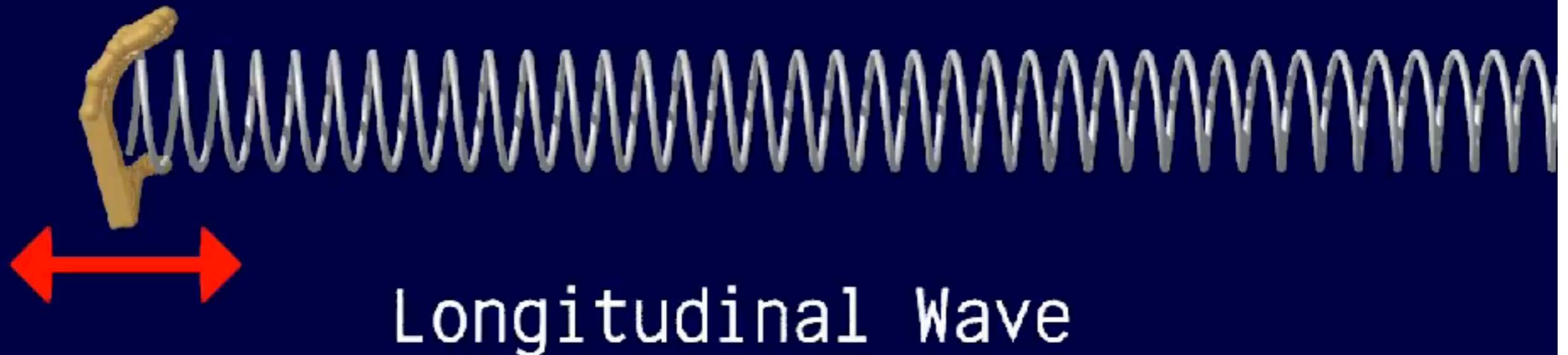


# Fisica Generale 2

Pierluigi Monaco

Laurea triennale in ingegneria elettronica ed informatica

Radiazione elettromagnetica, onde, ottica



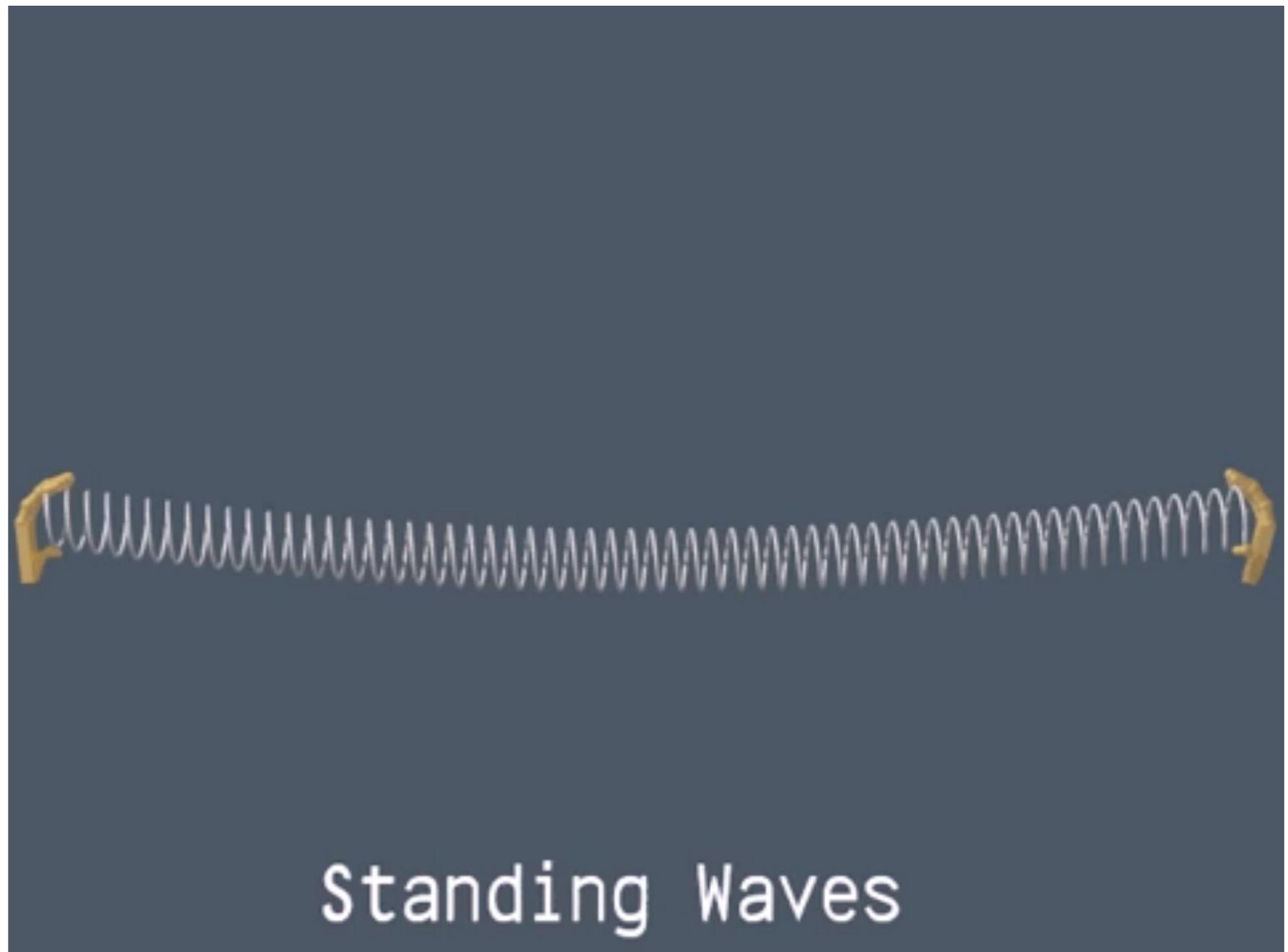
# Onde stazionarie

$$y_1(x, t) = A_0 \text{sen}(kx - \omega t)$$

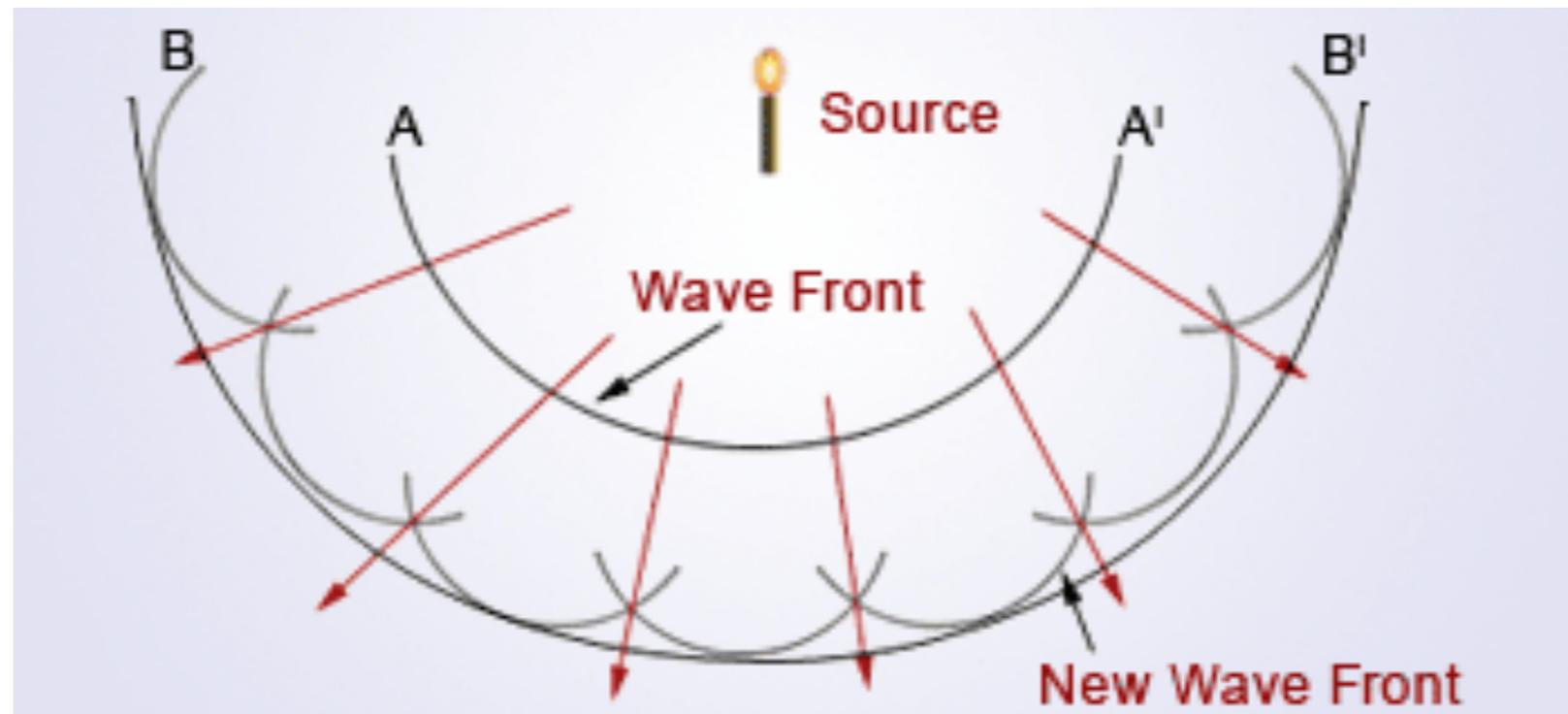
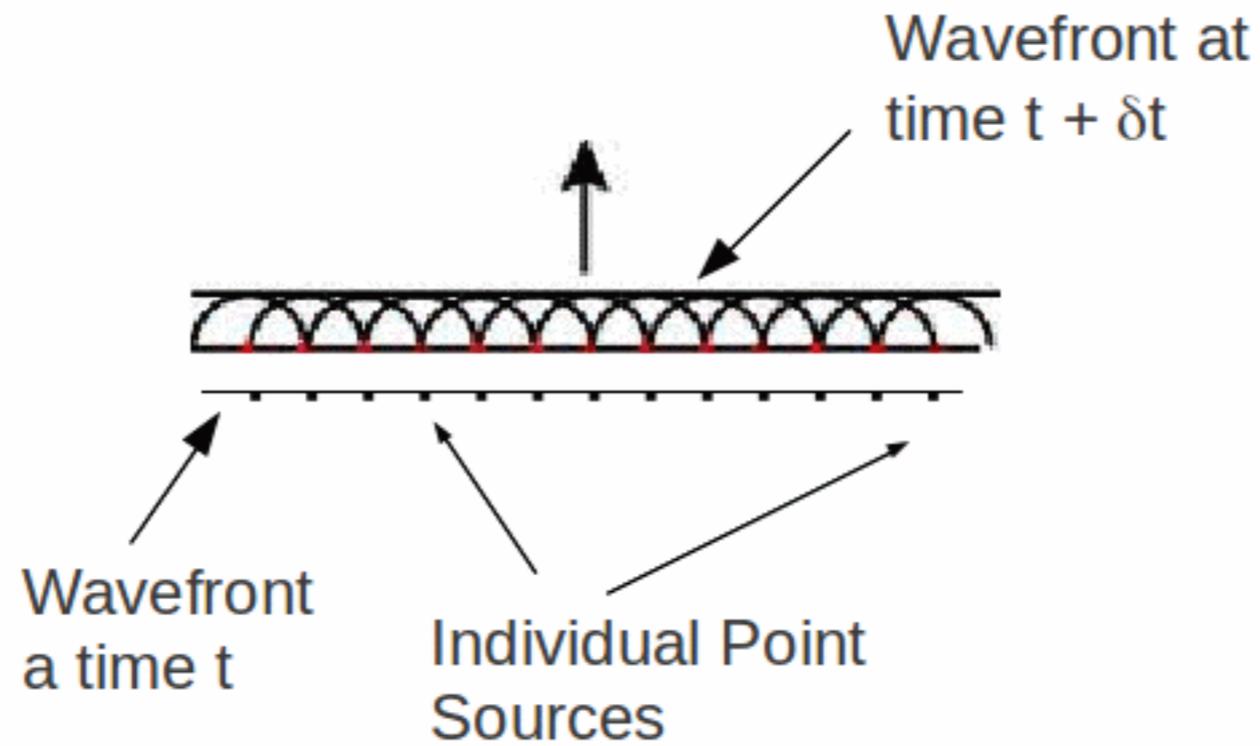
$$y_2(x, t) = A_0 \text{sen}(kx + \omega t)$$

$$y(x, t) = A_0 [\text{sen}(kx - \omega t) + \text{sen}(kx + \omega t)] \quad \text{sen } \alpha + \text{sen } \beta = 2 \text{sen} \left( \frac{\alpha + \beta}{2} \right) \cos \left( \frac{\alpha - \beta}{2} \right)$$

$$y(x, t) = 2A_0 \text{sen}(kx) \cos(\omega t)$$

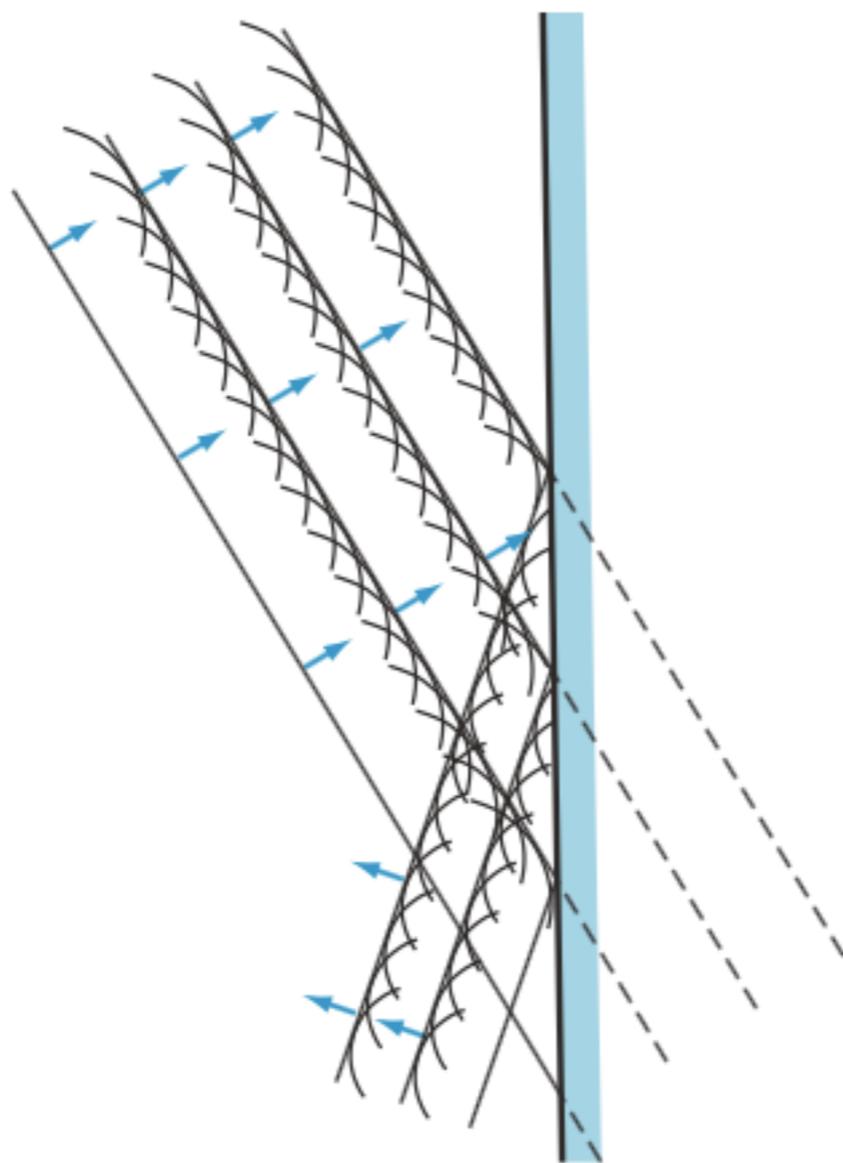


# Principio di Huygens-Fresnel

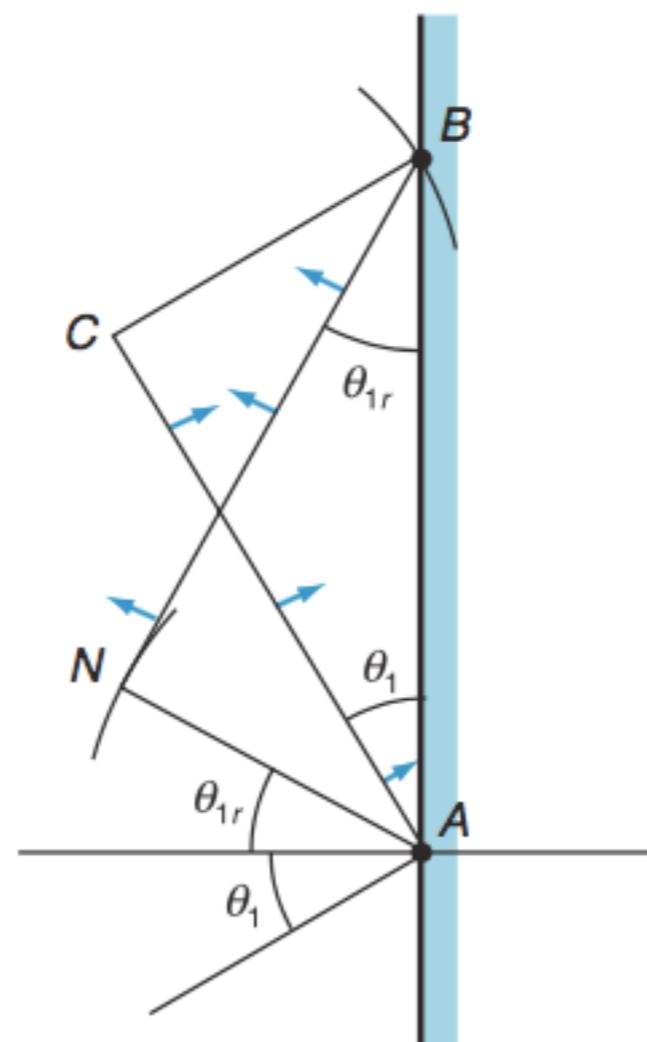


# Riflessione

$$\theta_{1r} = \theta_1$$



(a)



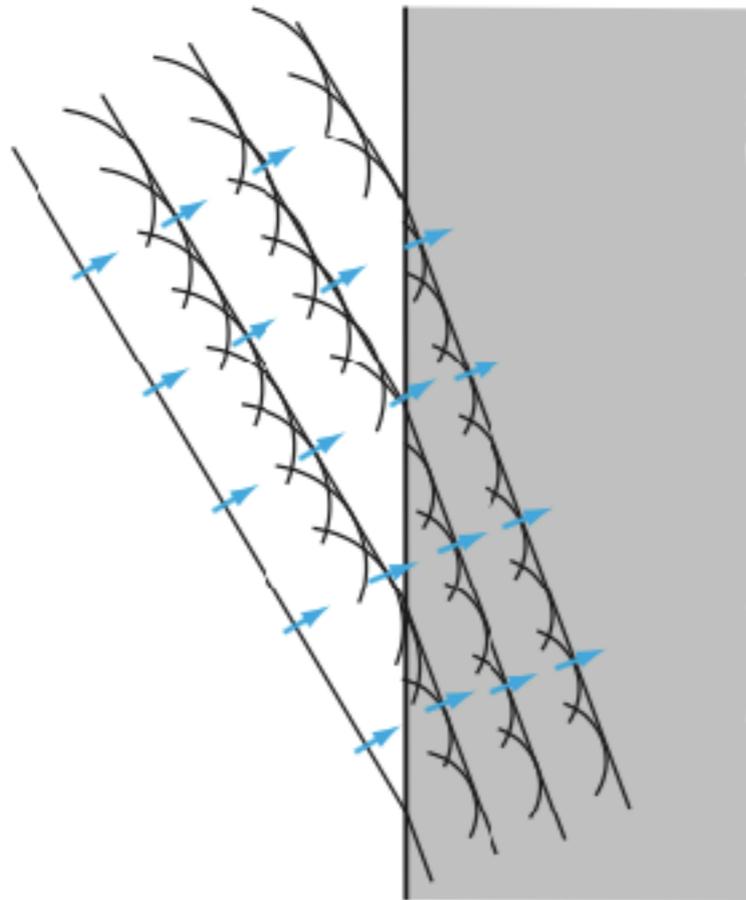
(b)

# Rifrazione

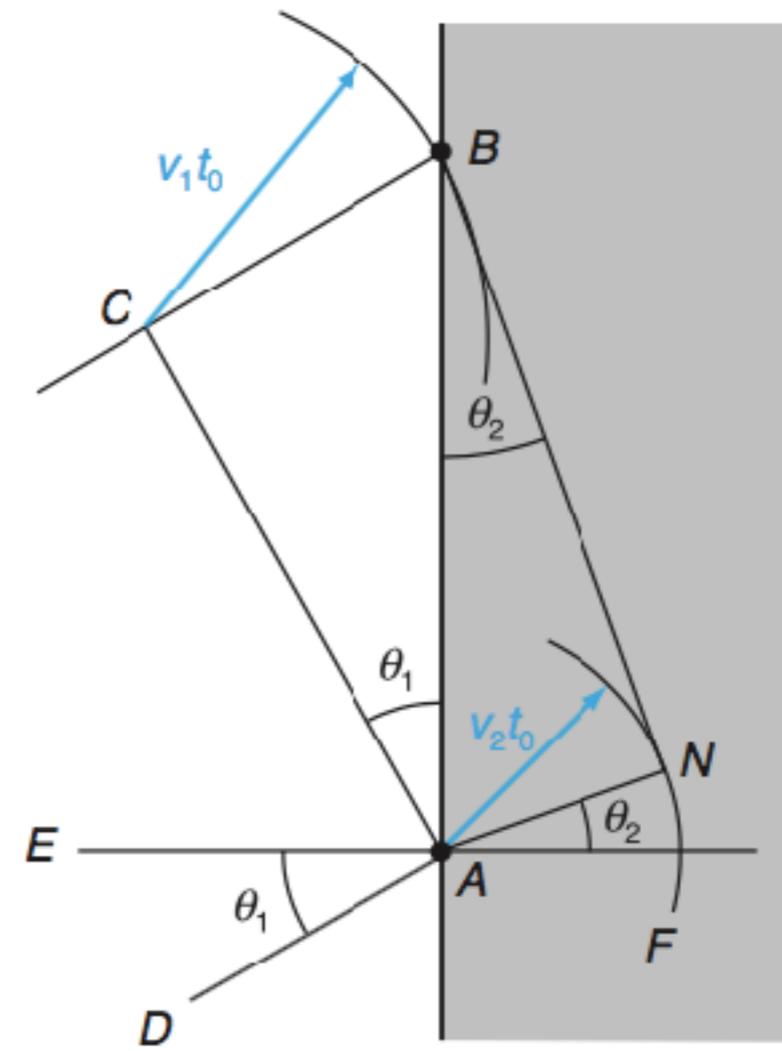
$$\left. \begin{array}{l} \text{sen } \theta_1 = \overline{BC}/\overline{BA} \\ \text{sen } \theta_2 = \overline{AN}/\overline{BA} \end{array} \right\} \Rightarrow \frac{\text{sen } \theta_1}{\text{sen } \theta_2} = \frac{\overline{BC}}{\overline{AN}} = \frac{v_1 t_0}{v_2 t_0}$$

Legge di Snell

$$v_1^{-1} \text{sen } \theta_1 = v_2^{-1} \text{sen } \theta_2 \quad \Rightarrow \quad n_1 \text{sen } \theta_1 = n_2 \text{sen } \theta_2$$



(a)



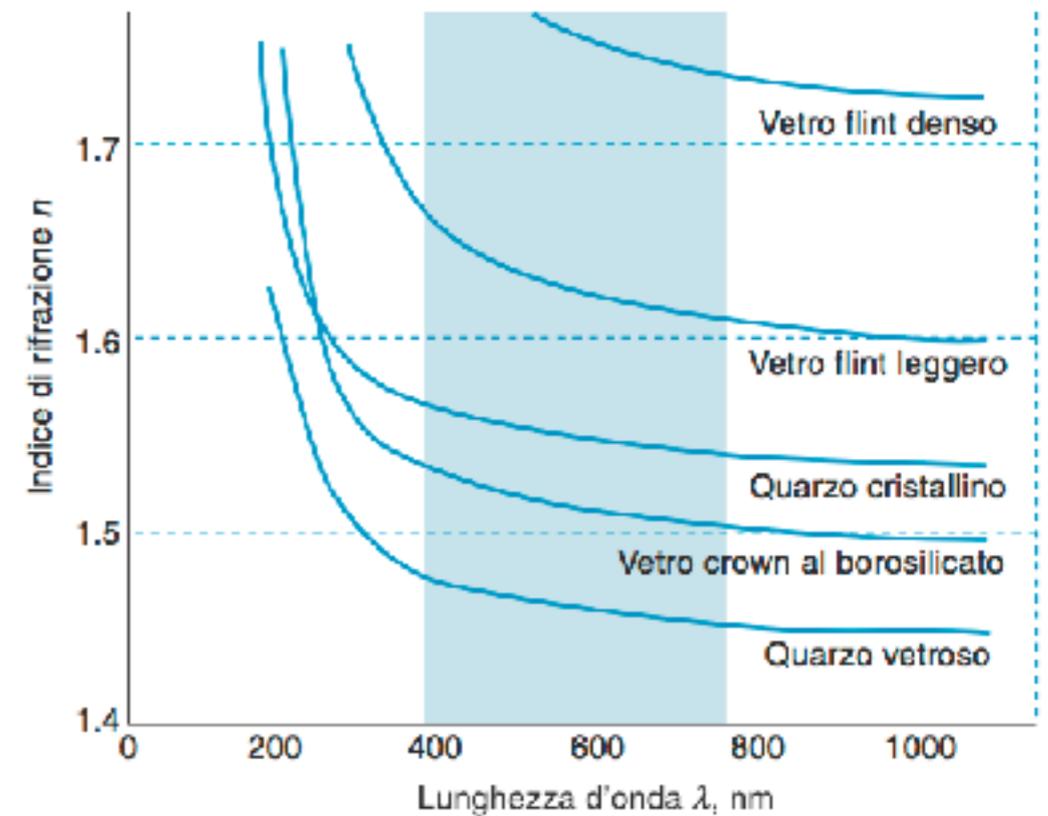
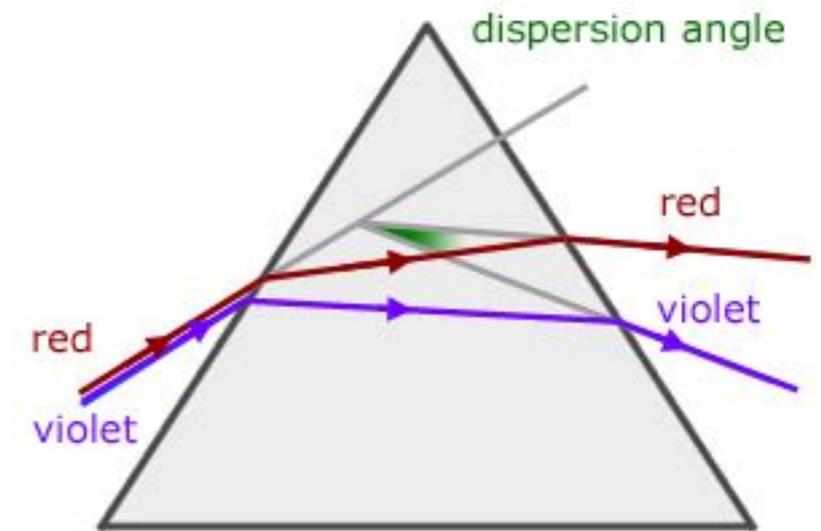
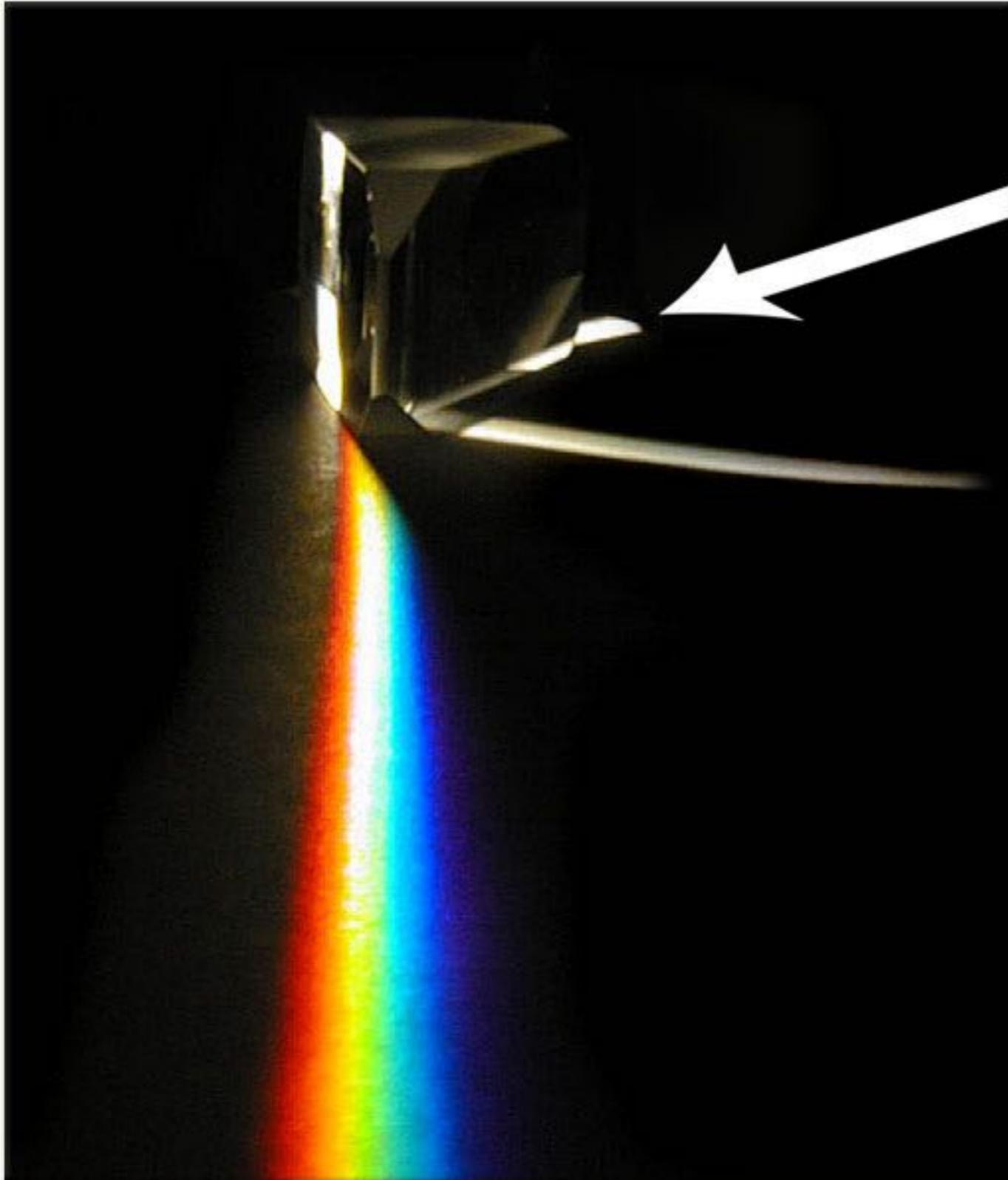
(b)

**Tabella 18.1** Indici di rifrazione approssimati di alcune sostanze

Sostanza	$n^*$
Gas (a 0 °C)	
Aria	1.000293
Ammoniaca	1.000376
Anidride carbonica	1.000451
Cloro	1.000773
Idrogeno	1.000132
Metano	1.000444
Anidride solforosa	1.000686
Liquidi	
Benzene	1.501
Solfuro di carbonio	1.625
Alcool etilico	1.362
Alcool metilico	1.329
Ioduro di metilene	1.726
Acqua	1.333
Solidi	
Zaffiro, rubino ( $\text{Al}_2\text{O}_3$ )	1.767
Diamante	2.417
Vetri: Vetro di quarzo	1.458
Vetro sodico-calcico	1.512
Pirex	1.474
Flint denso	1.655
Ghiaccio (0 °C)	1.310
Resina acrilica lucite	1.491
Rutilo, E (470 nm)	3.095
Sale da cucina (NaCl)	1.544

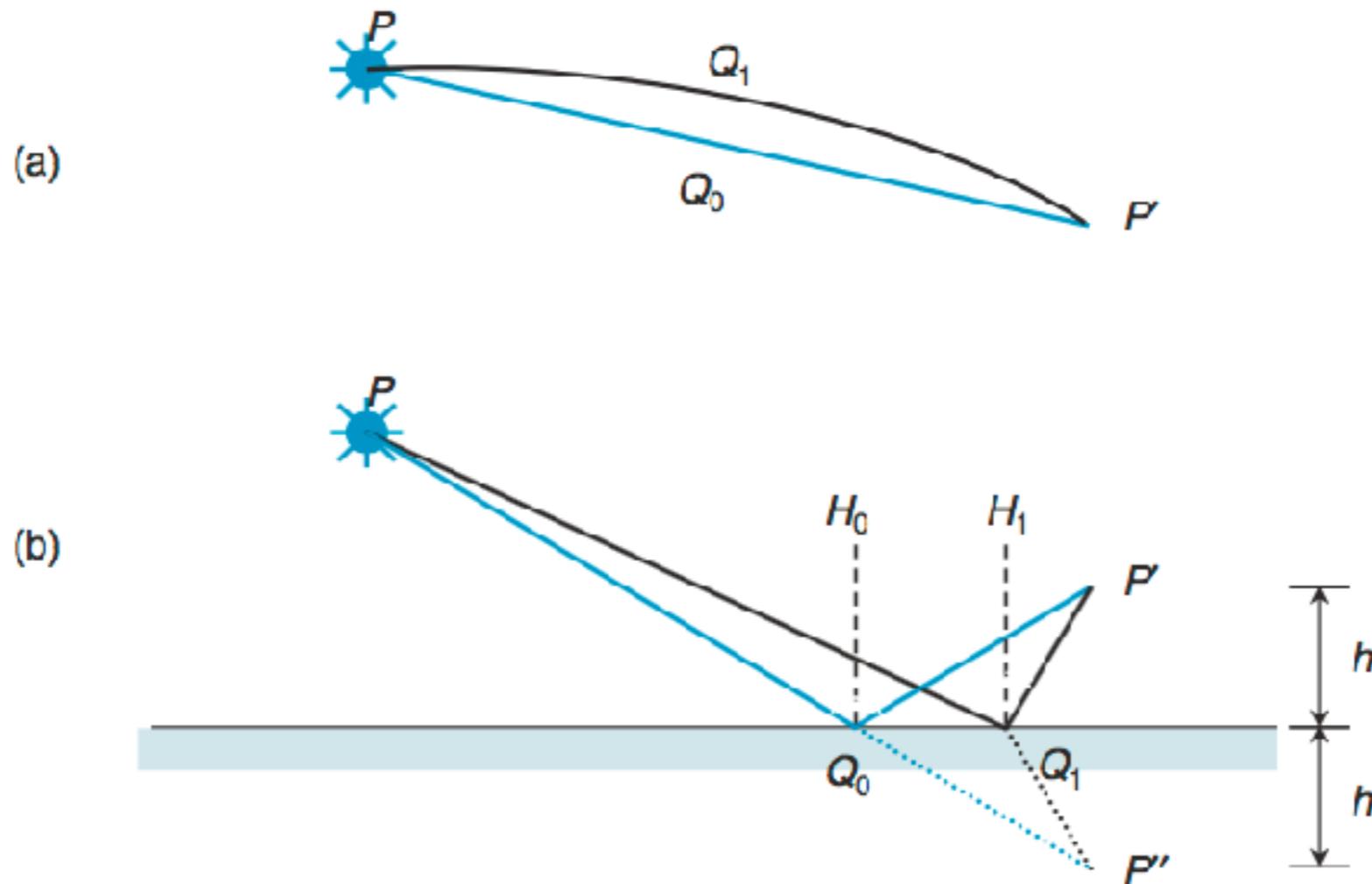
\* Valori a temperatura ambiente e a pressione atmosferica per luce di lunghezza d'onda 589 nm, salvo quando diversamente specificato.

# L'indice di rifrazione dipende da $\lambda$

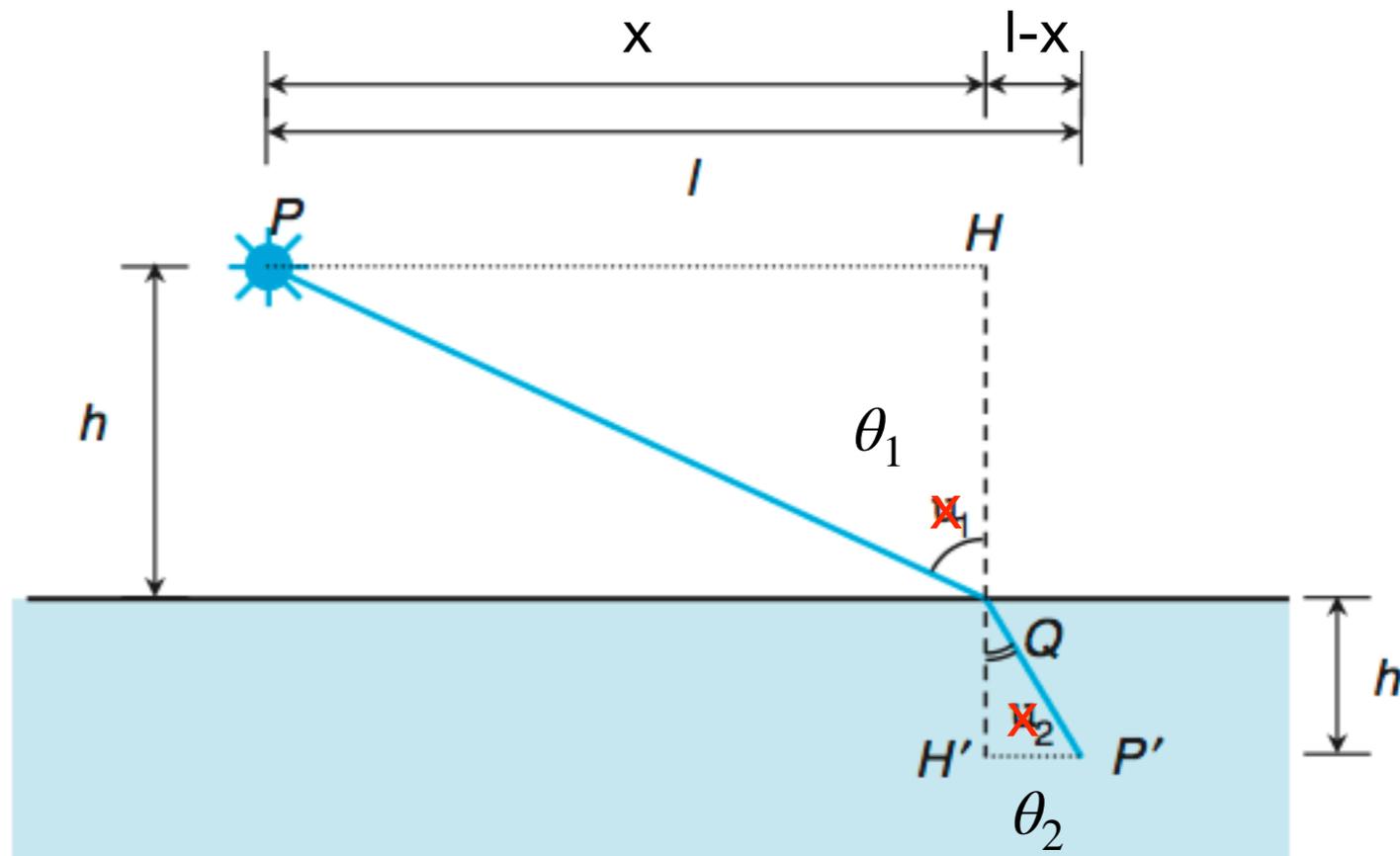


# Principio di Fermat

$$\tau(x) = \int_{\text{path}} \frac{1}{v} dx, \quad \frac{d\tau}{dx} = 0$$



# Rifrazione con il principio di Fermat



$$\tau(x) = \frac{\overline{PQ}}{v_1} + \frac{\overline{P'Q}}{v_2} = \frac{\sqrt{h^2 + x^2}}{v_1} + \frac{\sqrt{h'^2 + (l-x)^2}}{v_2}$$

$$\frac{d\tau}{dx} = \frac{1}{v_1} \frac{x}{\sqrt{h^2 + x^2}} - \frac{1}{v_2} \frac{l-x}{\sqrt{h'^2 + (l-x)^2}} = \frac{1}{v_1} \frac{\overline{PH}}{\overline{PQ}} - \frac{1}{v_2} \frac{\overline{P'H'}}{\overline{P'Q}} = \frac{n_1}{c} \text{sen } \theta_1 - \frac{n_2}{c} \text{sen } \theta_2 = 0$$

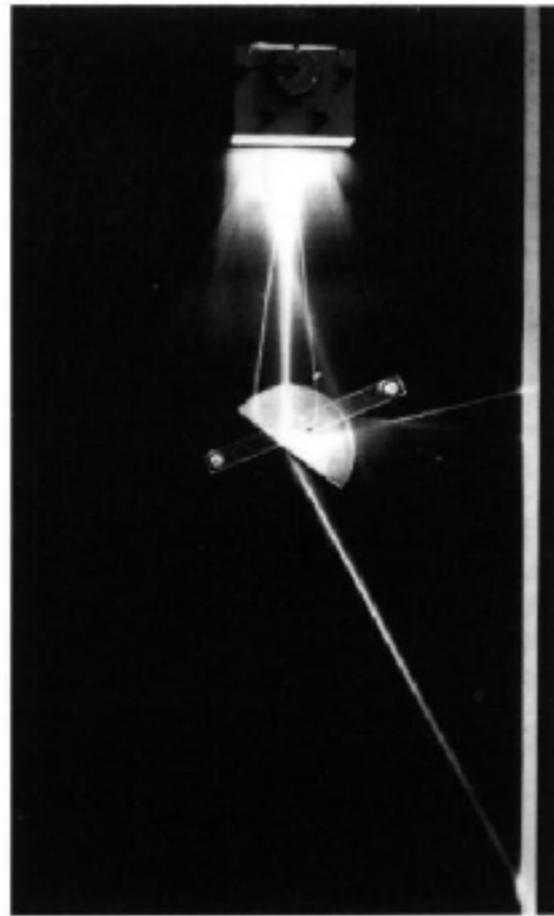
$$n_1 \text{ sen } \theta_1 = n_2 \text{ sen } \theta_2$$

# Angolo limite

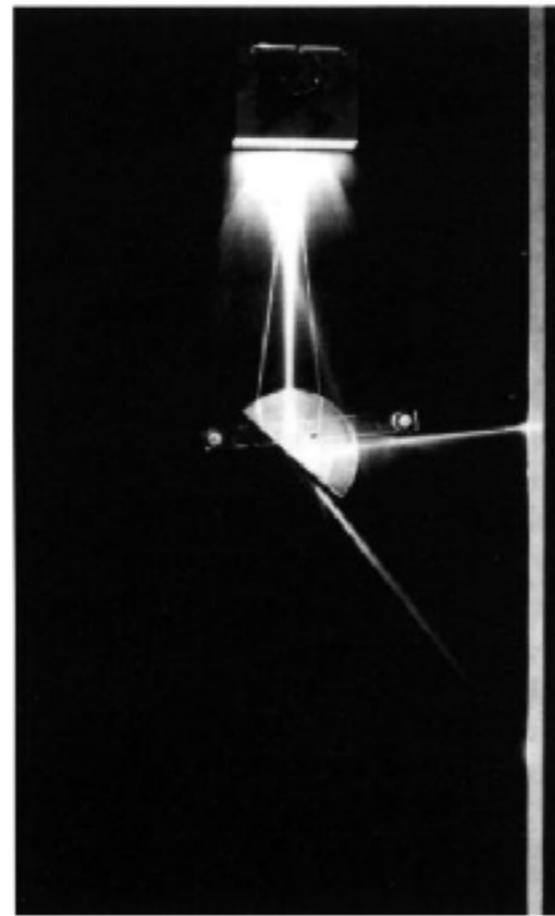
$$n_1 \sin \theta_c = n_2 \sin 90^\circ = n_2 \quad \Longrightarrow \quad \sin \theta_c = \frac{n_2}{n_1}$$



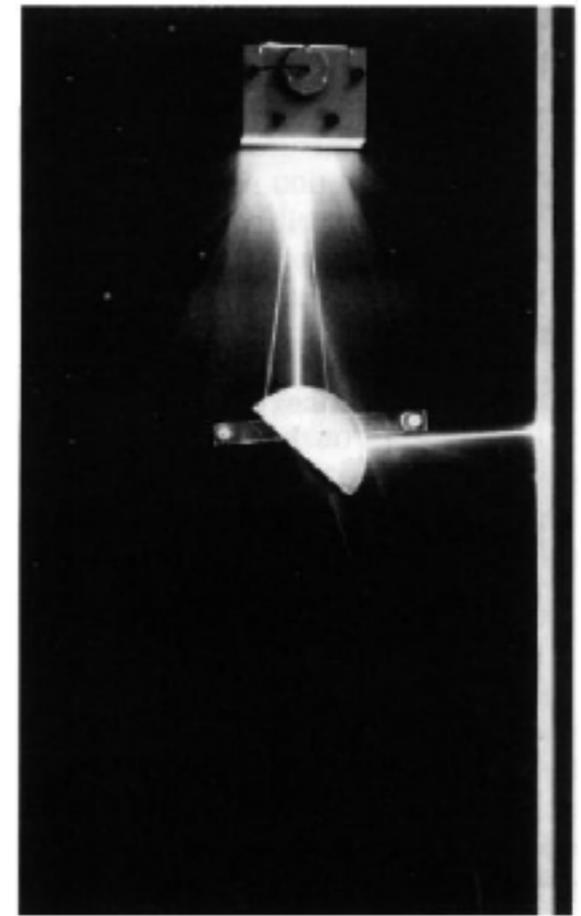
(a)



(b)

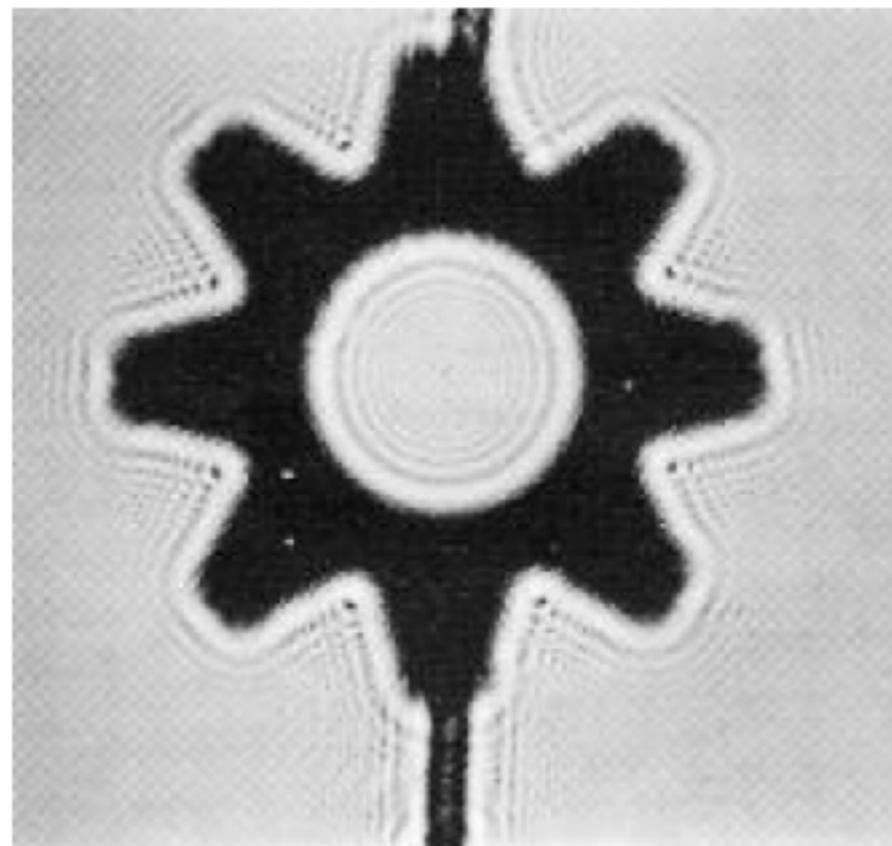
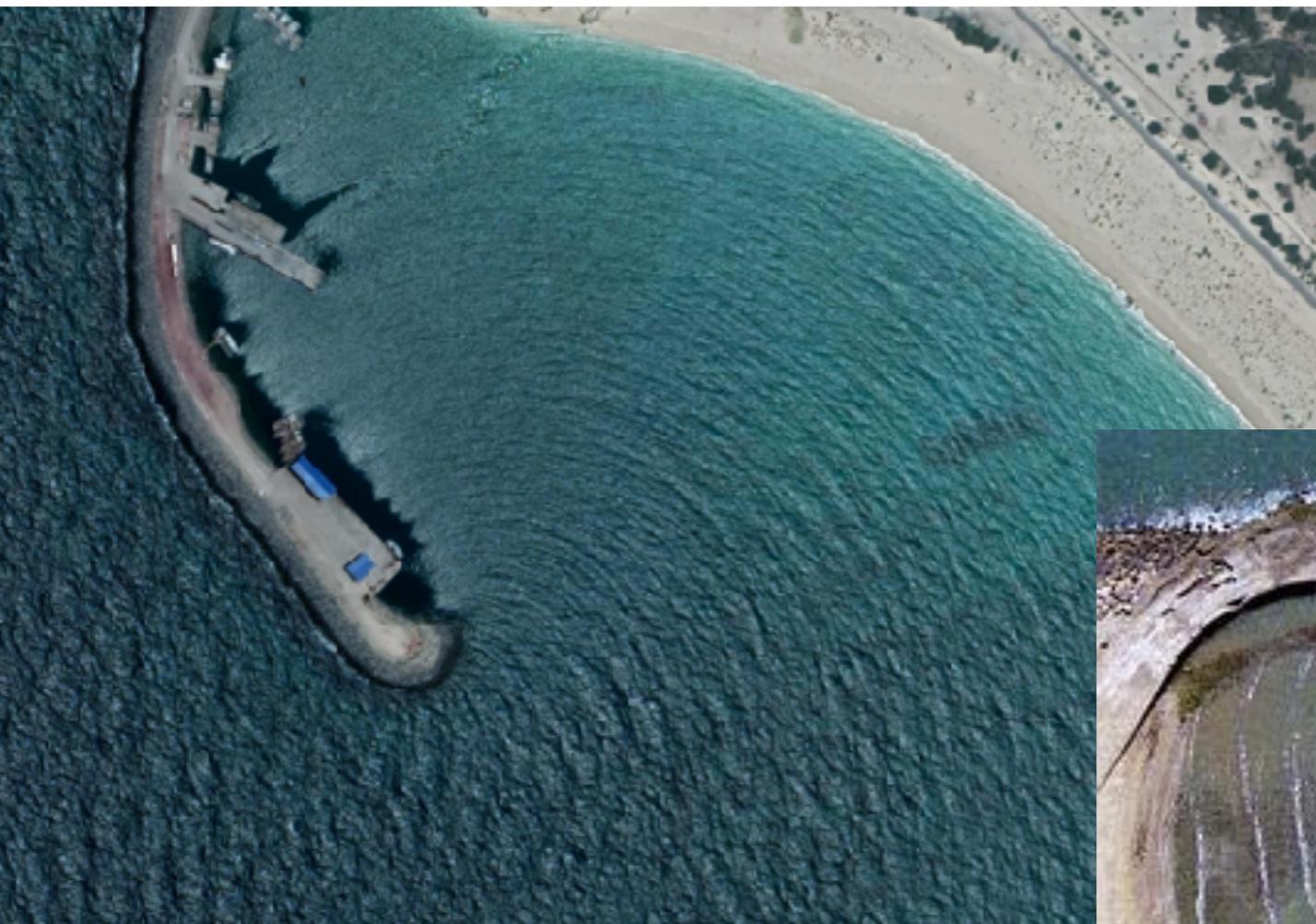


(c)

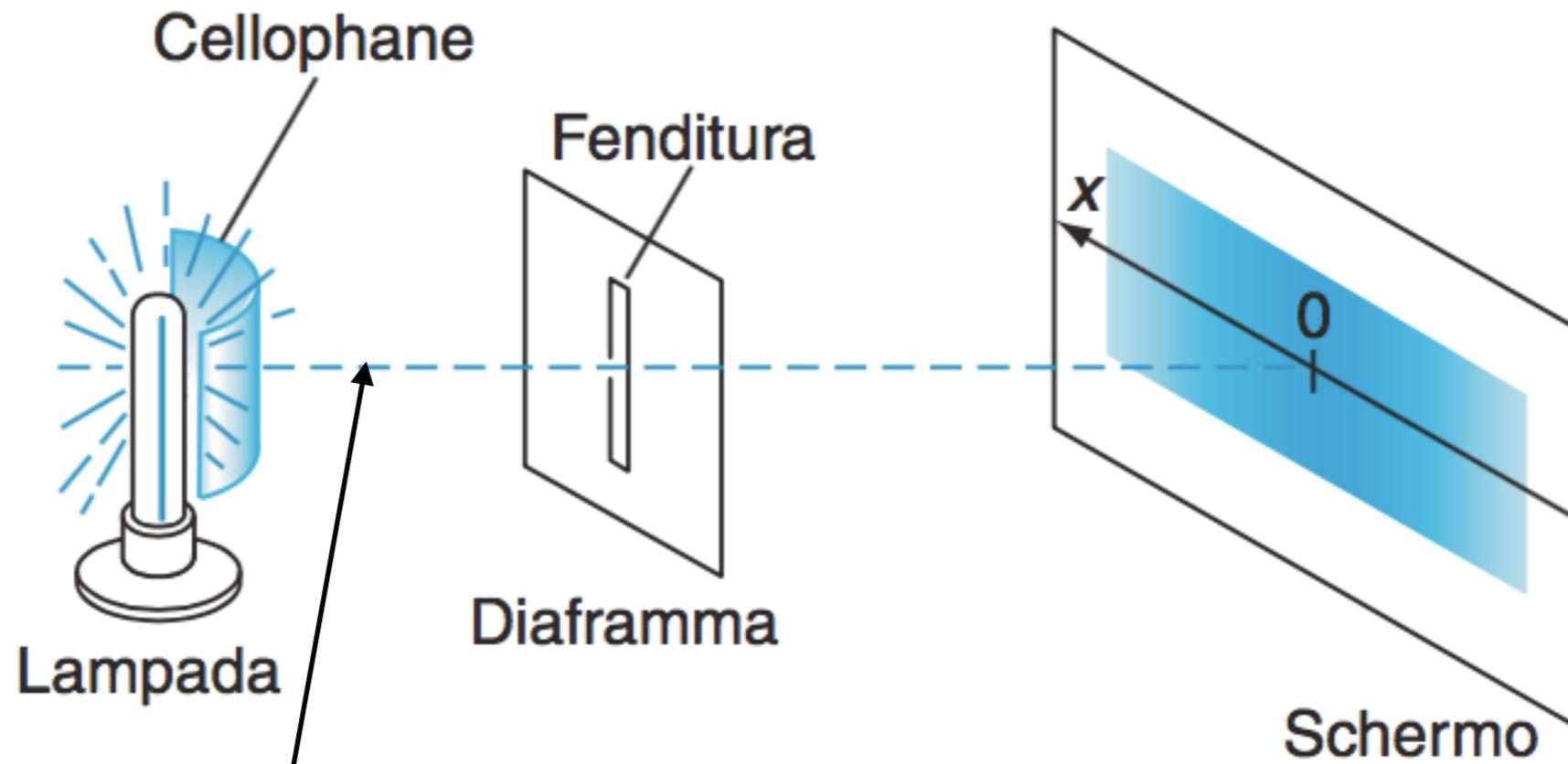


(d)

# Diffrazione



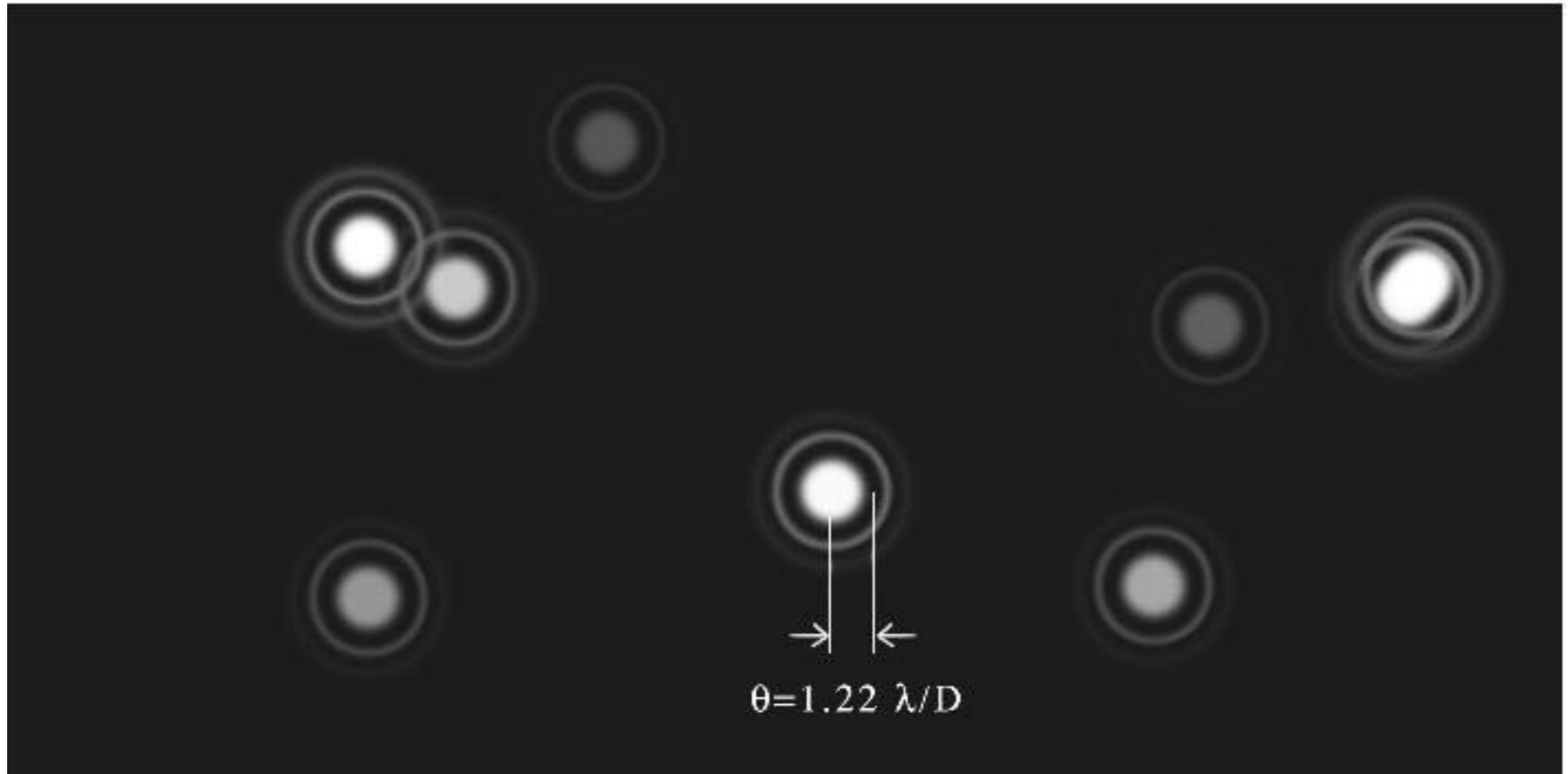
# Diffrazione



Luce  
monocromatica

Lo spessore della  
fenditura deve essere  $\sim \lambda$

# Limite di diffrazione



# Limite di diffrazione

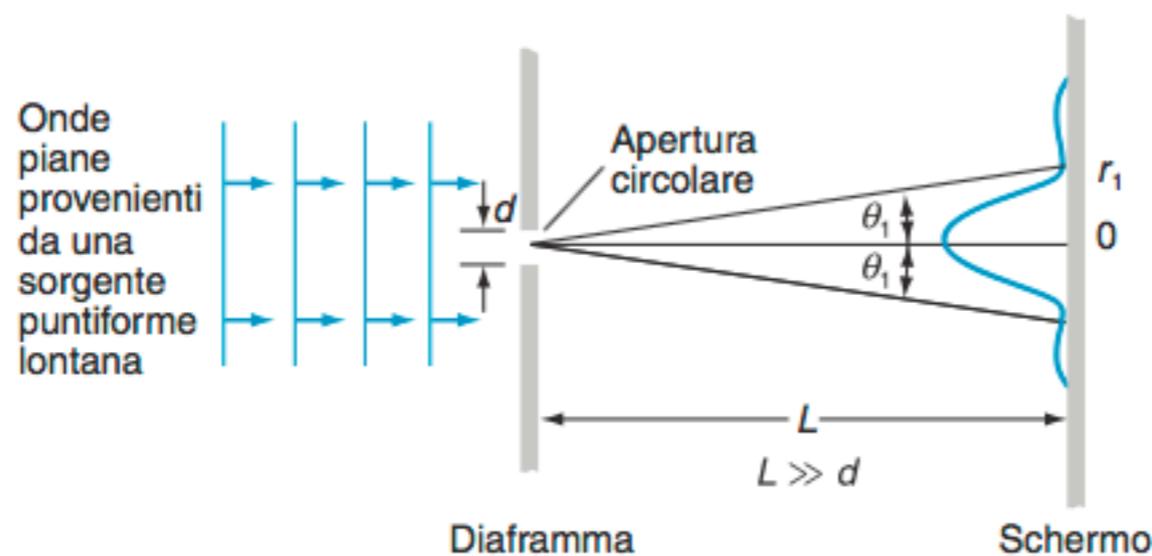
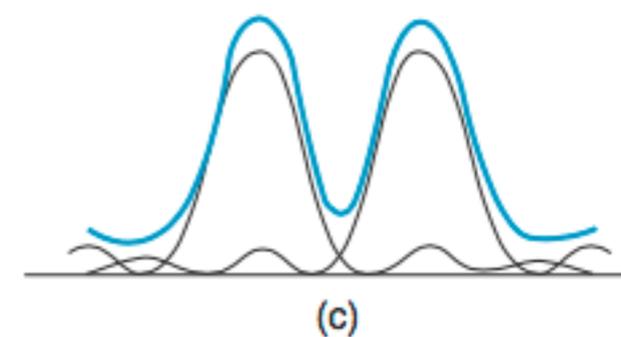
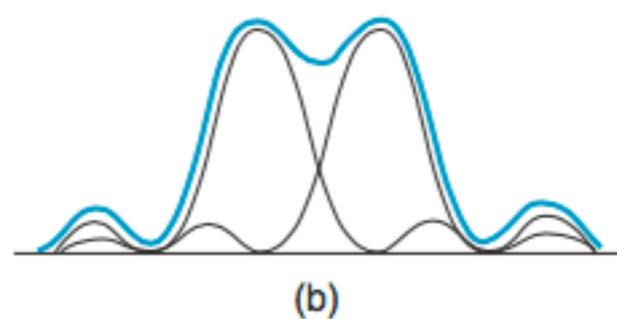
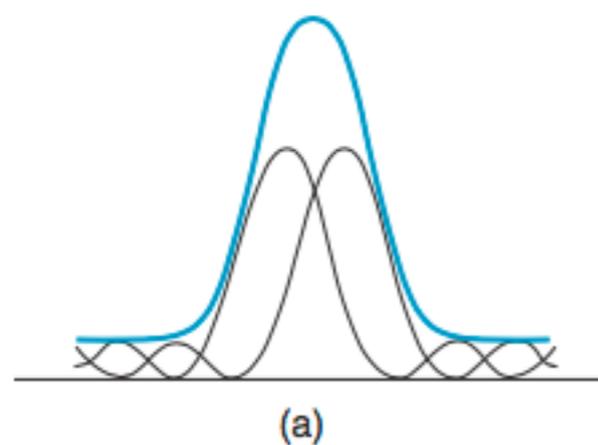
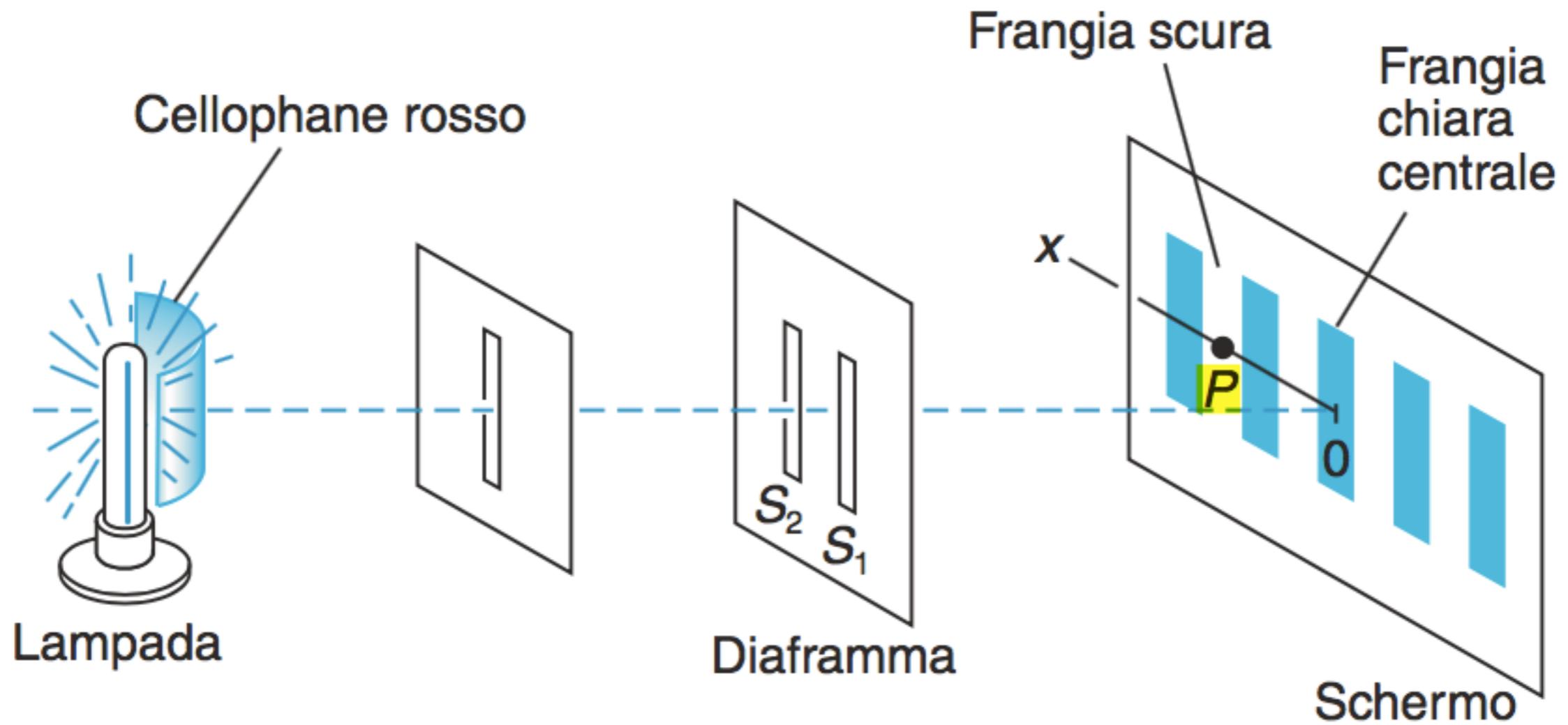


Figura 16.11

L'angolo  $\theta_1$  che individua il primo anello scuro della figura di diffrazione di Fraunhofer prodotta da un foro circolare è la semiapertura di un cono. La base del cono è delimitata dal primo anello scuro e il vertice del cono è al centro del foro.



# Interferenza



# Interferenza

$$y_1(x,t) = A_1 \sin(\Phi_1 - \omega t)$$

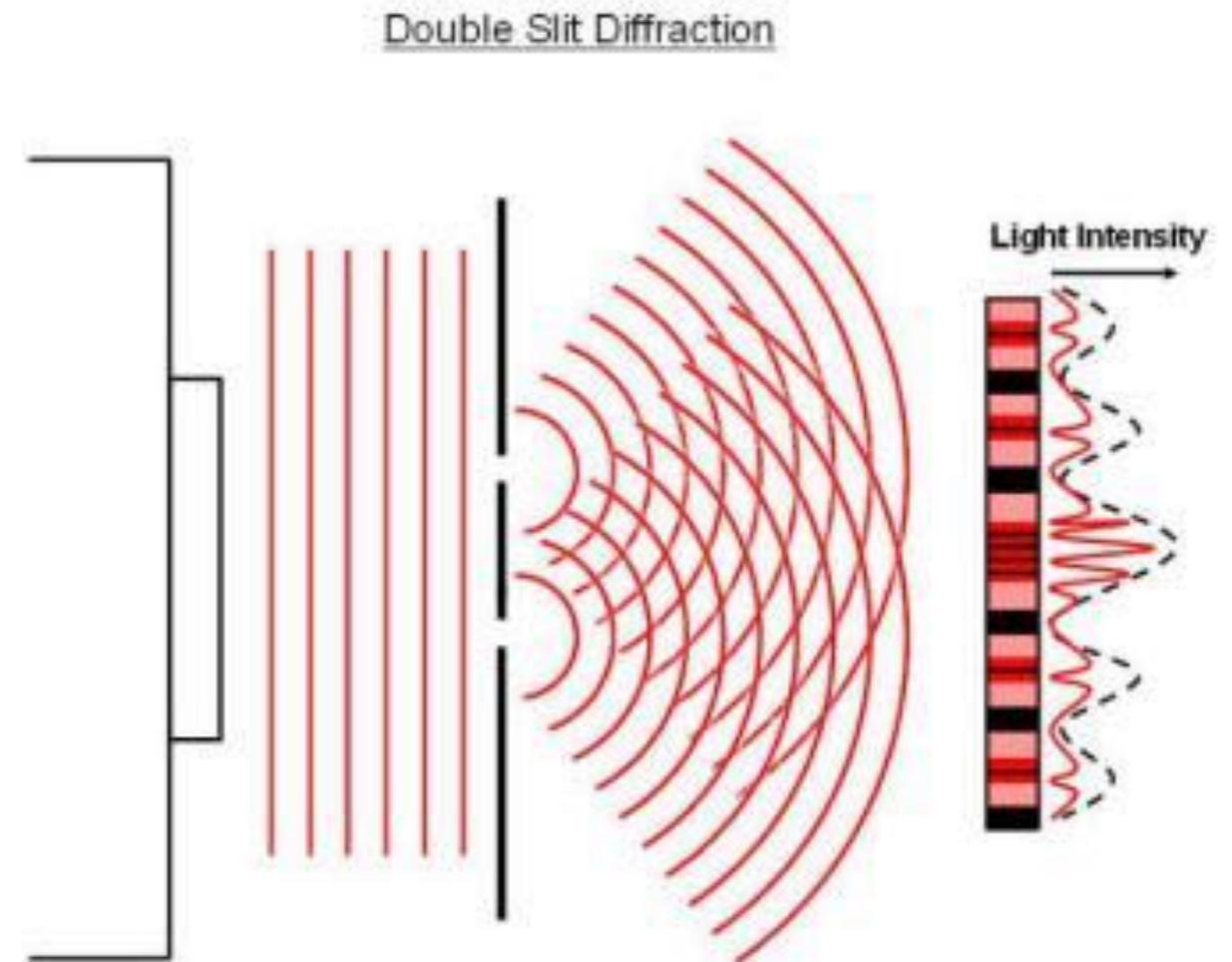
$$y_2(x,t) = A_2 \sin(\Phi_2 - \omega t)$$

$$y = A [\sin(\Phi_1 - \omega t) + \sin(\Phi_2 - \omega t)]$$

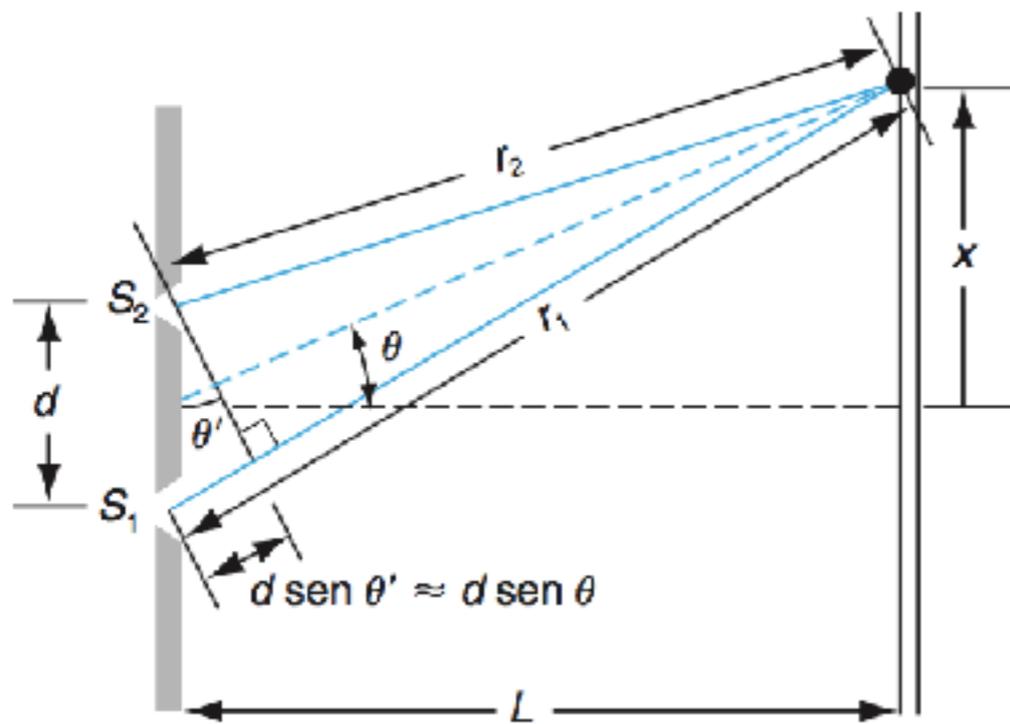
$$\sin \alpha + \sin \beta = 2 \sin\left(\frac{\alpha + \beta}{2}\right) \cos\left(\frac{\alpha - \beta}{2}\right)$$

$$\Delta\Phi = (\Phi_2 - \omega t) - (\Phi_1 - \omega t) = \Phi_2 - \Phi_1$$

poniamo  $\alpha = \Phi_1 - \omega t$  e  $\beta = \Phi_2 - \omega t$ .

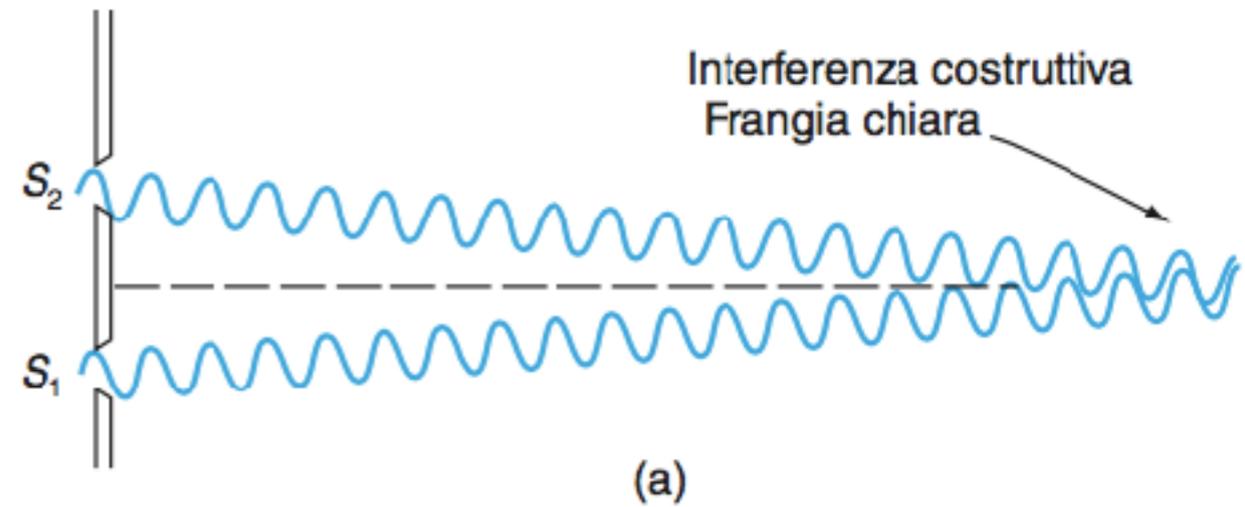


$$y(x,t) = 2A \cos(\Delta\Phi/2) \sin(\Phi_1 - \omega t + \Delta\Phi/2)$$

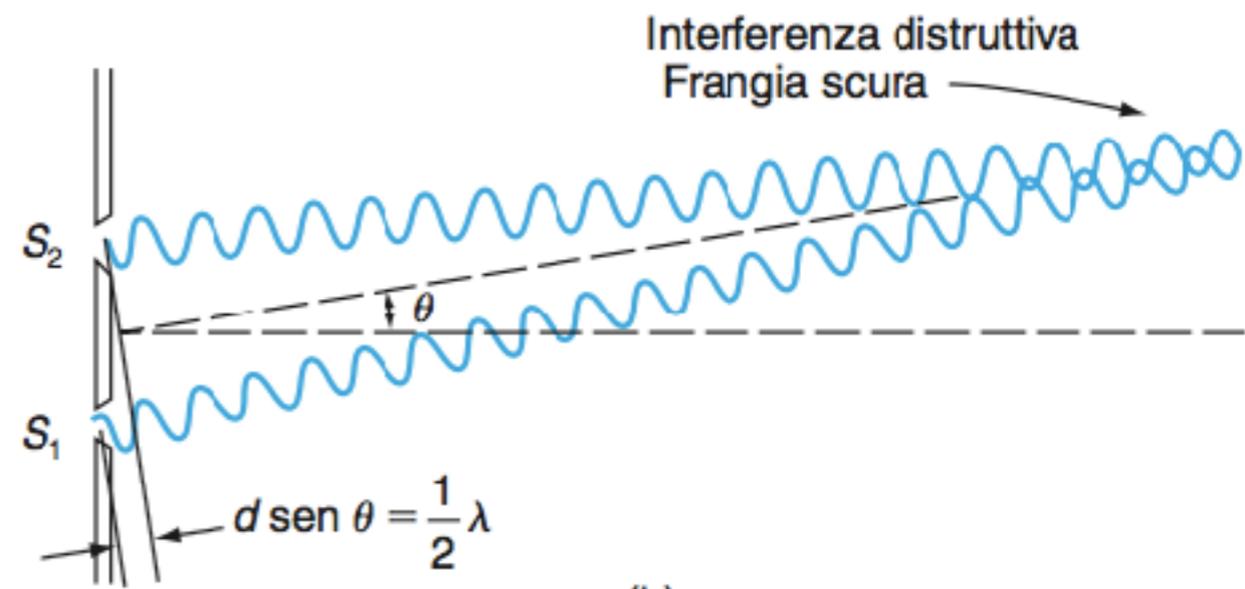


$$d \sin \theta_{m'} = \pm \left( m' + \frac{1}{2} \right) \lambda \quad (m' = 0, 1, 2, \dots)$$

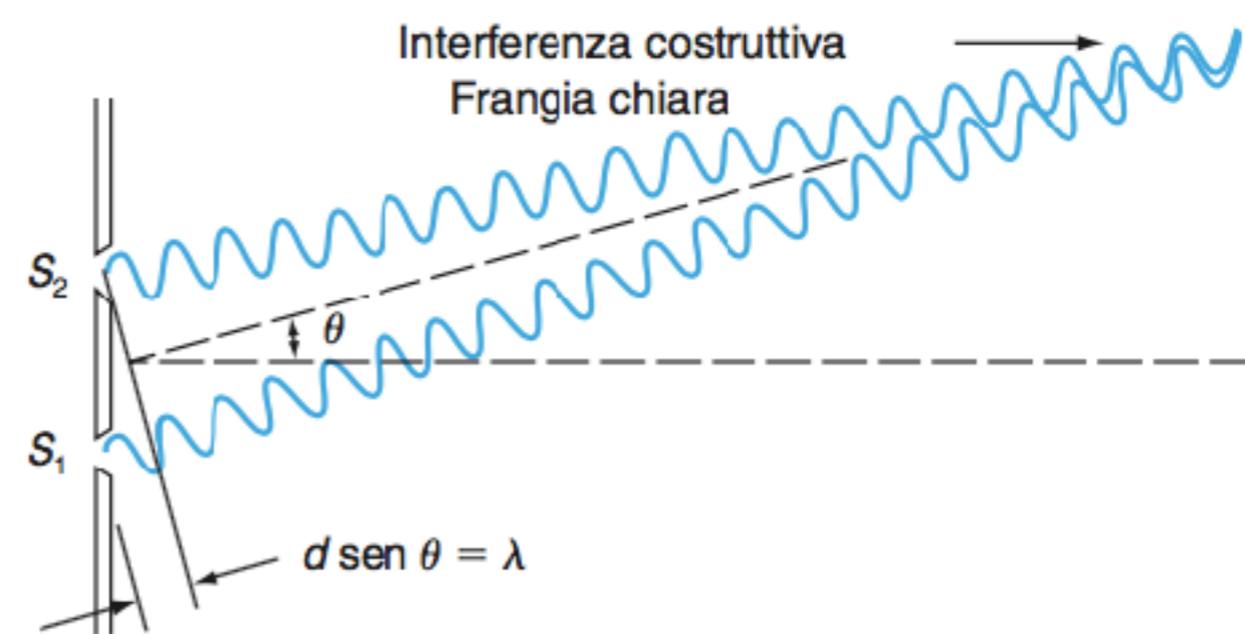
$$d \sin \theta_m = \pm m \lambda \quad (m = 0, 1, 2, \dots)$$



(a)

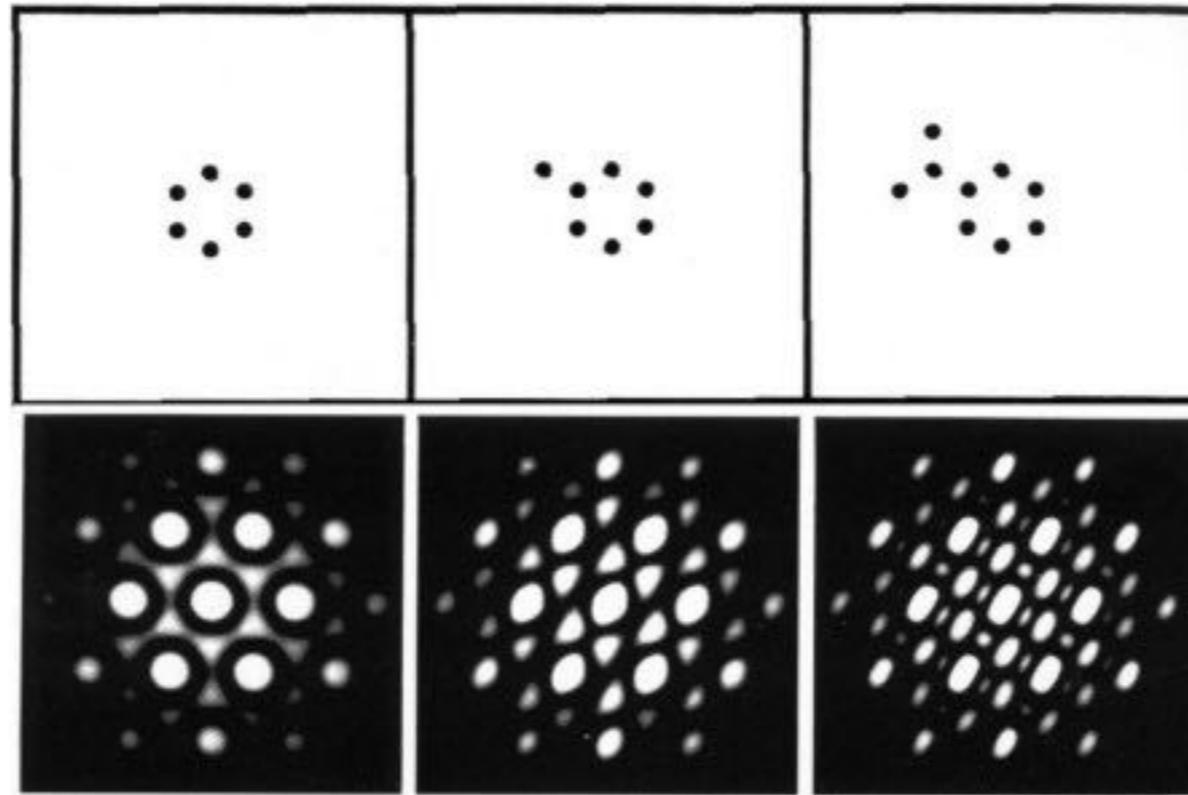
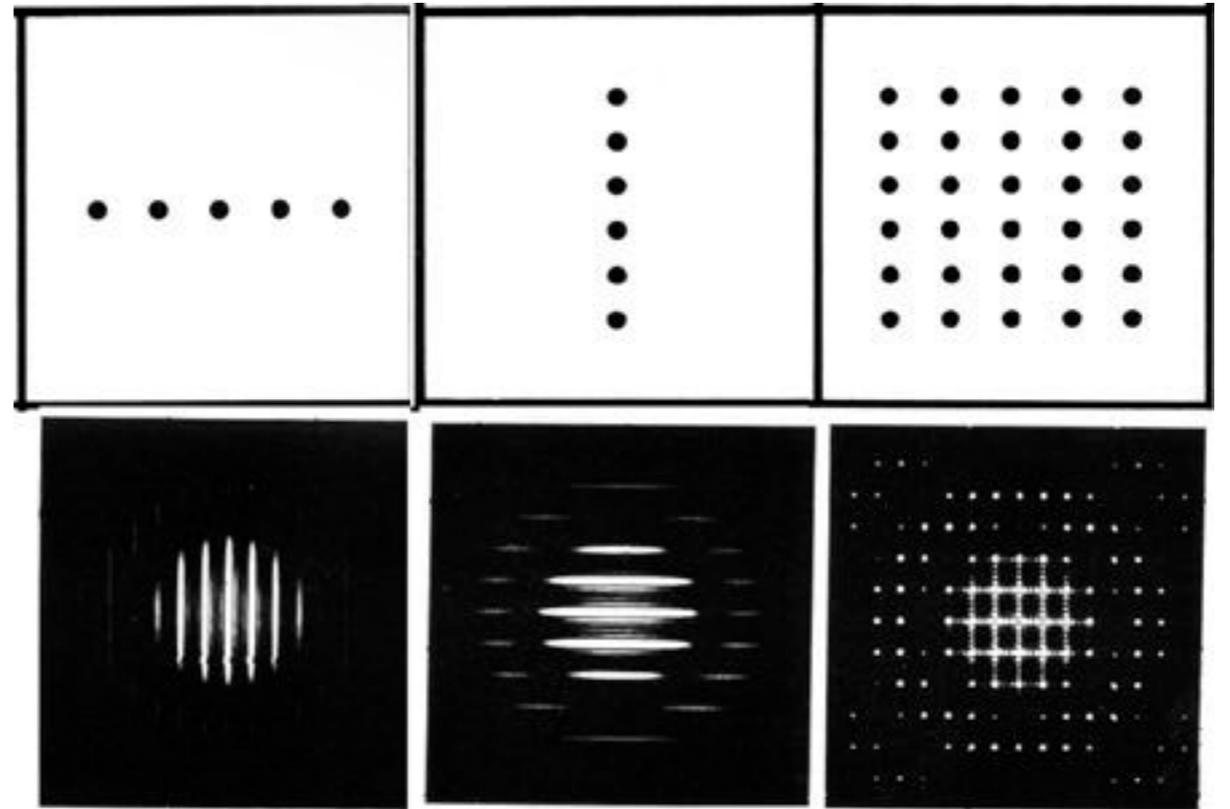
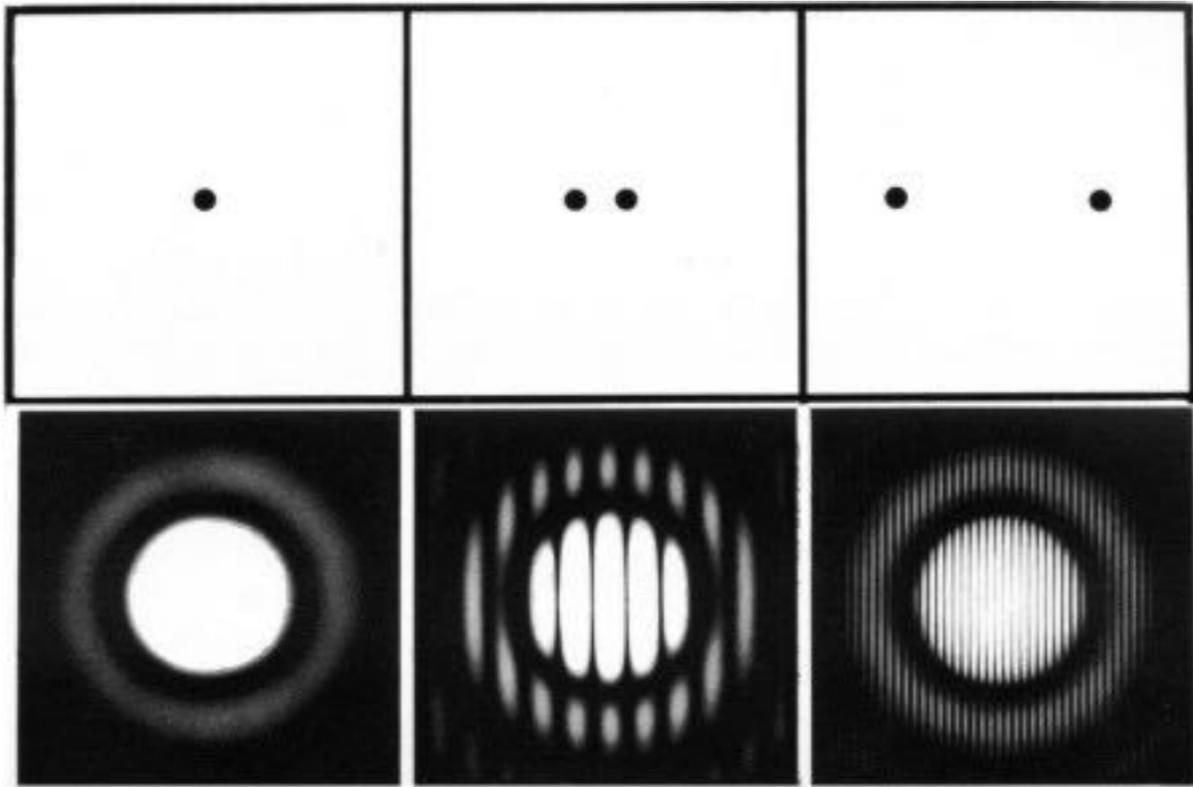


(b)

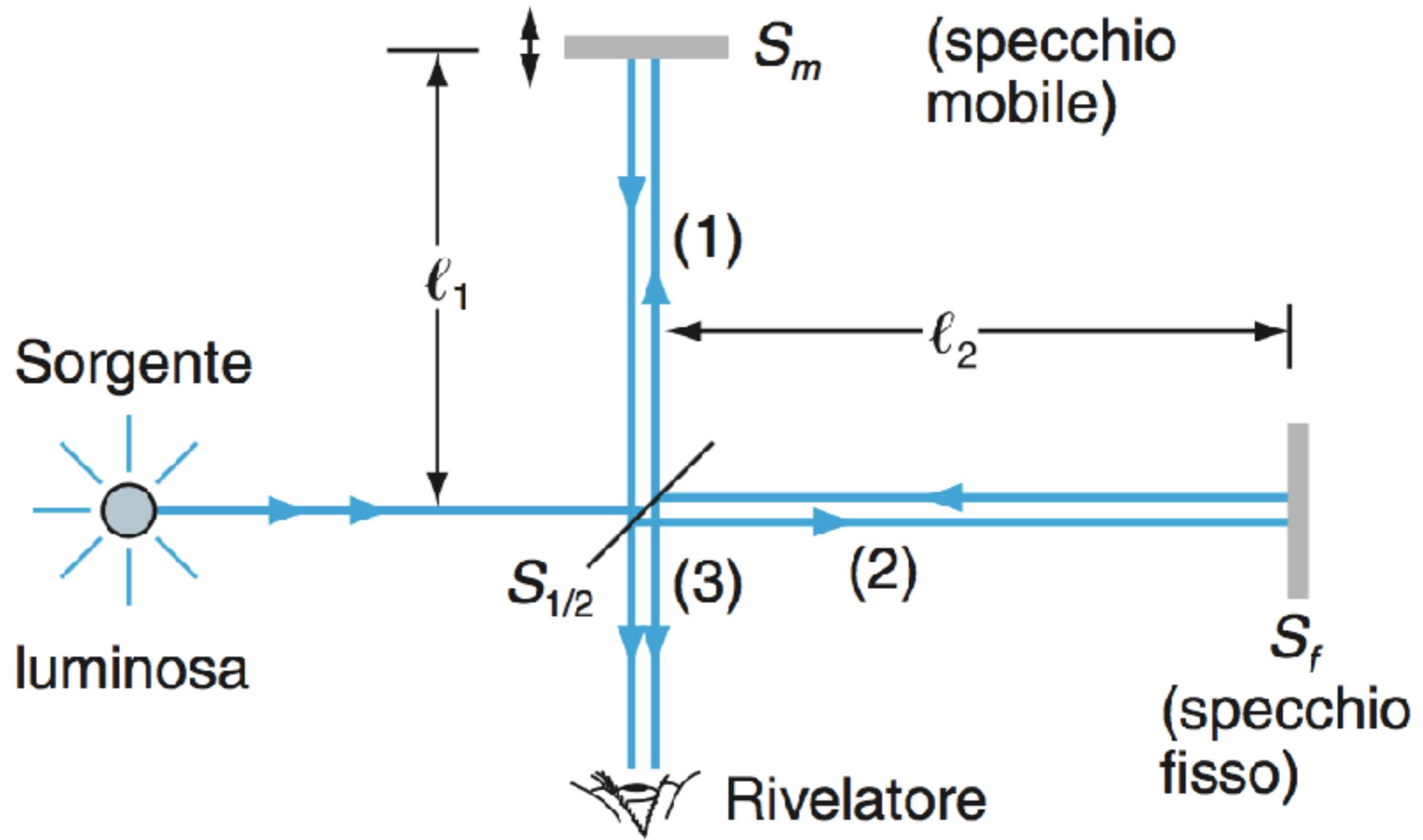


(c)



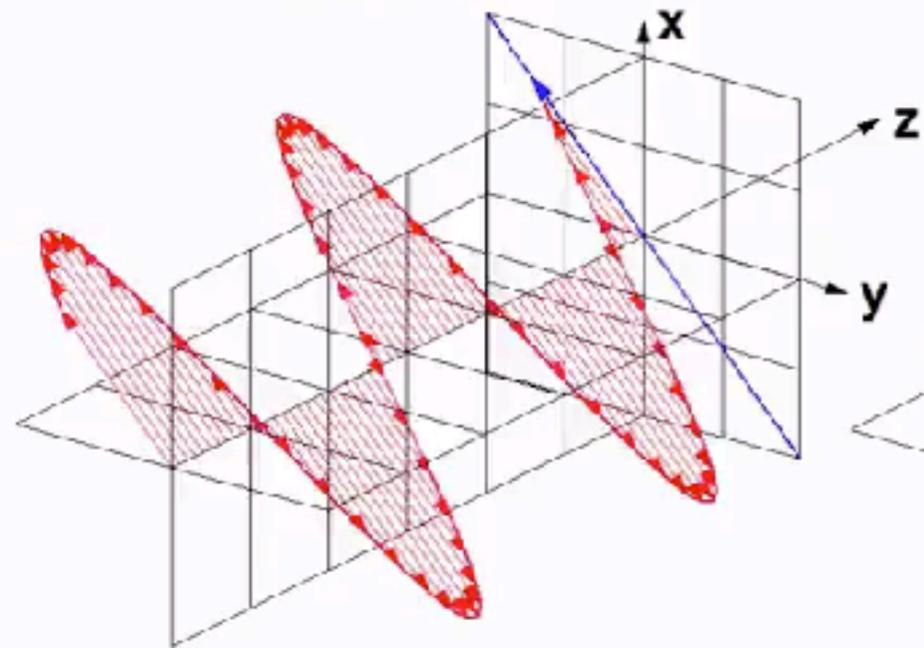


# L'interferometro di Michelson

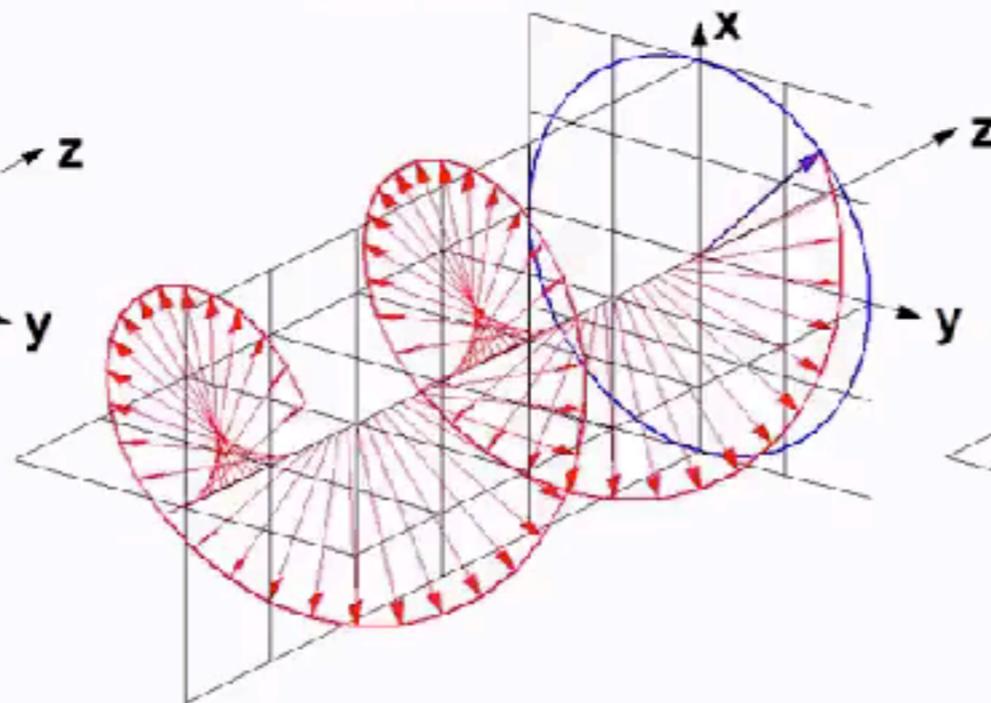


# Polarizzazione

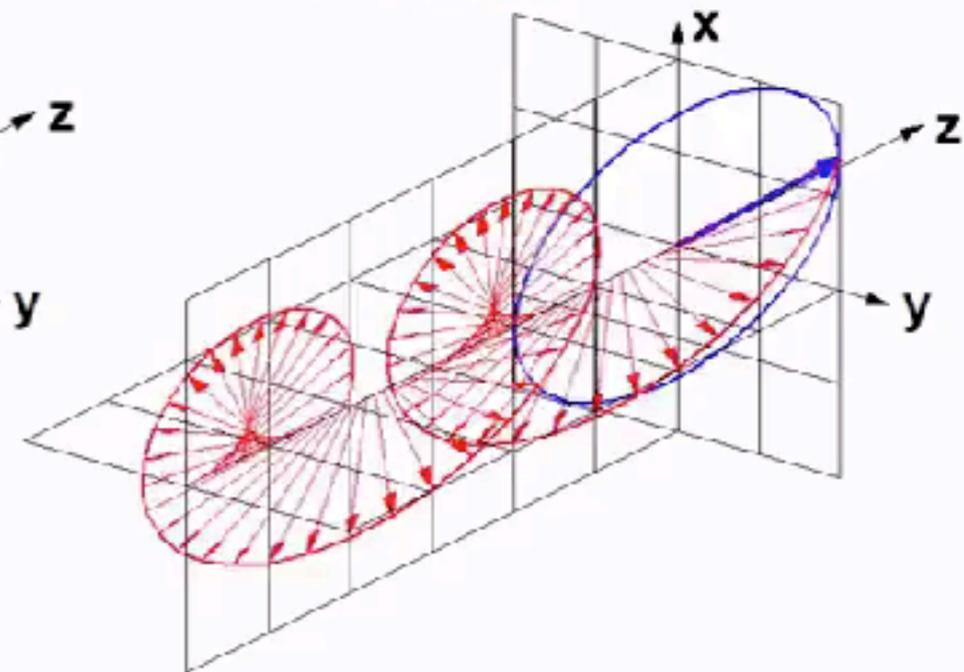
Linear Polarization

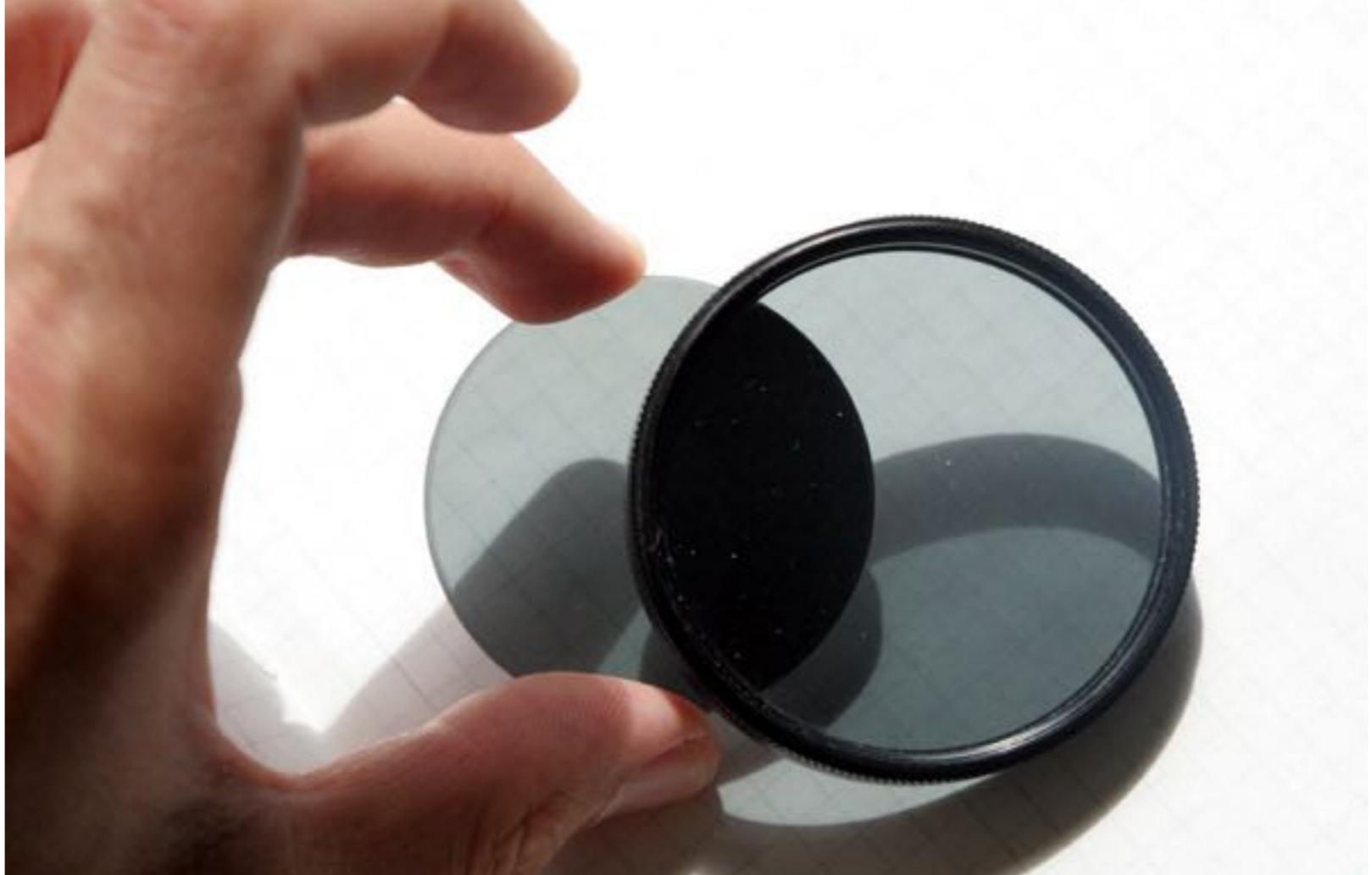
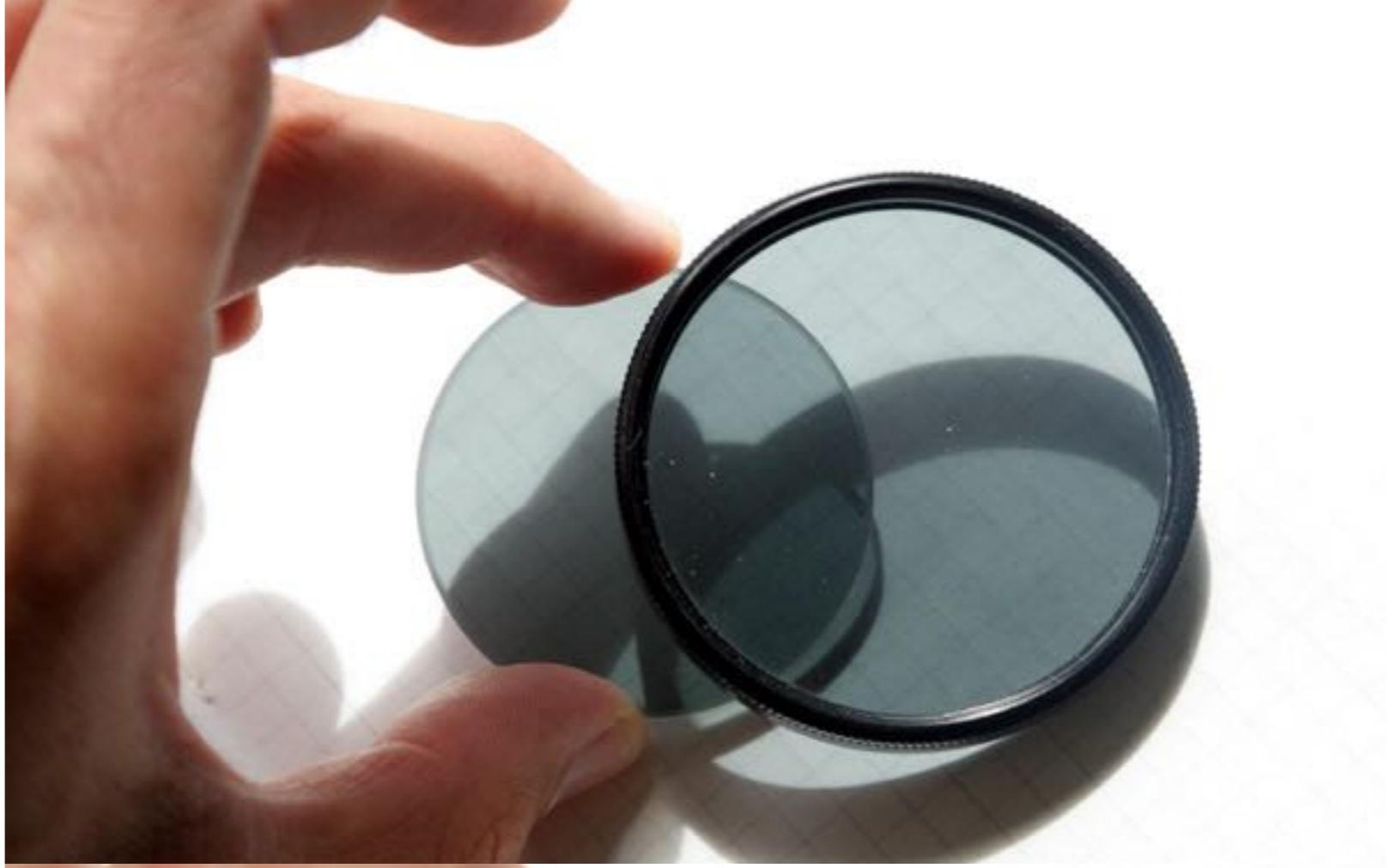


Circular (Right Hand) Polarization

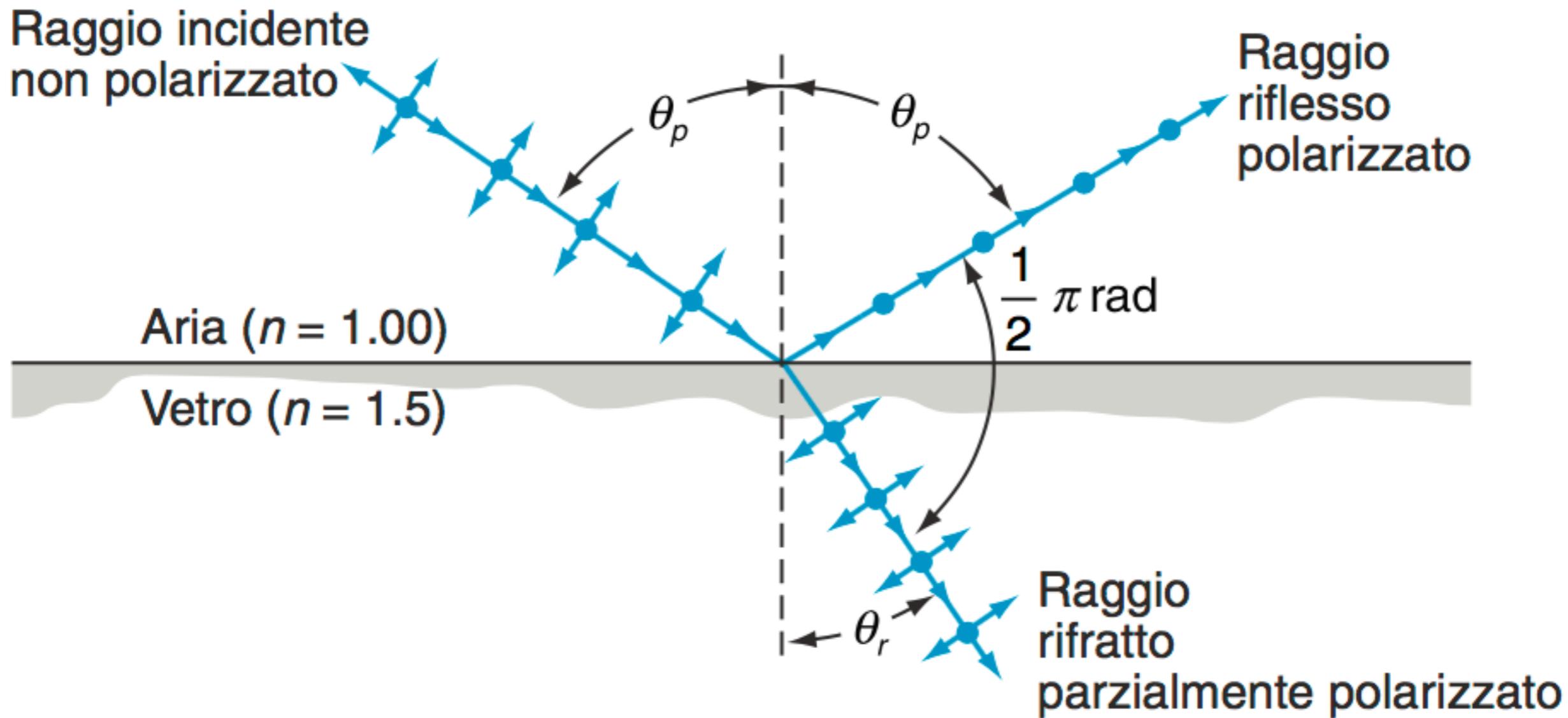


Elliptical (Right Hand) Polarization



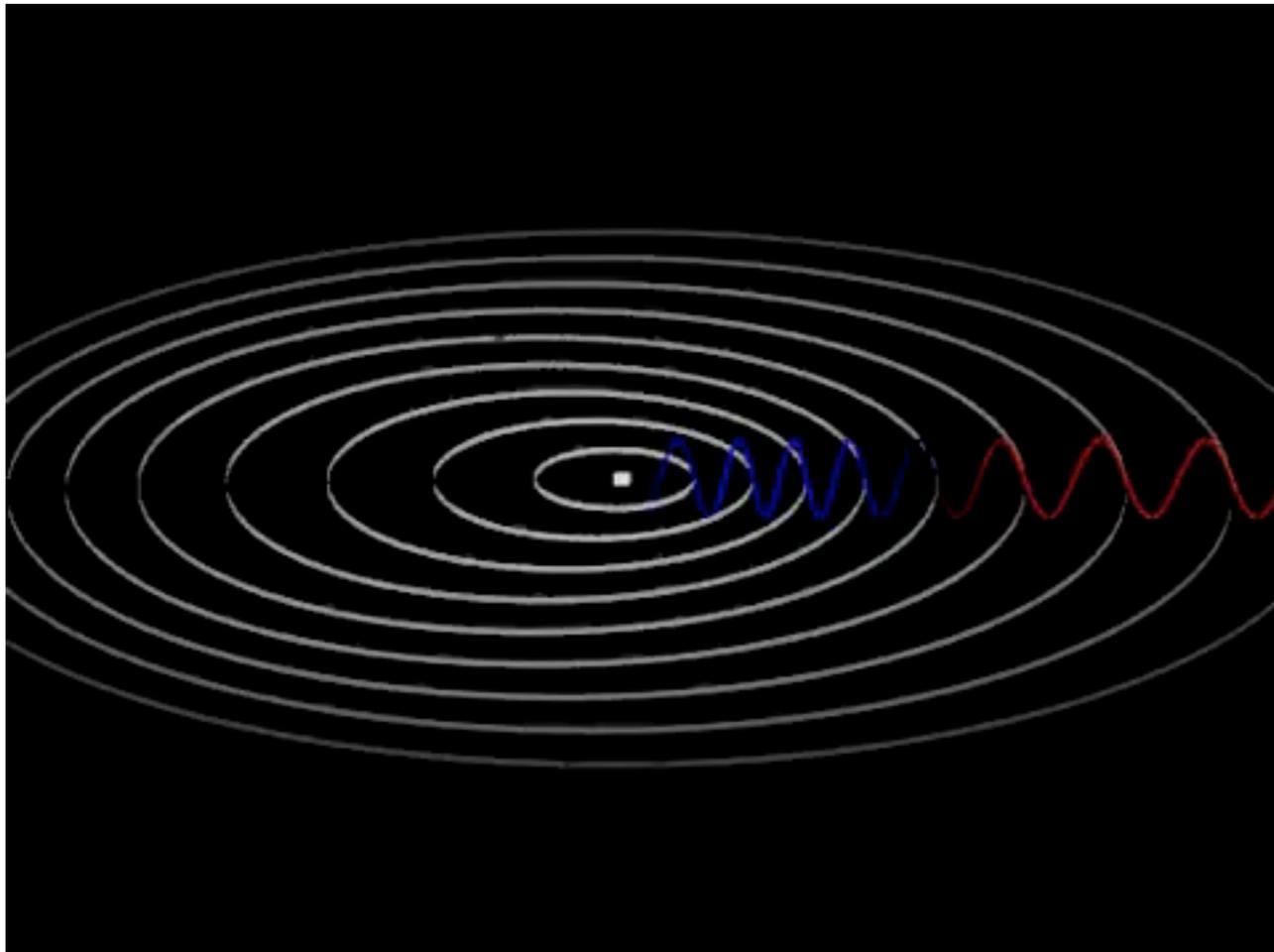


## Legge di Brewster:



$$\tan \theta_p = n_{21}$$

# Effetto doppler



$$\frac{\lambda_{\text{oss}} - \lambda_{\text{em}}}{\lambda_{\text{em}}} = \frac{v}{c}$$

$$v \ll c$$



[www.eso.org](http://www.eso.org)