23rd May, 2024 LEC-18 Thursday

LIQUID LASERS

1) **Dye Laser:-** In liquid lasers, we have dye lasers which are in liquid form. Dyes are basically organic compounds in different colours.

→ In dye laser, there is no metastable state, so the population inversion is achieved from the vibrational and rotational energy levels of the organic compounds.

Organic Compounds:-
We dissolve organic compounds in different solvents.
e.g:- dimethyl sulphide

→ Organic dye compounds if dissolved in methanol or other solvent, then the effect would be different and because of the transition of rotational and vibrational levels, laser output would be different.

→ The conc. of dyes is very important:-
If we want 10 mL to be dissolved in solution it should be 10 mL (not more or less)

Rodamine (Xanthene)
It is the most important dye. It gives us different wavelength between red and yellow according

to solvent concentration. It is in visible region.

→ To achieve the 2nd harmonic, double the frequency and the wavelength would be halfed.

Range of Wavelengths:-

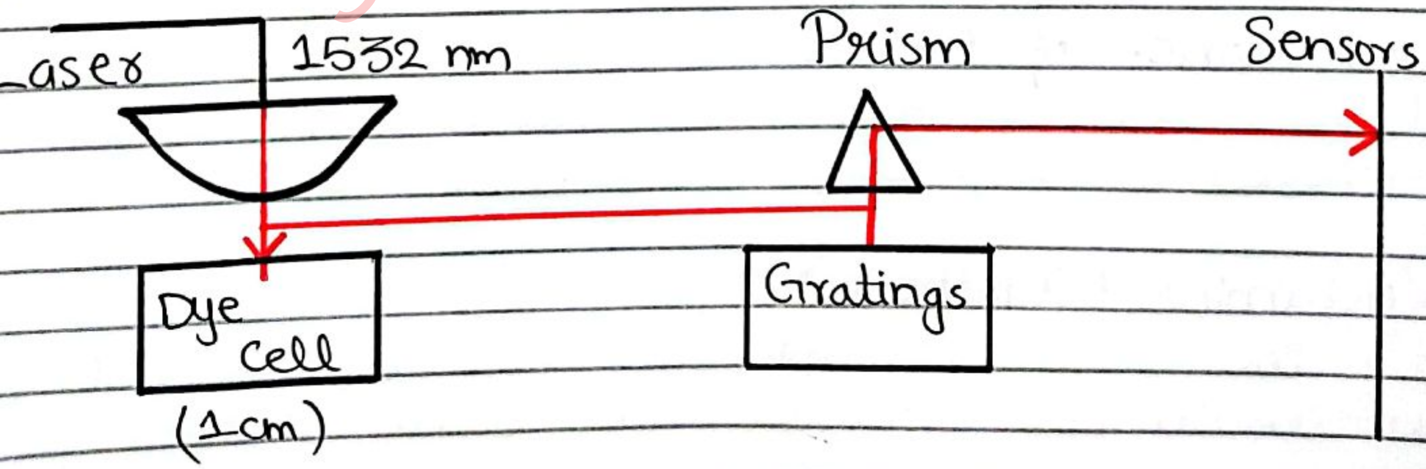
Dye lasers has advantage that we can tune it within a range of frequencies.

∴ In Nd:YAG Laser → we get exact wavelength (1064 nm)

∴ In Dye lasers → we have a range of λ's (600 – 800) nm

Construction:-

Initially, we do pumping by using any laser like (Nd:YAG or N_2 laser) and do **pumping** on dye cell. The dye cell is further connected to system, where dye within the solution is circulating for cooling.

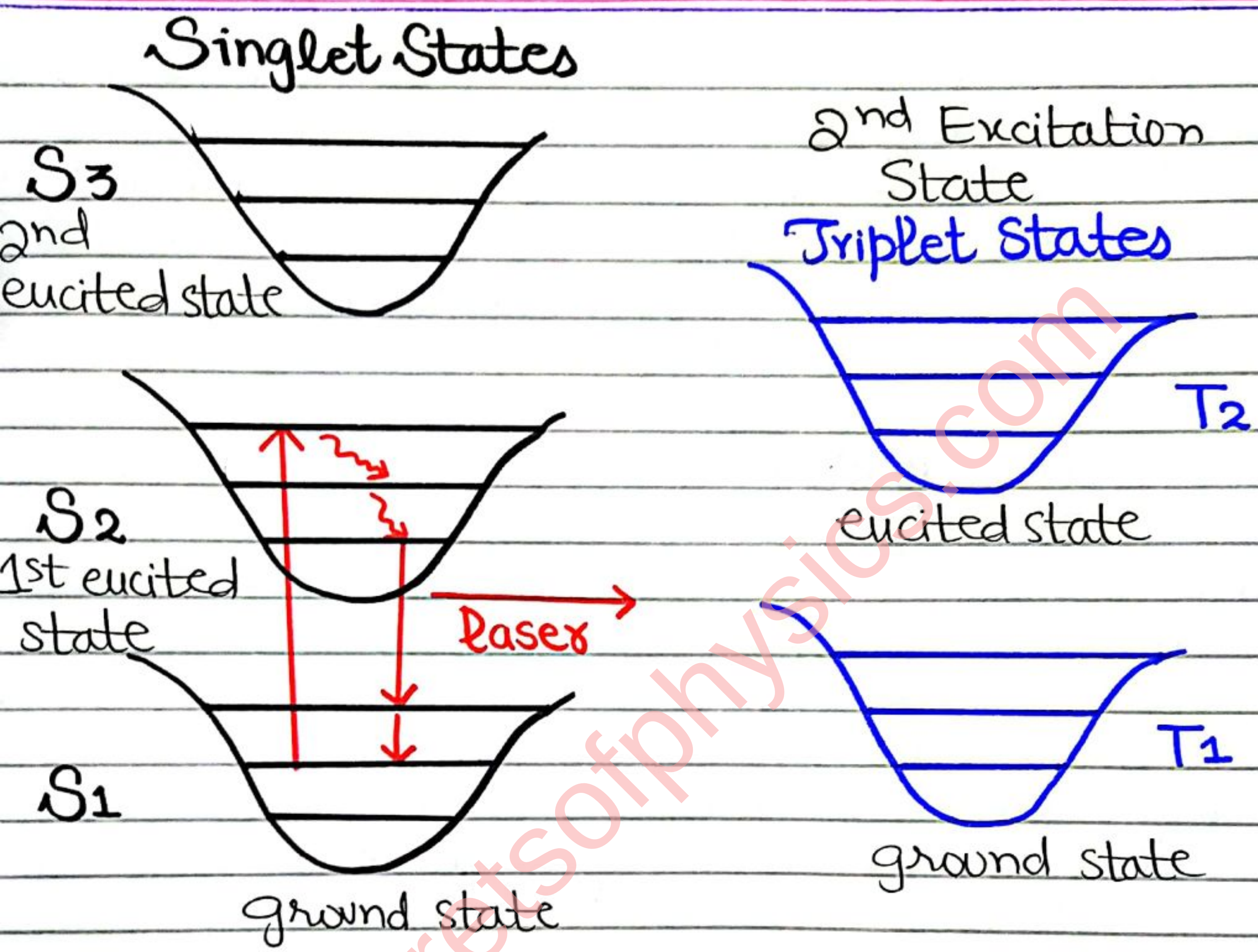


We already have laser light at the input for optical pumping. We use cylindrical lens to make dye cells (1cm). The lens focuses light on one point and excitation produces. The dye cell is further connected to a **cooling system** and fully reflective mirror is attached where photon reflects and go back to the cell.

We have **gratings** or **prism** that allows selection of a particular wavelength, allowing us to **tune** the laser. The prism makes the light to pass through it and same component wavelength could be achieved, at a specific threshold condition.

By rotating the grating continuously, we can set the angle where maximum laser output is given. To measure the laser, we use **sensor** in front of it, so sensor is further attached with a computer system and we can see the particular wavelength on computer.

Working:- Because of the rotational and vibrational energy levels, we gain the output laser. And energy levels have **singlet** and **triplet**. If the ground state is singlet, according to selection rules, singlet to singlet excitation is possible. $\Delta l = 0$
Singlet to triplet transition is not possible.

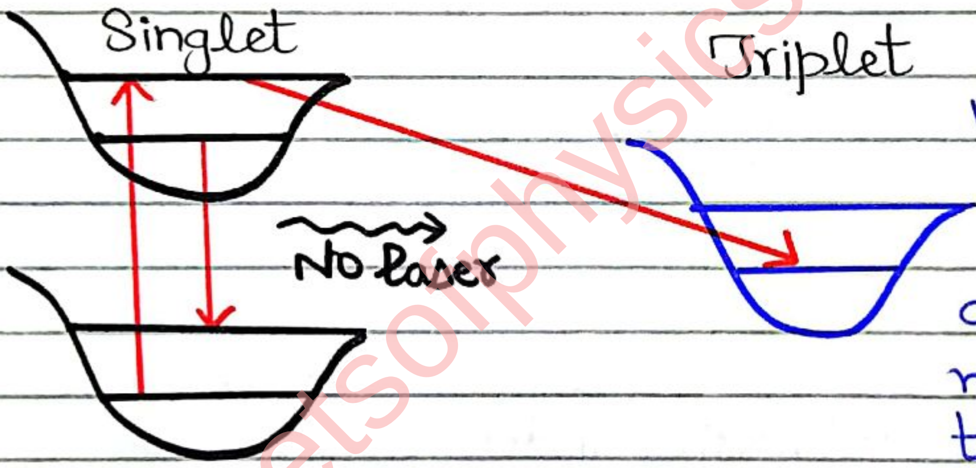


From pump source, atom takes up energy and goes to the excited state, after that de-excitation process occurs from the lower vibrational energy level of the excited state to the upper vibrational energy level of ground state and hence we obtain laser light.

Vibrational energy levels have small difference so multiple emissions are possible depending upon the cavity's wavelength. Due to multiple reflections b/w grating and fully reflective mirror, we get coherent light as laser.

Uses:- (1) Scientific purpose.
(2) To investigate energy levels.
(3) To find probability of energy levels.
(4) To investigate atomic levels.

* Some molecules de-excite and goes to the triplet state and remain trapped inside the triplet state, and no radiation is produced.



Solution:- We flow oxygen in dye lasers which act as quinching and molecules return to ground state.

Advantages:-
(1) They are tunable for wide range of visible and near infrared regions.
(2) They are capable of producing high intensity laser beam.
(3) Can be used with different dyes to achieve diff-wavelength ranges.

Disadvantages:-
(1) More complex than other laser systems.
(2) Dyes can degrade over time.
(3) Require careful handling of solvents and dyes.

Non-Linear Optics (NLO)

Non-linear optics is the branch of optics that describe the behaviour of light in non-linear medium (a medium in which polarization density **P** responds non-linearly to the electric field **E** of the light.

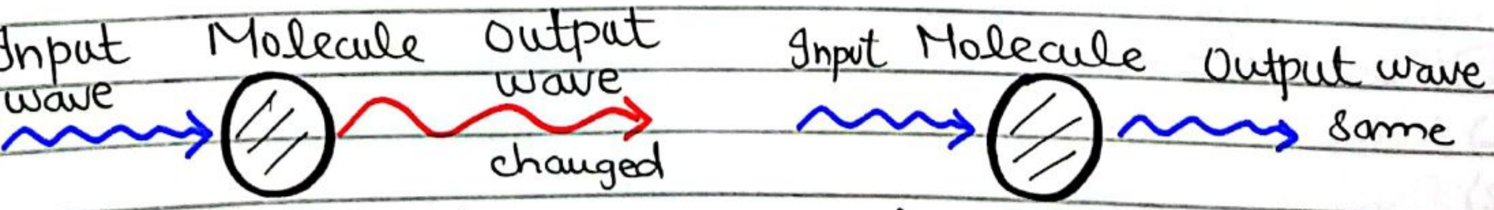
Strong Non-linear Effects:-

Non-linearity is typically observed only at very high intensities (when E·F is $>10^8$ V/m or 10^{11} V/m) such as those provided by lasers.

Weak Non-linear Effects:-

For low optical intensities, non-linear effects become weak. Therefore non-linear optical effects are difficult to observe. When intensities are low, the E·F interacts with the polarization state of material and no change in **refractive index** occurs, hence light behaves linearly.

So, if a photon interacts with a material and at the output, we get same photon, it is bcz the intensity is low and E·F is low so no polarization state changes.



Non-Linear Optiss   Linear Optics

Ordinary Light (Linear Behaviour)

Normally, the ordinary light is not much intense, and the electric field varies from (1–10,000) V/cm. So the behaviour of ordinary light is linear.

Laser Light (Non-linear Behaviour)

As, we know that laser light is highly intense light (10^{12} V/cm) and the electric field is (10^6–10^8) V/cm. When this light passes through the crystal, it interacts with the crystal and changes the polarization state of the material, Hence this phenomenon is called non-linear phenomenon.

$$\vec{P} \propto \vec{E} \quad \text{For ordinary light.}$$

$$P = \varepsilon \chi E$$

For laser light:-

$$\vec{P} = \varepsilon_0 \left(\chi^{(1)} E + \chi^{(2)} E^2 + \chi^{(3)} E^3 + \ldots \right)$$

$\chi^{(1)}E$	$\chi^{(2)}E^2$	$\chi^{(3)}E^3$
1st Harmonic (1064 nm)	2nd: $\frac{1064}{2}$ (532 nm)	3rd: $\frac{1064}{3}$ (355 nm)

Note:- Do applications of non-linear optics from notes (pdf)