First ICO-ICTP-TWAS Central American Workshop in Lasers, Laser Applications and Laser Safety Regulations

Laser Resonators

Dr. Eric Rosas

Centro Nacional de Metrología

México

International Commission for Optics
Commission Internationale d'Optique

The Abdus Salam International Centre for Theoretical Physics

twas the academy of sciences for the developing world

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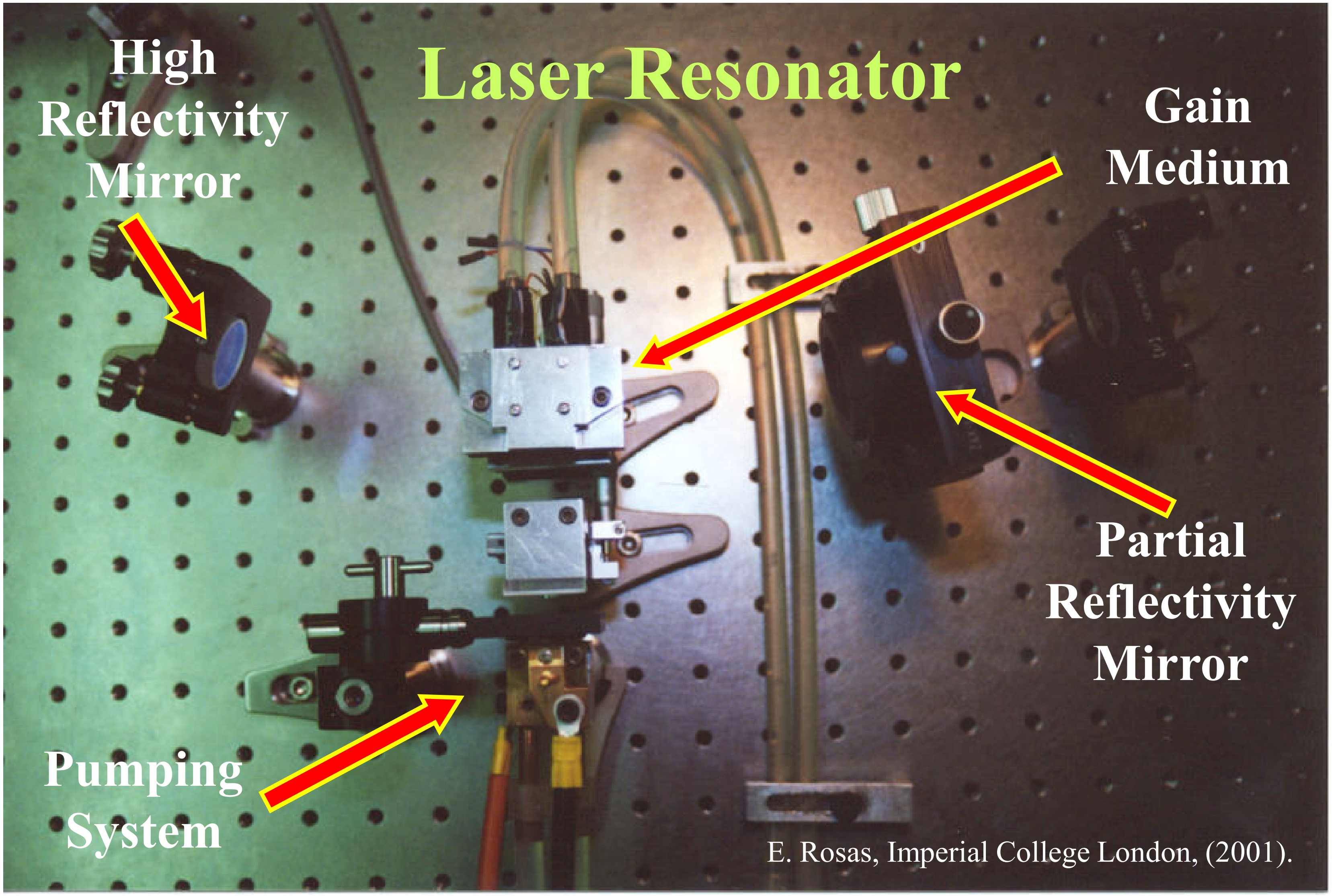
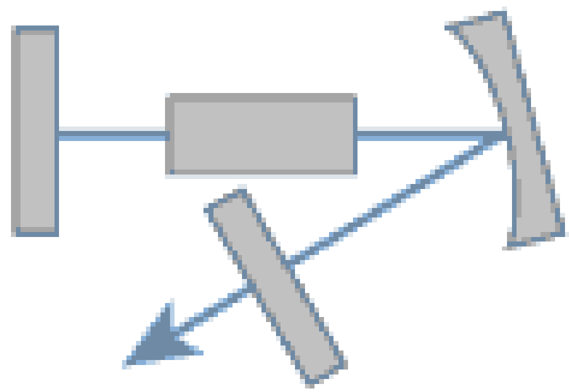
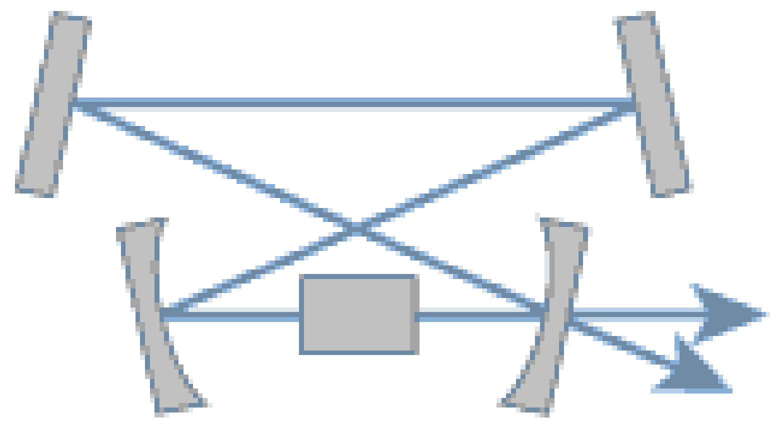

Laser Resonator
High Reflectivity Mirror
Gain Medium
Partial Reflectivity Mirror
Pumping System
E. Rosas, Imperial College London, (2001).

Laser Cavity Geometries.



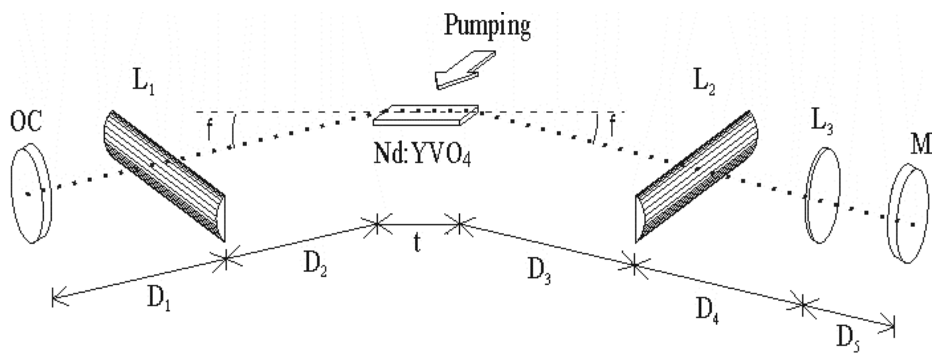


www.rp-photonics.com, (2012).

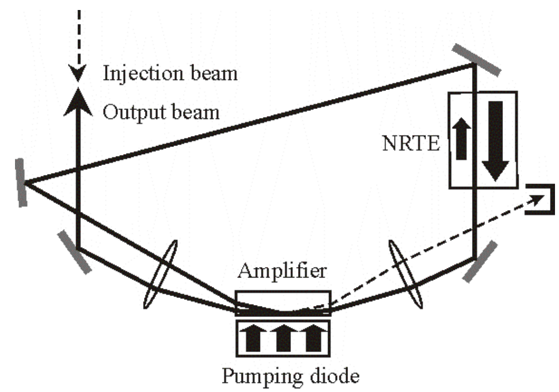
Linear cavity

Ring cavity (Bow tie)

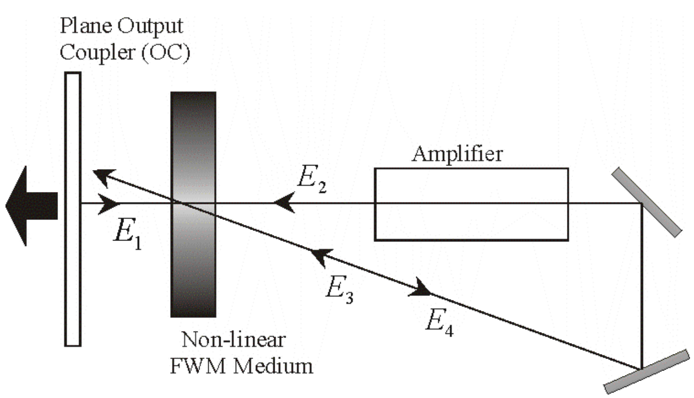
Laser Resonators.



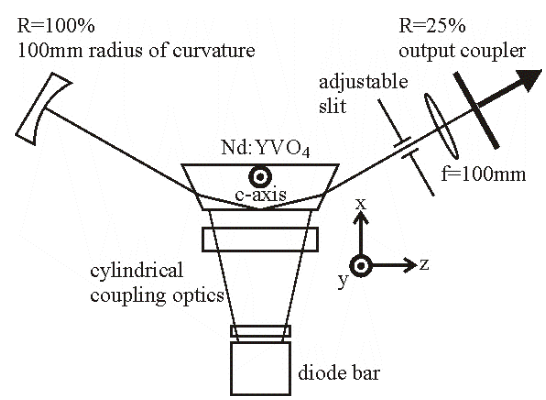
J. J. Soto-Bernal *et al*, Opt. Commun., **184**, (2000).



E. Rosas *et al*, Rev. Mex. Fís., **47**(3), (2001).

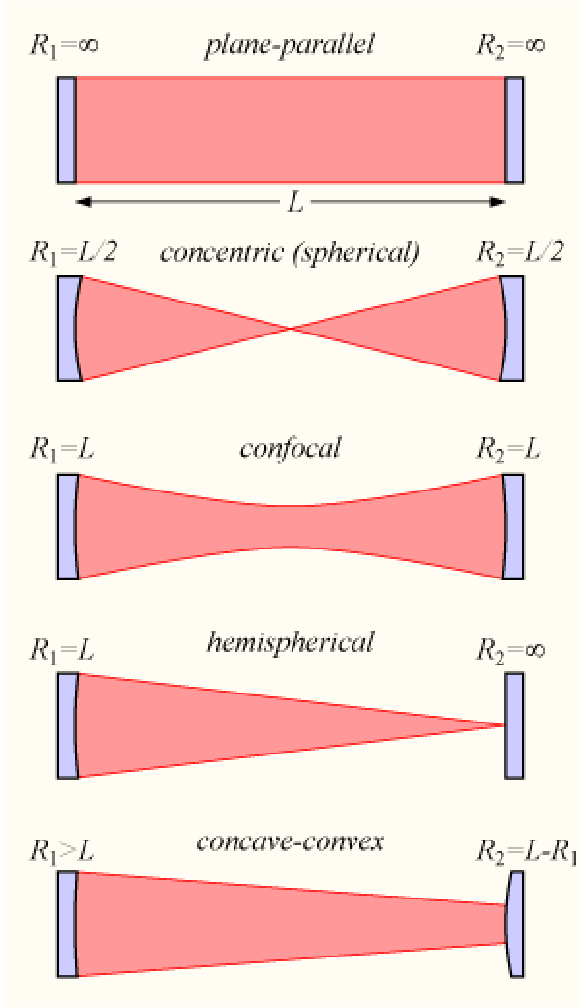


E. Rosas *et al*, Opt. Commun., **156**, (1998).

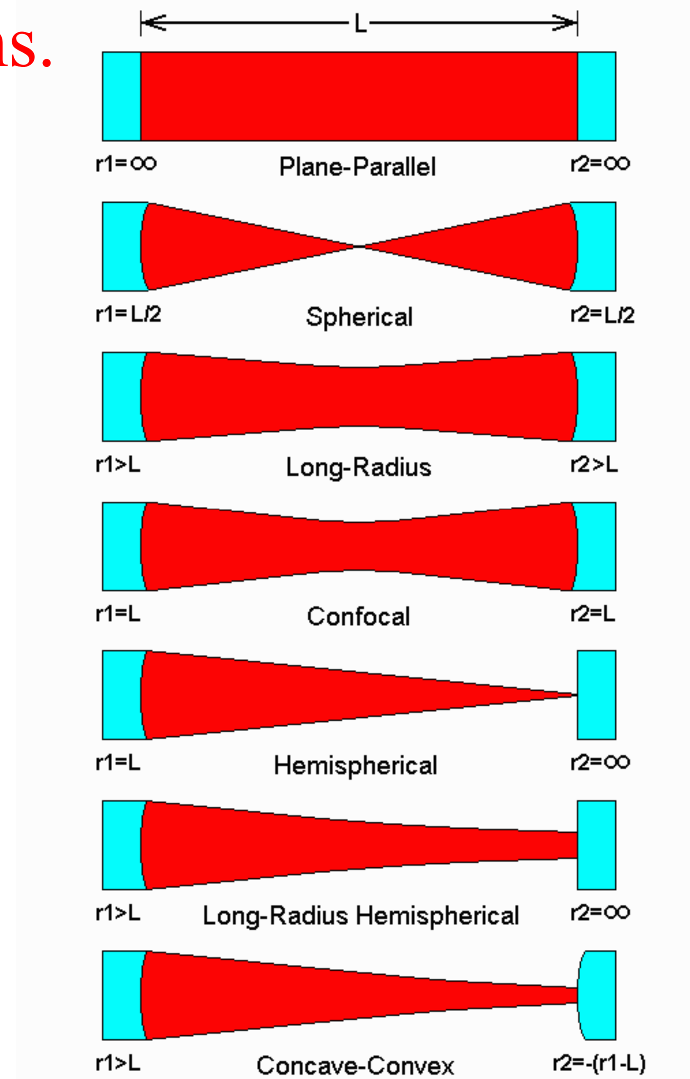


M . J. Damzen *et al*, Opt. Commun., **196**, (2001).

Laser Resonator Configurations.

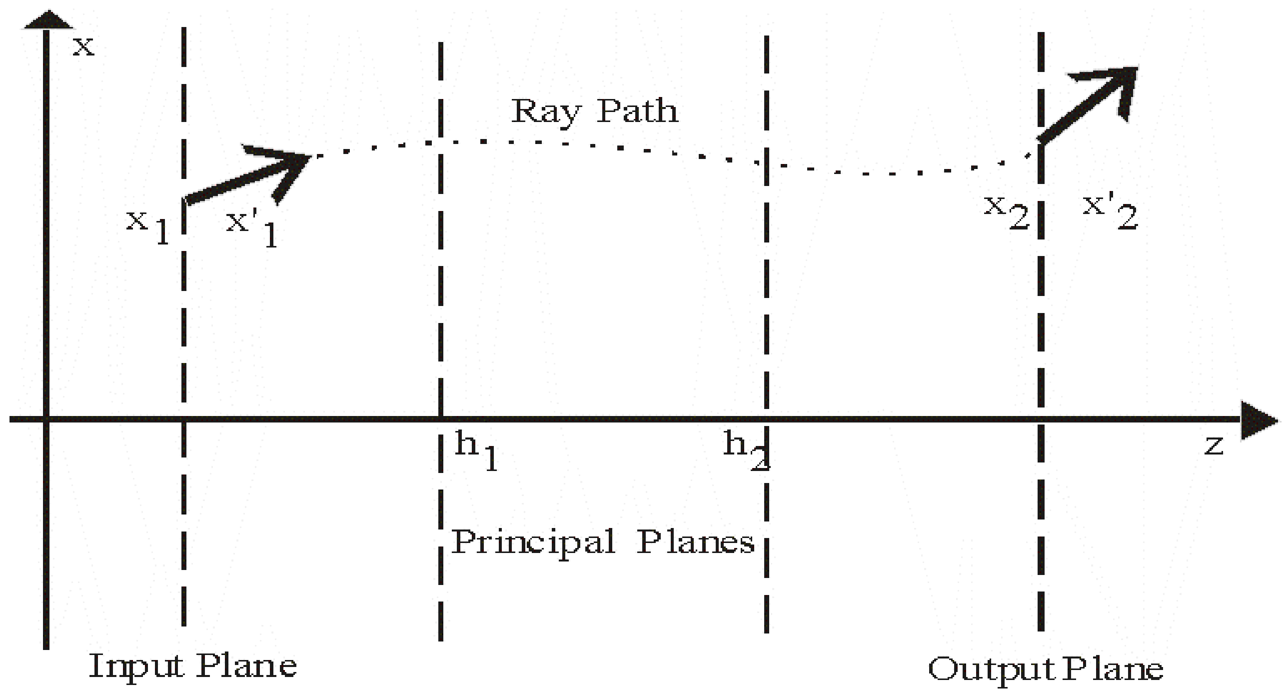


Wikipedia, (2012).



www.repairfaq.org , (2012).

Paraxial Rays Propagation.



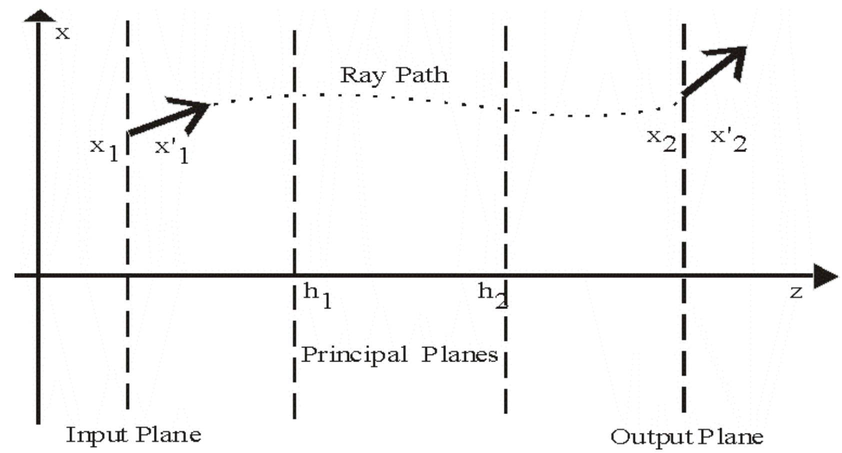
E. Rosas, Ph. D Thesis, CIO, *Universidad de Guanajuato*, (1998).

$$x_2 = A \cdot x_1 + B \cdot x_1'$$
$$x_2' = C \cdot x_1 + D \cdot x_1'$$

$$\Rightarrow \quad \begin{bmatrix} x_2 \\ x_2' \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_1' \end{bmatrix}$$

The Transfer Matrix.

$$\begin{bmatrix} x_2 \\ x_2' \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_1' \end{bmatrix}$$

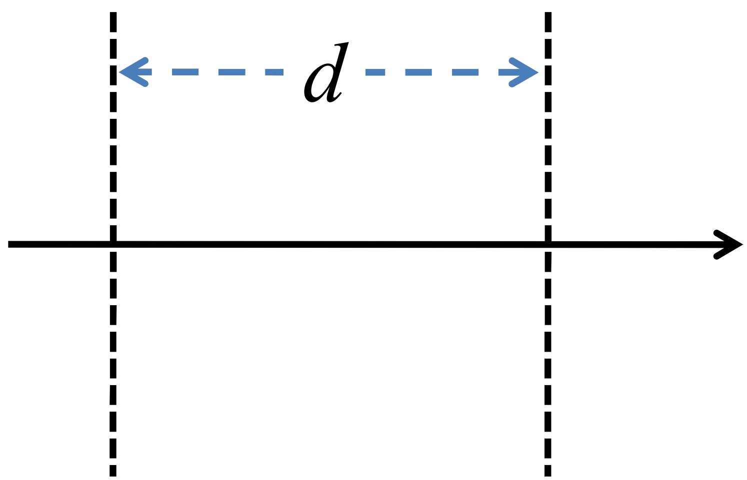


$$AD - BC = 1$$

E. Rosas, Ph. D Thesis, CIO, *Universidad de Guanajuato*, (1998).

$$f = -\frac{1}{C} \qquad h_1 = \frac{D-1}{C} \qquad h_2 = \frac{A-1}{C}$$

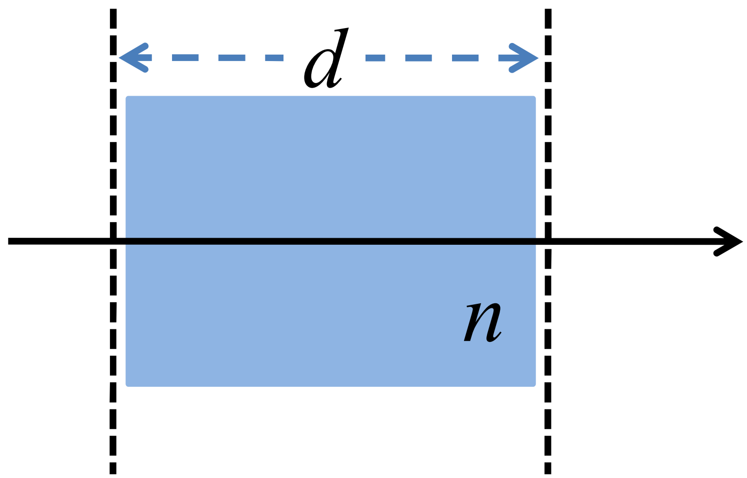
Distance d travelled in vacum (or air).



E. Rosas (2012).

$$\begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix}$$

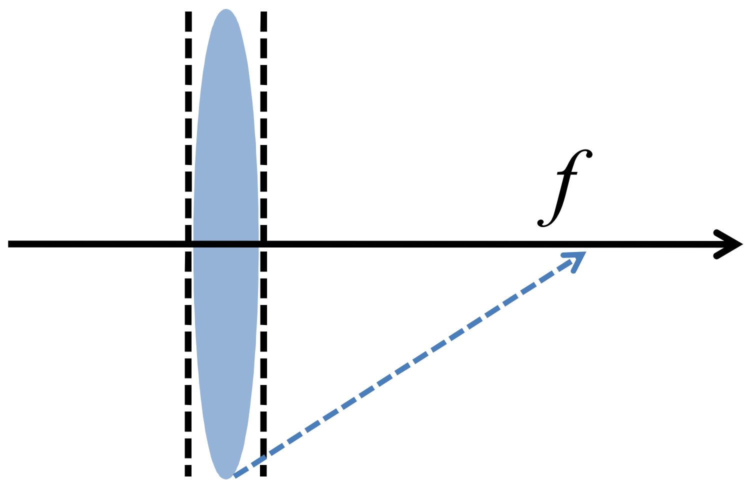
Distance *d* travelled in a medium with refractive index *n*.



E. Rosas, (2012).

$$\begin{bmatrix} 1 & d/n \\ 0 & 1 \end{bmatrix}$$

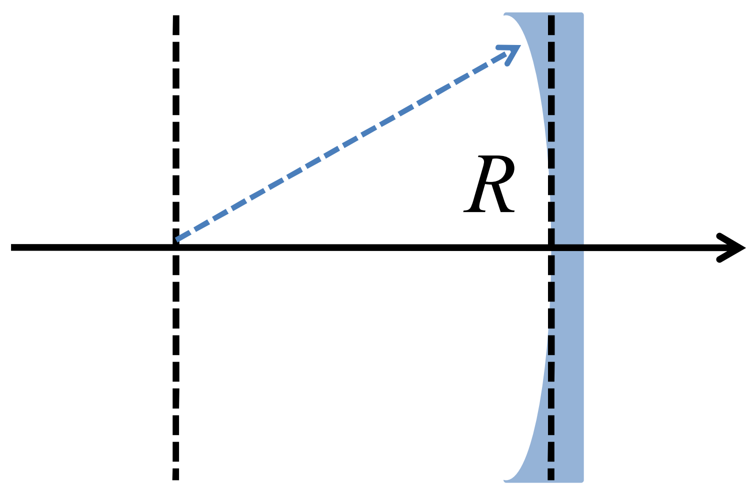
Thin lens with focal length f.



E. Rosas, (2012).

$$\begin{bmatrix} 1 & 0 \\ -1/f & 1 \end{bmatrix}$$

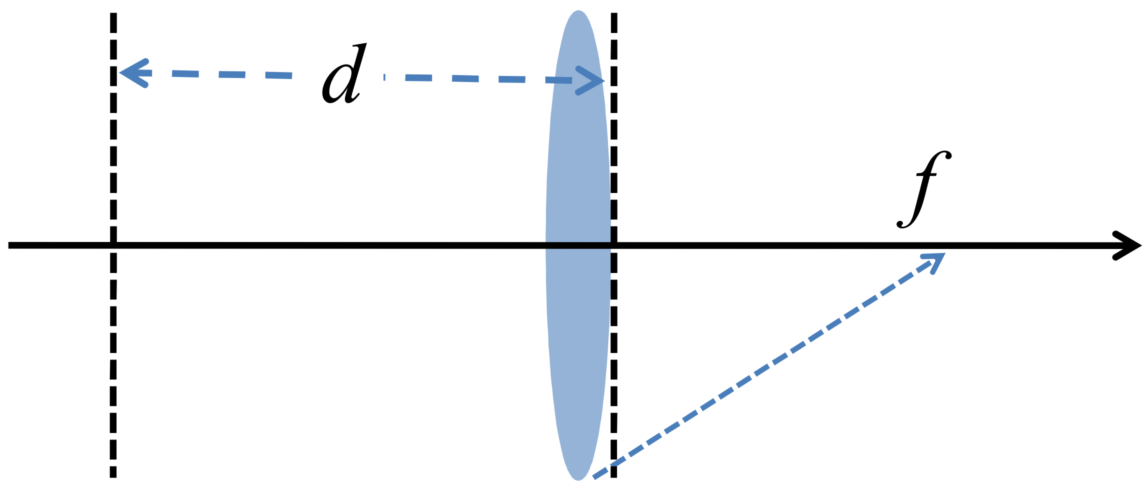
Spherical mirror with curvature radius *R*.



E. Rosas, (2012).

$$\begin{bmatrix} 1 & 0 \\ -2/R & 1 \end{bmatrix}$$

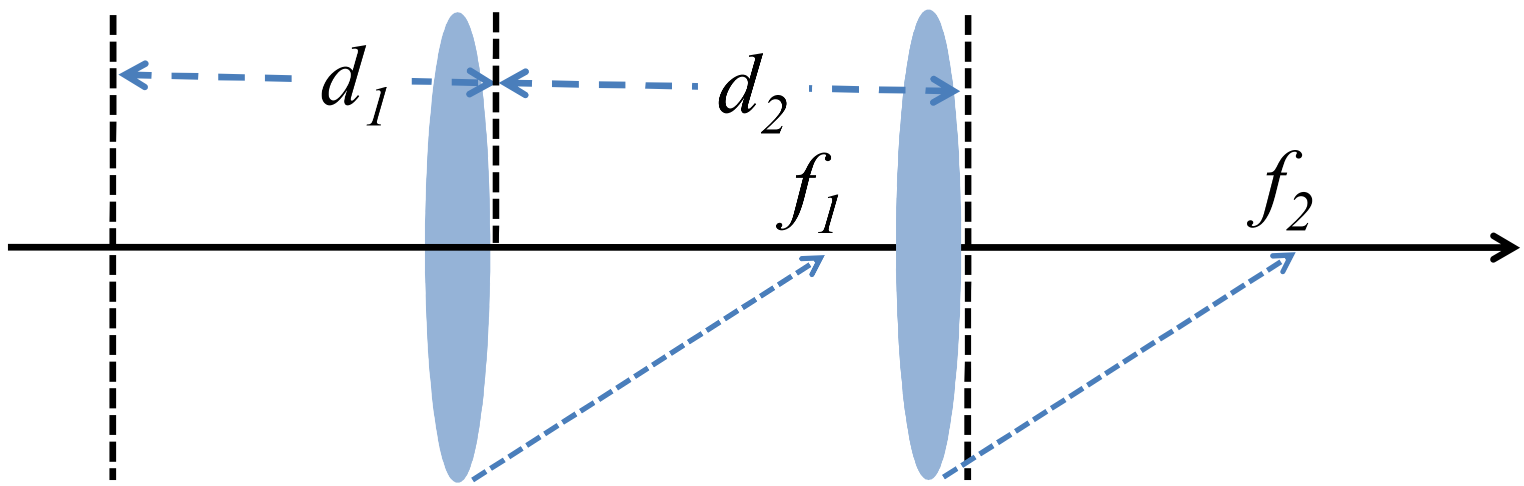
Distance d travelled in vacum (air) + thin lens with focal lenght f.



E. Rosas, (2012).

$$\begin{bmatrix} 1 & 0 \\ -1/f & 1 \end{bmatrix} \times \begin{bmatrix} 1 & d \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & d \\ -1/f & 1-d/f \end{bmatrix}$$

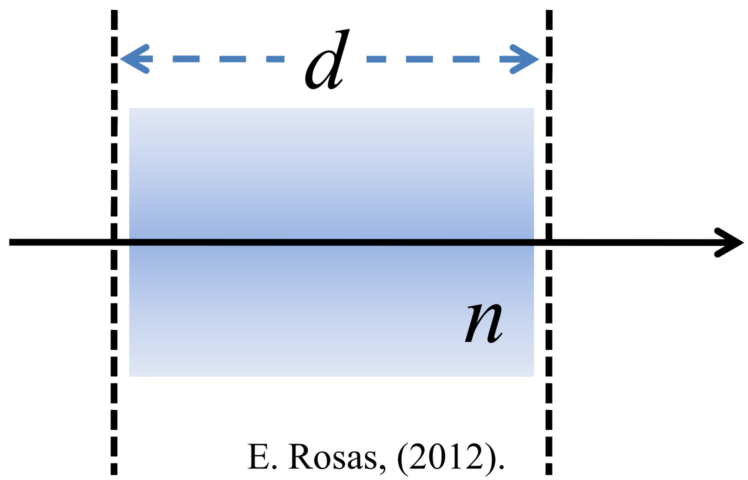
Two "distance + thin lens" sequence.



E. Rosas, (2012).

$$\begin{bmatrix} 1-\dfrac{d_2}{f_1} & d_1+d_2-\dfrac{d_1\cdot d_2}{f_1} \\ -\dfrac{1}{f_1}-\dfrac{1}{f_2}+\dfrac{d_2}{f_1\cdot f_2} & 1-\dfrac{d_1}{f_1}-\dfrac{d_2}{f_2}-\dfrac{d_1}{f_2}+\dfrac{d_1\cdot d_2}{f_1\cdot f_2} \end{bmatrix}$$

Distance *d* travelled in a lenslike medium.

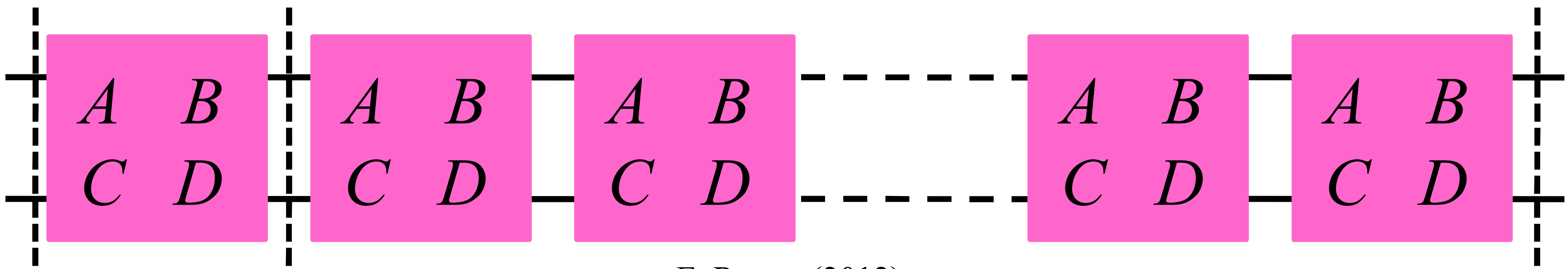


E. Rosas, (2012).

$$n = n_0 - \frac{1}{2} n_2 \cdot r^2$$

$$\begin{bmatrix} \cos d \cdot \sqrt{\frac{n_2}{n_0}} & \frac{1}{\sqrt{n_0 \cdot n_2}} \sin d \cdot \sqrt{\frac{n_2}{n_0}} \\ -\sqrt{n_0 \cdot n_2} \sin d \cdot \sqrt{\frac{n_2}{n_0}} & \cos d \cdot \sqrt{\frac{n_2}{n_0}} \end{bmatrix}$$

Periodic Sequences.



E. Rosas, (2012).

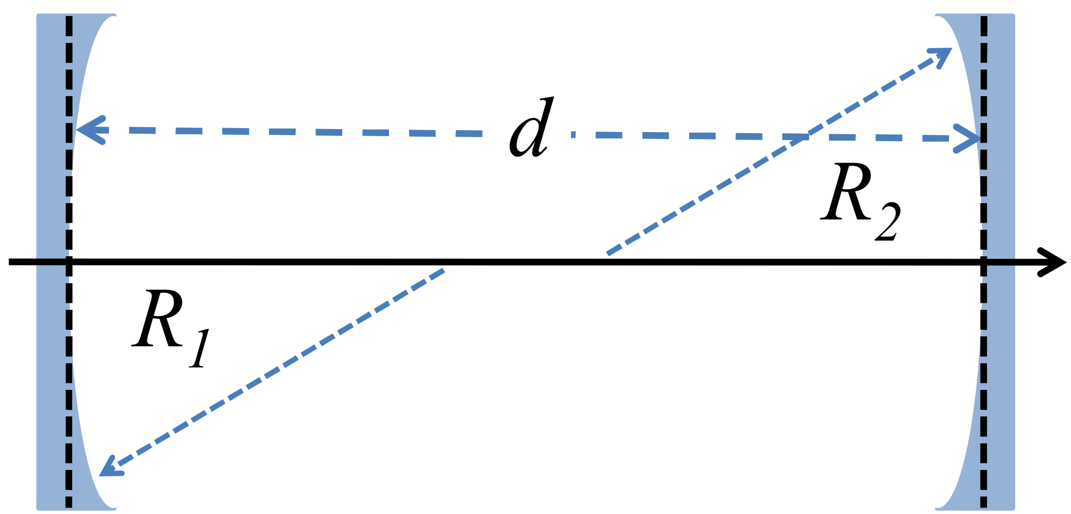
$$\begin{pmatrix} x_0 \\ x_0' \end{pmatrix} \qquad \begin{pmatrix} x_1 \\ x_1' \end{pmatrix} \qquad \begin{pmatrix} x_m \\ x_m' \end{pmatrix}$$

Sylvester's Theorem.

$$\cos\Theta = \frac{A+D}{2}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}^m = \frac{1}{\sin\Theta} \cdot \begin{bmatrix} A\sin m\Theta - \sin(m-1)\Theta & B\sin m\Theta \\ C\sin m\Theta & D\sin m\Theta - \sin(m-1)\Theta \end{bmatrix}$$

And cavities are periodic sequences.

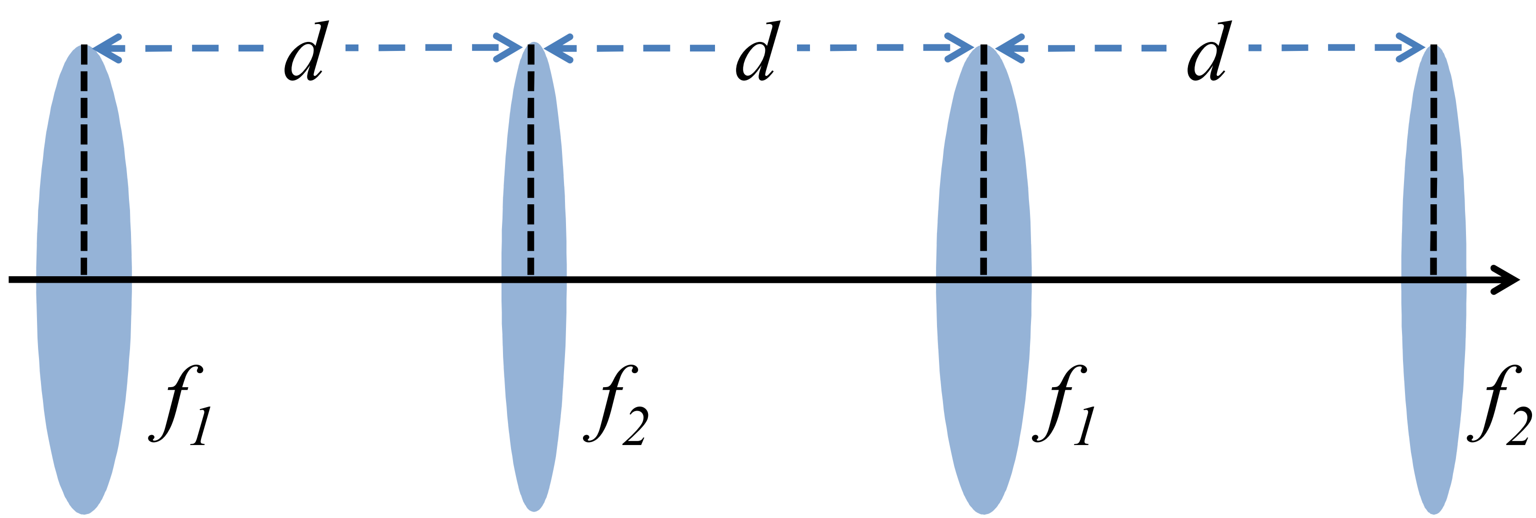


E. Rosas, (2012).

Either as a pair of mirrors…

Or as a sequence of lenses (The mirrors cavity's dual).

$$f_1 = \frac{R_1}{2} \qquad f_2 = \frac{R_2}{2}$$



E. Rosas, (2012).

Stability Condition.

$$-1 < \frac{A+D}{2} < 1$$

Stability condition for periodic sequences.

$$0 < \left(1 - \frac{d}{R_1}\right)\left(1 - \frac{d}{R_2}\right) < 1$$

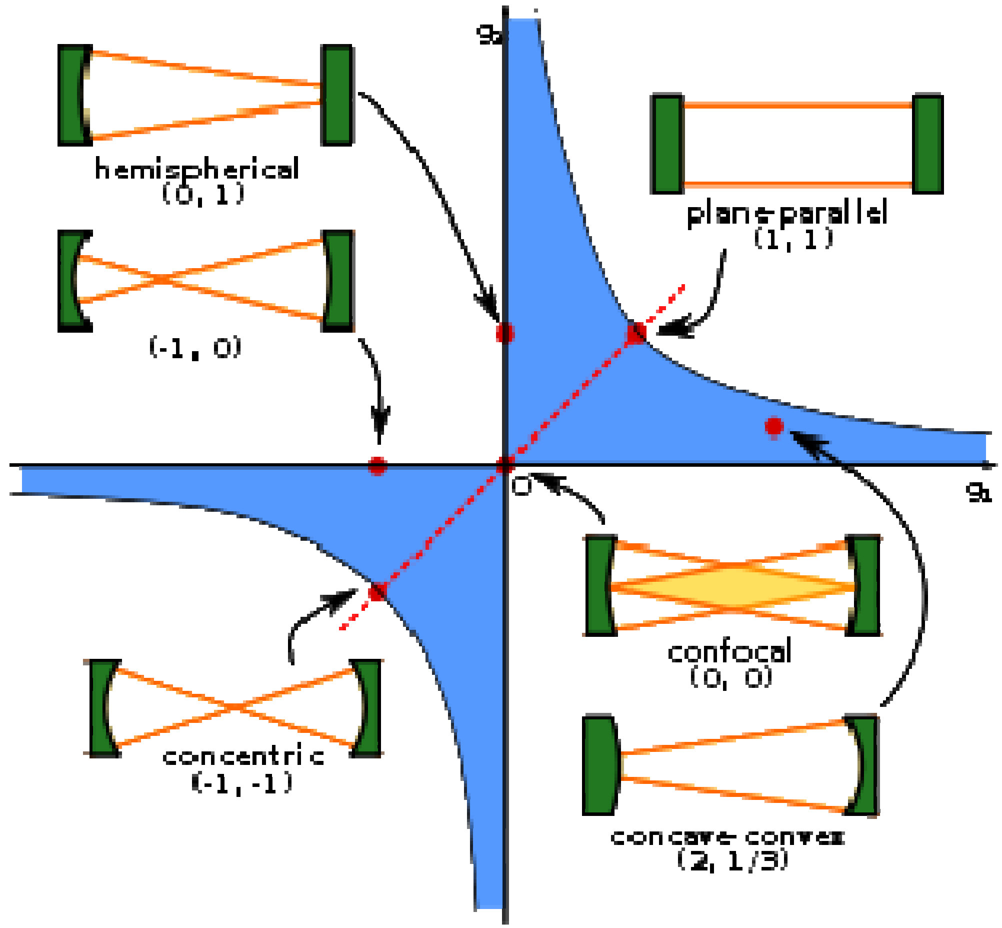
Stability condition for laser cavities.

Laser Resonator's Stability.

$$0 < \left(1 - \frac{d}{R_1}\right)\left(1 - \frac{d}{R_2}\right) < 1$$

$$g_1 = 1 - \frac{d}{R_1} \qquad g_2 = 1 - \frac{d}{R_2}$$

$$0 < g_1 \cdot g_2 < 1$$



Wikipedia, (2012).

End of Session One.

Thank you very much for your attendance.