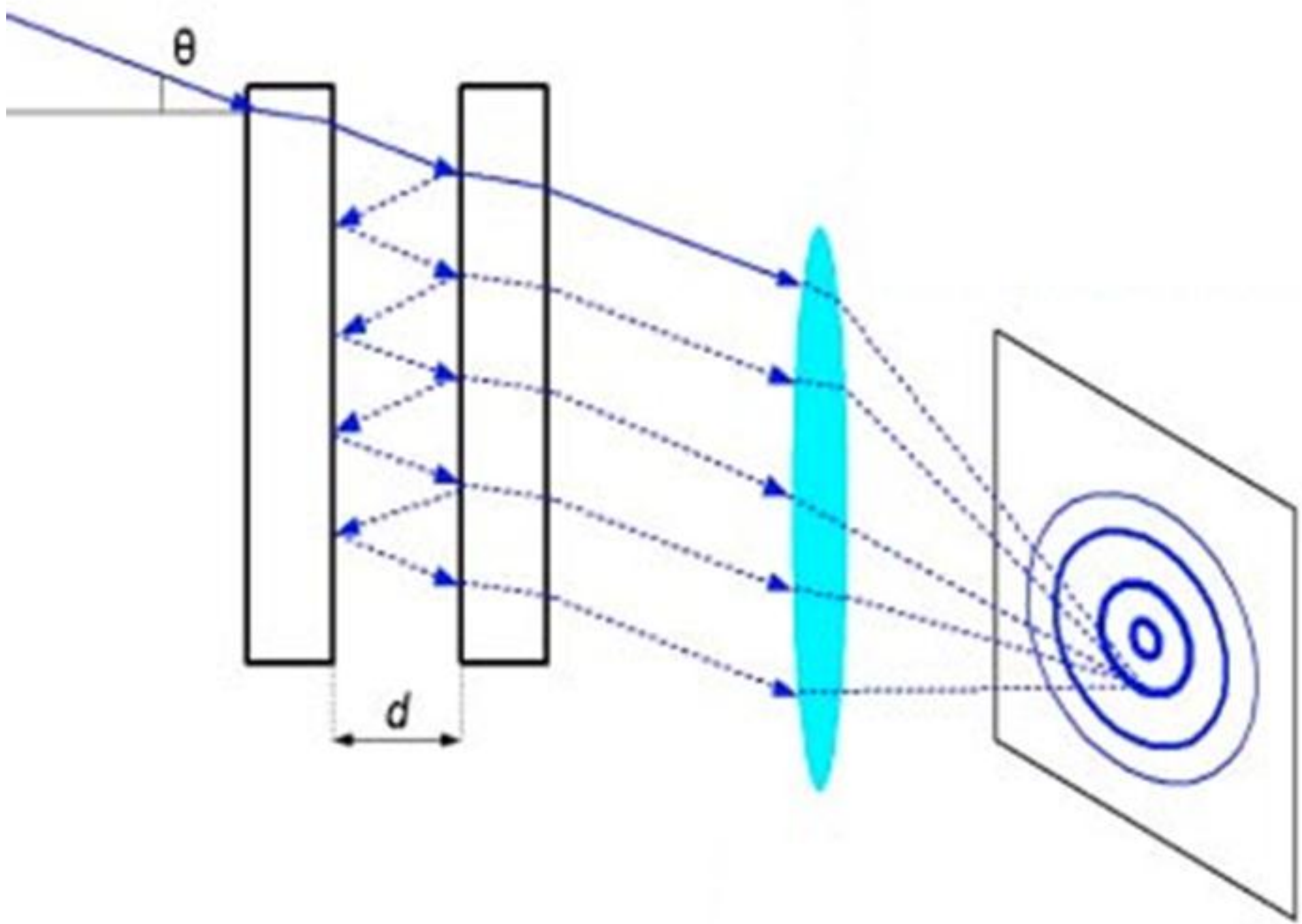
High resolution spectroscopy

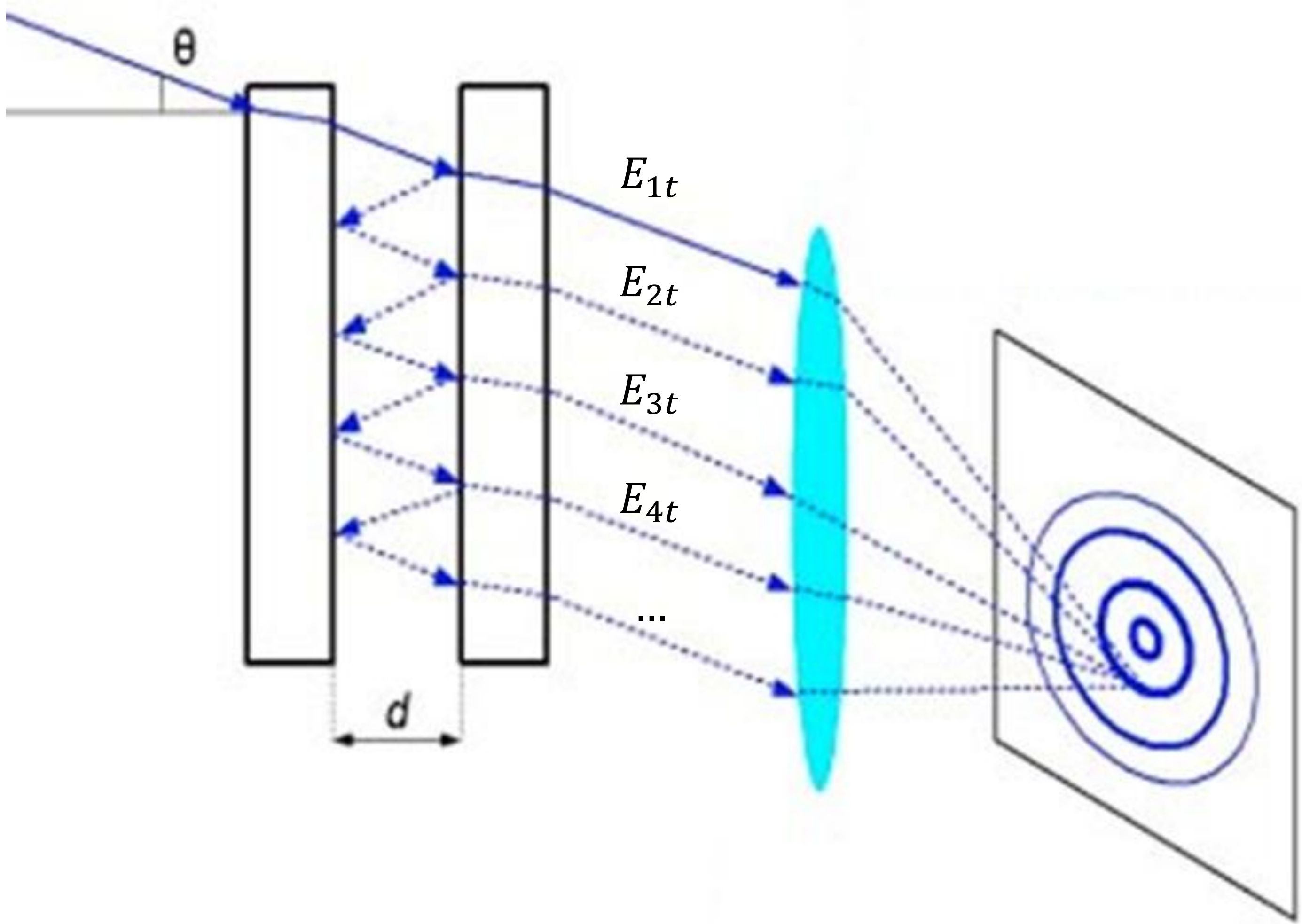
Fabry-Perot Interferometer

Student: Victor-Cristian Palea
Coordinator: Ș. L. Liliana Preda

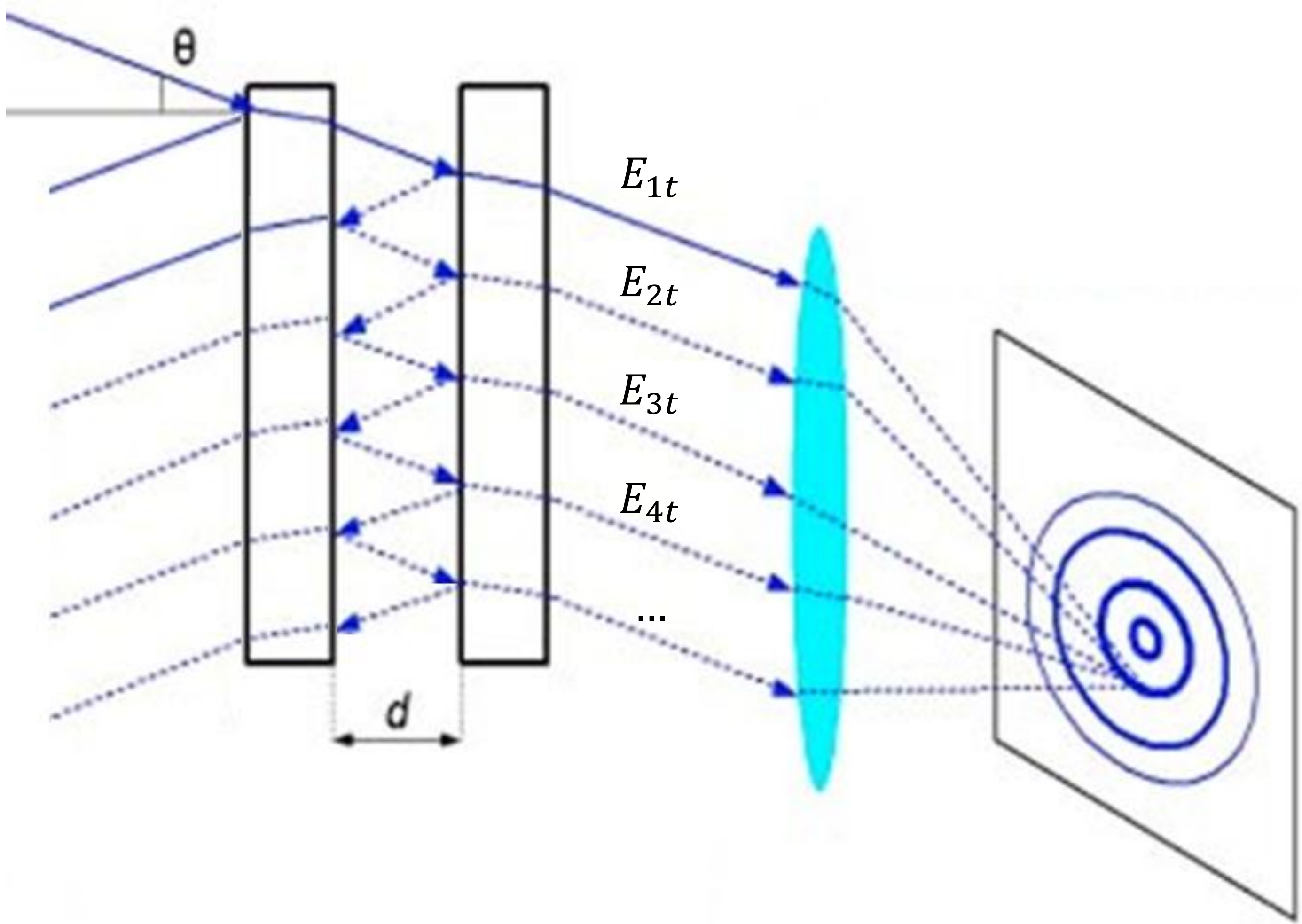
Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



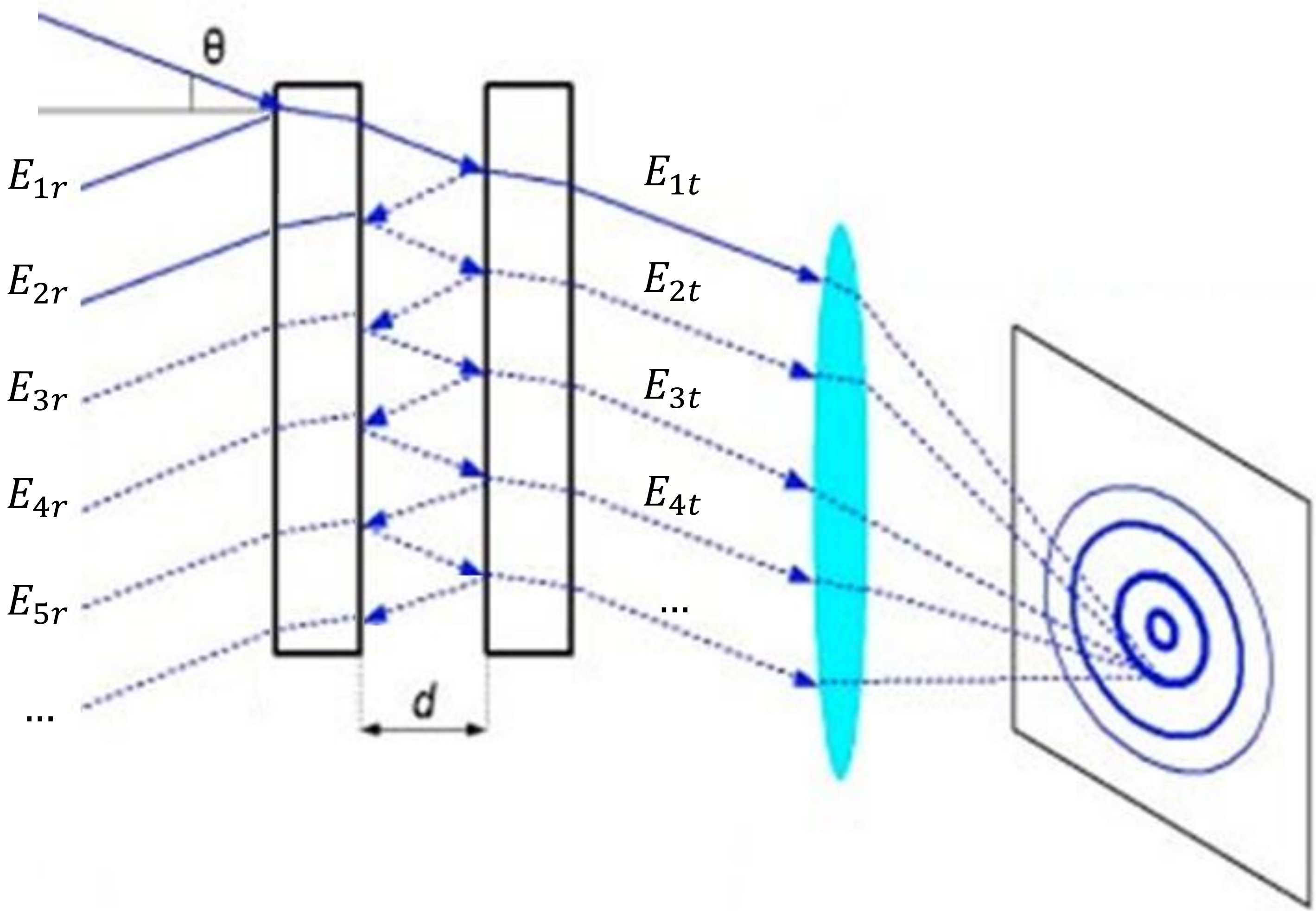
Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



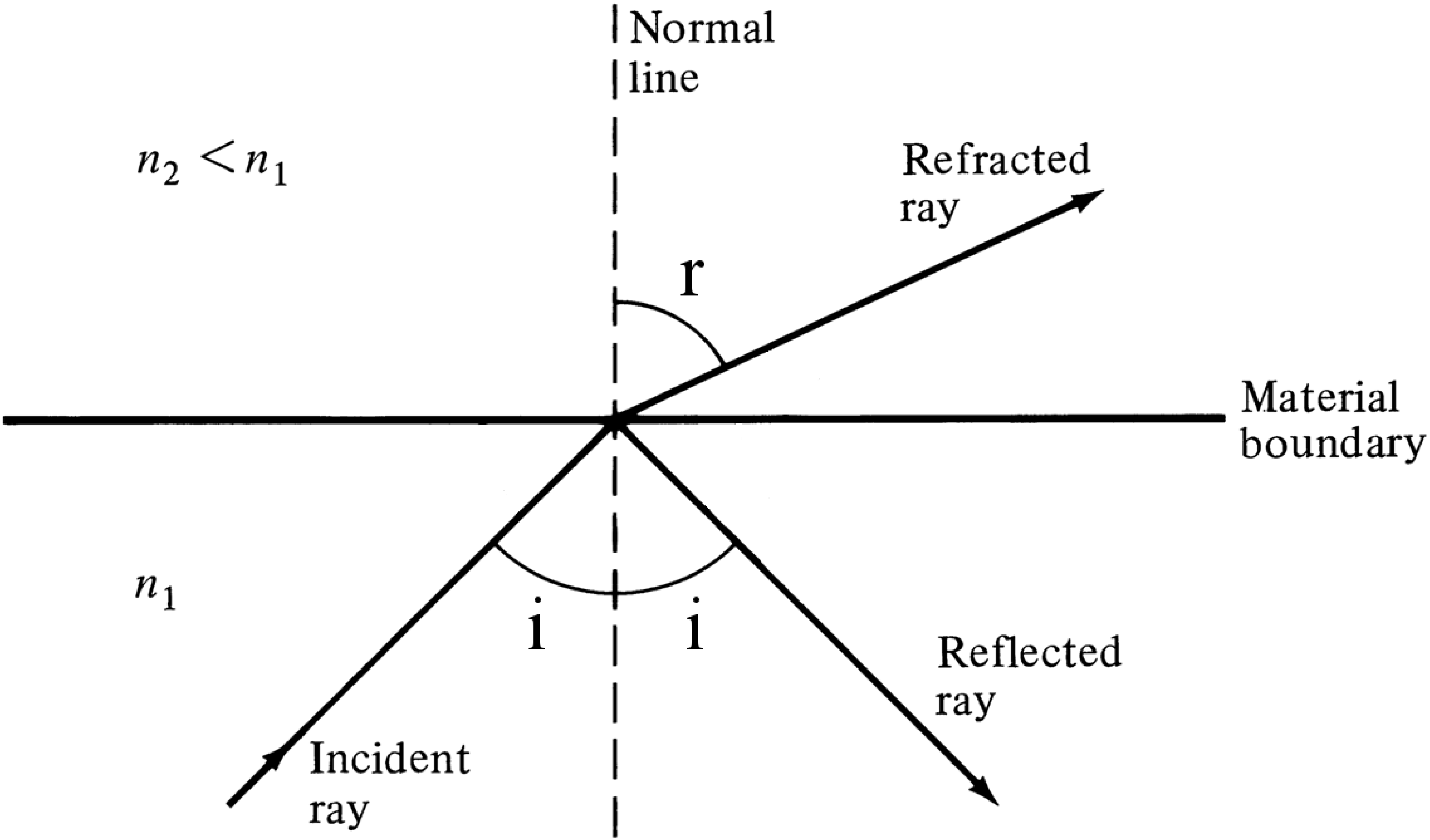
Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



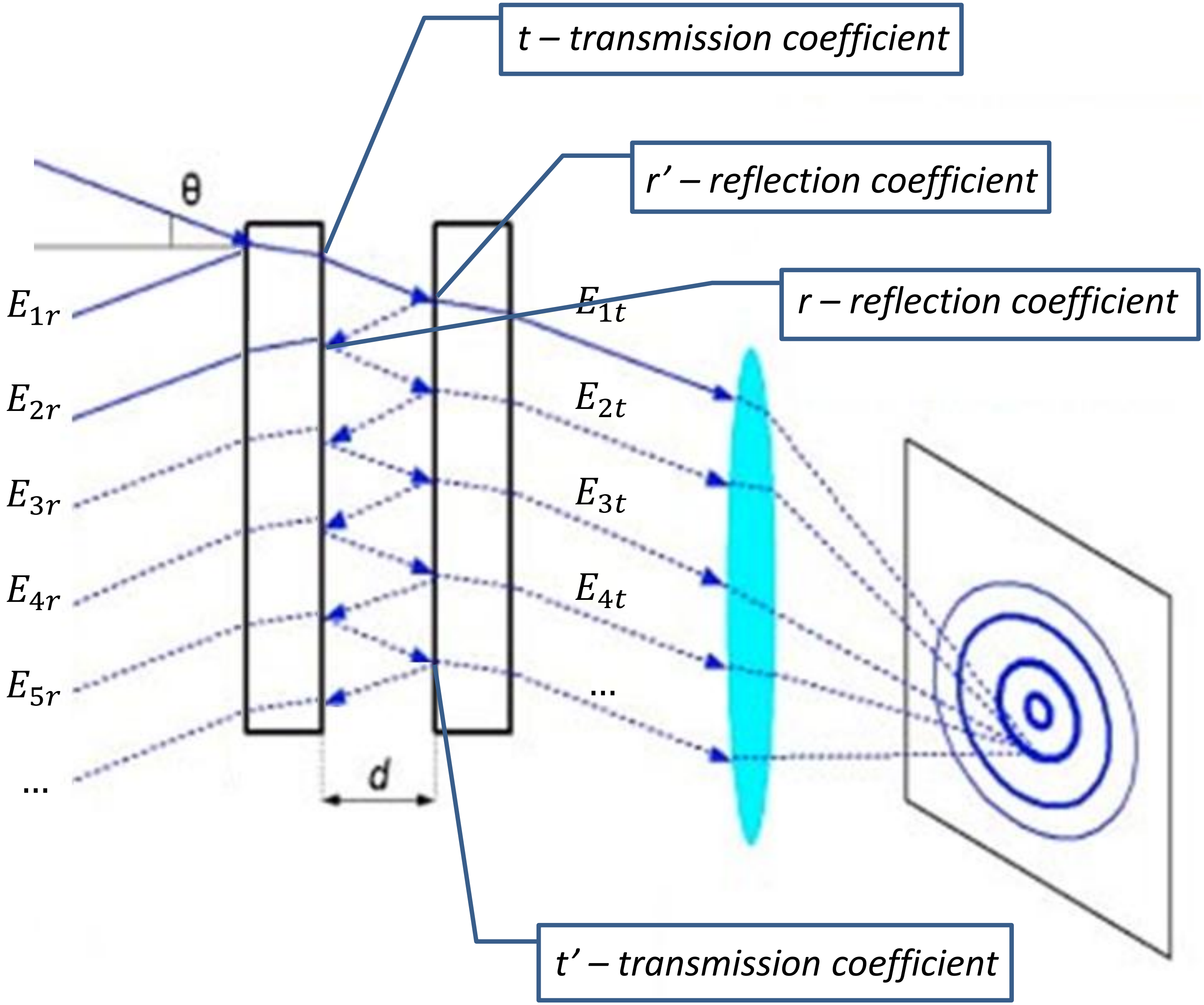
Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



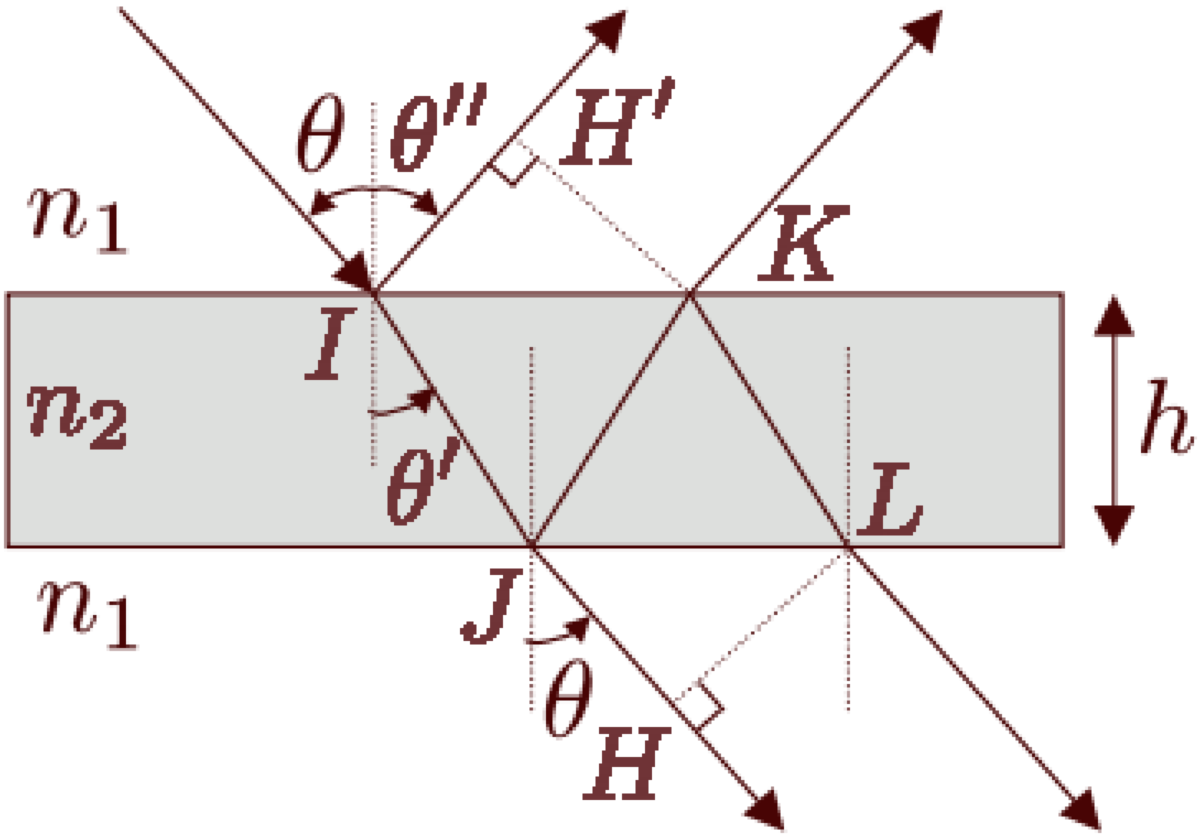
Source: https://physi.wordpress.com/tag/reflection/



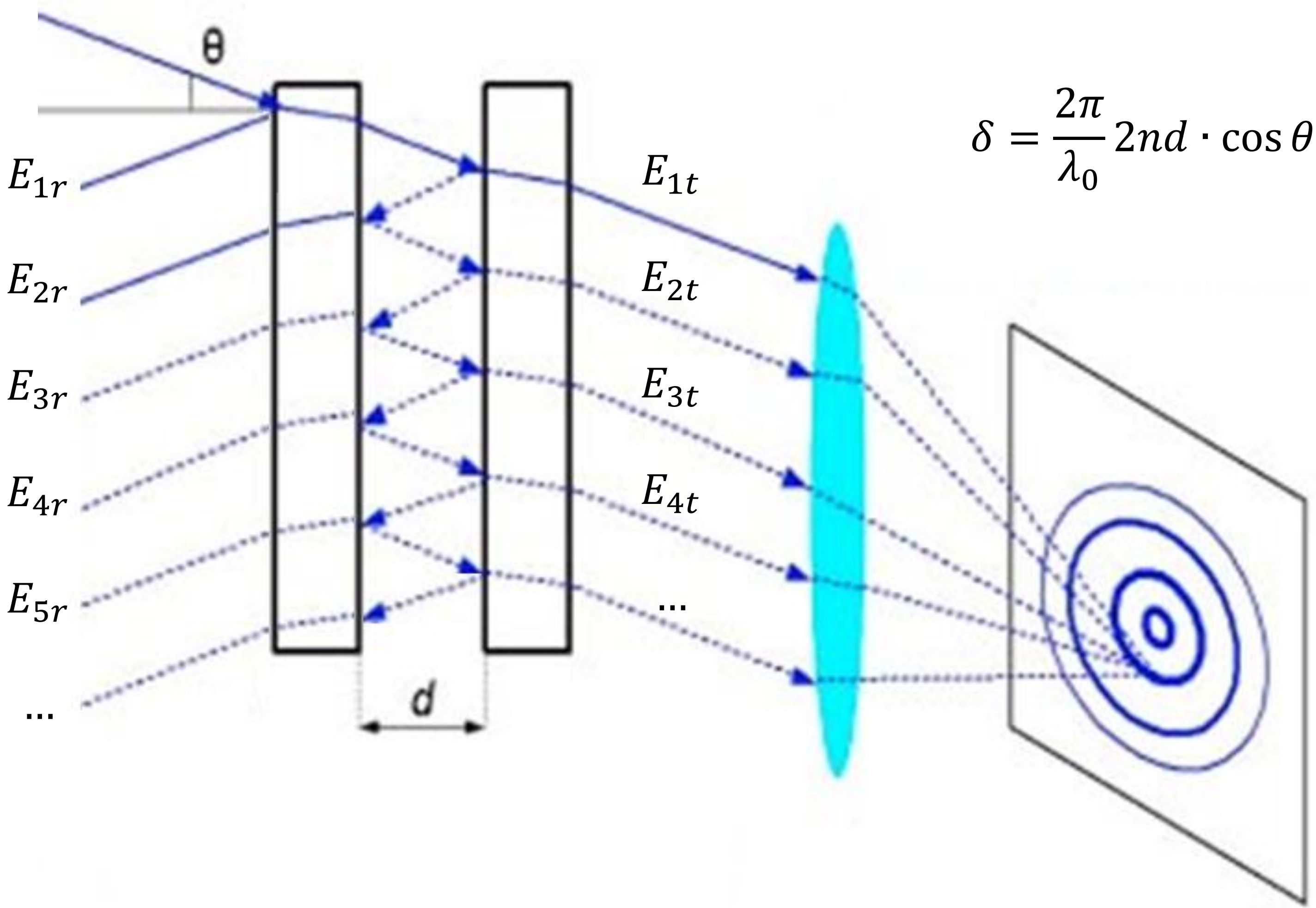
Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



Source: References [1]

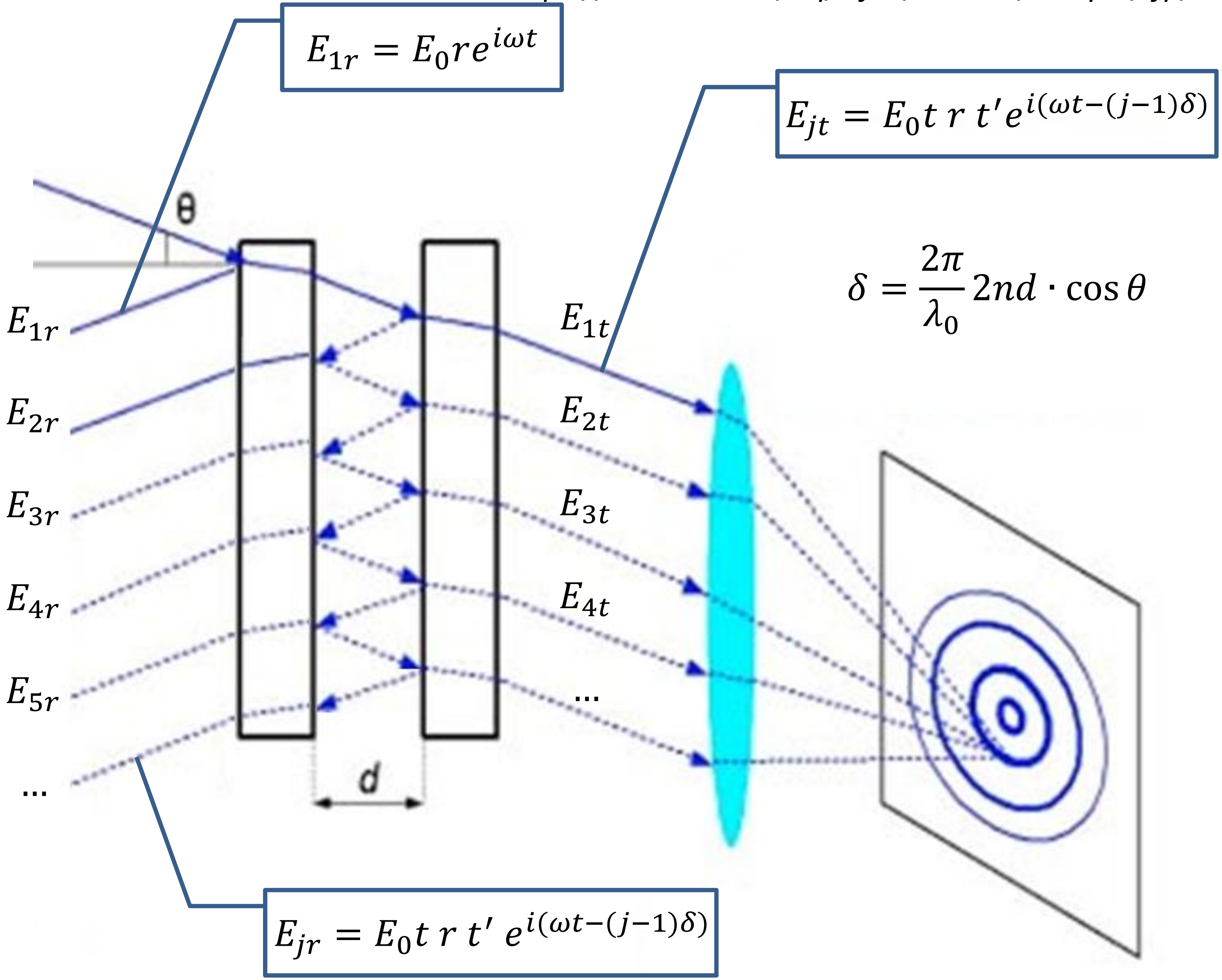


Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



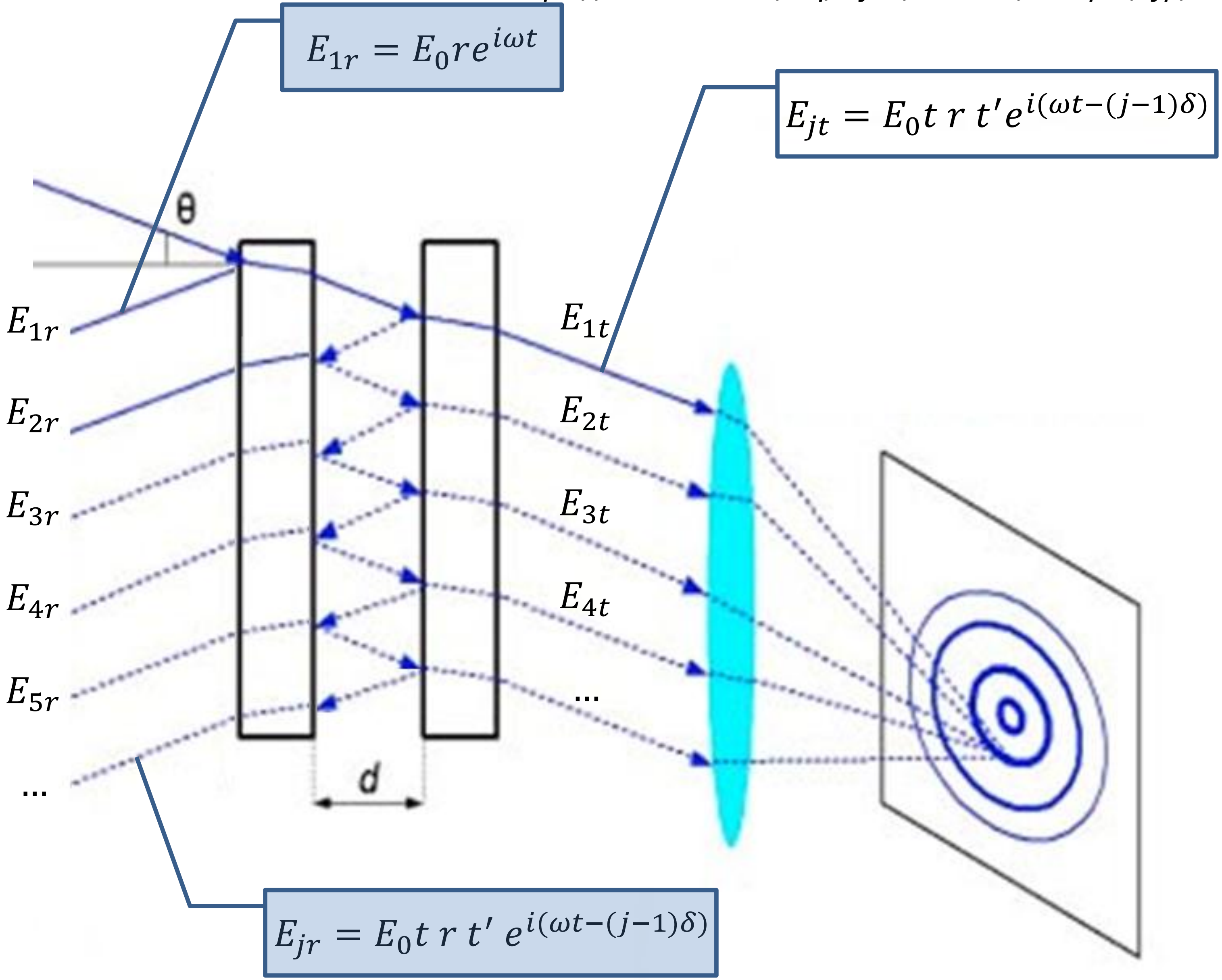
$$\delta = \frac{2\pi}{\lambda_0} 2nd \cdot \cos\theta$$

Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



$$\delta = \frac{2\pi}{\lambda_0} 2nd \cdot \cos\theta$$

Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



$$E_r = \sum_{j}^{N} E_{jr} =$$

$$E_r = \sum_{j}^{N} E_{jr} = E_0 r e^{i\omega t} + \sum_{j=2}^{N} E_0 t\ r\ t'\ e^{i(\omega t-(j-1)\delta)}$$

$$E_r = \sum_{j}^{N} E_{jr} = E_0 r e^{i\omega t} + \sum_{j=2}^{N} E_0 t\, r\, t'\, e^{i(\omega t-(j-1)\delta)}$$

$$E_r = E_0 e^{i\omega t}\left[r + \frac{r' t t' e^{-i\delta}}{1 - r'^2 e^{-i\delta}}\right]$$

$$E_r = \sum_{j}^{N} E_{jr} = E_0 r e^{i\omega t} + \sum_{j=2}^{N} E_0 t\; r\; t'\; e^{i(\omega t-(j-1)\delta)}$$

$$E_r = E_0 e^{i\omega t}\left[r + \frac{r' t t' e^{-i\delta}}{1 - r'^2 e^{-i\delta}}\right] = E_0 e^{i\omega t}\left[\frac{r\left(1 - e^{-i\delta}\right)}{1 - r'^2 e^{-i\delta}}\right]$$

$$E_r = \sum_{j}^{N} E_{jr} = E_0 r e^{i\omega t} + \sum_{j=2}^{N} E_0 t\, r\, t'\, e^{i(\omega t-(j-1)\delta)}$$

$$E_r = E_0 e^{i\omega t}\left[r + \frac{r' t t' e^{-i\delta}}{1 - r'^2 e^{-i\delta}}\right] = E_0 e^{i\omega t}\left[\frac{r\left(1 - e^{-i\delta}\right)}{1 - r^2 e^{-i\delta}}\right]$$

$$I_r = \frac{E_r {E_r}^*}{2}$$

$$E_r = \sum_{j}^{N} E_{jr} = E_0 r e^{i\omega t} + \sum_{j=2}^{N} E_0 t\ r\ t'\ e^{i(\omega t-(j-1)\delta)}$$

$$E_r = E_0 e^{i\omega t}\left[r + \frac{r' t t' e^{-i\delta}}{1 - r'^2 e^{-i\delta}}\right] = E_0 e^{i\omega t}\left[\frac{r\left(1 - e^{-i\delta}\right)}{1 - r^2 e^{-i\delta}}\right]$$

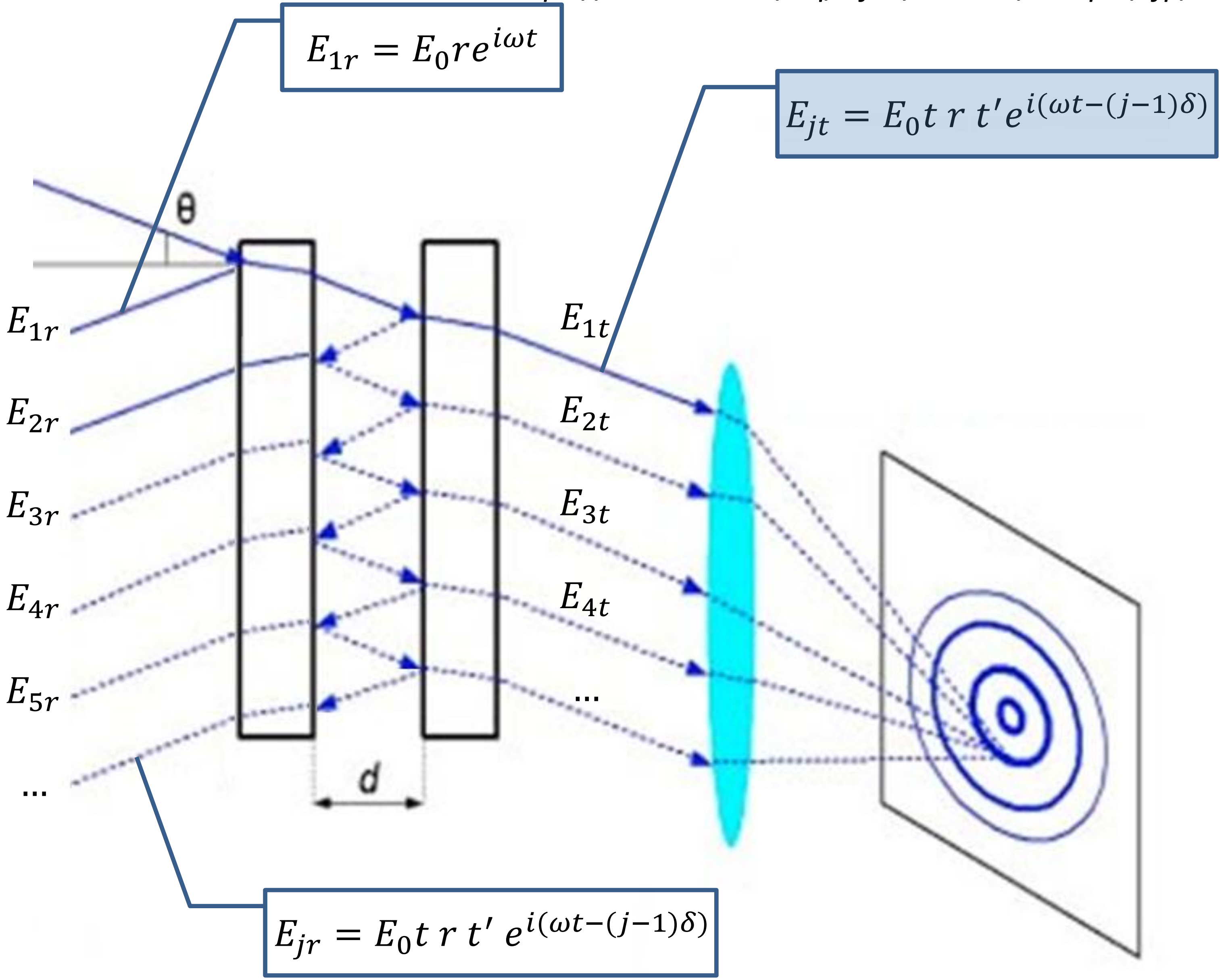
$$I_r = \frac{E_r {E_r}^*}{2} = I_i \frac{2r^2(1-\cos\delta)}{(1+r^4) - 2r^2\cos\delta}$$

$$E_r = \sum_{j}^{N} E_{jr} = E_0 r e^{i\omega t} + \sum_{j=2}^{N} E_0 t\, r\, t'\, e^{i(\omega t - (j-1)\delta)}$$

$$E_r = E_0 e^{i\omega t}\left[r + \frac{r' t t' e^{-i\delta}}{1 - r'^2 e^{-i\delta}}\right] = E_0 e^{i\omega t}\left[\frac{r\left(1 - e^{-i\delta}\right)}{1 - r^2 e^{-i\delta}}\right]$$

$$I_r = \frac{E_r {E_r}^*}{2} = I_i \frac{\left[\frac{2r}{1-r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}{1 + \left[\frac{2r}{1-r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}$$

Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



$$E_t = \sum_{j}^{N} E_{jt}$$

$$E_t = \sum_{j}^{N} E_{jt} = \sum_{j}^{N} E_0 t\, t' r'^{(2j-1)} e^{i(\omega t-(j-1)\delta)}$$

$$E_t = \sum_{j}^{N} E_{jt} = \sum_{j}^{N} E_0 t\, t' r'^{(2j-1)} e^{i(\omega t-(j-1)\delta)}$$

$$E_t = E_0 e^{i\omega t}\left[\frac{tt'}{1-r'^2 e^{-i\delta}}\right]$$

$$E_t = \sum_{j}^{N} E_{jt} = \sum_{j}^{N} E_0 t\, t' r'^{(2j-1)} e^{i(\omega t-(j-1)\delta)}$$

$$E_t = E_0 e^{i\omega t}\left[\frac{tt'}{1-r'^2 e^{-i\delta}}\right] = E_0 e^{i\omega t}\left[\frac{1-r^2}{1-r^2 e^{-i\delta}}\right]$$

$$E_t = \sum_{j}^{N} E_{jt} = \sum_{j}^{N} E_0 t\, t' r'^{(2j-1)} e^{i(\omega t-(j-1)\delta)}$$

$$E_t = E_0 e^{i\omega t}\left[\frac{tt'}{1-r'^2 e^{-i\delta}}\right] = E_0 e^{i\omega t}\left[\frac{1-r^2}{1-r^2 e^{-i\delta}}\right]$$

$$I_r = \frac{E_t {E_t}^*}{2} = I_i \frac{1}{1+\left[\frac{2r}{1-r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}$$

$$I_t = \frac{E_t {E_t}^*}{2} = I_i \frac{1}{1 + \left[\frac{2r}{1 - r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}$$

$$I_r = \frac{E_r {E_r}^*}{2} = I_i \frac{\left[\frac{2r}{1 - r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}{1 + \left[\frac{2r}{1 - r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}$$

$$I_r = \frac{E_t {E_t}^*}{2} = I_i \frac{1}{1 + \left[\frac{2r}{1 - r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}$$

$$I_r = \frac{E_r {E_r}^*}{2} = I_i \frac{\left[\frac{2r}{1 - r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}{1 + \left[\frac{2r}{1 - r^2}\right]^2 \sin^2\left(\frac{\delta}{2}\right)}$$

$$I_i = I_r + I_t$$

$$I_r = \frac{E_t E_t{}^*}{2} = I_i \frac{1}{1 + F\sin^2\left(\frac{\delta}{2}\right)}$$

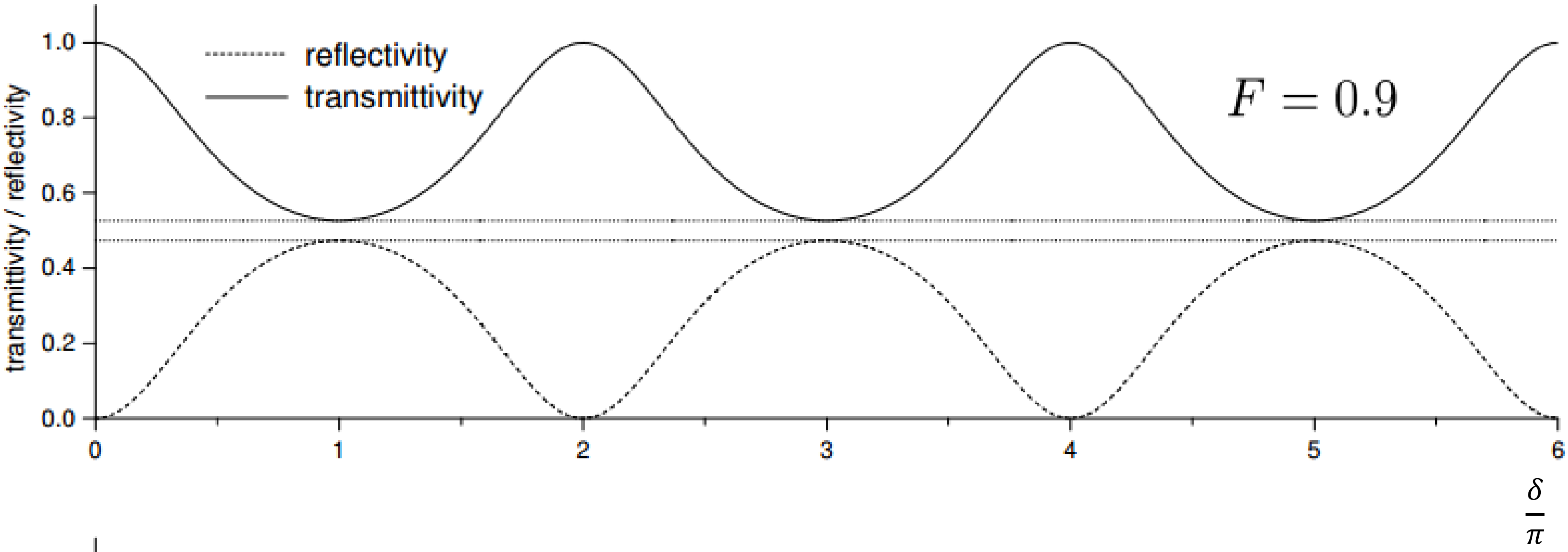
$$I_r = \frac{E_r E_r{}^*}{2} = I_i \frac{F\sin^2\left(\frac{\delta}{2}\right)}{1 + F\sin^2\left(\frac{\delta}{2}\right)}$$

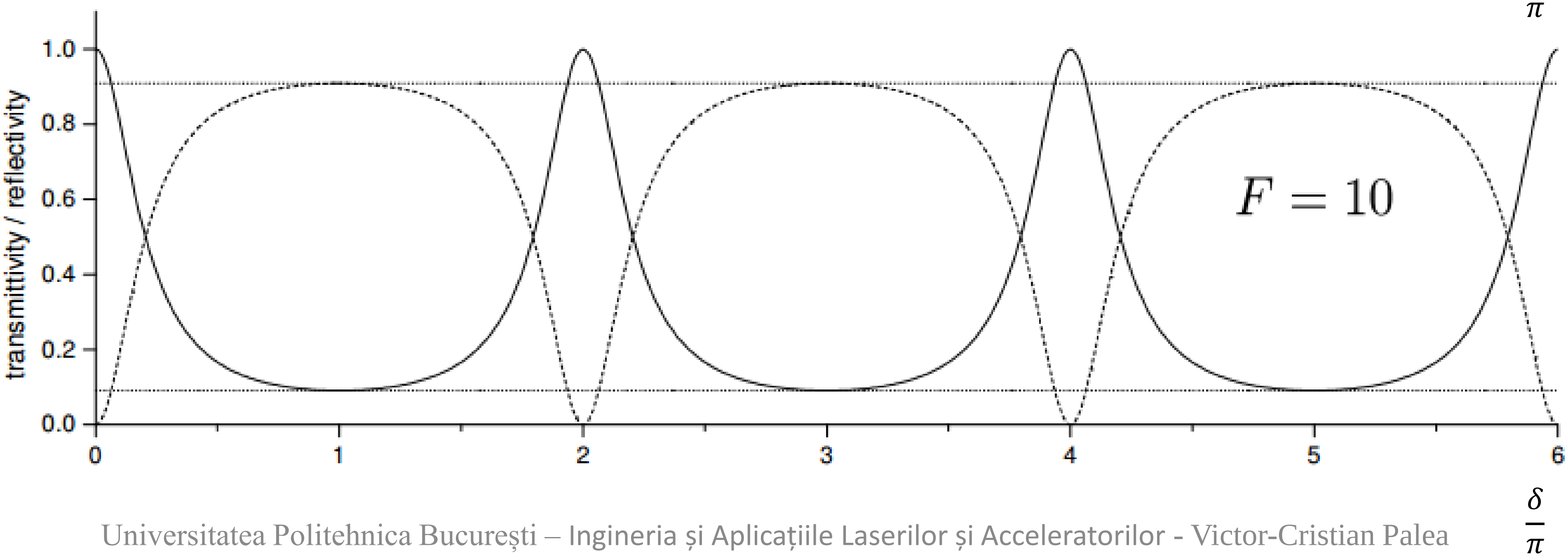
$$I_i = I_r + I_t$$

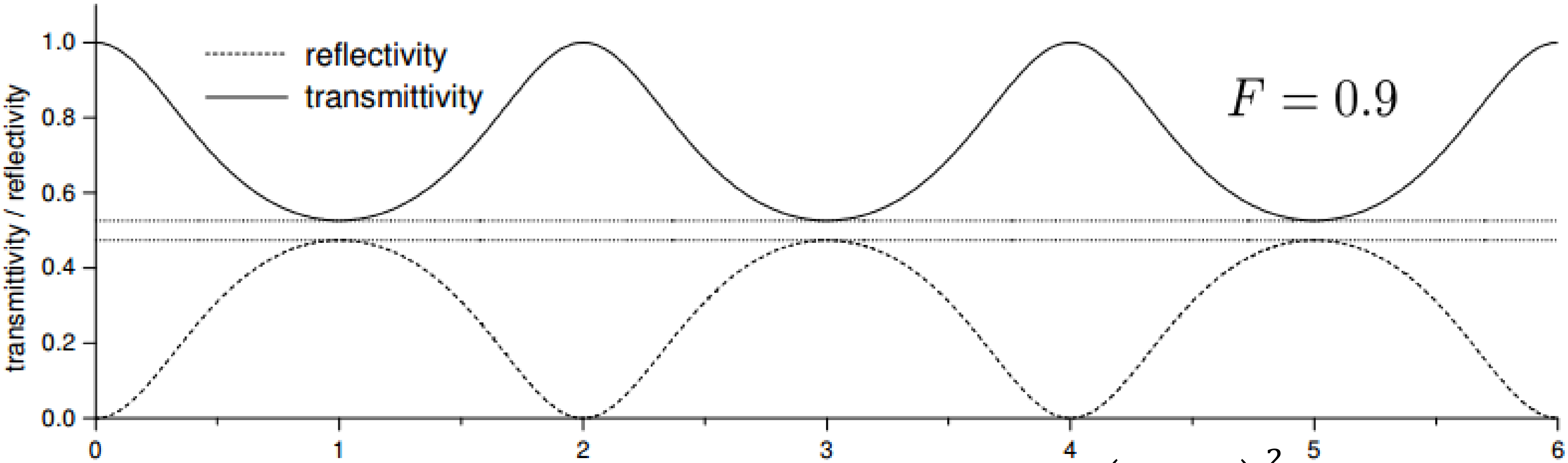
$$I_t = \frac{E_t {E_t}^*}{2} = I_i \frac{1}{1 + F \sin^2\left(\frac{\delta}{2}\right)}$$

$$I_r = \frac{E_r {E_r}^*}{2} = I_i \frac{F \sin^2\left(\frac{\delta}{2}\right)}{1 + F \sin^2\left(\frac{\delta}{2}\right)}$$

$$I_i = I_r + I_t \Rightarrow 1 = \frac{I_r}{I_i} + \frac{I_t}{I_i} \equiv R + T$$

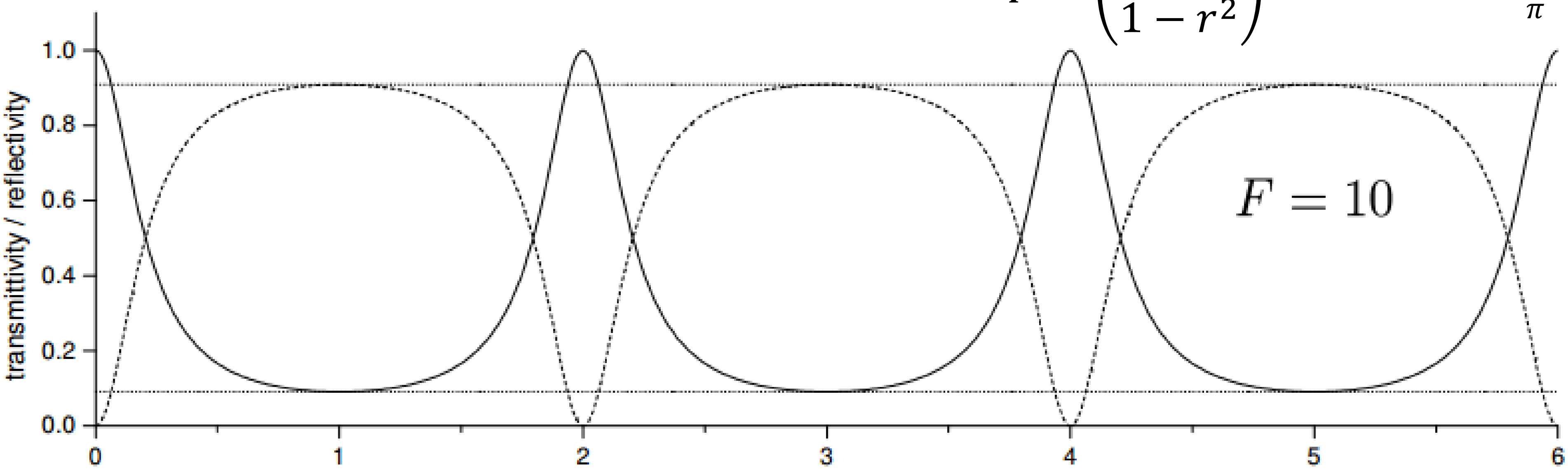

reflectivity
transmittivity
$F = 0.9$
transmittivity / reflectivity
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
$\frac{\delta}{\pi}$


$F = 10$
transmittivity / reflectivity
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
$\frac{\delta}{\pi}$

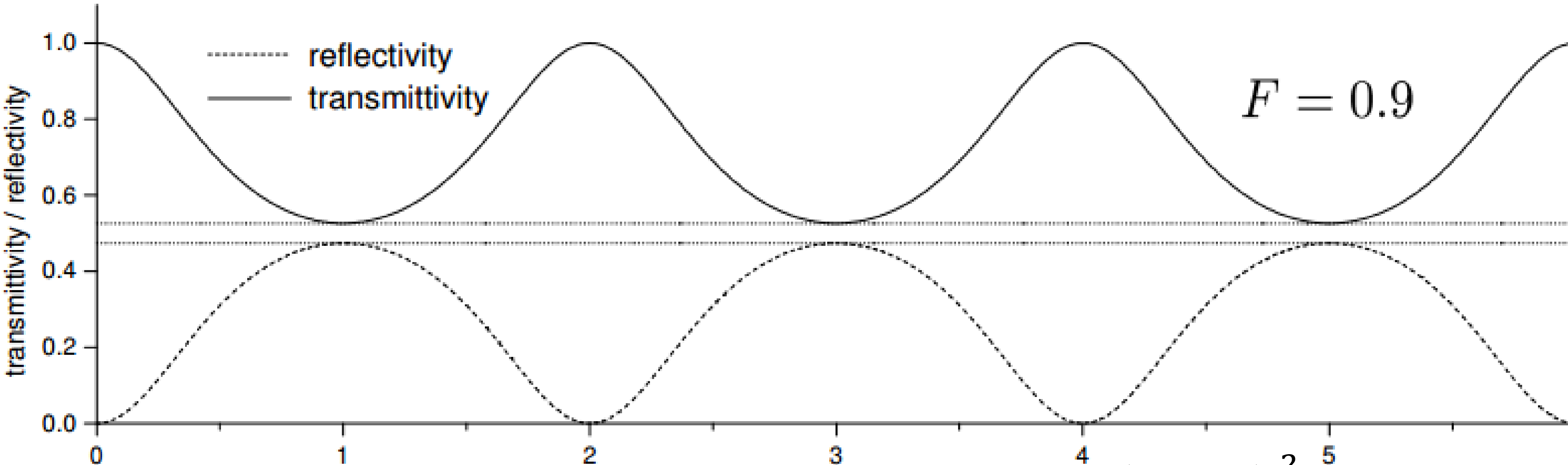


$$F = \left(\frac{2r}{1-r^2}\right)^2$$

$\frac{\delta}{\pi}$



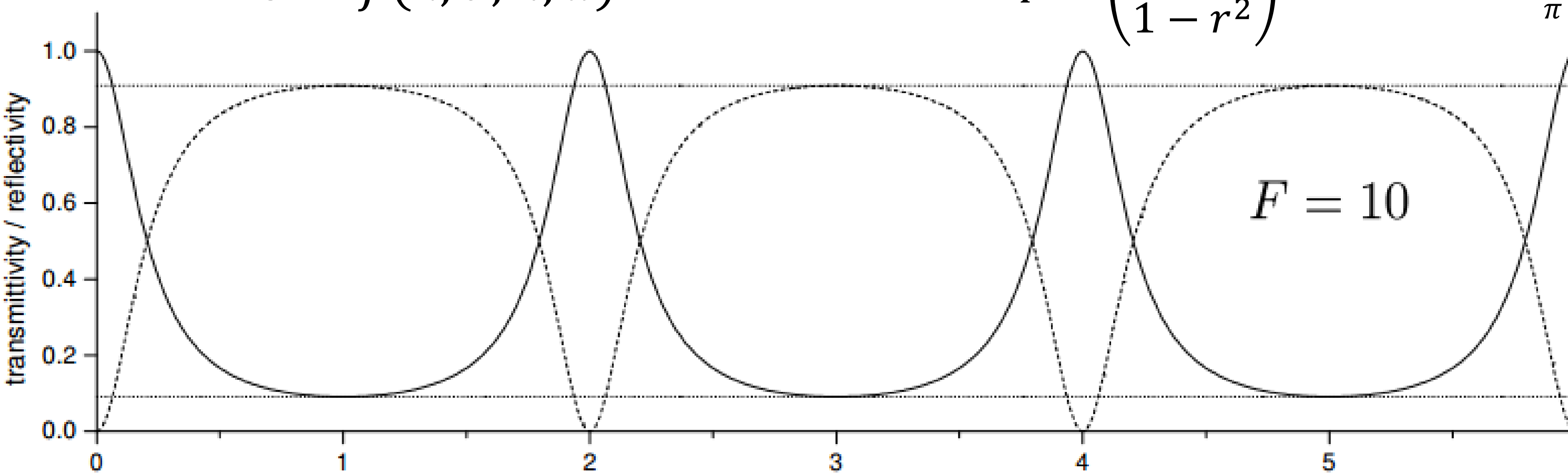
$\frac{\delta}{\pi}$



$$\delta = f(\lambda, \theta, n, d)$$

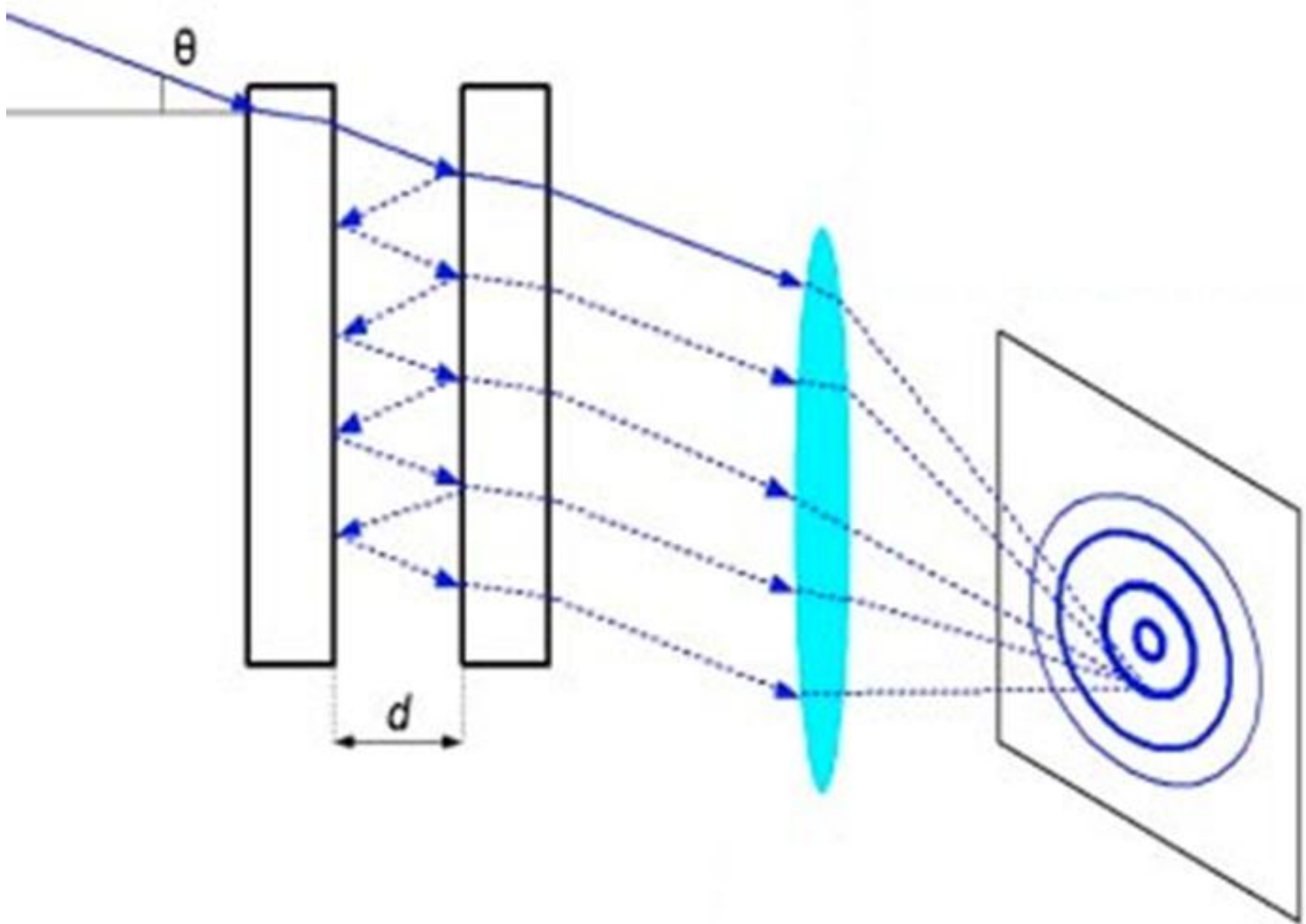
$$F = \left(\frac{2r}{1 - r^2}\right)^2$$

$\frac{\delta}{\pi}$



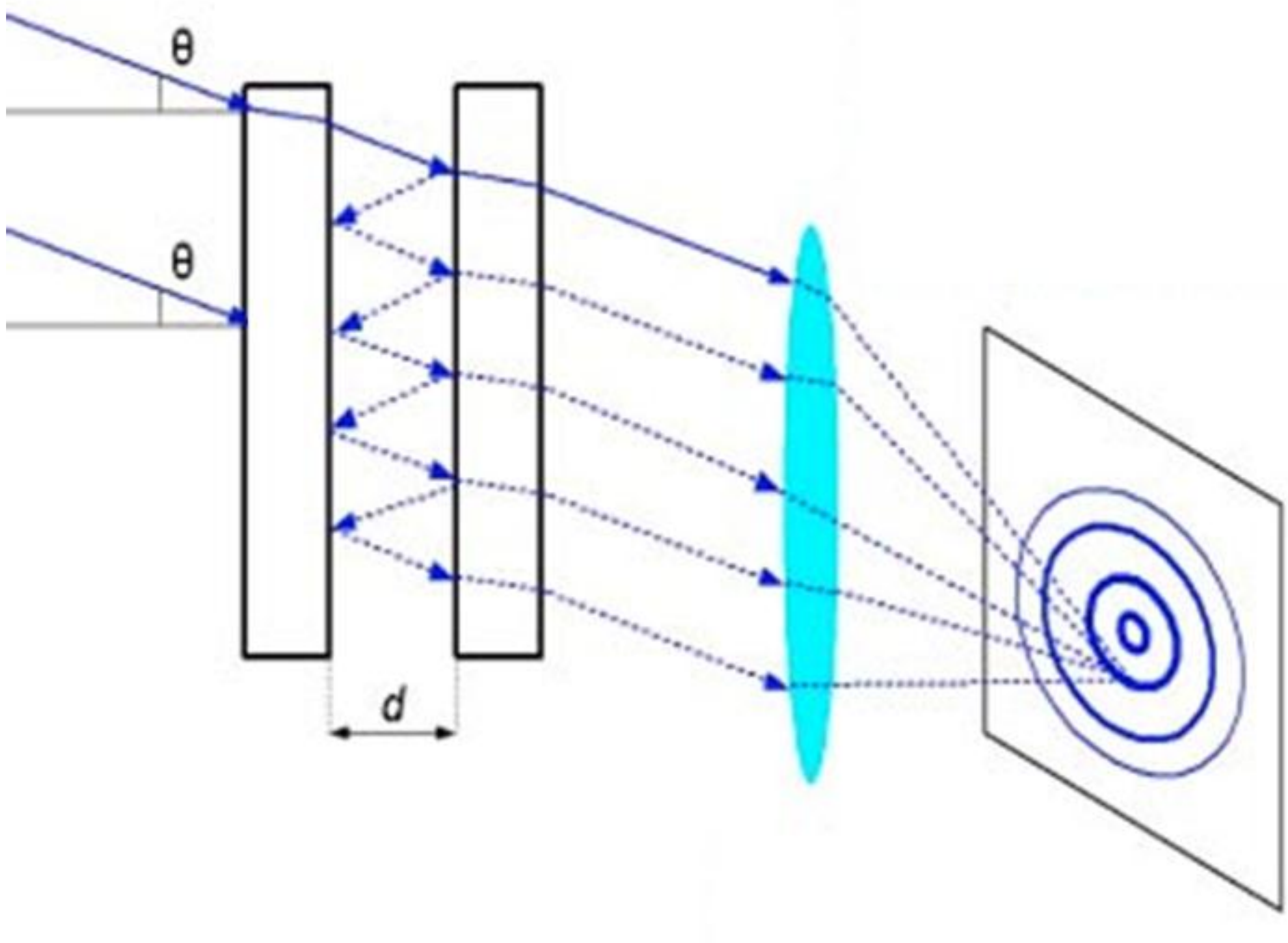
$\frac{\delta}{\pi}$

Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html

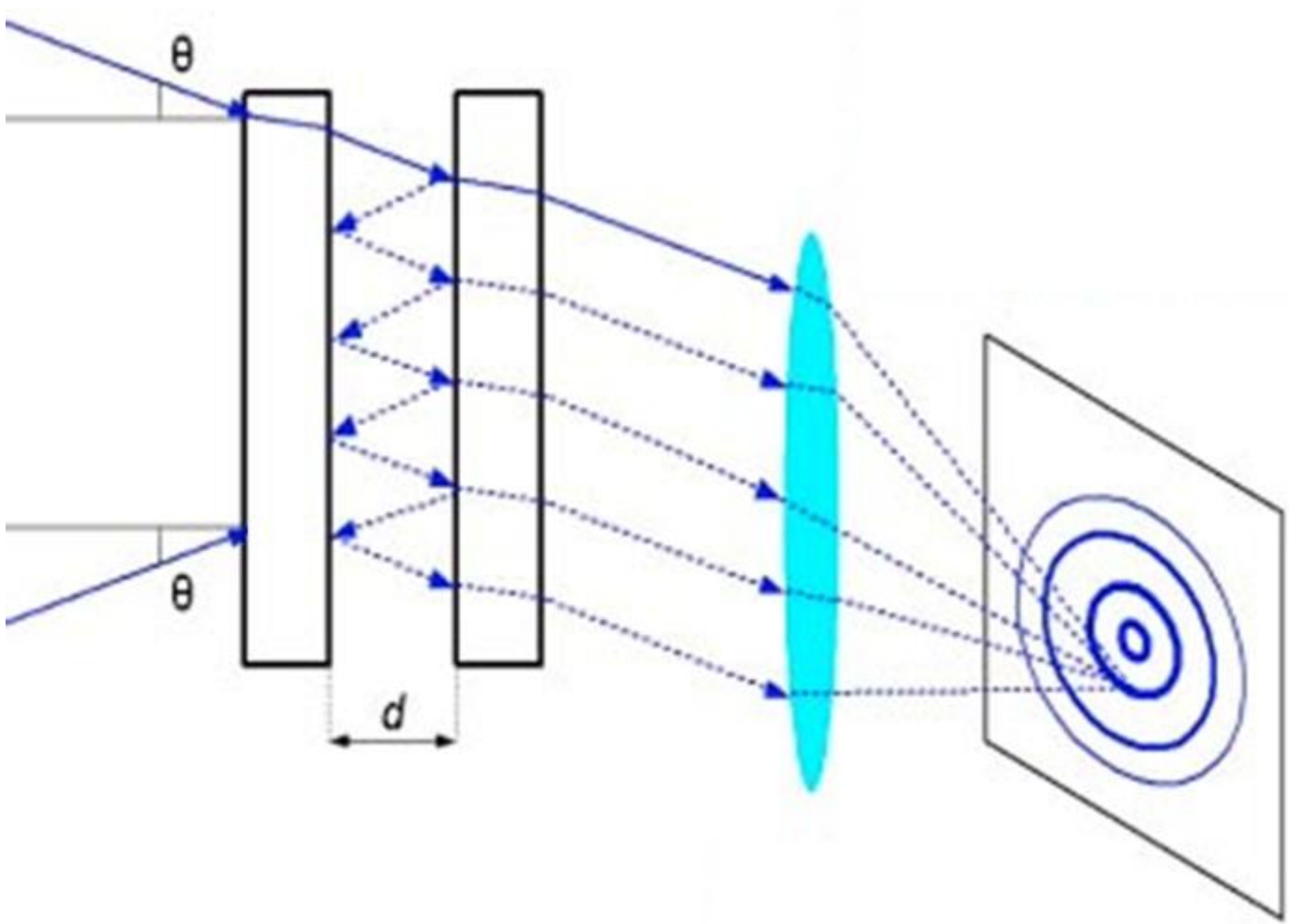


Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html

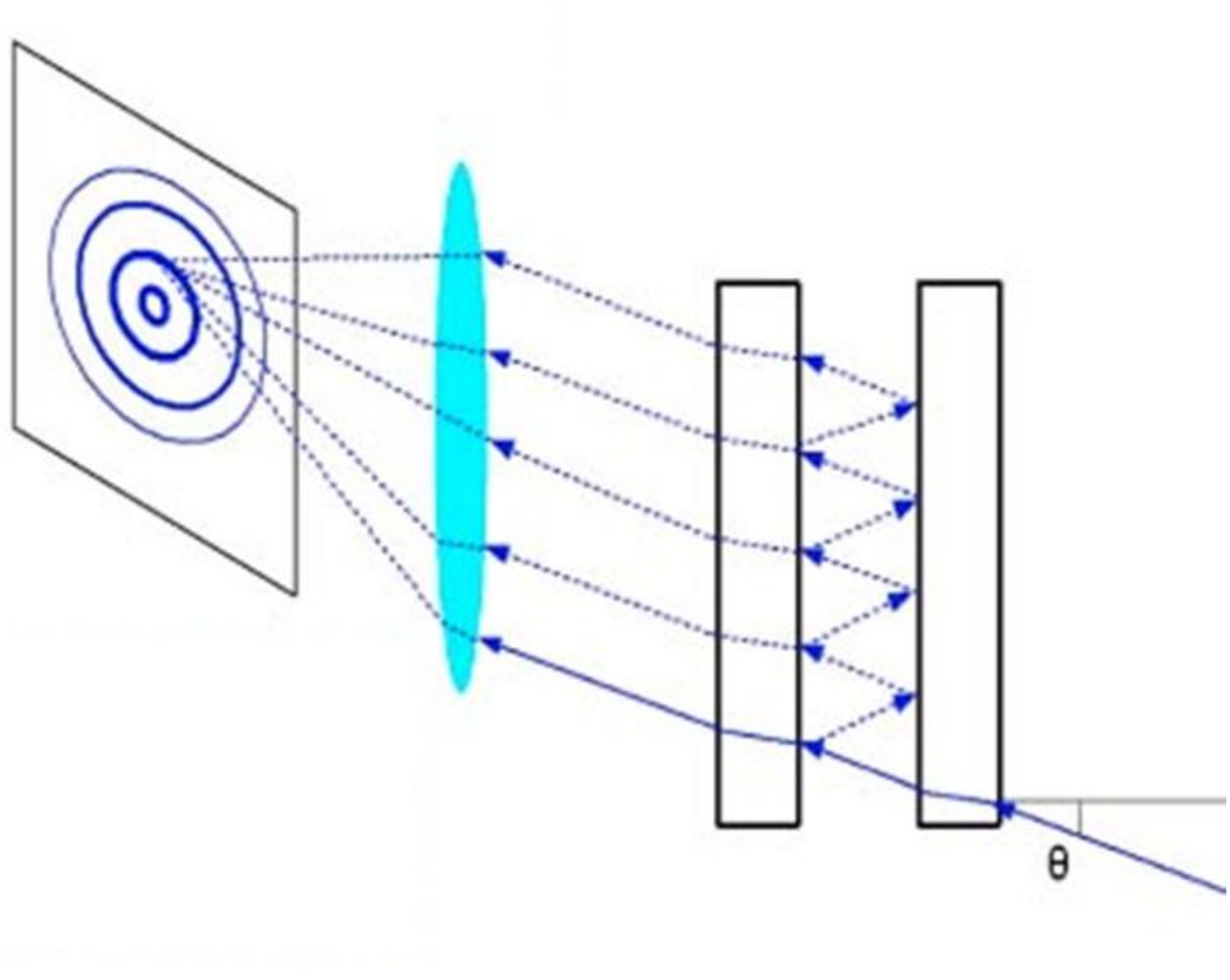
???



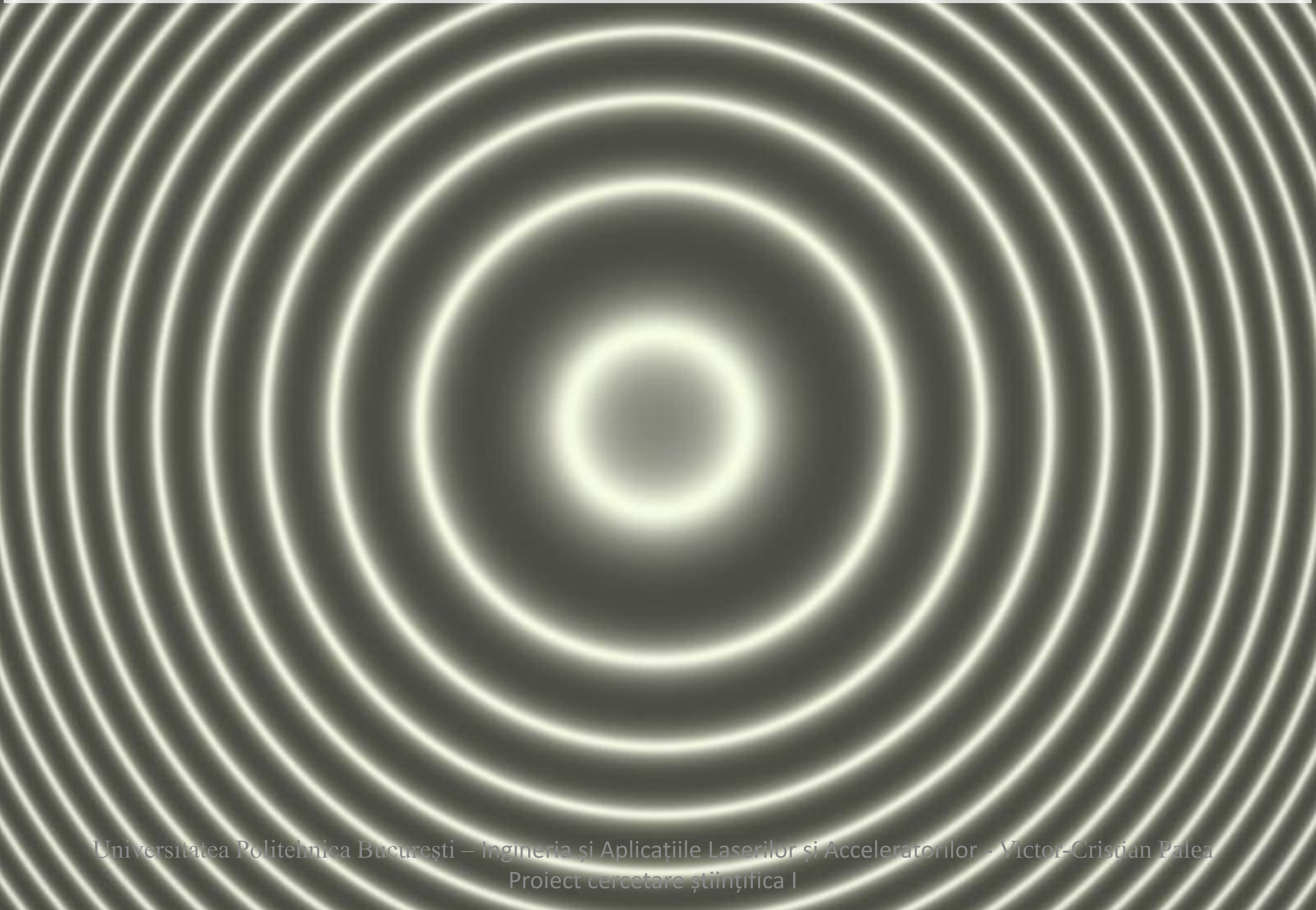
Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



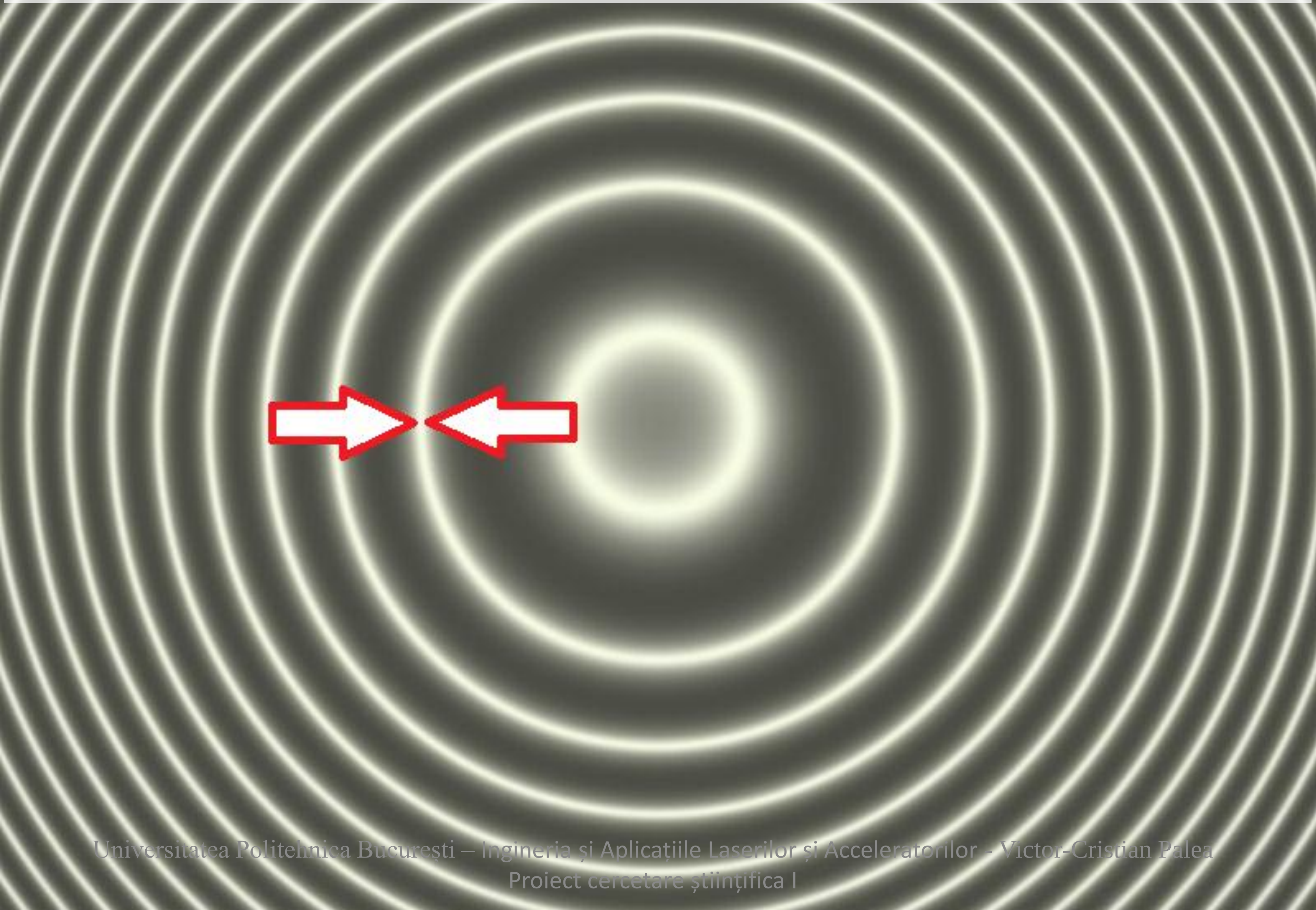
Source: https://www.sao.ru/hq/lsfvo/devices/scorpio/ifp/cubes.html



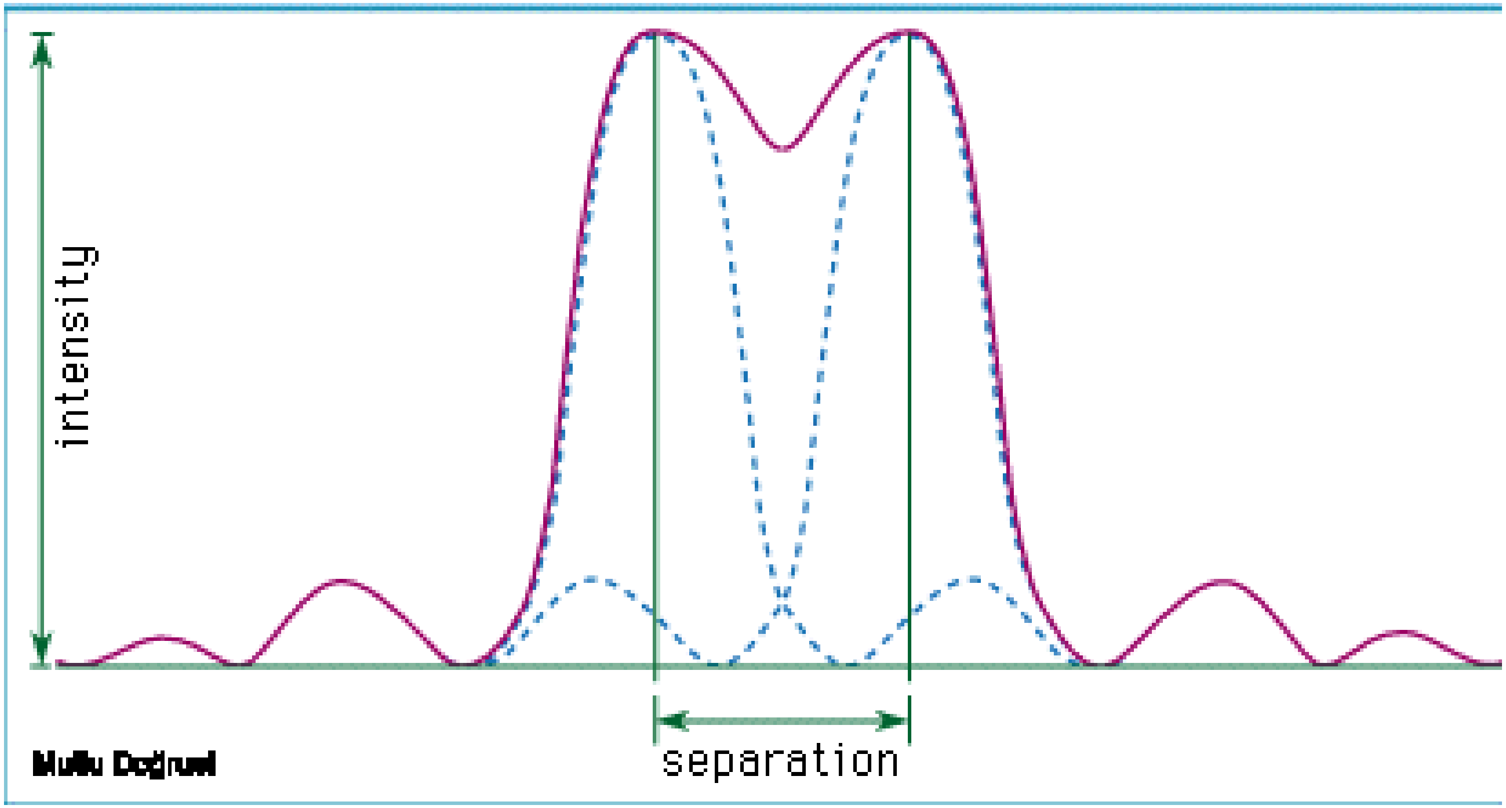
Source:https://nl.wikipedia.org/wiki/Fabry-P%C3%A9rot-interferometer#/media/File:Fabry-Perot_interferences_figure.jpg

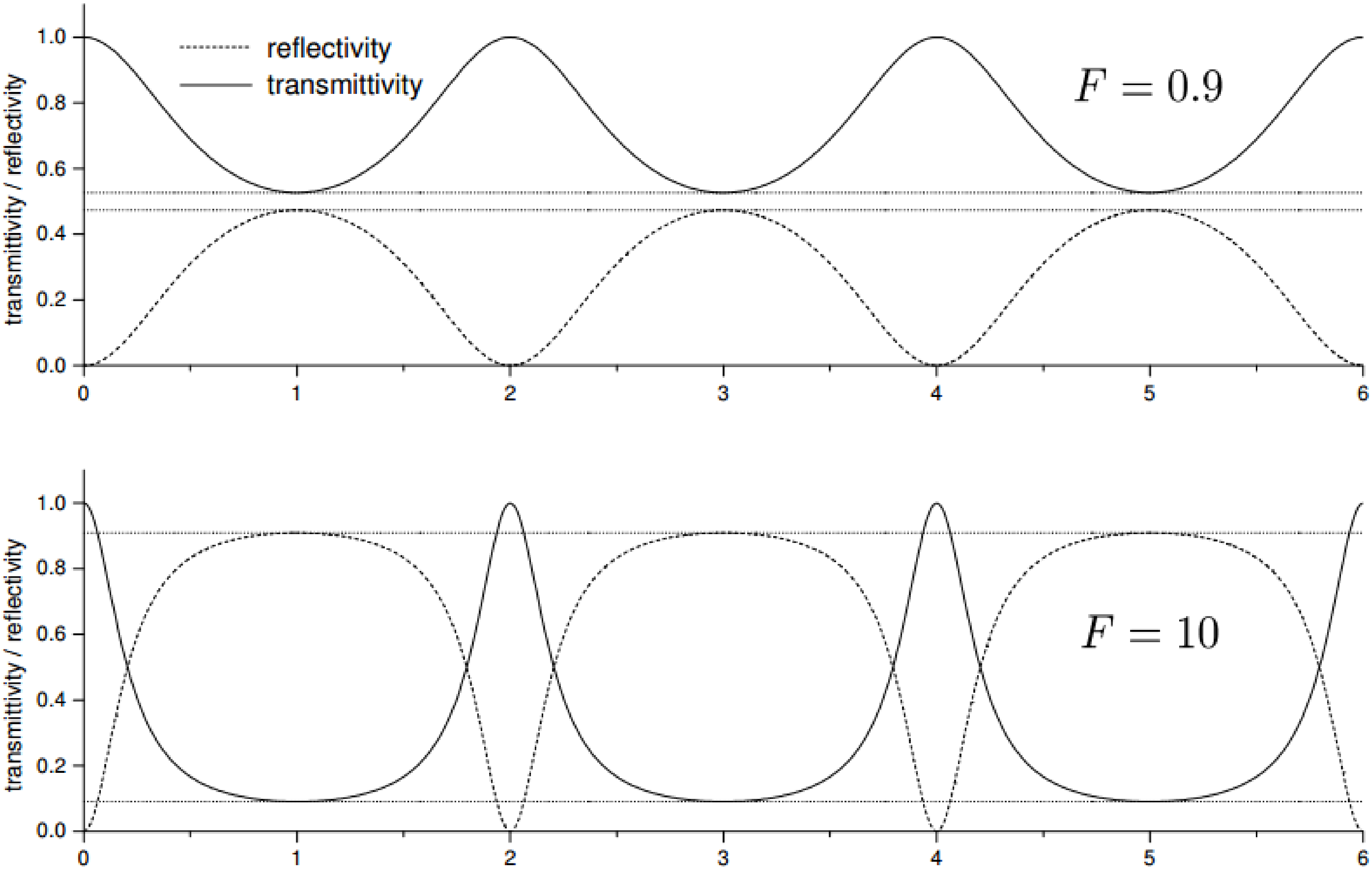


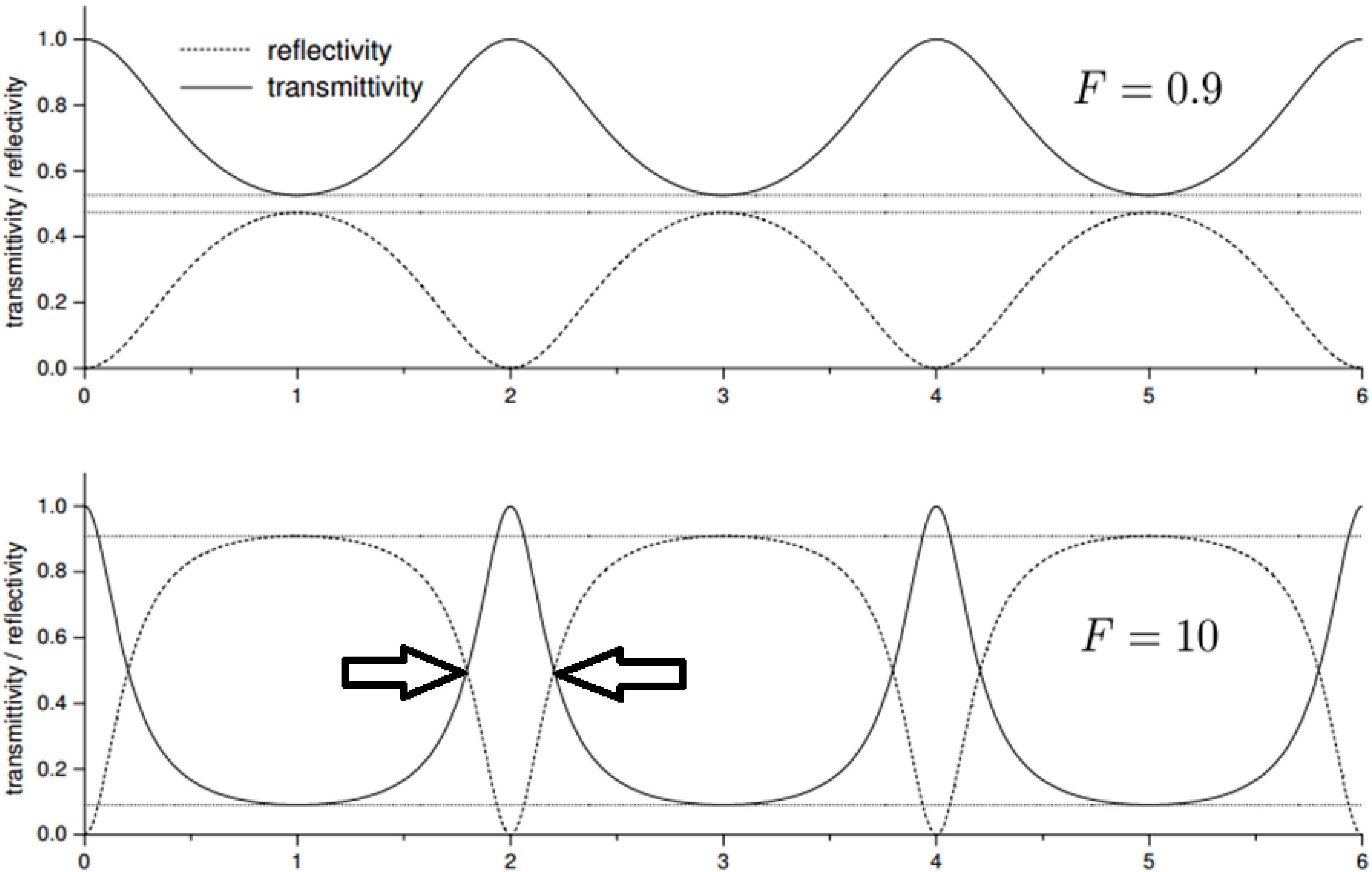
Source:https://nl.wikipedia.org/wiki/Fabry-P%C3%A9rot-interferometer#/media/File:Fabry-Perot_interferences_figure.jpg



Source: http://newton.physics.metu.edu.tr/~mdogruel/ht0017a4.gif




reflectivity
transmittivity
$F = 0.9$
$F = 10$
transmittivity / reflectivity
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5
6


reflectivity
transmittivity
transmittivity / reflectivity
$F = 0.9$
$F = 10$
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6

$$I_t = \frac{E_t {E_t}^*}{2} = I_i \frac{1}{1 + F \sin^2\left(\frac{\delta}{2}\right)}$$

$$I_t = \frac{E_t {E_t}^*}{2} = I_i \frac{1}{1 + F \sin^2\left(\frac{\delta}{2}\right)}$$

$$\frac{I_t}{I_i} = \frac{1}{1 + F \sin^2\left(\frac{\delta_{\frac{1}{2}}}{2}\right)} = \frac{1}{2}$$

$$I_t = \frac{E_t {E_t}^*}{2} = I_i \frac{1}{1 + F \sin^2\left(\frac{\delta}{2}\right)}$$

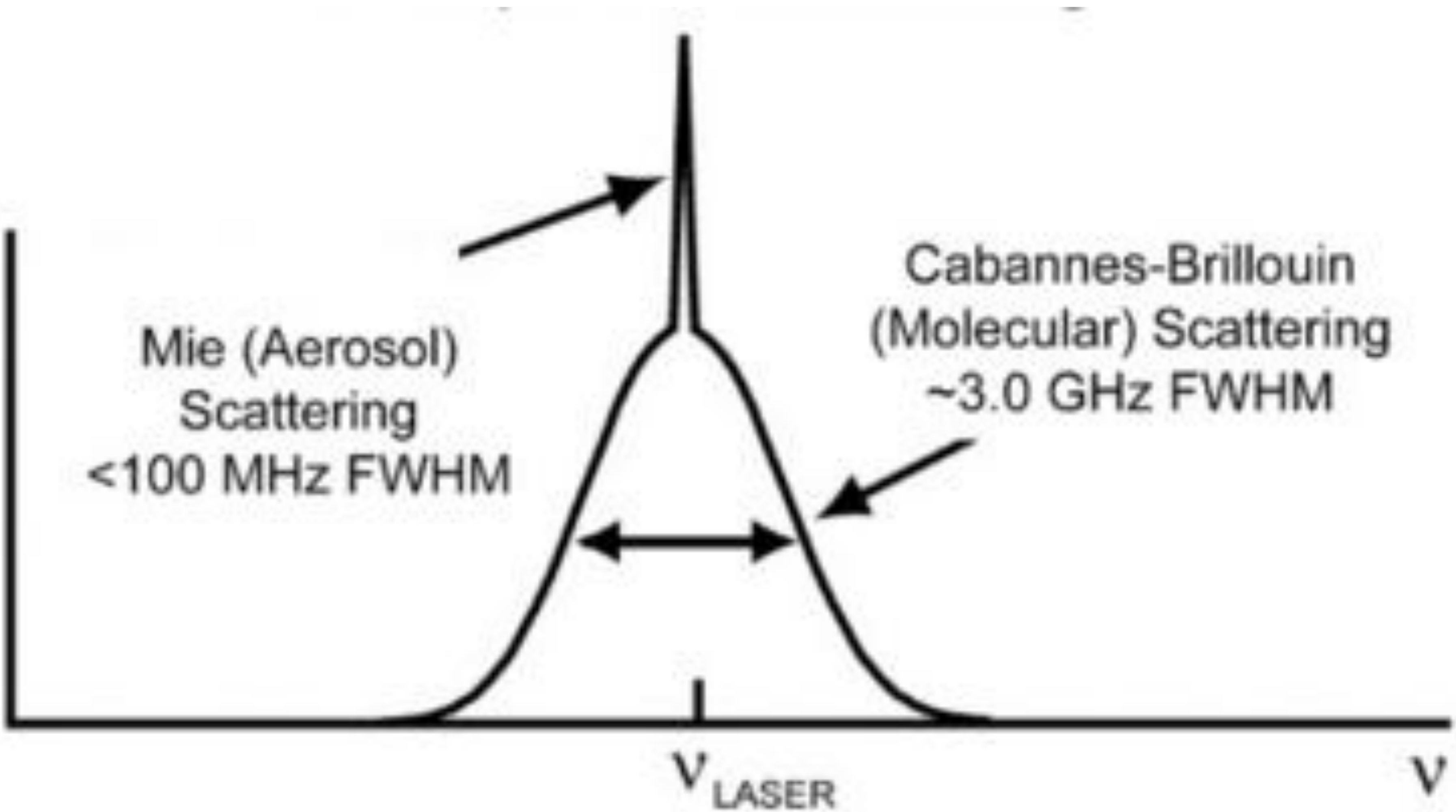
$$\frac{I_t}{I_i} = \frac{1}{1 + F \sin^2\left(\frac{\delta_{\frac{1}{2}}}{2}\right)} = \frac{1}{2}$$

$$\delta_{\frac{1}{2}} = 2 \sin^{-1}\left(\frac{1}{\sqrt{F}}\right)$$

$$\delta_{\frac{1}{2}} = 2\sin^{-1}\left(\frac{1}{\sqrt{F}}\right)$$

$$\delta_{\frac{1}{2}} = 2 \sin^{-1}\left(\frac{1}{\sqrt{F}}\right)$$

$$F = \left(\frac{2r}{1 - r^2}\right)^2$$


Mie (Aerosol)
Scattering
<100 MHz FWHM
Cabannes-Brillouin
(Molecular) Scattering
~3.0 GHz FWHM
ν LASER
ν

References

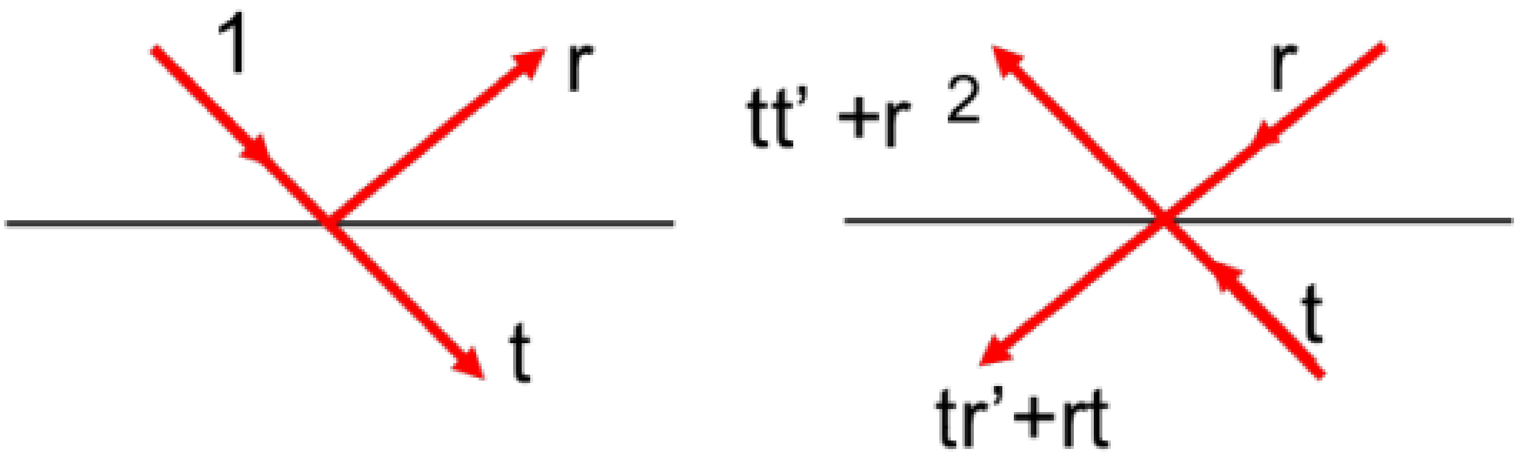
[1] Peucheret, C. *Note on Fabry-Pérot Interferometers*

[2] Born, M., Wolf, E. (1999) *Principles of Optics* Cambridge, University Press

[3] Wyant, J. *Multiple Beam Interference* Retrieved from http://wyant.optics.arizona.edu/MultipleBeamInterference/MultipleBeamInterference.pdf

Appendix

Reversibility principle



$$1 = tt' + r^2$$
$$0 = tr' + rt$$