3.3 LASER MODES

Surely laser cavity is also very important for a laser in many other aspects, for example, its dimension decides the longitudinal laser modes. Generally speaking light modes means possible standing EM waves in a system. The number of modes in this meaning is huge. Laser mode means the possible standing waves in laser cavity. We see that stimulated lights are transmitted back and forth between the mirrors and interfere with each other, as a result only light whose round trip distance is integer multiples of the wavelength l can become a standing wave. That is:

$$m = 2L/(c/f) = 2L/l \text{ , or } f = m\, c/(2L), \text{ D } f = c/(2L)$$

Where L is the length of cavity, c is the light speed in laser cavity, f is the frequency of standing wave, l is the wavelength, m is an integer , D f is the frequency difference between two consecutive modes. The number of longitudinal modes may be very large, it can also be as small as only a few (below 10). If we intersect the output laser beam and study the transverse beam cross section, we find the light intensity can be of different distributions (patterns). These are called Transverse Electromagnetic Modes (TEM). Three index are used t_o indicate the TEM modes TEM_{plq}, P is the number of radial zero fields, l is the number of angular zero fields, q is the number of longitudinal fields. We usually use the first two index to specify a TEM mode, like TEM00, TEM10, etc. Clearly, the higher the order of the modes the more difficult it is poor to focus the beam to a fine spot. That is why some times TEM00 mode or Gaussian beam is preferred

TEM Mode, Beam Diameter, Focal Spot Size and Depth of Focus

Modes are the standing oscillating electromagnetic waves which are defined by the cavity geometry. In the above section, we already computed the Longitudinal Modes frequencies for some simple cases. If the cavity is of closed form, i.e., both the mirrors and side walls are reflective, there will be large amounts of longitudinal modes oscillating inside the cavity, a typical value can be 109 modes for a He-Ne laser.

When these modes oscillate, they interfere with each other, forming the transverse standing wave pattern on any transverse intersection plane. This mechanism decides the Transverse Electromagnetic Modes (TEM) of the laser beam, which is the wave pattern on the output aperture plane. We use the sign TEMpql to specify a TEM mode, where p is the number of radial zero fields, q is the number of angular zero fields, q is the number of longitudinal fields, and we usually use TEMpq to specify a TEM mode, without the third index. A table of TEM patterns is shown below. Clearly, the mode pattern affects the distribution of the output beam energy, which will thus affect the machining process. Then what is the diameter of a laser beam? Usually this diameter is defined as the distance within which 1/e2 of the total power exists. The higher the or der of the mode, the more difficult it is to focus the beam to a fine spot, since the beam of higher order is not from a virtual point, but from patterns as those in the table below.

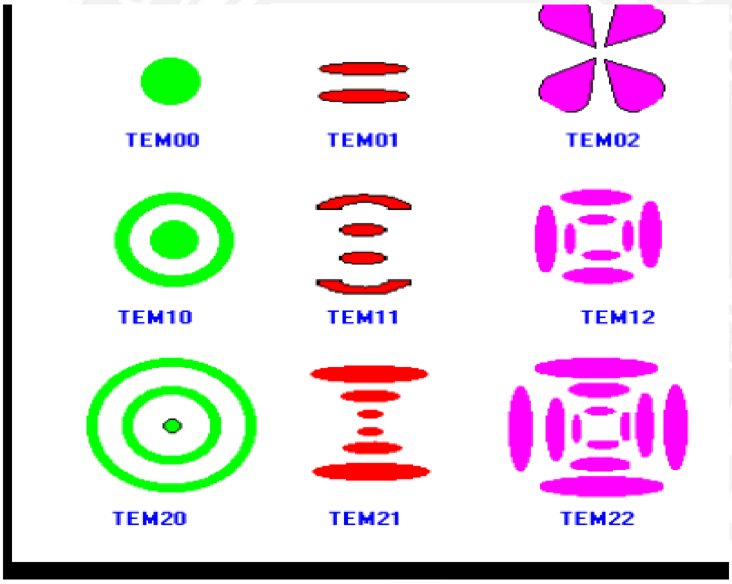

Figure 3.3.1 Transverse Electromagnetic Modes

[Source: "Optical Fibre Communications" by J.M.Senior, Page:361]

Focal Spot Size:

Focal spot size determines the maximum energy density that can be achieved when the laser beam power is set, so the focal spot size is very important for material processing.When a beam of finite diameter D is focussed by a lens onto a plane, the individual parts of the beam striking the lens can be imagined to be point radiators of new wave front. The light rays passing through the lens will converge on the focal plane and interfere with each other, thus constructive and destructive superposition take place.