PH 201

OPTICS & LASERS

Lecture_Lasers_13

Ref.: William T. Silfvast, *Laser Fundamentals*, 2nd ed., Cambridge Univ. Press (2004)

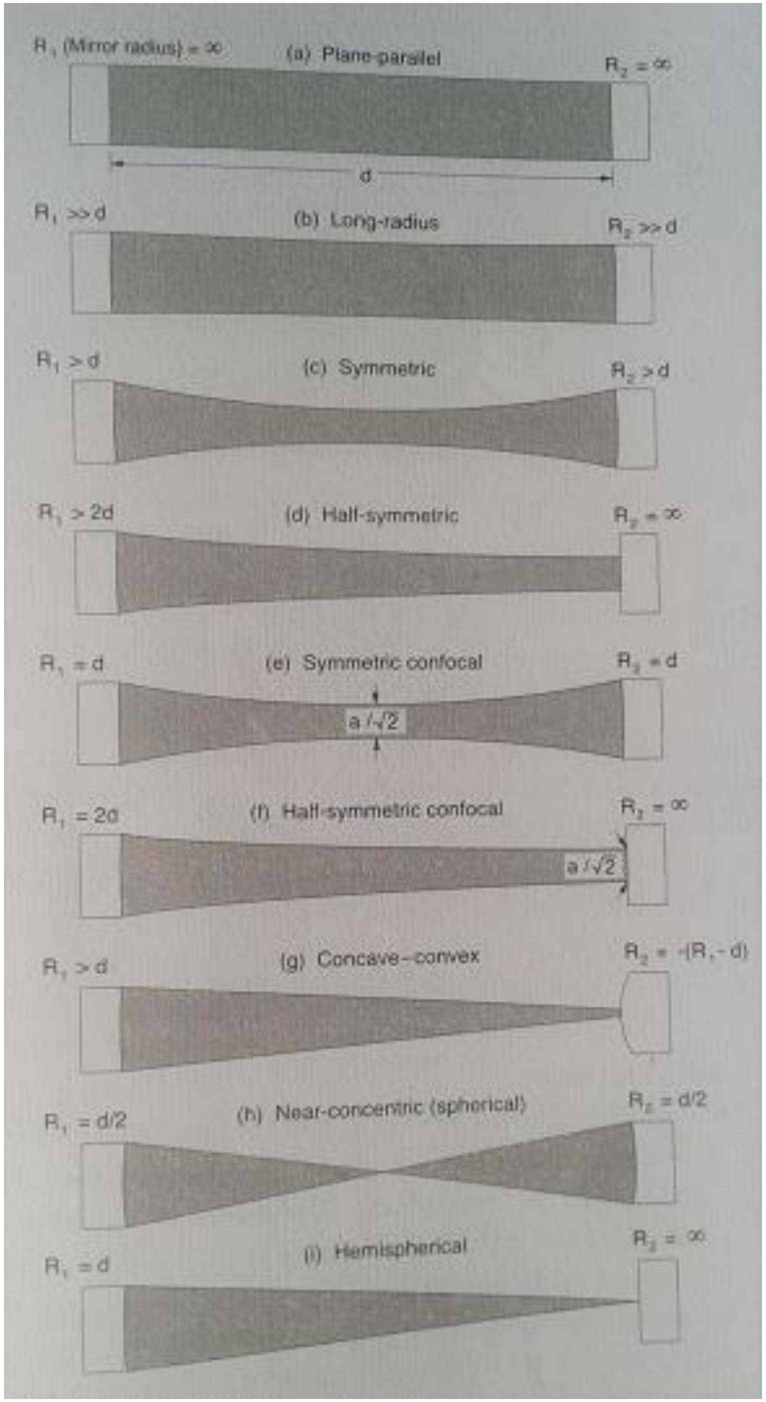
Stable Curved Mirror Cavities

Curved mirrors have lower diffraction losses than plane-parallel mirrors.

There are a number of different types of curved mirror laser cavities, distinguished from each other in terms of radius of curvature and separation between two mirrors.

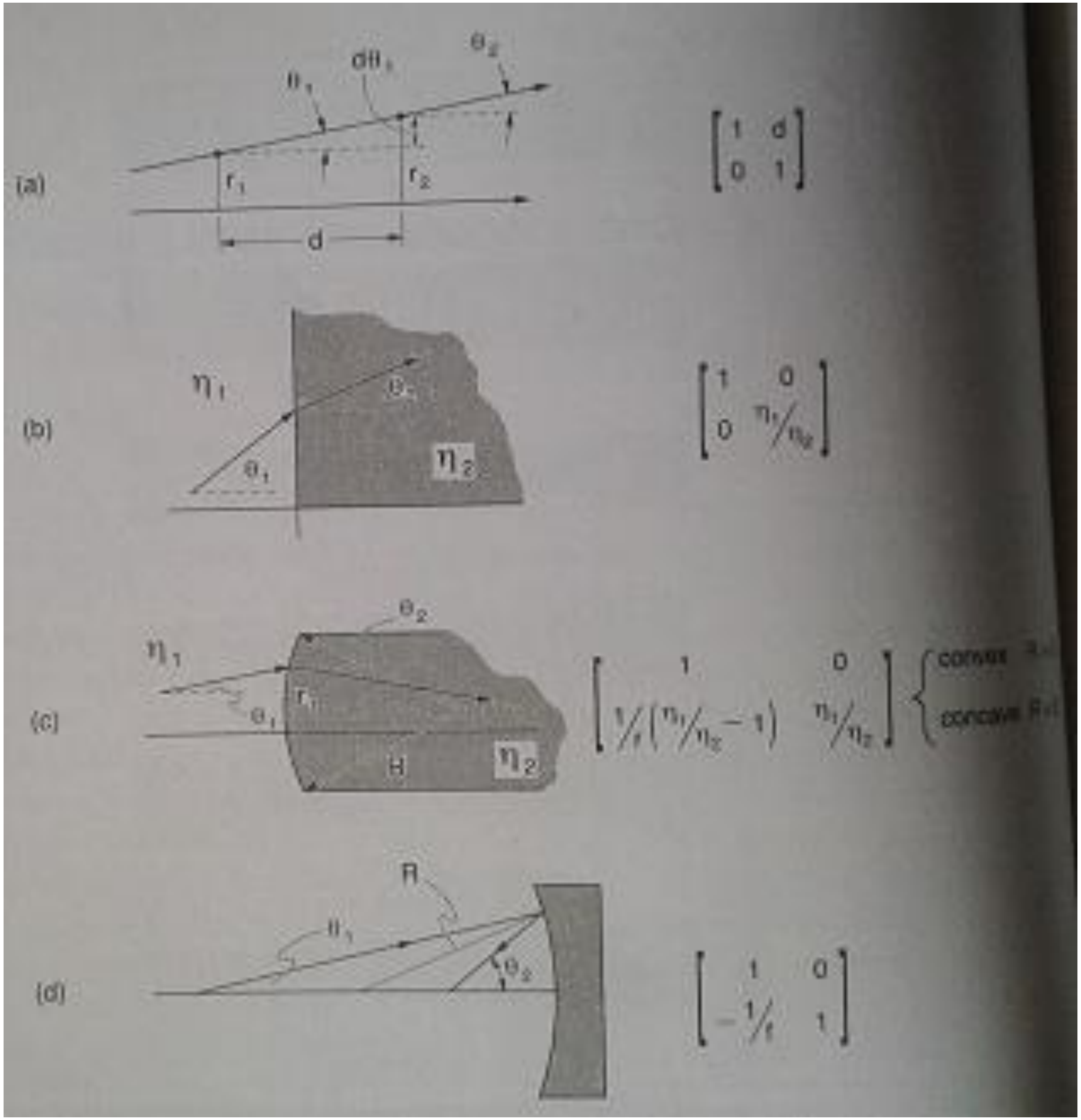
Stable laser cavities: Analyze round trip propagation of a beam from one mirror to other many successive times & then determine conditions for which beam remains concentrated within cavity as opposed to diverging out of cavity. Conditions for which beam converges are designated as stable conditions.

Stability criteria for curved laser resonators – ABCD matrix



Two-mirror laser cavities

ABCD Matrices



ABCD matrices associated with (a) translation, (b) index-of-refraction change, (c) passing through a curved boundary with an index change, & (d) reflecting from a curved mirror.

ABCD Matrices

It offers a convenient form for describing propagation of optical rays through various optical elements.

$$r_2 = r_1 + d\theta_1$$

$$\theta_2 = \theta_1$$

$$\begin{bmatrix} r_2 \\ \theta_2 \end{bmatrix} = \begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ \theta_1 \end{bmatrix}$$

Matrix for translation over a distance *d* can be expressed as,

$$\begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix} \Rightarrow \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

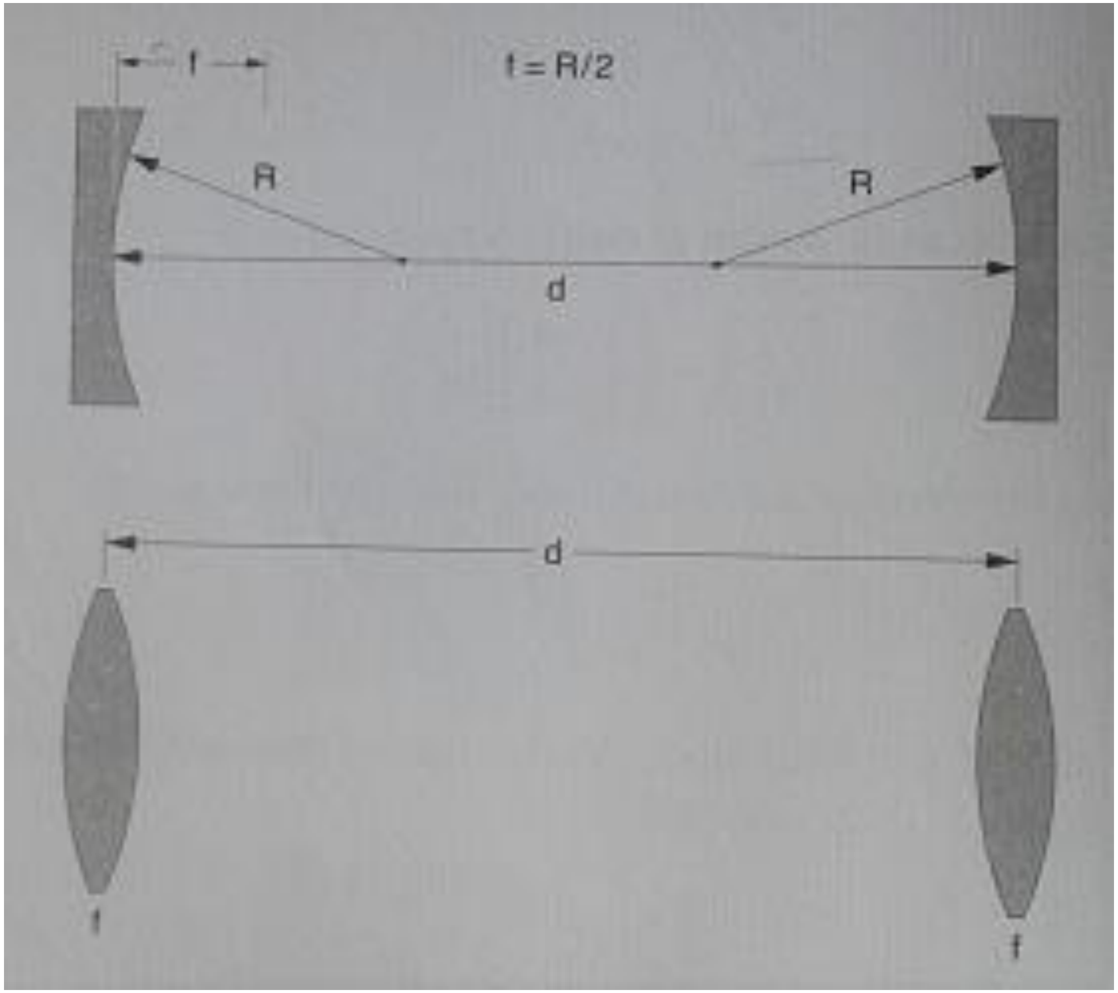
Consider two thin lenses of focal lengths f_1 & f_2 placed adjacent to each other.

$$\begin{bmatrix} r_2 \\ \theta_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -1/f_2 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -1/f_1 & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ \theta_1 \end{bmatrix}$$

$$\begin{bmatrix} r_2 \\ \theta_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -(1/f_1 + 1/f_2) & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ \theta_1 \end{bmatrix}$$

A = 1, B = 0, C = -(1/f_1 + 1/f_2), & D = 1.

Cavity Stability Criteria



Parameters associated with stability analysis of a two-mirror laser cavity

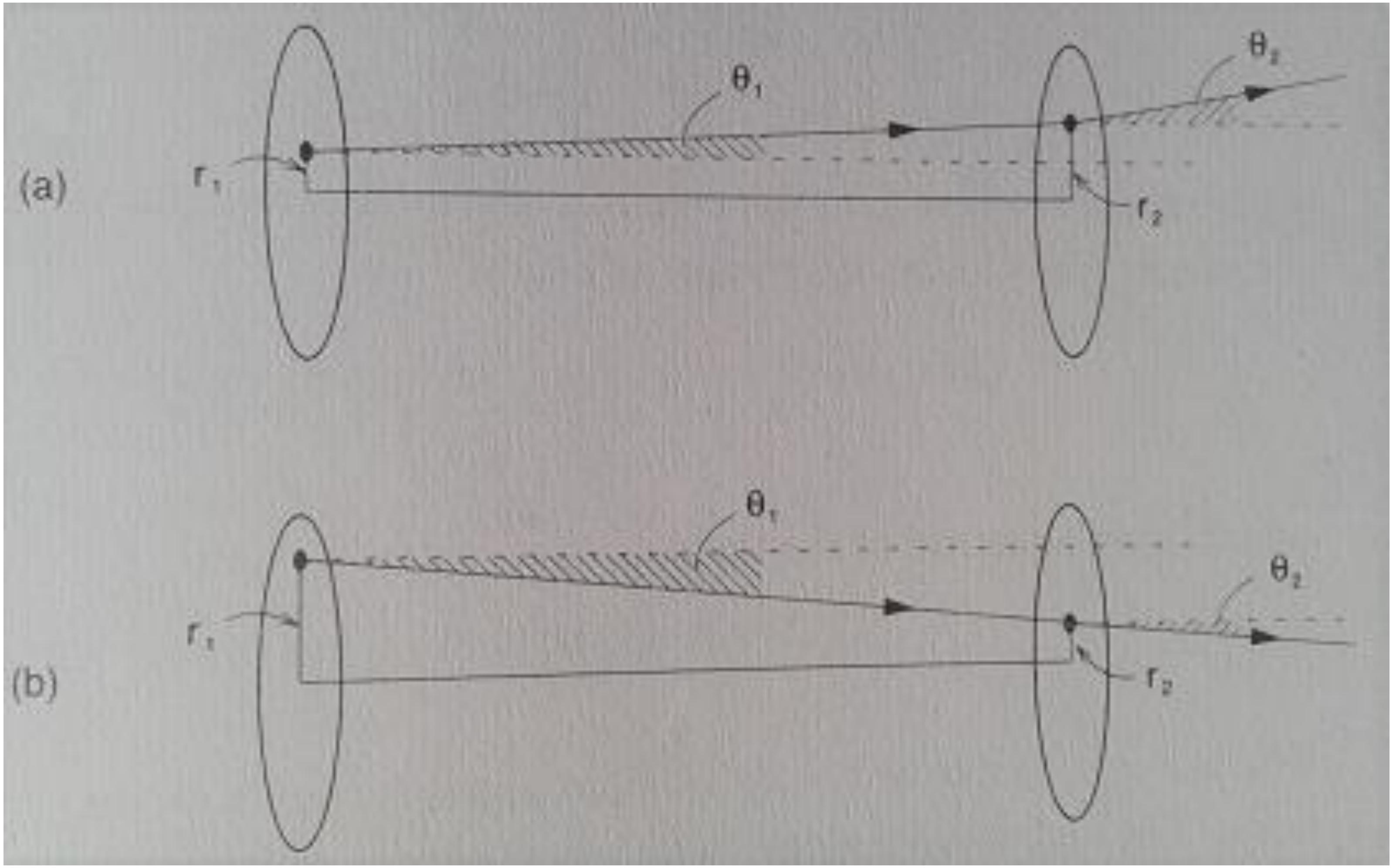
Cavity Stability Criteria

Consider a cavity composed of two mirrors of equal curvature *R* & focal length *f* = *R*/2, separated by a distance *d* on axis.

Propagation of a ray over a distance of one pass through cavity & then reflected by mirror is equivalent to an axial displacement *d* & then a refraction due to lens.

$$\begin{bmatrix} r_2 \\ \theta_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -1/f & 1 \end{bmatrix} \begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ \theta_1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & d \\ -1/f & 1-d/f \end{bmatrix} \begin{bmatrix} r_1 \\ \theta_1 \end{bmatrix}$$



Laser beam tending to (a) instability & (b) stability.

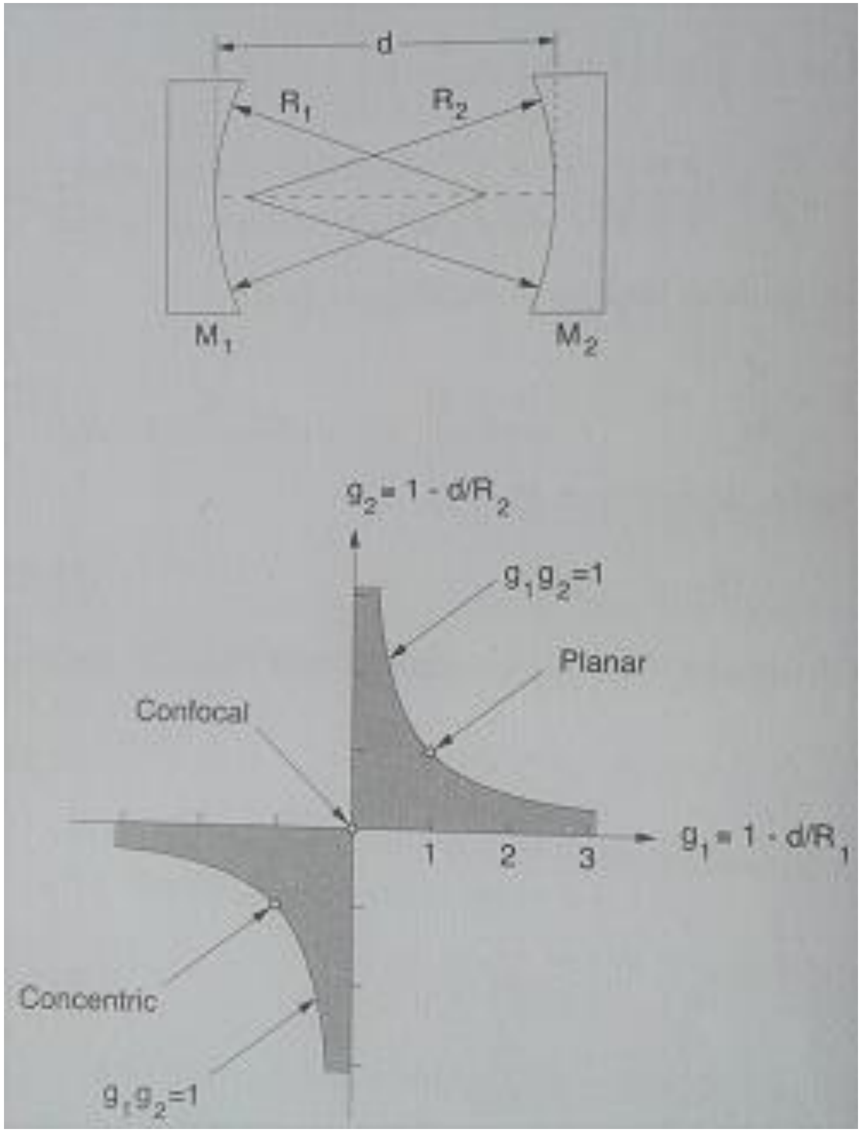
STABILITY:

If a ray leaves lens 1 (mirror 1), propagates to lens 2 (mirror 2), & is refracted by lens 2 (reflected from mirror 2), we can ask whether r_2 is greater than or less than r_1 at that point & whether θ_2 is greater or less than θ_1.

If $r_2 > r_1$ & $\theta_2 > \theta_1$ then beam will be on a diverging path that would lead to instability after many passes, since beam would sooner or later walk its way out of cavity.

If $r_2 < r_1$ & $\theta_2 < \theta_1$ then beam would tend toward stability, since it would always be attempting to converge to optic axis.

$$R_1 = R_2 = d/2$$
$$(symmetric\, concentric)$$
$$R_1 = R_2 = d$$
$$(confocal)$$
$$R_1 = R_2 = \infty$$
$$(plane\ parallel)$$



Stability diagram for two mirrors with radii of curvature *R_1* & *R_2*.