3.4 RESONATOR CONFIGURATION

The most widely used laser resonators or cavities have either plane or spherical mirrors of rectangular or circular shape, separated by some distance L. There have appeared Plane Parallel Resonators, Concentric (Spherical) Resonators, Confocal Resonators, Generalized Spherical Resonators and Ring Resonators.

Plane Parallel Resonator consists of two plane mirrors set parallel to each other, as Shown in the figure below. The one round trip of wave in the cavity should be an integral number times 2ı , the resonant frequencies is ı = kc/(2L), k is an integral number, c is the speed of light in the medium, L is the cavity length. The frequency difference between two consecutive modes (possible standing wave in the cavity) is c/(2L). This difference is referred to as the frequency difference between two consecutive longitudinal modes; the word longitudinal is used because the number k indicates the number of half wavelengths of the mode along the laser resonator, i.e., in the longitudinal direction.

Concentric resonator consists of two spherical mirrors with the same radius R separated by a distance L=2R, so that the centers are coincident. The resonant frequencies use the same equation as above. Confocal resonator consists of two spherical mirrors of the same radius of curvature R separated by a distance of L such that their foci F1 and F2 coincident. In this case, the center of curvature of one mirror lies on the surface of another mirror, L=R. The resonant frequency cannot be readily obtained from geometrical optics consideration.

Resonators formed by two spherical mirrors of the same radius of curvature R and separated by a distance L such that R<L<2R, i.e., in between confocal and concentric, are called Generalized Spherical Resonators, which is also often used.

Ring Resonator is a particularly important class of laser resonators. The path of the optical rays is arranged in a ring configuration or more complicated configurations like folded configurations. We can compute the resonant frequencies by imposing the constraints that the total phase shift along the ring path or the closed loop path must be equal to the integral numbers of 2ı . Then the resonant frequencies are ı = kc/Lp, where k is an integral number, Lp is the loop path length.

Cavities can be identified as stable or unstable according to whether they make the oscillating beam converge into the cavity or spread out of the cavity. The output mirror of the laser resonator is finely coated to reach the required reflection into the cavity, if the beam is too intense, the mirror May suffer breakage. Breakage is serious because it causes shut down of the production. So for powers up to 2kW, lasers mainly use stable cavity designslaser output is from the center of optical axis. Stable cavity design allows the beam to oscillate many times inside the cavity to get high gain, the focal property and directionality are improved. For higher powered lasers, unstable cavities are often used laser output comes from the edge of the output mirror, which is often a totally reflecting metal mirror. The ring shaped beam reduces the intensity of the beam, thus reduces the risk of breakage. In the same time ring shaped beam is poor for focusing. Unstable cavities are suitable for high gain per round trip laser systems, which don't require large numbers of oscillation between the mirrors.

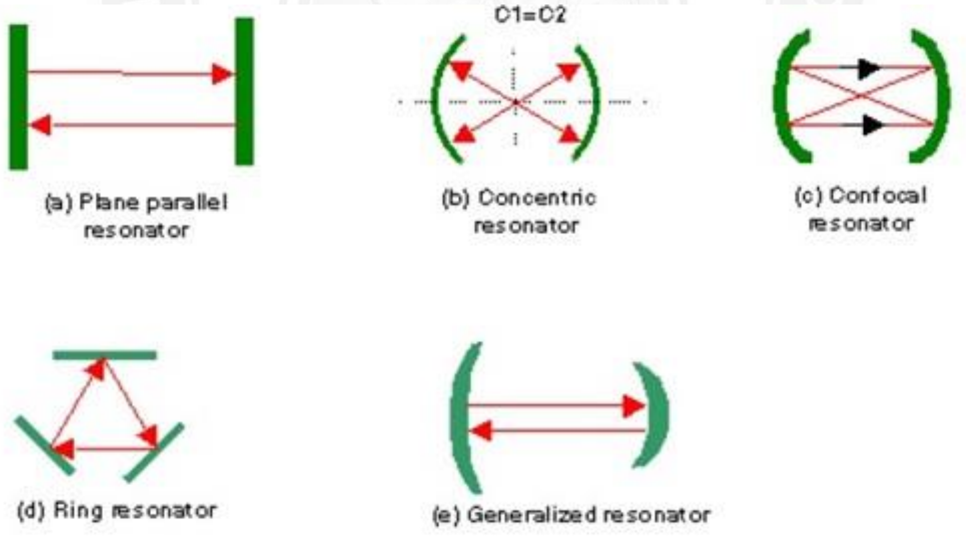

Figure 3.4.1 Various Resonator

a)Plane Parallel b)Concentric c)Confocal d)Ring e)General

[Source: "Optical Fibre Communications" by J.M.Senior, Page:372]

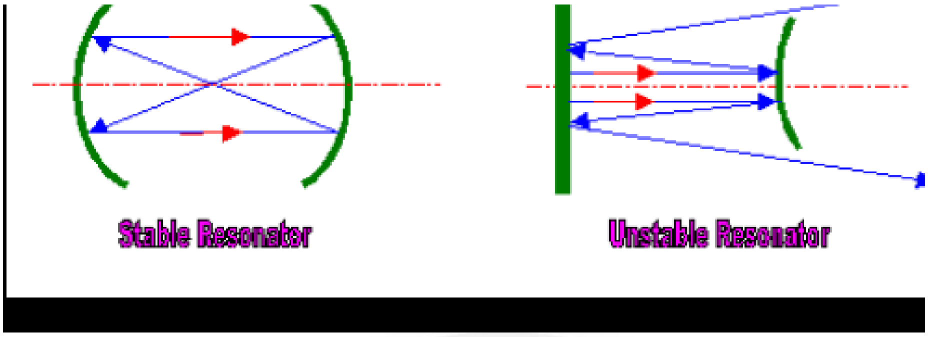

Figure 3.4.2 Stable and Unstable Resonator

[Source: "Optical Fibre Communications" by J.M.Senior, Page:374]

Q-Switching and Mode Locking

Q-Switching

If the energy stored in the dominant mode is very large, we get high Q. Q – switching means maintaining the population inversion to a very high value above the threshold population inversion and simultaneously bringing down all the atoms to undergo laser transition. This will lead to a gaint pulse with very high power(>10^9 W)

Energy of the pulse(E)= $h\lambda(N_Q-N_t)V$

Q Switching Technique:

Pockel cell acts as a quarter wave plate producing a phase difference of . When there is no voltage given to cell, there is no phase shift for linearly polarized light from the polarizer. Let the light photon travel from mirror M1 to M2. Whem=n the voltage is given to the cell, there is a phase shift of . Therefore, the linearly polarized light ius converted into circularly polarized light. Reflection at the mirror M2 changes the direction of rotation of circularly polarized light. So, the polarizer does not allow this light to pass through it. Now, the cavity is switched off. Thus, when the voltage given to the cell is zero, the cavity is Q- switched and if there is voltage, the cavity is inactive to produce laser oscillation. The changes of voltage from zero to a non-zero, the cavity is Q switched and if there is voltage, the cavity is inactive to produce laser oscillations.

Mode Locking:

Modelocking is a technique in optics by which a laser can be made to produce pulses of light of extremely short duration, on the order of picoseconds (10-12s) or femto seconds (10-15s).The basis of the technique is to induce a fixed phase relationship between the modes of the laser's resonant cavity. The laser is then said to be phase-locked or mode-locked. nterference between these modes causes the laser light to be produced as a train of pulses. Depending on the properties of the laser, these pulses may be of extrem ely brief duration, as short as a few femtoseconds Methods for producing modelocking in a laser may be classified as either active or passive. Active methods typically involve using an external signal to induce a modulation of the intra-cavity light. Passive methods do not use an external signal, but rely on placing some element into the laser cavity which causes self-modulation of the light

Cavity Damping

In addition to Q- switching , cavity dumping is a method for producing short pulses with duration is the nano second to microsecond time. Here the laser is excited simultaneously. The resonance cavity has a high Q so that the laser light simply remains in the cavity.