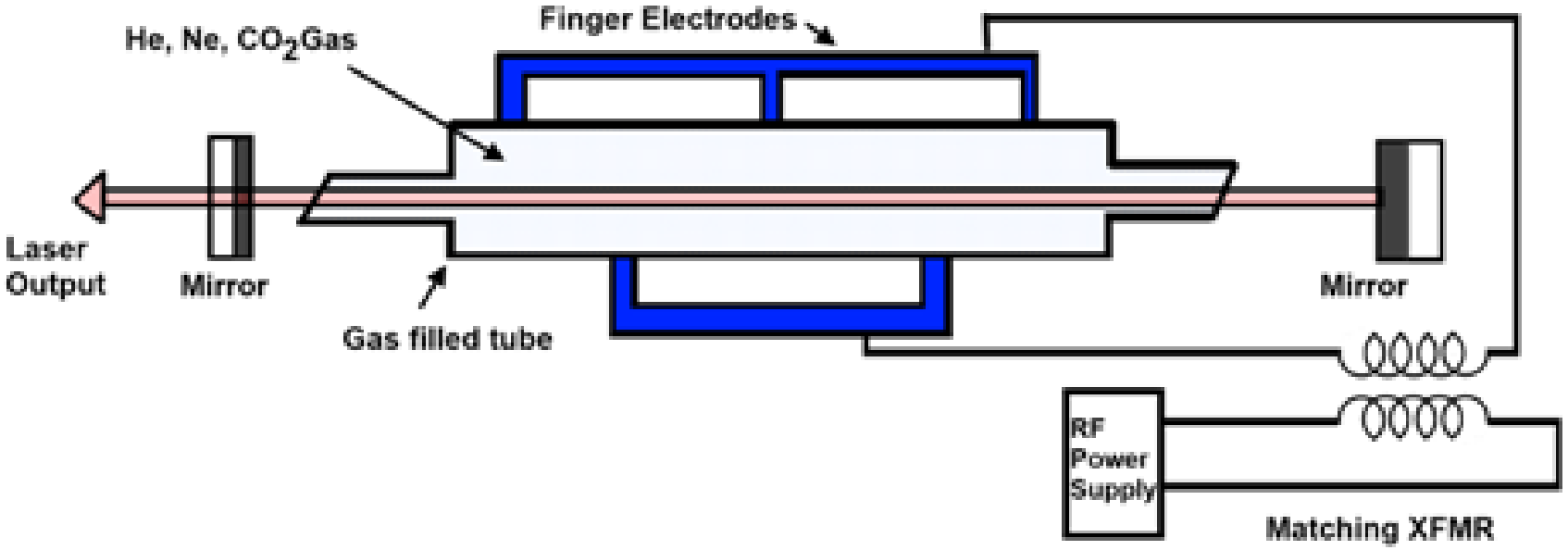




Construction of CO2 Laser

- This consists of a mixture of **carbon dioxide, nitrogen and helium gases** in a ratio of about 1:4:5. Other additives such as water vapor are also added.
- The setup consists of a discharge tube of length 26cm and cross section of about 1.5 **mm^2.**
- The pressure inside the tube is about 1mm of Hg.
- Power source was used to create a potential difference of 18,000 Volts across the tube.
- A CO_2 laser is a type of gas laser. This means that electricity is run through a gas to produce light. A CO_2 laser has a tube filled with gas with a transparent mirror on one end, meaning that some light can get through it, and a fully reflective mirror on the other end. This gas mixture is generally comprised of carbon dioxide, nitrogen, hydrogen and helium. The beam produced by a CO_2 laser is emitted through the transparent mirror.

Schematic diagram of CO_2 Laser

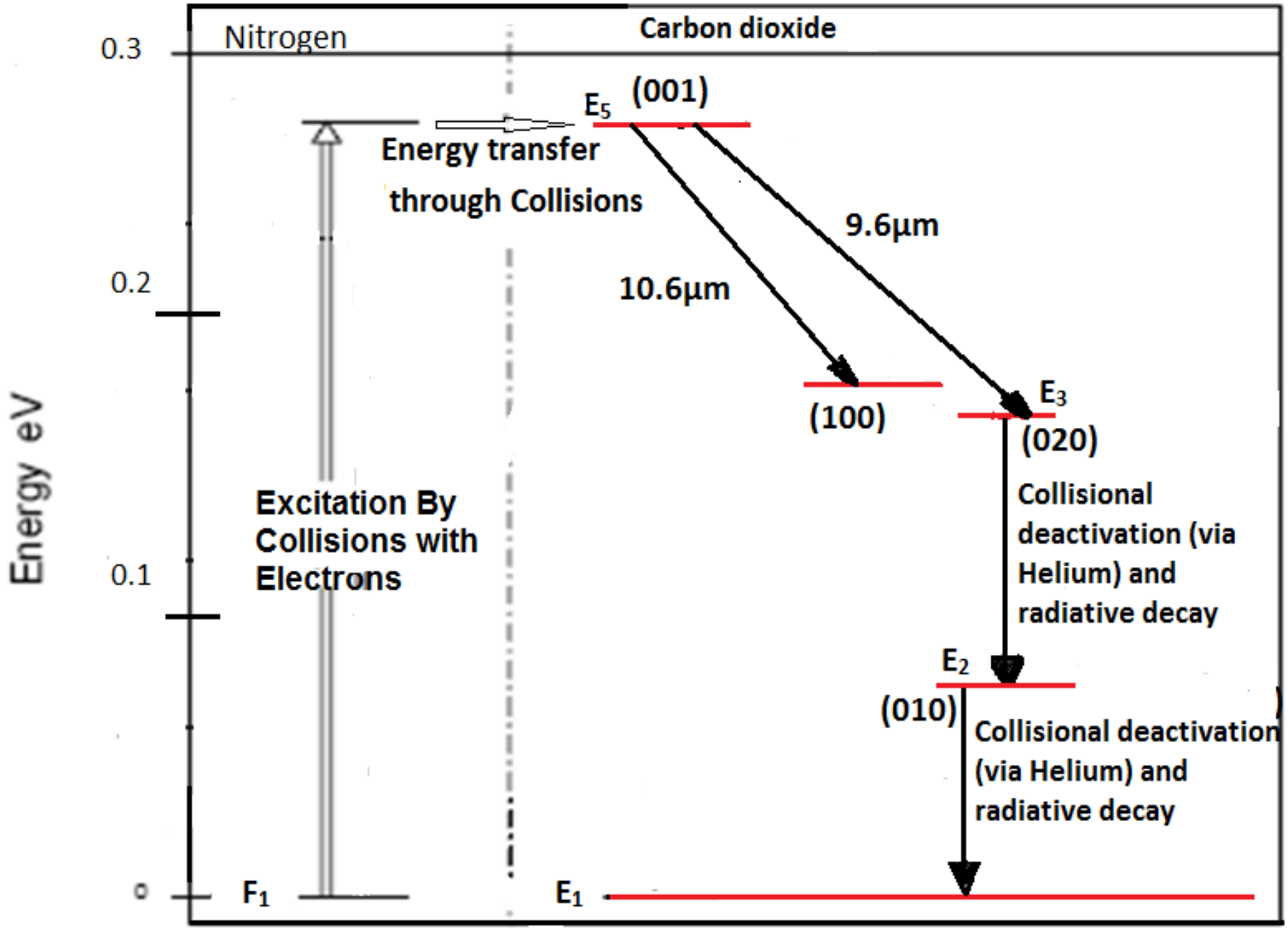


Working of CO_2 Laser

- When electricity is run through the gas mixture, the particles of nitrogen become excited, meaning that they gain more energy.
- Nitrogen is used because it can hold this excited state for long periods of time without discharging the energy in the form of photons, or light. (Nitrogen plays a similar role as that of He in He-Ne laser). Nitrogen gas is used to achieve population inversion in active medium i.e CO_2 gas.
- The excited vibrations of the nitrogen then cause the carbon dioxide to become excited to (001) level.
- At this point, population inversion has been achieved between (001) and (100) giving stimulated emission **(10.6µm)** and (9.6µm) between (001) and (020) levels

Contd…..Working of CO2 Laser

- Helium is used to increase the thermal conductivity of the walls of the tube, efficiency by decreasing the population of (020), (010) levels and indirectly depleting the linked (100) level.
- The light produced is so powerful compared to normal light because the tube of gases in a laser beam is surrounded by mirrors, which serve to reflect at least part of the light traveling through the tube. This reflection of light causes the light waves being produced by the nitrogen to reinforce themselves. This means that the light is amplifying as it travels through the gas tube, only coming out after reaching a certain intensity, making it extremely powerful.



Relevant Energy levels of nitrogen and carbon dioxide

Applications of CO_2 Laser

- Because of the high output power (combined with reasonable cost for the laser), CO_2 lasers are frequently used in industrial applications for cutting , welding and hole drilling
- In medical field Co2 laser are used to destory infected tissue in a wound.
- Because the atmosphere is quite transparent to infrared light, CO_2 lasers are also used for military rangefinding
- Easily shows the molecular properties of CO_2