Active Resonator

In this section we will analyze the changes that occur if a lasing medium is inserted into the resonator. In CW and high-average-power solid state lasers the dominant effect that distorts the mode structure in a resonator is thermal lensing. Heat removed from the rod surface generates a thermal gradient.

The thermally induced spatial variations of the refractive index cause the laser rod to act as a positive lens with a focal length that depends on the power dissipated as heat from the pump source.

Resonator Containing a Thin Lens. We will analyze the case of a resonator containing an internal thin lens. To a first approximation, this lens can be thought of as representing the thermal lensing introduced by the laser rod.

Beam properties of resonators containing internal optical elements are described in terms of an equivalent resonator composed of only two mirrors. The pertinent parameters of a resonator equivalent to one with an internal thin lens are

$$g_1 = 1 - \frac{L_2}{f} - \frac{L_0}{R_1}, \quad g_2 = 1 - \frac{L_1}{f} - \frac{L_0}{R_2}, \qquad \ldots (1)$$

where $L_0 = L_1 + L_2 - (L_1 L_2/f)$ and f is the focal length of the internal lens; L_1 and L_2 are the spacings between mirrorsM_1,M_2 and the lens, as shown in Fig.2a. The stability condition remains unchanged.

For the subsequent discussions we find it convenient to express the spot sizes in terms of g_1 and g_2. By combining R_1, R_2, and L with the relevant g_1 and g_2 parameters, can be written

$$w_1^2 = \frac{\lambda L}{\pi}\left[\frac{g_2}{g_1(1-g_1 g_2)}\right]^{1/2},$$
$$w_2^2 = \frac{\lambda L}{\pi}\left[\frac{g_1}{g_2(1-g_1 g_2)}\right]^{1/2}. \qquad \ldots (2)$$

From (2) follows

$$w_1^2/w_2^2 = g_2/g_1. \qquad \ldots (6)$$

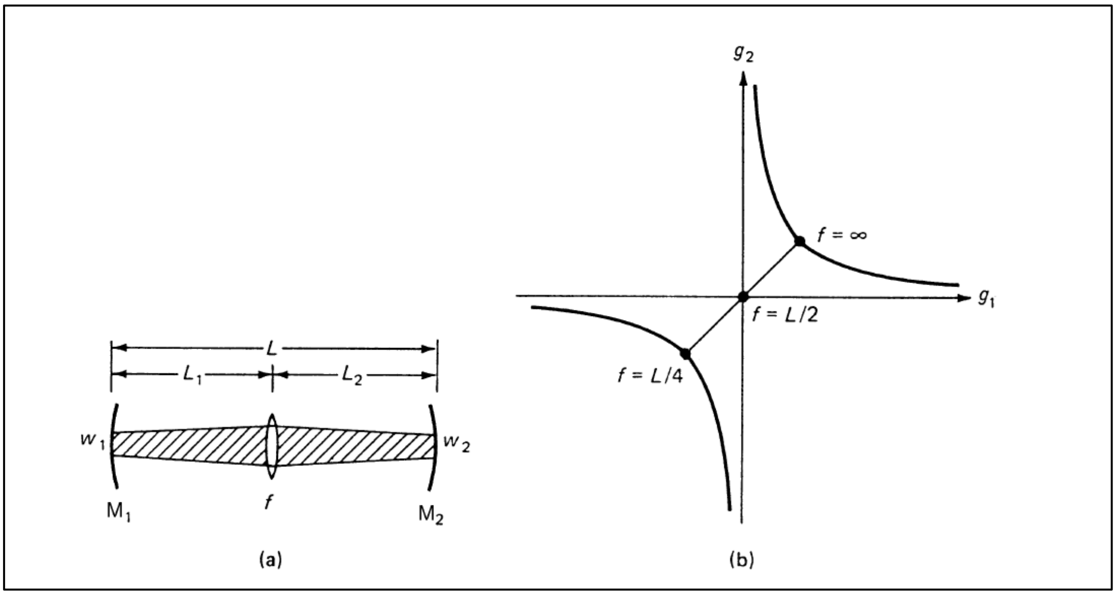

Fig.1 (a) Geometry and (b) stability diagram of a resonator containing a thin positive lens

As an example we will consider a resonator with flat mirrors ($R_1 = R_2 = \infty$) and a thin lens in the center ($L_1 = L_2 = L/2$). From (1) and (2) we obtain

$$g = g_1 = g_2 = 1 - \frac{L}{2f}, \quad w_1^2 = w_2^2 = \left(\frac{\lambda L}{\pi}\right)(1 - g^2)^{-1/2}. \qquad \dots (3)$$

For $f = \infty$the resonator configuration is plane–parallel; for $f = L/2$ we obtain the equivalent of a confocal resonator; and for $f = L/4$ the resonator corresponds to a concentric configuration.

The mode size in the resonator will grow to infinity as the mirror separation approaches four times the focal length of the laser rod. Figure 2b shows the location of a plane–parallel resonator with an internal lens of variable focal length in the stability diagram.

Resonator Sensitivity to Mirror Misalignment.

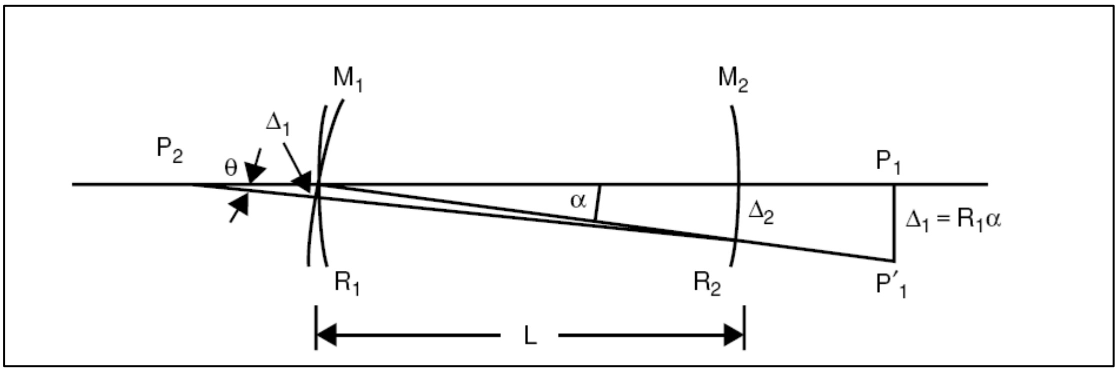

Fig.3 Misalignment of mirror M_1

If mirror M_1 is titled by an angle α, the center of curvature of mirror M_1 moves by $\Delta_1 = R_1\alpha$ to point P'_1. The resonator axis is rotated by an angle θ and the center of the mode pattern is shifted by Δ_1 and Δ_2 at mirror M_1 and M_2, respectively. From geometric considerations one obtains

$$\Delta_1 = \frac{R_1(R_2 - L)}{R_1 + R_2 - L}\,\theta \qquad \Delta_2 = \frac{R_1 R_2}{R_1 + R_2 - L}\,\theta \qquad \ldots (4)$$

We can establish the following criteria for the design of an efficient and practical laser system emitting a high-quality beam:

– The diameter of the TEM00 mode should be limited by the active material.
– The resonator should be dynamically stable, i.e., insensitive to pump-induced fluctuations of the rod's focal length.
– The resonator modes should be fairly insensitive to mechanical misalignments.

H.W

- Consider the lamp-pumped Nd:YAG laser shown in fig. The pumping beam induces a thermal lens of focal length (f) in the rod. Assume that the rod is simulated by a thin lens of focal length (f=25cm) placed at the resonator center. Calculate the TEM_{00} mode spot size at the lens and at the mirror locations.

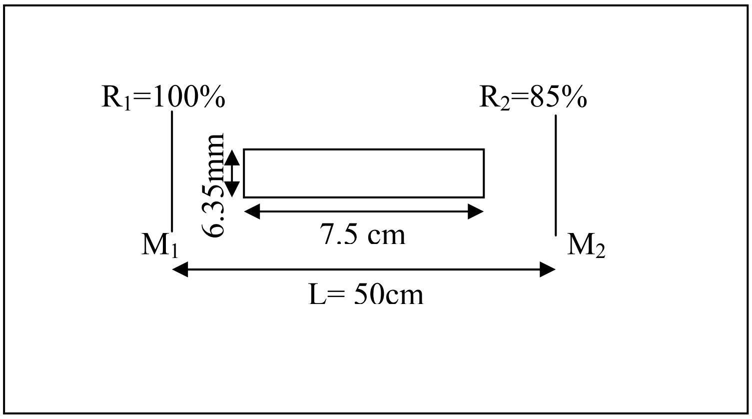

Fig.1

- Due to its relatively small sensitive to mirror misalignment a nearly hemispherical resonator (plane-spherical resonator) with $R=L+\Delta$ and ($\Delta<<L$) is often used for He-Ne laser at λ=630nm, if the cavity length (L=30cm) calculate:
  1. The radius of curvature of the spherical mirror, so that the spot size at this mirror is (0.5mm).
  2. The location in g_1-g_2 plane corresponding to this resonator.
  3. The spot size at the plane mirror.