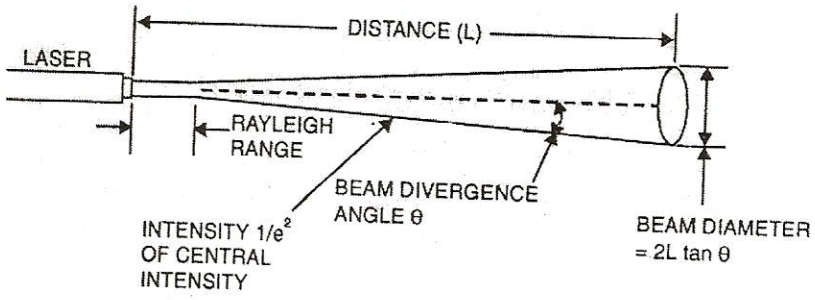
CHIEF CHARACTERISTICS OF LASER

The word LASER stands for Light Amplification by Stimulated Emission of Radiation. Laser is a light source very much different from traditional light sources like candle or electric bulb, which are basically used for illumination purposes.

The chief characteristics of laser are:

Directionality – The conventional light sources emit light in all directions. In case of laser, active material is in a cylindrical resonant cavity. Any light that is traveling in a direction other than parallel to the cavity axis is eliminated and only light that is traveling parallel to the axis emerges from the cavity and becomes the laser beam. Hence, the light emitted by a laser is only in one direction. The directionality of a laser beam is expressed in terms of beam divergence. Light from a laser diverges very little. Up to certain distance, beam remains a bundle of parallel light rays. The distance from the laser over which the light rays remain parallel is known as Rayleigh range. The laser beam diverges beyond Rayleigh range.



Divergence of a laser beam

The beam divergence due to size of the beam waist d_o and wavelength λ is given by

$$\theta = \frac{2\lambda}{\pi d_o}$$

The beam divergence due to diffraction is determined from Rayleigh's criterion and is given by

$$\theta = \frac{1.22\lambda}{D}$$ Where λ is wavelength and D is diameter of laser's aperture.

From the above two formulae, we see that beam divergence is inversely proportional to d_o or D.

Intensity – The power output of laser may vary from a few mW to a few kW. But this energy is concentrated in a beam of very small cross-sectional area. Hence, intensity of a laser beam is very high.

The intensity of a laser beam is given by

$$Intensity = \frac{Power}{Area}$$ Unit is watt per square meter

$$I = \frac{P}{A}$$

The intensity is also given by (approximately)

$$I = \left(\frac{10}{\lambda}\right)^2 P$$

Coherence – Light waves are said to be coherent if they are in phase with each other. The light that emerges from conventional light sources are incoherent but light from a laser is a resultant of a large number of identical photons, which are in phase and therefore exhibits a high degree of coherence. Thus, we get a highly coherent beam of light from a laser source.

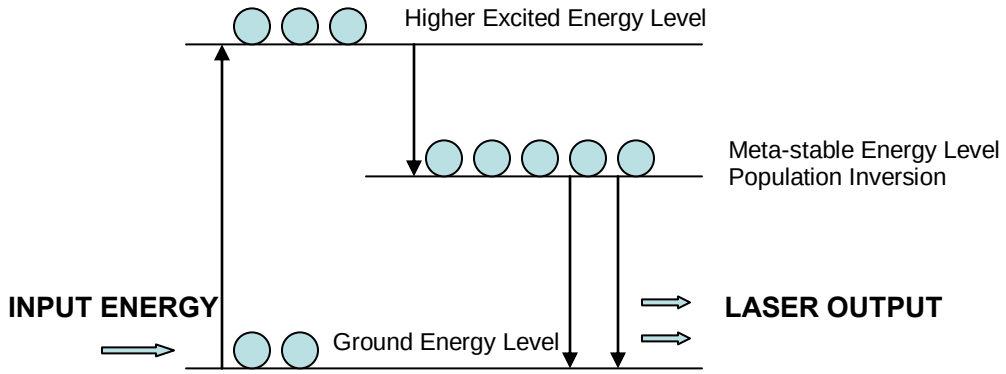
Monochromaticity – Light containing single wavelength or frequency of oscillation is said to be monochromatic and the source a monochromatic source. In actual practice, light from any source consists of a band of frequencies, $\Delta\nu$, closely spaced around the central frequency ν_o. The band of frequencies $\Delta\nu$ is called the line-width or bandwidth.The light from conventional sources has large bandwidths of the order of 10^{10} Hz or more. On the other hand, light from a laser, is highly monochromatic having bandwidth of the order of 100 Hz or so.

Thus, laser is a highly directional, energetic, coherent and monochromatic beam of light, far different from ordinary light.

Population inversion – Under ordinary conditions of thermal equilibrium, the number of atoms in higher energy level is considerably smaller than the number of atoms in lower energy level, so that there is very little stimulated emission compared to absorption. In such situation, incident photon is more likely to be absorbed rather than emission. Hence, laser action will not take place. If however, the larger numbers of atoms are made available in the higher energy level as compared to lower energy level, then, stimulated emission will take place easily. This process of achieving the larger number of atoms in the higher energy level than the lower energy level is known as population inversion. This means

that population inversion is a necessary condition to be satisfied for causing the amplification of light.

Pumping – In order to realize and maintain the state of population inversion, it is necessary that the atoms must be continuously promoted from the lower level to the excited level. Energy is to be supplied somehow to the laser medium to raise atoms from the lower level to the excited level and for maintaining population at the excited level at a value greater than that of the lower energy. The process by which atoms are raised from the lower level to the upper level is called pumping. Population inversion cannot be achieved by heating the material. The most commonly used pumping methods are: optical pumping, electric discharge, direct conversion, chemical reaction, inelastic atom-atom collision etc.



Meta-stable states – An atom can be excited to a higher energy level by supplying energy to it. Normally, excited states have short life times and release their excess energy in a matter of nano-seconds (10^{-9} second) by spontaneous emission. Thus, population inversion cannot be established. To achieve this, an excited state with a longer life time is needed. Such states where atoms remain for an appreciable time (10^{-6} to 10^{-3} second) are known as meta-stable states. In meta-stable state, population of atoms can exceed the population of atoms of a lower level and lead to the state of population inversion. If the meta-stable states do not exist, there could be no population inversion, no stimulated emission and hence no laser action.

Source : http://msk1986.files.wordpress.com/2011/04/sem-ii-coherence-laser.pdf