UNIT – II WAVES AND OPTICS

TOPIC – IV Nd YAG AND CO_2 LASER

Characteristics of Nd-YAG laser

Type – Doped Insulator laser [Solid state laser]

Active medium - Yttrium Aluminium Garnet [$Y_3Al_5O_{12}$]

Active centre – Neodymium [Nd^{3+} ions]

Pumping method – optical pumping

Pumping source – Xenon flash lamp

Optical resonator – ends of the rods polished with silver and two mirrors, one of them is totally reflecting and the other is partially reflecting.

Power output – 2 x 10^4 watts

Nature of output – pulsed

Wavelength emitted – 1.064 μm.

Introduction

Nd-YAG laser is a Doped Insulator laser. It is a four level system in which the active medium is taken in the form of crystal. Here the crystal is intentionally doped during its growth. Those types of lasers have number of energy levels with same energy.

The laser is used to generate high power intensity.

Principle

The term "Doped Insulator laser" refers to active medium, yttrium aluminium garnet doped with Neodymium Nd^{3+}. The Neodymium ion has many energy levels. Due to optical pumping these ions are raised to excited levels. During the transition from meta stable to E_1 state, the laser beam of wavelength 1.064μm is emitted.

Construction

The active medium is made as a rod which has yttrium aluminium garnet [$Y_3Al_5O_{12}$] doped with a rare earth metal ion Neodymium Nd^{3+}. The Nd^{3+} ion normally occupy the yttrium ions and provide the energy levels for both the lasing transitions and pumping. This rod is placed inside a highly reflecting elliptical cavity as shown in figure 5.5. A close optical coupling is made by placing the Xenon flash lamp near by the laser rod, in such a way that most of the radiation from the flash tube passes through the laser rod due to the elliptical cavity. The flash tube may be switched on and controlled with the help of a capacitor. The discharge of capacitor is initiated using a high voltage source.

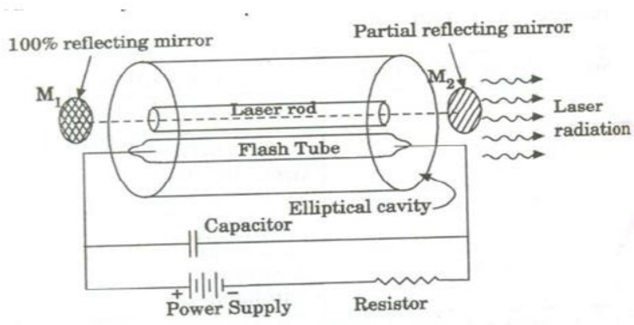

Fig. 5.5

The optical resonator is formed by grinding the ends of the rods and coated with silver accompanied by two mirrors, one is 100% reflecting and the other is partially reflecting which is included to increase the efficiency of the output beam.

Working

(i) The xenon flash lamp is switched on and the light is allowed to fall on the laser rod.

(ii) The intense white light excites the neodymium (Nd^{3+}) ions from the ground state to group higher levels in E_3 as illustrated in the energy level diagram.

(iii)From these energy levels the ion make non-radiative decay and is gathered in a state called as meta stable state, until the population inversion is achieved.

(iv)Once the population inversion is achieved, the stimulated emission builds up rapidly. Hence, pulsed form of laser beam of wavelength 1.064μm is emitted during the transition from E_4 to E_1.

(v) A large amount of heat is produced by the flash tube during the working. Hence cooling arrangement is made either by blowing air or circulating water over the crystal.

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Applications of Nd-YAG laser

(i) It is used in transmitting signals to longer distances.

(ii) It is used in long haul communication system.

(iii)It is used in endoscopic applications.

(iv)It plays a vital role in remote sensing applications.

5.10 CARBON – DI - OXIDE LASER

Characteristics of co_2 laser

Type – Molecular Gas laser

Active medium – Mixture of CO_2 , N_2 and helium or Water vapour

Active centre – Co_2

Pumping method – Eletric discharge method

Optical resonator – Metallic mirror of gold or silicon mirrors coated with aluminium

Power output – 10Kw

Nature of output – continuous or pulsed

Wavelength emitted – 9.6µm & 10.6 µm

Introduction

An Indian engineer C.K.N designed the co_2 laser we know I n the case if atoms, electrons can be excited to higher energy levels of the molecule eg. He - Ne laser. Besides these electronic energy levels, the molecule can have other energy levels also due to rotation and vibration of the molecule (co_2) they give rise to various vibrational and rotational energy levels as shown in figure 5.6.

Where, E_1E_2 – electronic energy levels

v', v'' – vibrational energy levels

j,j' – rotational energy levels.

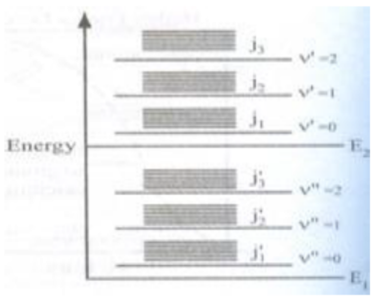


Fig.5.6

Principle

The transition between these vibrational and rotational energy levels leads to the construction of molecular gas laser. Here the nitrogen atoms are initially raised to excited stare. The nitrogen atoms deliver the energy to co_2 atoms which has closest energy level to it. Then, the transition takes place between the vibrational energy 7 levels of the CO_2 atoms and hence laser beam is emitted. The molecular gas laser can have two types of transitions such as,

i. Transition between vibrational levels of same electronic state as shown in figure 5.7.

ii. Transition between vibrational levels of different electronic state as shown in figure 5.7.

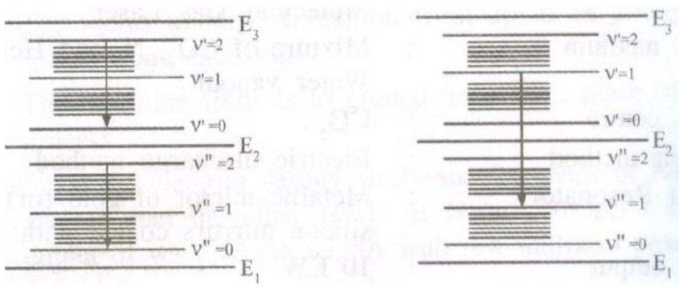


Fig.5.7

CO_2 laser satisfies them first condition. i.e. here the laser transition occurs between vibrational levels of same electronic state.

Fundamental modes of vibration of the co_2 molecule.

There are three fundamental modes of vibration.

1. Symmetric stretching mode (10˚0)
2. Bending mode (01˚0, 02˚0)
3. Asymmetric stretching mode (00˚1, 00˚2)

Symmetric stretching mode (10˚0)

The carbon atom is stationary and the oxygen atoms oscillate or vibrate along the axis of the molecule as shown in figure 5.8. The state of vibration is given by 3 integers (mn^{1}q) here (10˚0), which corresponds, to the degree of excitation.

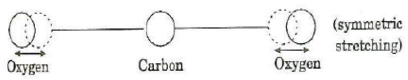


Fig.5.8

Bending mode (01˚0, 02˚0)

Here the atoms will not be linear, rather the atoms will vibrate perpendicular to the molecular axis as shown in figure 5.9. This gives rise to two quanta of frequency represented by (01˚0, 02˚0).

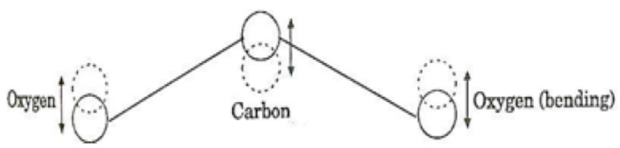
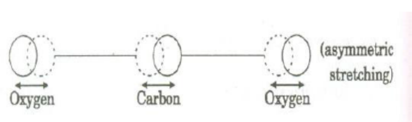


Fig.5.9

Asymmetric stretching mode (00˚1, 00˚2)

Here all the atoms will vibrate. Here the oxygen atoms vibrate in the opposite direction to the vibration direction of carbon atom as shown in figure 5.10. This gives the quanta of frequency (00◦1, 00◦2).



Construction

It consists of a discharge tube in which co_2 is taken along with nitrogen and helium gases with their pressure level of 0.33:1.2:7 mm of Hg for co_2, nitrogen and the He respectively. Nitrogen helps to increase the population of atoms in the upper level of co_2, while helium helps to depopulate the atoms in the lower level of co_2 and also to cool the discharge tube.

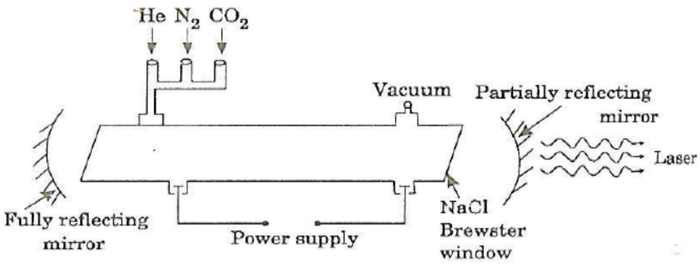


Fig.5.11

The discharge is produced by DC excitation. At the ends of the tube sodium chloride/Brewster windows are placed as shown in figure 5.11. Confocal silicon mirrors coated with aluminium or metallic mirror of gold is employed for proper reflection, which form the resonant cavity. The output power can be increased by increasing the diameter of the tube.

Working

(i) The discharge is passed through the tube first, the nitrogen atoms are raised to excited state $e^- + N_2 \rightarrow N_2^*$

(ii) The excited N_2 atoms undergo resonant energy transfer with co_2 atom and raises co_2 ($00^\circ1$) to excited state due to closer energy level of co_2 ($00^\circ1$) and nitrogen.

$$N_2^* + CO_2 + CO_2^* + N_2$$

(iii) When transition takes place between $00^\circ1$ to $10^\circ0$, the laser of wavelength 10.6 μm is emitted as shown in figure 5.12.

(iv) Similarly when transition takes place between $00^\circ1$ and $02^\circ0$ laser beam of wavelength 9.6 μm is emitted as shown in figure 5.12.

(v) Since $00^\circ1$ to $10^\circ0$ has higher gain than $00^\circ1$ to $02^\circ0$ transition, usually the laser beam of wavelength 10.6μm is produced more.

(vi) When the gas flow is longitudinal power output is 50 to 60 watts but if the gas flow is perpendicular to the discharge tube the output power may be raised to 10 kilo watt/m.

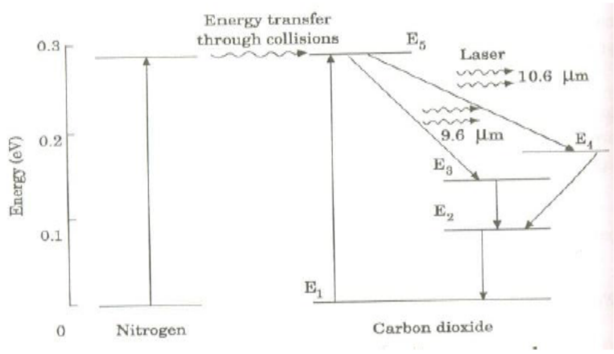


Fig.5.12

(vii) This type of co_2 laser is known as TEA laser.

(i.e.), (Transversely Excited Atmospheric Pressure laser).

(viii)The contamination of carbon monoxide and oxygen will also have some effect on the laser action. To avoid these unused gases can be pumped out and fresh CO_2 must be inside the discharge tube.

Application of CO_2 laser

(i) This laser has applications in medical field such as neurosurgery. Microsurgery, treatment of liver, lungs and also in bloodless operations.

(ii) It is widely used in open air communication.