LIQUID LASERS/ DYE LASERS:

Originally, a dye was defined as an organic compound (i.e., one that contains the element carbon) that emitted a brilliant color when exposed to visible light. This color could be imparted to other materials such as cloth, which was then said to be "dyed."

* Dye lasers can be operated in both pulsed and CW modes. In the pulsed mode, they usually are pumped by other lasers (e.g., pulsed-nitrogen gas lasers or frequency-doubled ruby or Nd:YAG) or by various types of flash lamps. In the continuous mode, the output of a CW argon ion laser generally is used as the pumping source.
* The most useful feature of dye lasers is their tenability; that is, the lasing wavelength for a given dye may be varied over a wide range. Taking advantage of the broad fluorescent line widths (50-100 nm) available in organic dyes, one uses a wavelength-dispersive optical element such as a diffraction grating or prism in the laser cavity to perform selective tuning. Such tuning can yield extremely narrow line widths.
* Organic dye lasers, because they are both tunable and coherent light sources, are becoming increasingly important in spectroscopy, holography, and in biomedical applications. A recent important application of dye lasers involves isotope separation.
* A dye laser can be considered to be basically a four-level system.
* The optical cavity of the dye laser consists of three mirrors. The output coupler is along-radius or flat mirror. Its transmission is typically between 10 and 20 percent. The two high-reflectance mirrors are curved and mounted at the proper separation and alignment to produce a focal point in the beam within the dye jet. Pump light in the form of the argon laser beam is focused into the dye jet at the same point as the dye laser beam.

Email (alaa.hussein.ali@uomus.edu.iq)

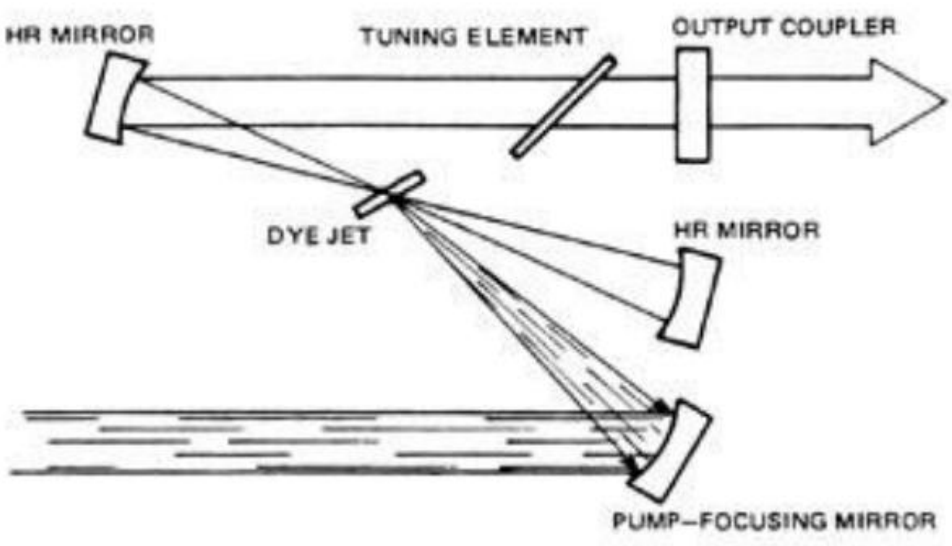

Fig.(12): Dye Laser

Active Medium and Energy Levels in Dye Laser:

Color molecule is made of big organic fluorescent compound which contains large number of cyclic structures.

The active medium in Dye laser is made of color molecule dissolved in liquid which is usually a type of alcohol.

Because of the interaction of the color molecules and the solvent, there is a broadening of the vibrational energy levels. As a result, wide spectrum bands are formed.

Solutions of organic color molecules have wide absorption and emission bands. An example of the spectral bands for the common color: Rhodamin 6G can be seen in figure (13).

Email (alaa.hussein.ali@uomus.edu.iq)

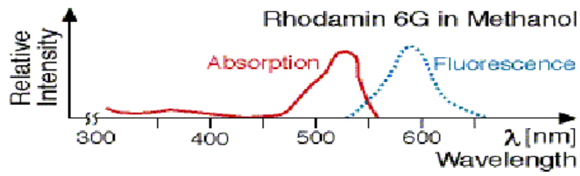

Figure (13): Absorption Spectrum (solid line) and Emission Spectrum (dashed line) of Rhodamin 6G in Methanol.

Simplified Energy Level Diagram of Dye Laser

The structure of energy levels of organic dye molecules in a solvent is very complex. The explanation below is based on a simplified energy level diagram described in figure (14).

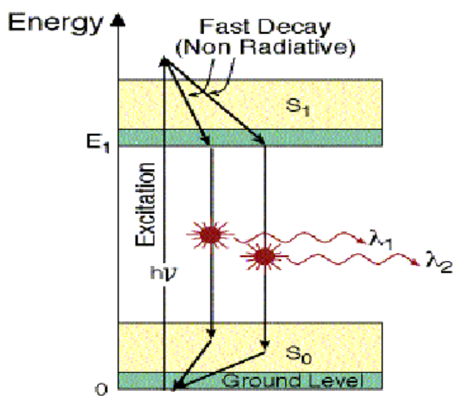

Figure (14): Simplified Energy Level Diagram of Dye Laser.

The width of each energy band is of the order of tenths of electron volts [eV]. At room temperature, the thermal energy of vibration is of the order of 1/40 [eV]. Thus only the bottom of the each energy level is filled (marked darker in figure 14).

Email (alaa.hussein.ali@uomus.edu.iq)

Excitation of Dye laser

Population inversion in Dye laser is done by optical pumping illumination by electromagnetic radiation at the proper wavelength. Since each photon carry a certain amount of energy, and since there is some loss of energy (which turn into heat) in the optical pumping process. Thus, the wavelength emitted from the laser is of longer wavelength than the wavelength of the pump.
When a color molecule is optically excited by absorbing a photon, it "jumps" to an excited state. In a very short time, of the order of picoseconds, the excited molecule will decay to the bottom of the energy band by a non-radiative transition. From this position the molecule can make lasing transition to any place in the lower band, and then, by a non-radiative transition to the bottom of the energy of the ground level. Since lasing transition can occur into any position in the wide lower level, a wide spectrum range of electromagnetic radiation can be emitted from a dye laser.

There are two common arrangements for the dye in a Dye laser:

1. The liquid dye is inside a transparent container, and the optical pump energy is coming through the walls of the container.
2. The liquid dye is flowing through a special nozzle, and the optical pump energy is shining on it while it flow out of the nozzle (see figure 15).

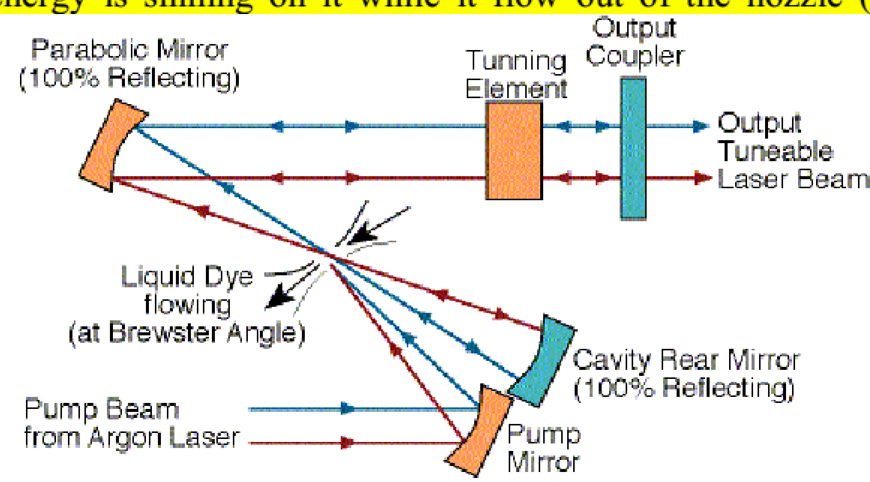

Figure (15): Tunable Dye Laser with Flowing Dye.

Email (alaa.hussein.ali@uomus.edu.iq)

Tuning a Dye laser:

Choosing the right wavelength from a Dye laser is done **by a prism** or **grating at the end of the optical cavity**. An example of tuning with a prism is described in figure (16 a).

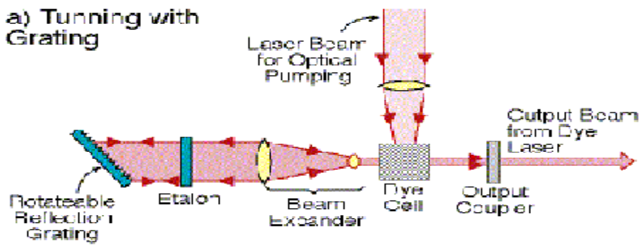

Figure (16 a):Tuning a Dye Laser with a Prism.

An example of tuning with a grating is described in figure (16 b).

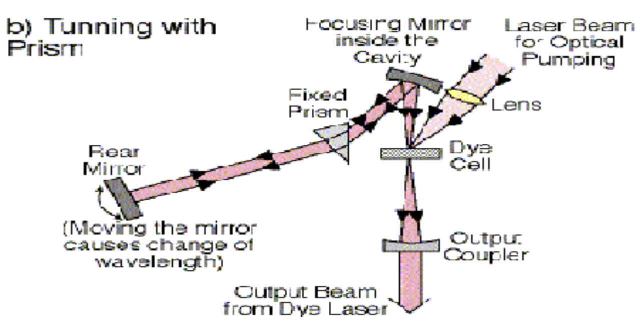

Figure (16 b): Tuning a Dye Laser with a Grating.

Email (alaa.hussein.ali@uomus.edu.iq)

Advantage of Dye Laser:

- Liquid is homogeneous by nature, and there is no difficulty of manufacturing homogeneous perfect solid with no defects.
- It is relatively easy to change the type of liquid used as an active medium. Thus, changing the wavelength range of the emitted radiation.
- The liquid carry with it the heat evolved during the lasing process, so cooling the laser is simple. The active medium is replaced continuously.
- Special properties of the output radiation of a Dye laser are very narrow linewidth and very short pulses.

Disadvantages of Dye Laser:

- Most Dye lasers use liquid as the active medium, which complicate maintenance of the laser.
- The excitation is done by another laser, which complicate the system.
- Short dye lifetime. Dye quality degrades with time and need to be changed.
- Continuing operating expenses.
- Potentially toxic (poisonous) chemicals.

In recent years, Solid state Dye Laser are being developed.
By embedding the dye molecules in a solid matrix, the disadvantages of the liquid are eliminated.

Classification of Dye Laser according to Groups:

- Liquid active medium.
- Operate mostly in the visible spectrum.
- Excited optically-usually by another laser.
- Can emit radiation continuously or in pulses- as determine by the excitation mechanism and the laser structure.
- Four level lasers.
- Tunable laser.

Email (alaa.hussein.ali@uomus.edu.iq)