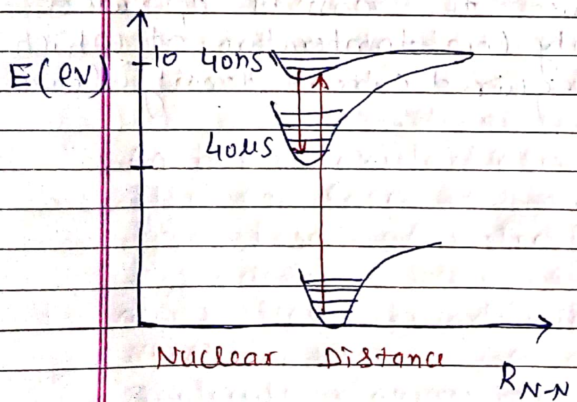
Nitrogen Laser:- The Nitrogen Laser is prototype of a vibronic laser. The electronic energy depends on the distance R_{N-N} between nitrogen nuclei. A vibronic energy level of N_2 has electronic and vibrational energy

$$E_{n,v} = E_n + \left(v+\frac{1}{2}\right) h\nu_{vib}$$



Here E_n is electronic energy in the n^{th} state and for ground state $n=1$, $n=2,3$ represent excited states $v=0,1,2 ---$ are the vibrational quantum numbers.
ν_{vib} is vibrational frequency having value 70.8 Tera Hertz.
Electron collission in a gas discharge excite Nitrogen molecules to vibronic states belonging to the $n=3$ electronic state. Stimulated transistions to vibronic levels of $n=2$ electronic level produce laser radiation in the near ultra violet nearly 337 nm. The life time 40 nanosecond of upper laser lever is shorter than the life time of lower laser level. Hence continous operation is not possible the laser is self terminating laser suitable for pumping are very short gas discharge pulses duration is about 1 nano second.

The ~~efficiency~~ spectral bandwidth of Nitrogen laser is of 0.1 nm. Spatial coherence is also small.

Applications of Nitrogen Laser

(1) It is three level laser
(2) measurement of air pollution
(3) Treatment of non healing wounds, pulmonary tuberculosis.
(4) Transverse optical pumping of dye laser

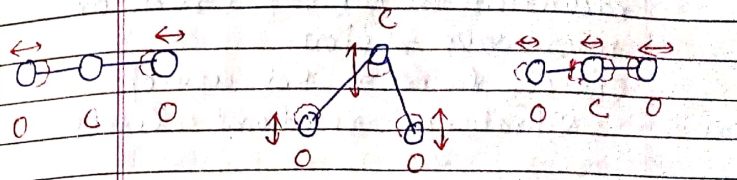
Draw backs of Nitrogen laser.

(1) Energy lost in lower laser level is 40%.
(2) only 3% inversion by electron Impact is 10 to 1 due to Franck Condon principle.

Carbon Dioxide Laser (CO_2) :-

The CO_2 laser is molecule gas laser. A molecule is made up of two or more atoms. Hence in addition to the electronic motions, atoms in molecule may vibrate in different modes and molecule as a whole may rotate about some axis.

The different modes are shown in given figure below

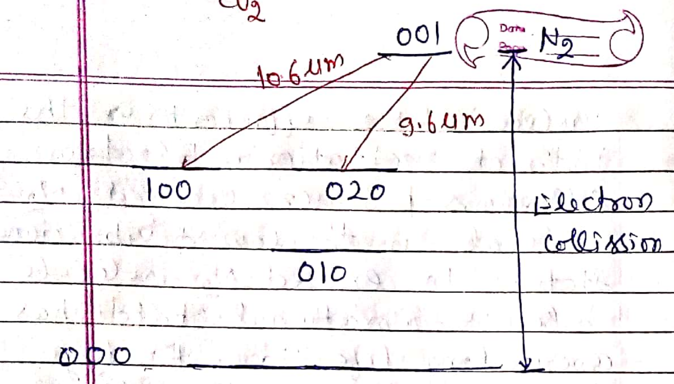


Symmetric stretching — Bending — Antisymm. stretching

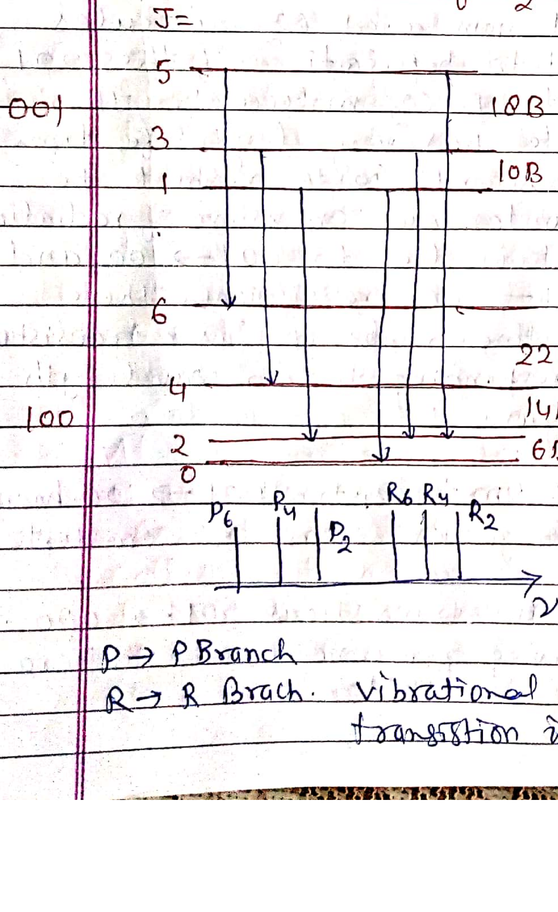
The different modes are
(a) symmetric stretching mode having frequency ν_1 1337 cm^{-1}
(b) Bending mode frequency ν_2 667 cm^{-1}
(c) Anti symmetric stretching mode frequency $\nu_3 = 2349\ cm^{-1}$

Molecule has discrete electronic levels (like atoms) each electronic level has a number of rotational levels associated with it.
A transistion between two electronic levels give radiation in visible region a transistion between vibrational levels of same electronic levels gives radiation in the near infra red region. While transistion between rotational levels of same vibrational level gives

CO_2



Vibrational levels of CO_2 and N_2



P → P Branch

R → R Brach. Vibrational Rotational transition in CO_2

A vibrational transition in CO_2 molecule is associated with change of rotational energy shown in above figures. The selection rules are

$$\Delta J = \pm 1$$

must be fullfilled.

$\Delta J = +1$ corresponds to laser lines in P Branch

$\Delta J = -1$ Corresponds to laser lines in R Branch.

The rotational energy is

$$E_{Rot} = BJ(J+1) \text{ and } B = \frac{h}{8\pi^2 IC}$$

B is rotational Constand and I is moment of Inertia of CO_2 molecule.

B have value of 15 GHz times value of Planck Const.

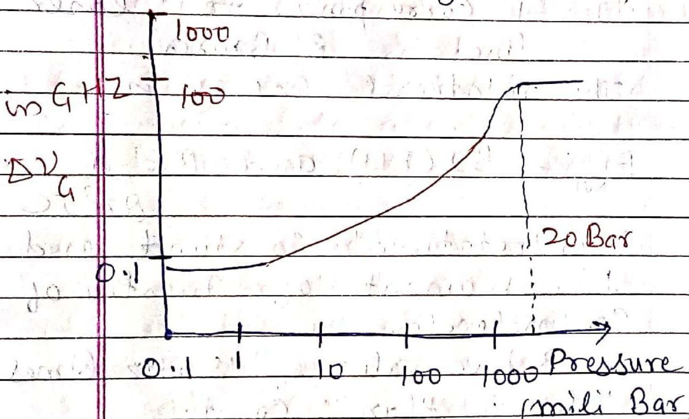
$$B = 15 \times 10^9 \times 6.6 \times 10^{34}$$

Each J state is 2J+1 fold degenerate.

The CO_2 molecule is a boson. Interchange of two oxygen atoms must leave the total wavefunction of molecule unchanged the

the wave function must be an even function. It follows that J is odd for antisymmetric ~~wave~~ vibration ~~function~~ and J is even for symmetric vibration.

Broadening of vibrational Rotational level of CO_2 is shown in figure.



At small pressure Doppler Broadening of vibrational Rotational lines of CO_2 determines the width of lines. Collission broadening dominates at pressure between 5 mili Bar and 1000 mili Bar. In this range gain bandwidth ($\Delta\nu_G$) increases proportionally to pressure. At higher pressure the vibrational rotational lines overlap partly and above a pressure of 20 Bar the single vibrational rotational lines overlap completely. The gain profile of each of four branches is ~~continous~~ continous and has a width of 500 Giga Hertz. A mode locked CO_2 laser operating on one of four branches produces picosecond pulse consisting of radiation around a frequency of 30 Tera Hertz.

Applications of CO_2 laser.

(1) It has high efficiency (10-50%) for conversion of electrical power to power of laser radiation.

2. Different ways are possible ie. Continous wave (CW) operation, Pulsed operation and Transverse Excited atmospheric (TEA) operation.

3. The CW CO_2 laser generates CW radiations of large power (100 watt at a length

of active medium of about 1m and upto 1000 watt or more at very large length of active medium.

4. The TEA CO_2 laser produces pulses of 100 nano second duration of high peak power ~~100 kilo~~ 100 Kilo watt.

5. Used in material processing (cutting welding, hardening of metal surfaces)

6. Used in Medical Fields

7. Long life about 20000 Hours.

Drawbacks of CO_2 laser:-

(1) Beam width varies from 3 mm to 100mm.

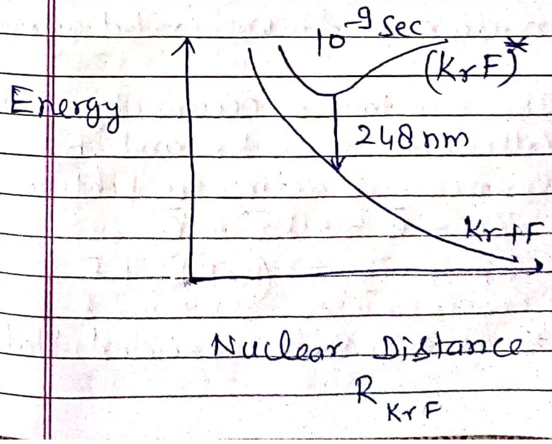
(2) It has short and thick optical cavity.

(3) Its cost is very high as compared to other laser.

(4) It requires cooling system which is disadvantage for some of configurations.

Excimer Laser:- A laser that emits very concentrated light in the ultraviolet region of the spectrum called as Excimer Laser. It uses noble gas halide. Excimer is chemical term that refers to substance formed by the joining of two atoms or two molecules of same chemical composition in an excited state. It is an excited dimer.

The excimer laser makes use KrF excimer or other excimers. The following processes occur in KrF excimer laser shown in figure.



A gas discharge in a mixture of Krypton and Flourine gas produces $(KrF)^x$ molecules i.e. KrF molecules is an excited electronic state. The life time of the excited life time is 10^{-9} sec.

Stimulated ~~emission~~ transistions take place to non bonding KrF states. Therefore lower laser level has shorter life time than upper laser level. During an optical transistion in a KrF excimer the nuclear distance between nucleus of Kr and nucleus of F does not change. The transistion corresponds to a vertical line in energy nuclear is shown in diagram.

The excitation occurs by electron collissions with Kr and by a chemical reaction respectively.

$Kr + \bar{e} \rightarrow Kr^* + \bar{e}$

$Kr^* + F_2 \rightarrow (KrF)^x + F$

$* \rightarrow$ represents excited state

Examples of ~~Exc~~ Excimer ~~...~~

Ar_2^x emission at 126 nm

Kr_2^x — emission at 146 nm

Xe_2^x — " at 172 nm

Excited state complex or excimer is also called exciplex.

Examples of Excimer Laser

ArF	laser line at	193 nm
KrF	" "	248 nm
XeCl	" "	308 nm
XeF	" "	351 nm
KrBr	" "	206 nm
ArBr	" "	161 nm
NeF	" "	108 nm

The excimer laser is Transverse Excited Atmospheric Laser (TEA laser). The laser gas of Krypton Fluoride excimer has composition Helium as buffer gas pressure 1 Bar, Krypton 10% and Flourine F_2 0.1%.

Scanned by CamScanner

At a large pump power density 200 MW per litre gas volume the gain is about 10% per cm. The gain Coefficient $\alpha = 10\ m^{-1}$.
Pumping by electric discharge pulses having
Voltage ≃ 1 MV
Current ≃ 10 KA
Pulse Duration 30 nano Second
Electric energy per pulse = 100 Joule
Laser Pulse energy = 1 Joule
Efficiency = 1%
Repetion Rate – 1–50 HZ.

Applications of Excimer Laser

(1) Labelling of semi conductor chips, glasses, polymers.

(2) During Mass Production

(3) Structuring of materials by means of UV lithography in 2011.

(4) Semiconductor structures of lateral size of 45 nm are prepared by use of ArF laser having wavelength 193 nm.

(5) ArF excimer laser is used in refractive laser surgery

(6) low operating and service costs long warranty.

(7) Long optical life time.

(8) No noise

(9) ophthalmic surgical Microscope and video Imaging

Drawbacks of Excimer Laser

(1) Beam quality that is difficult to reproduce.

(2) Kept stable over a long time

(3) Need for poisonous expendables (F_2 gas).