Table1 is a comparison of energies involved in electronic, vibrational, and rotational transitions. The total energy of a molecule is the sum of its electronic, vibrational, and rotational energies.

Type of transition	Typical Energy (eV)	Wavelength Range
Electronic	1-10	UV, Visible ,near IR
Vibrational	0.1-2	Near IR-Middle.IR
Rotational	10^{-5}-10^{-3}	Far IR-Microwave

Table 1: Energies involved in different transitions.

Energy levels for a laser might involve more than one mechanism. In the nitrogen laser, for example, the lasing transition is a vibronic one involving both electronic and vibrational levels. This leads to a gas laser transition with relatively broadband output.

Dye lasers usually involve all three mechanisms which leads to a continuum output over a given range. By tuning the feedback mechanism one can selectively amplify a given wavelength–these lasers are truly tunable.

In ion lasers there are a number of laser transitions closely spaced (in the case of an argon ion laser, ten lasing lines appear in the blue – green - violet region).

1.2.3 Level Lifetime

One problem that might be encountered along the way is the lifetime of lasing levels. Some levels have very long lifetimes (metastable). If the lower level of the lasing transition has a longer lifetime than the upper level then lasing action may not be possible at all or might be possible only in pulsed mode. Many practical lasers such as the nitrogen and copper–vapor laser have this situation and they operate strictly in pulsed mode and CW laser action cannot be achieved.

1.3 The Pump Source

The pump source is the part that provides energy to the laser system. The type of pump source used principally depends on the gain medium, and this also determines how the energy is transmitted to the medium. The lasers can be pumped by multiple ways:

Flash lamps are the oldest energy source for lasers. They are used for lower energies in both solid slate and dye lasers. They produce a broad spectrum, causing most of the energy to be wasted as heat in the gain medium. Flash lamps also tend to have short lifetime.

Lasers of a suitable type can be used to pump another laser. Their narrow spectrum makes them more efficient way of energy transfer than flash lamps. Diode lasers are used to pump DPSS lasers.
Microwaves are used to excite gas lasers.

Electric glow discharge is common in gas lasers. eg. in the helium–neon laser.

Electron beams are used in special applications, e.g. the free electron lasers or excimer lasers.

Direct electric current, used to power diode lasers and their subtypes.

Chemical reaction is used as a power source in chemical lasers. This allows for very high output powers difficult to reach by other means.
Solar pumping, strongly focused sunlight is quite capable of producing CW lasing as it has been demonstrated in Nd:YAG laser.

1.4 The Optical Cavity

An optical resonator is an arrangement of optical components, which allows a beam of light to circulate in a closed path so that it retraces its own path multiple times, in order to increase the effective length of the media with the aim of large light amplification analogous to the positive feedback in electronic amplifiers. Combination of optical resonator with active medium is known as optical oscillator.

In the design of a real-world laser, the optical resonator is often the most critical component, and, particularly for low-gain lasers, the most critical components of the resonator are the mirrors themselves

The critical factors for a mirror, other than transmission and reflection, are scatter, absorption, stress, surface figure, and damage resistance.

In commercial lasers the rear mirror (totally reflecting) is almost always a dielectric mirror designed to reflect as much light as possible back into the gain medium. Such a mirror may have twenty or more alternating thin dielectric films (such as magnesium fluoride, cerium oxide, or similar dielectric material). A regular aluminized mirror reflects only about 80% of incident light (absorbing 20%). That represents a huge loss in a laser and may not allow lasing of weak transitions (like most gas lasers have). Dielectric mirrors also have the property of being reflective at only one band of wavelengths. HeNe laser mirrors (which are always dielectric) reflect red light very well but actually transmit blue.

The output coupler must also be selected with respect to the ratio of how much light is reflected to how much is transmitted. High transmission ratios represent a high loss to the laser. Many gas lasers use output couplers with transmissions between 1% and 5%. It should be evident from these figures why high performance dielectric mirrors are required for most lasers to work.

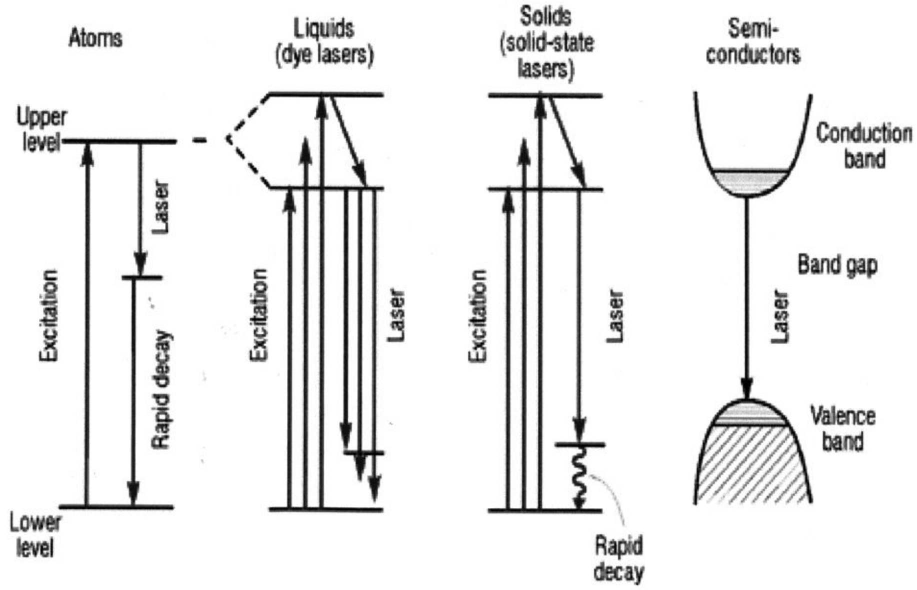
Many cavity configurations are possible including the use of plane (flat) mirrors and/or concave mirrors. Flat mirrors are the easiest to obtain however a cavity built with two flat mirrors is very difficult to align. Flat mirrors work well in short lasers with a large diameter gain medium (e.g. YAG, N_2, etc) but not with long gas lasers with small bores (e.g. Argon). Concave mirrors may be used and make cavity alignment much easier but focal lengths must be chosen so that light is trapped within the cavity. As an example, if a cavity consists of one flat and one concave mirror, then the concave mirror must have a focal length longer than the distance between the mirrors in order to ensure light within the cavity does not escape. If two concave mirrors are used, their focal lengths must be greater than half the distance between the mirrors. Geometric optics formulae must be used to ensure the cavity is stable and will resonate.

1.5 Population Inversion in lasing medium

- Gas laser — electrical gas discharge
  - −optical pumping (with another laser)
  - −electron beam irradiation
  - −Chemical reaction
- Solid state laser — flash lamp

−optical pumping with semiconductor lasers

- Liquid laser −flash lamp
  −optical pumping (with another laser)
- Semiconductor laser −injection current



Inversion processes in gases, liquids, solids, and semiconductors.

1.6 Modes of Operation

Lasers may operate in continuous mode (known as continuous wave (CW) or in a pulsed mode. For maximum efficiency, the composition and concentration of the lasing medium, as well as construction of the laser cavity and mirrors must be optimized for pulsed or CW operation.

1.6.1 Continuous wave lasers (CW lasers)

With CW lasers, energy is continuously applied, or pumped into a lasing medium, producing a continuous laser output. Because gain medium is constantly being excited, the power of CW lasers is limited since the gain medium can overheat.

1.6.2 Pulsed lasers

With pulsed lasers, the pump energy is applied in pulses, usually with a flashlamp in the case of solid state lasers, or pulsed radiofrequency energy in the case of gas laser. Laser light is emitted very briefly, 10 ms to 10 fs. Laser pulses can appear as a single pulse or repetitive pulses, and the rate of pulses can be as high as thousands of millions per second.

1.7 Output Parameters

Many output laser parameters will be discussed as follows:

1.7.1 Laser power and laser energy

The power (p) is expressed in Watts (W), and the energy (Q) in Jouls (J). These parameters are related by the expression: $Q=p\times t$, where t is the time in seconds.

The output of CW lasers, like that of a light bulb or electric heater, is measured as power in Watts, referring to the rate at which work is performed, or the energy applied per unit time. Because of the spiking output of pulsed lasers, the precise output power of a given laser pulse may be difficult to determine although the energy and pulse duration usually remain constant. For this reason, the output of pulsed lasers is more conveniently expressed as energy in joules.

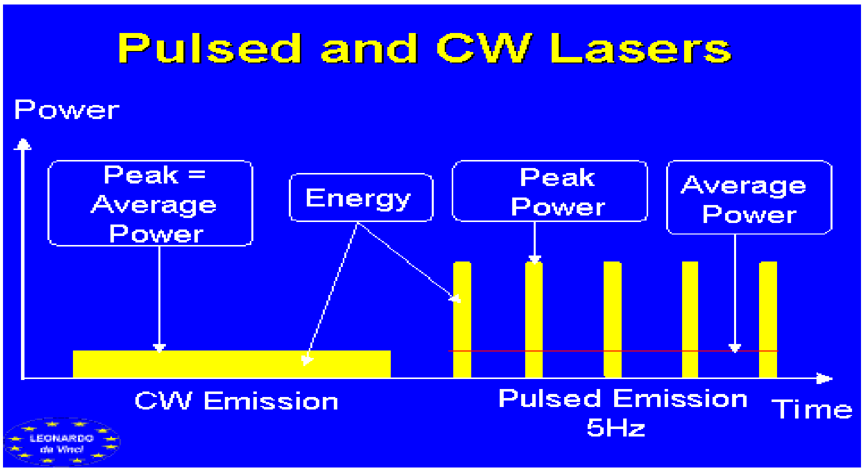


Figure1.4: Pulsed and CW lasers

Energy is not enough, since the same amount of energy can be transmitted in a short time using high power, or in a long time using low power. For pulsed laser, the following detailed parameters of the pulses are important :

- Energy per pulse (E_p): the average energy of each pulse.
- Pulse duration ($\Delta t_{1/2}$), which is called pulse width that measured at half maximum (FWHM).