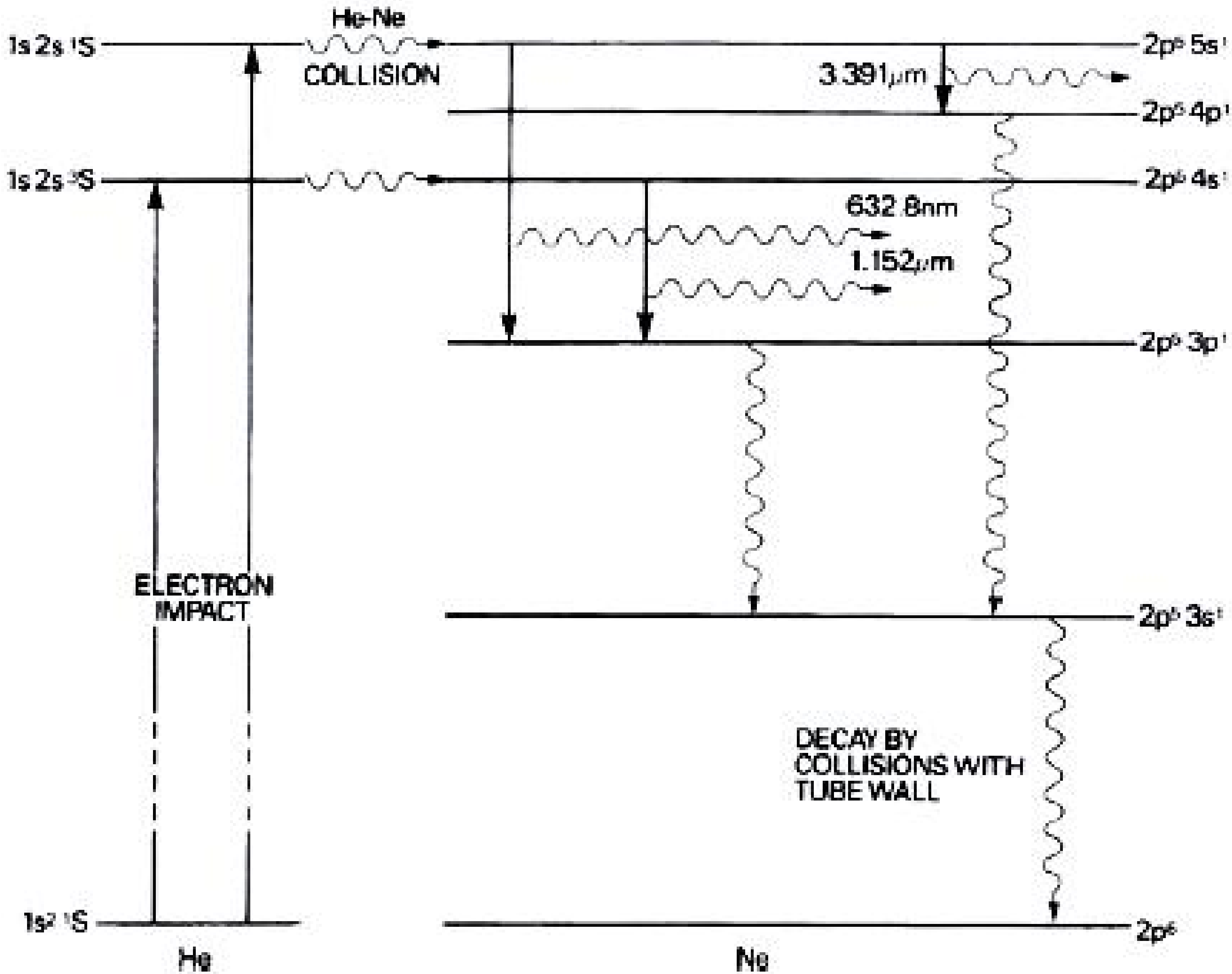
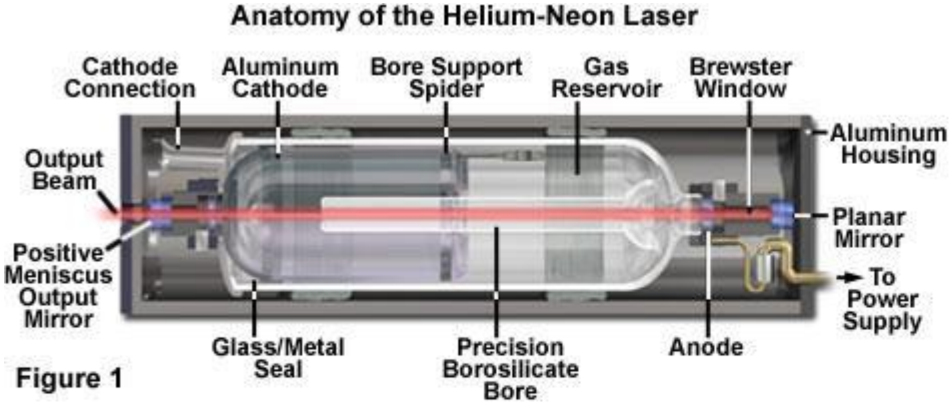
Helium – Neon LASER

- First Continuous Wave laser ever constructed.
- The active medium is a mixture of the two gases He & Ne in a glass tube.
- Partial pressure of helium is approximately 1 mbar and that of neon is 0.1 mbar
- The initial excitation is provided by an electrical discharge and serves primarily to excite helium atoms by electron impact.
- Certain levels of helium and neon are very close in energy, excited helium atoms subsequently undergo a process of collisional energy transfer to neon atoms, very efficiently.


He-Ne
COLLISION
1s 2s ¹S
1s 2s ³S
1s² ¹S
3.391μm
632.8nm
1.152μm
2p⁵ 5s¹
2p⁵ 4p¹
2p⁵ 4s¹
2p⁵ 3p¹
2p⁵ 3s¹
2p⁶
ELECTRON IMPACT
DECAY BY COLLISIONS WITH TUBE WALL
He
Ne

- Because the levels of neon so populated lie above the lowest excited states, a population inversion is created relative to these levels, enabling laser emission to occur.
- Three wavelengths generated 632.8nm, 1.152 µm and 3.391 µm.
- Following emission, neon undergoes a two-step radiation less decay back down to its ground state. This involves transition to a metastable $2p^5 3s^1$ level, followed by collisional deactivation at the inner surface of the tube.
- To assure that last step is rapid for efficient laser working, surface/volume ratio of the laser tube has to be kept as large as possible, which generally means keeping the tube diameter small.
- Generally tube diameters are in few millimeters.
- Narrow bandwidth, small and inexpensive.


Anatomy of the Helium-Neon Laser
Cathode Connection
Aluminum Cathode
Bore Support Spider
Gas Reservoir
Brewster Window
Aluminum Housing
Output Beam
Planar Mirror
Positive Meniscus Output Mirror
To Power Supply
Glass/Metal Seal
Precision Borosilicate Bore
Anode
Figure 1

Argon LASER

- Single component inert gas, Argon , act as active medium.
- Argon at a pressure of 0.5mbar is contained in plasma tube of 2 – 3 mm bore.
- Excitation is achieved by continuous electric discharge.
- Atoms are ionized and further excited by electron impact.
- This pumping process produces a population of several ionic excited states, and those responsible for laser action are on average populated by two successive impacts.
- This results in emission at a series of discrete wavelengths over the range 350-530 nm.
- The two strongest lines appear at 488.0 and 514.5 nm as a result of transition from the singly ionised states with electron configuration $3s^2 3p^4 4p^1$ down to the $3s^2 3p^4 4s^1$ state. Further radiative decay to the multiplet associated with the ionic ground configuration $3s^2 3p^5$ then occurs

- LASER cycle is completed by electron capture or further impact excitation.

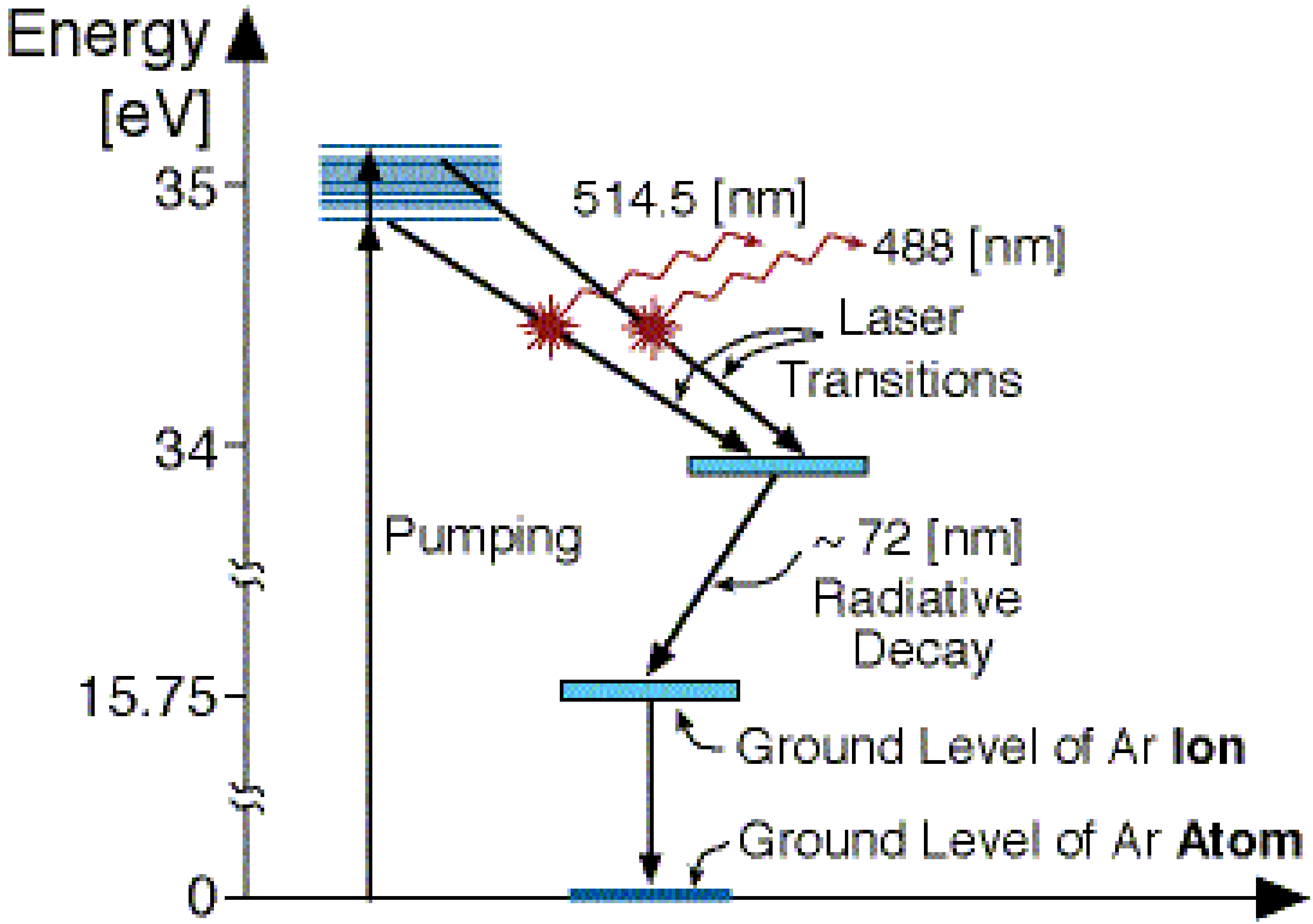
- As several wavelength is produced etalon or dispersing prism is needed.

- By selecting a single longitudinal mode, an output linewidth of only 0.0001 cm^{-1} is obtainable.

- Requires large and continuous flow of energy.

- The output power of a CW argon laser usually lies in the region running from milliwatts up to about 25 W.

- Expensive and fragile.



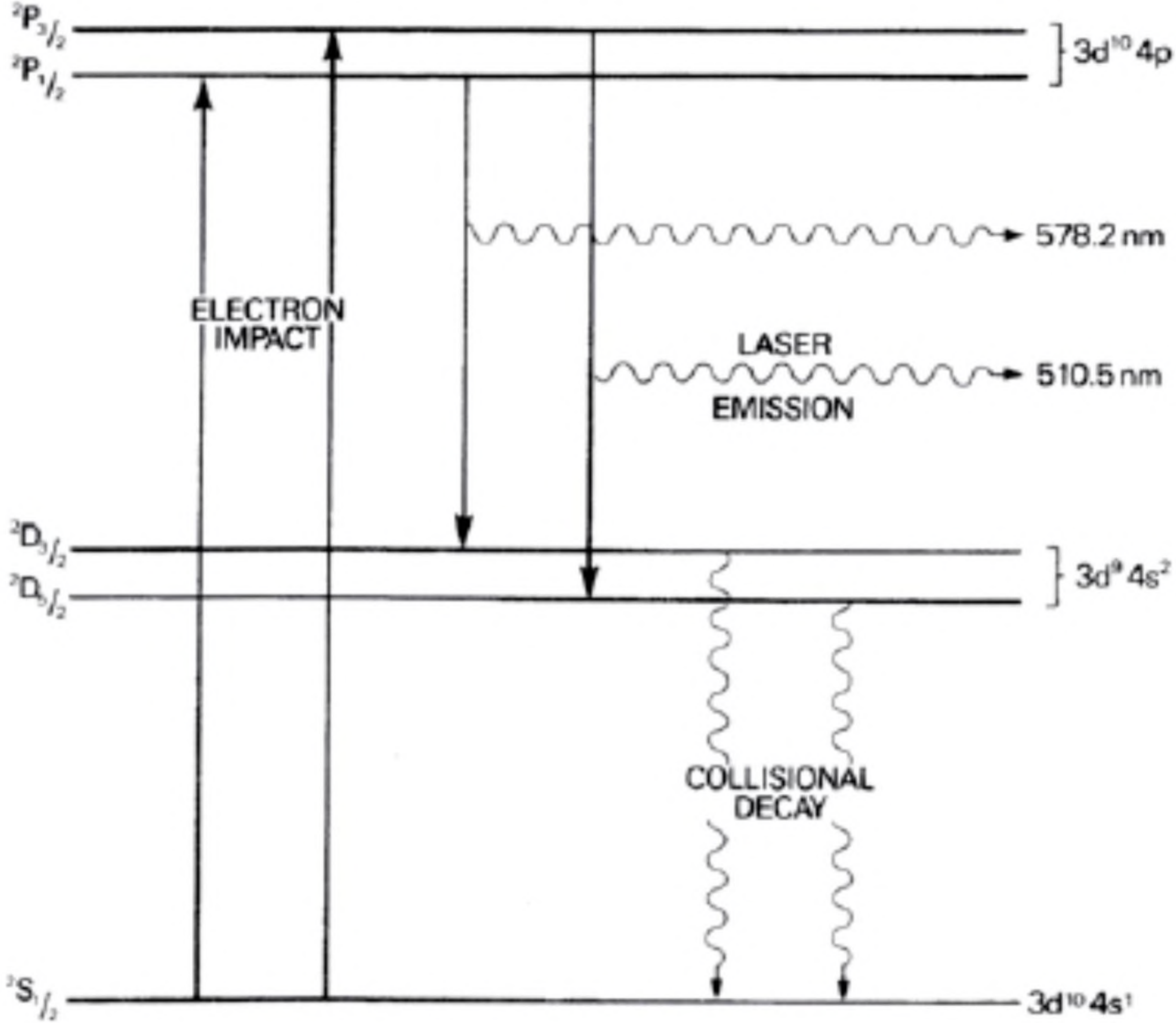
Energy
[eV]
35
34
15.75
0
Pumping
514.5 [nm]
488 [nm]
Laser
Transitions
~ 72 [nm]
Radiative
Decay
Ground Level of Ar **Ion**
Ground Level of Ar **Atom**

Copper Vapor LASER

- The copper laser is essentially a three-level system.

- Electron impact on the ground state copper atoms results in excitation to ^2P states belonging to the electron configuration $3d^{10}\,4p^1$, from which transitions to lower-lying $3d^9 4s^2\ ^2D$ levels can take place.

- Laser emission thus occurs at wavelengths of 510.5 nm and 578.2 nm.



$^2P_{3/2}$
$^2P_{1/2}$
$3d^{10}4p$
578.2 nm
ELECTRON IMPACT
LASER
510.5 nm
EMISSION
$^2D_{3/2}$
$^2D_{5/2}$
$3d^9 4s^2$
COLLISIONAL DECAY
$^2S_{1/2}$
$3d^{10}4s^1$

- Collisions of the excited atoms with electrons or the tube walls subsequently result in decay back to the ground state.

- Operates in pulse mode with pulse repetition frequency of about 5 kHz.

- The physical design of the laser involves an alumina plasma tube containing small beads or other sources of metallic copper at each end.

- The tube also contains a low pressure of neon gas (approximately 5 mbar) to sustain an electrical discharge.

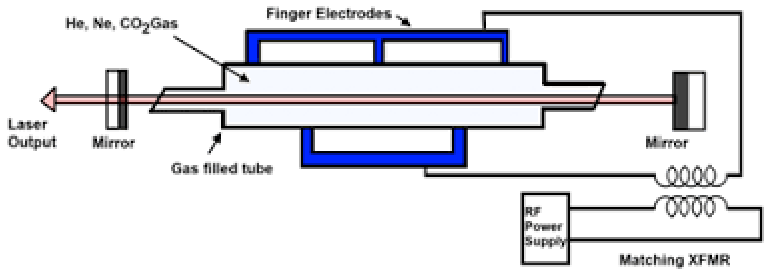
- The chief advantages of the copper vapour laser are that it emits visible radiation at very high powers

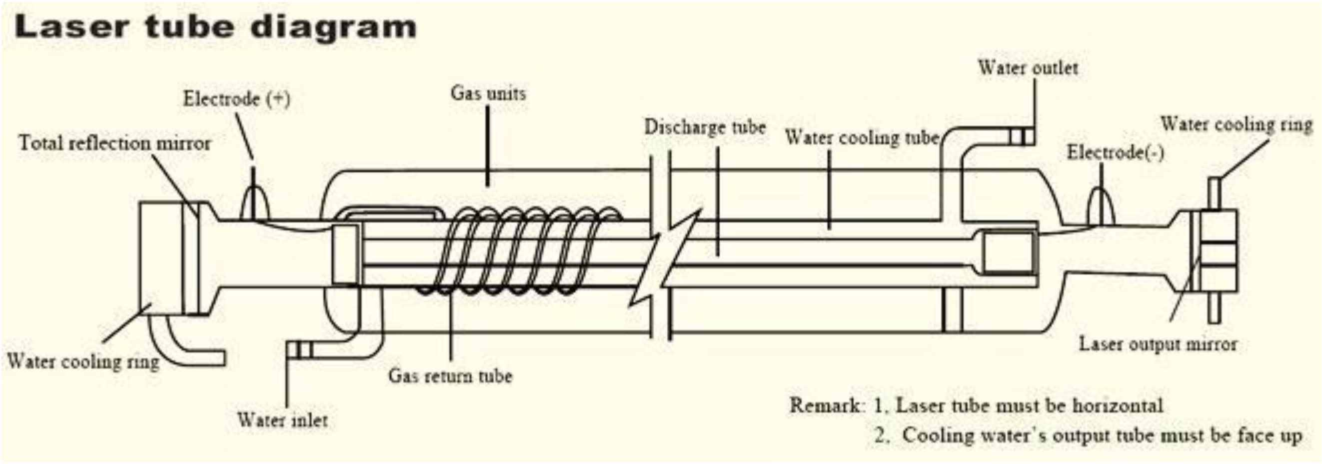
Molecular Gas LASERs

Carbon dioxide LASER

- Energy levels involved in LASER action are vibration-rotation.

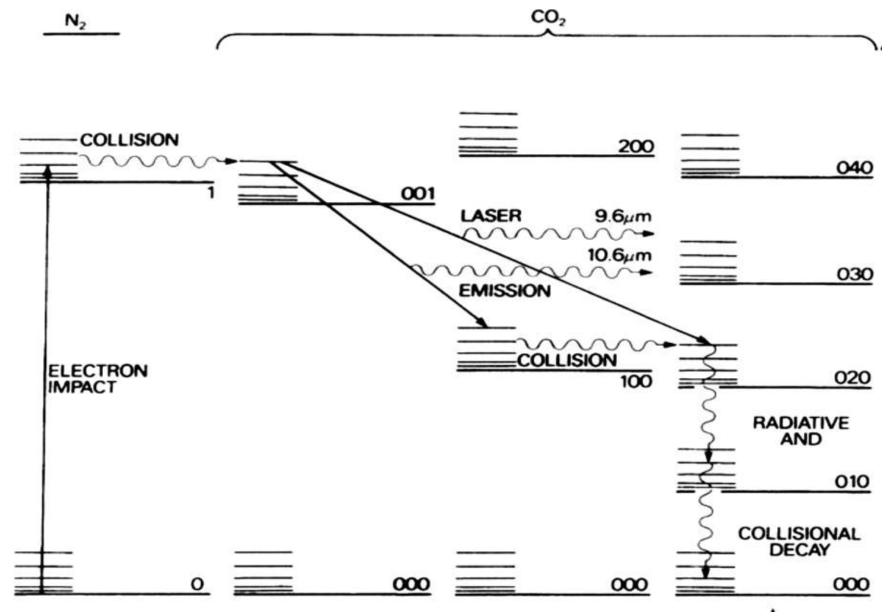
- The lasing medium consists of a mixture of CO_2, N_2 and He gas in varying proportions.





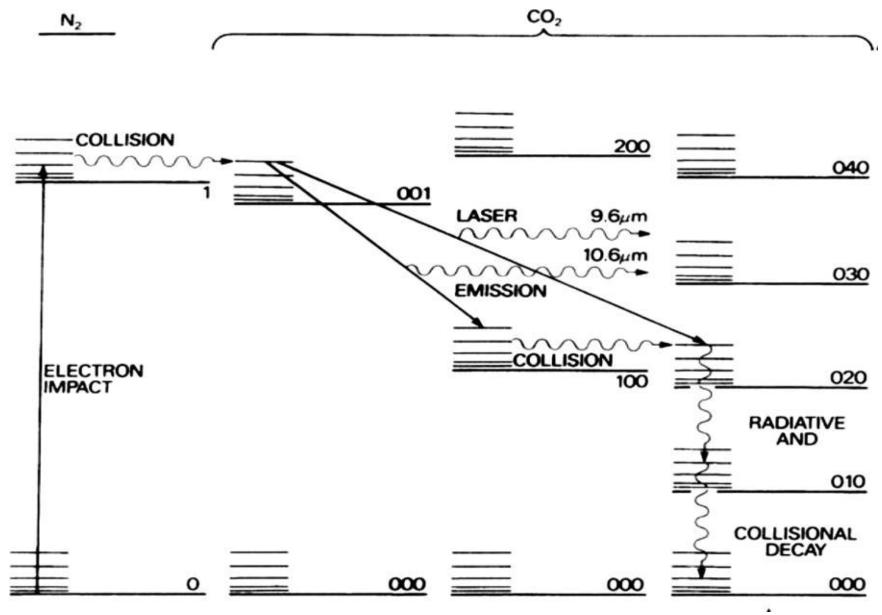
Carbon dioxide LASER

- The first step is population of the first vibrationaly excited level of nitrogen by electron impact.
- Various rotational sub-levels belonging to the vibrationaly excited state are populated by the electron collision.
- These levels are all metastable, as radiative decay back down to the vibrational ground state is forbidden by the normal selection rules for emission.



Consequently, collision between the two molecules results in a very efficient transfer of energy to the carbon dioxide.

- Laser emission in the CO_2 then occurs by two routes, involving radiative decay to rotational sub-levels belonging to the (100) and (020) states.
- They exist in a population inversion with respect to the (001) levels.
- Transitions results in emission of wavelengths of around 10.6 µm and 9.6 µm.



A small carbon dioxide laser, with a discharge tube about half a metre in length, may have an efficiency rating as high as 30% and produce a continuous output of 20 W.

Nitrogen LASER

Similar to CO_2 LASER, with following **main differences**:

- Electronic states are involved in LASER action, transition occurs between $C^3\pi_u$ to $B^3\pi_g$.
- Upper laser level has a lifetime of 40ns and hence cannot sustain population inversion.
- all the excited nitrogen molecules undergo radiative decay together to give *Super Radiant Emission.*
- 10 ns pulse of wavelength 337.1,with bandwidth 0.1nm is generated with a repetition rate of 1-200Hz