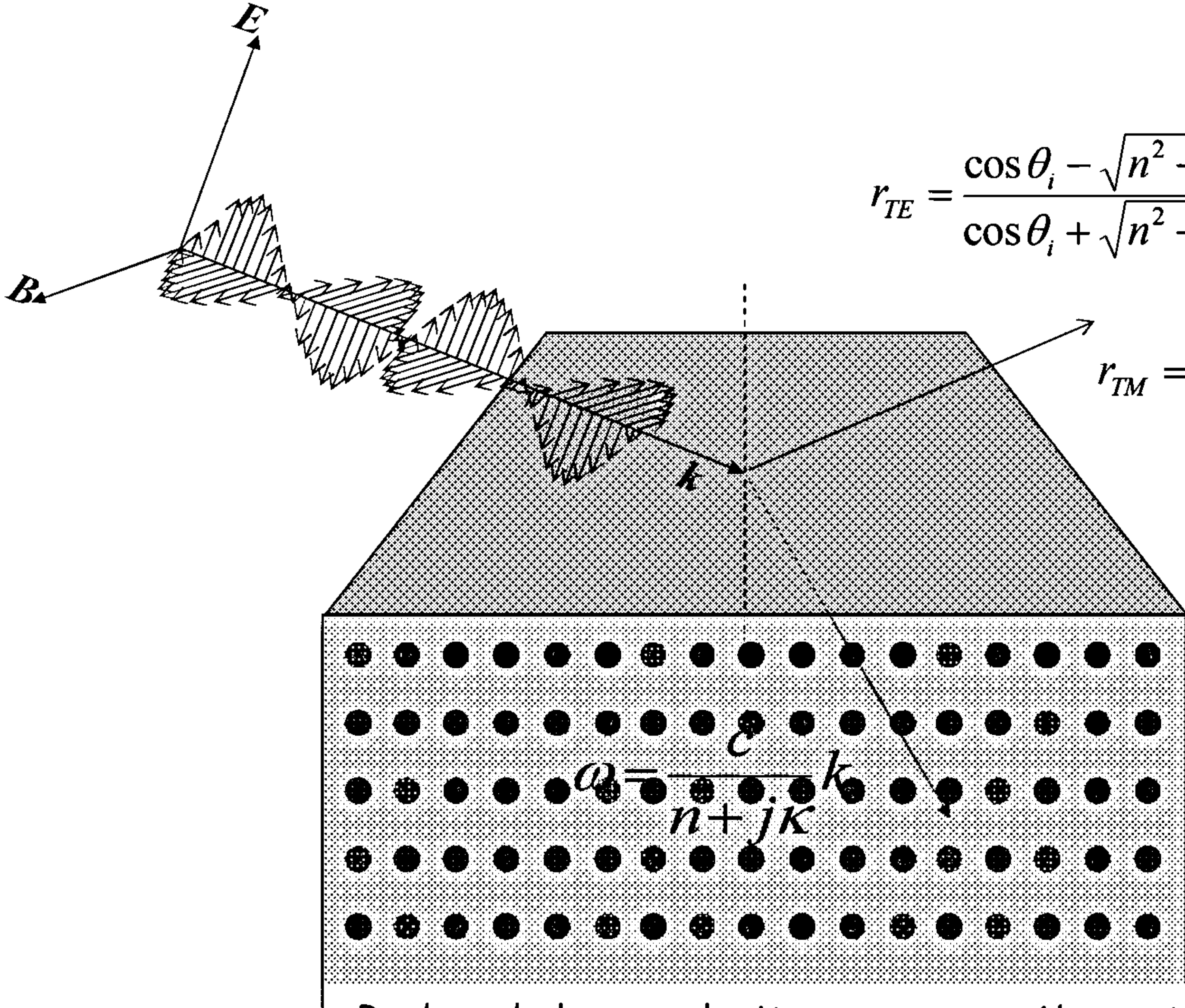
Through the Looking Glass and What We Found There



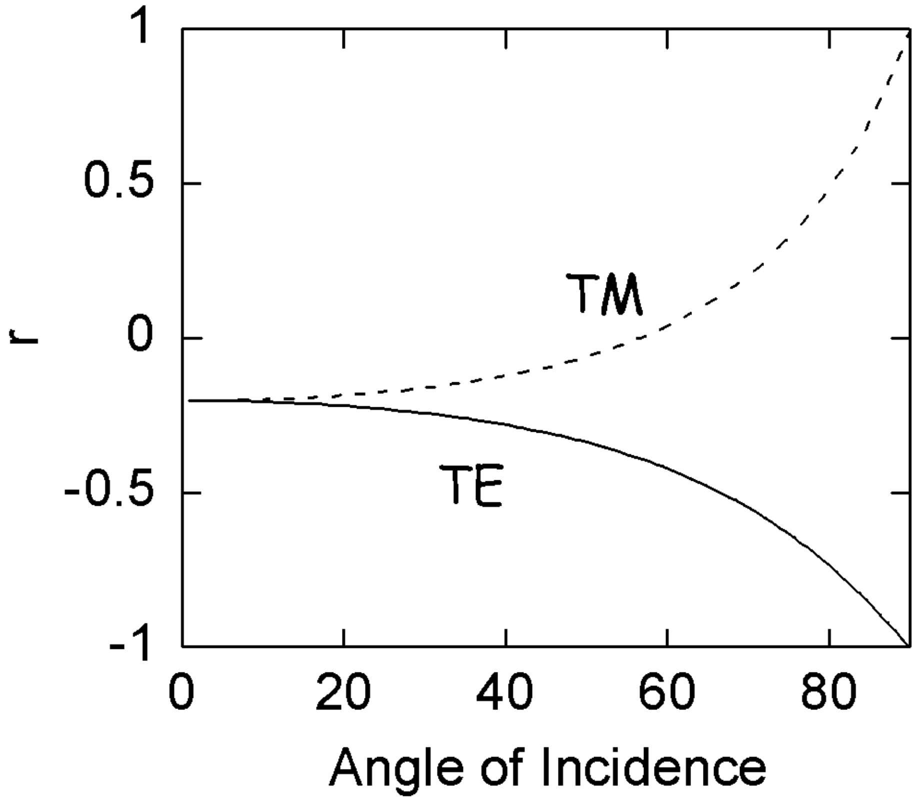
$$r_{TE} = \frac{\cos\theta_i - \sqrt{n^2 - \sin^2\theta_i}}{\cos\theta_i + \sqrt{n^2 - \sin^2\theta_i}}$$

$$r_{TM} = \frac{-n^2\cos\theta_i + \sqrt{n^2 - \sin^2\theta_i}}{n^2\cos\theta_i + \sqrt{n^2 - \sin^2\theta_i}}$$

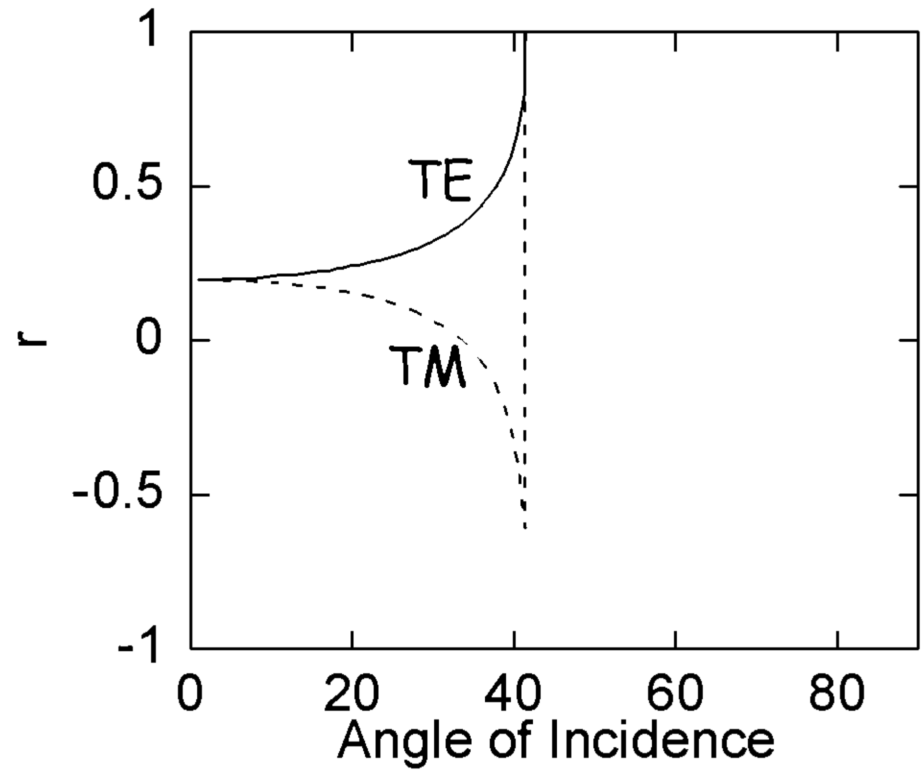
Reduced phase velocity: n Absorption: κ

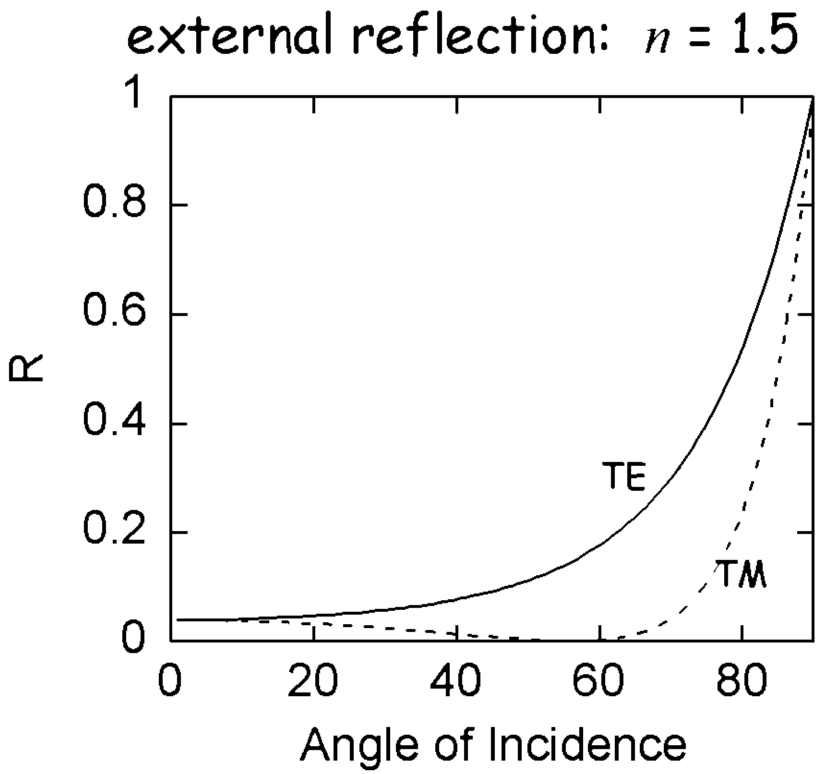
$$r_{TE} = \frac{\cos\theta_i - \sqrt{n^2 - \sin^2\theta_i}}{\cos\theta_i + \sqrt{n^2 - \sin^2\theta_i}} \qquad r_{TM} = \frac{-n^2\cos\theta_i + \sqrt{n^2 - \sin^2\theta_i}}{n^2\cos\theta_i + \sqrt{n^2 - \sin^2\theta_i}}$$

external reflection: n = 1.5

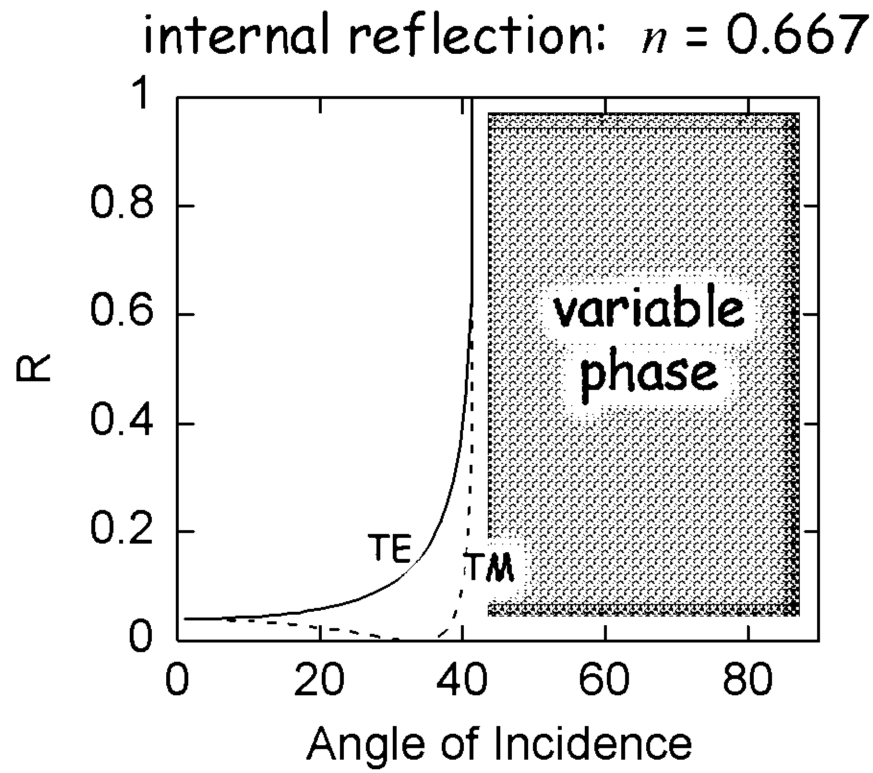


internal reflection: n = 0.667





external reflection: n = 1.5
R
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
TE
TM
Angle of Incidence



internal reflection: n = 0.667
R
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
TE
TM
variable phase
Angle of Incidence

write r in this form:

$$r = \frac{e^{-j\alpha}}{e^{j\alpha}}$$

Why? Because:

$$E_r = rE_i e^{j(kz-\omega t)}\hat{x}$$

$$E_r = \frac{e^{-j\alpha}}{e^{j\alpha}} E_i e^{j(kz-\omega t)}\hat{x}$$

$$E_r = e^{-2j\alpha} E_i e^{j(kz-\omega t)}\hat{x}$$

$$E_r = E_i e^{j(kz-\omega t-2\alpha)}\hat{x}$$

phase shift = 2α

Great, but what is α?

$$r = \frac{e^{-j\alpha}}{e^{j\alpha}}$$

$$= \frac{\cos(-\alpha) + j\sin(-\alpha)}{\cos(\alpha) + j\sin(\alpha)}$$

$$= \frac{\cos(\alpha) - j\sin(\alpha)}{\cos(\alpha) + j\sin(\alpha)}$$

TE: $\cos(\alpha) = \cos\theta_i$ $\sin(\alpha) = \sqrt{\sin^2\theta_i - n^2}$

$$\tan(\alpha) = \frac{\sqrt{\sin^2\theta_i - n^2}}{n^2\cos\theta_i}$$

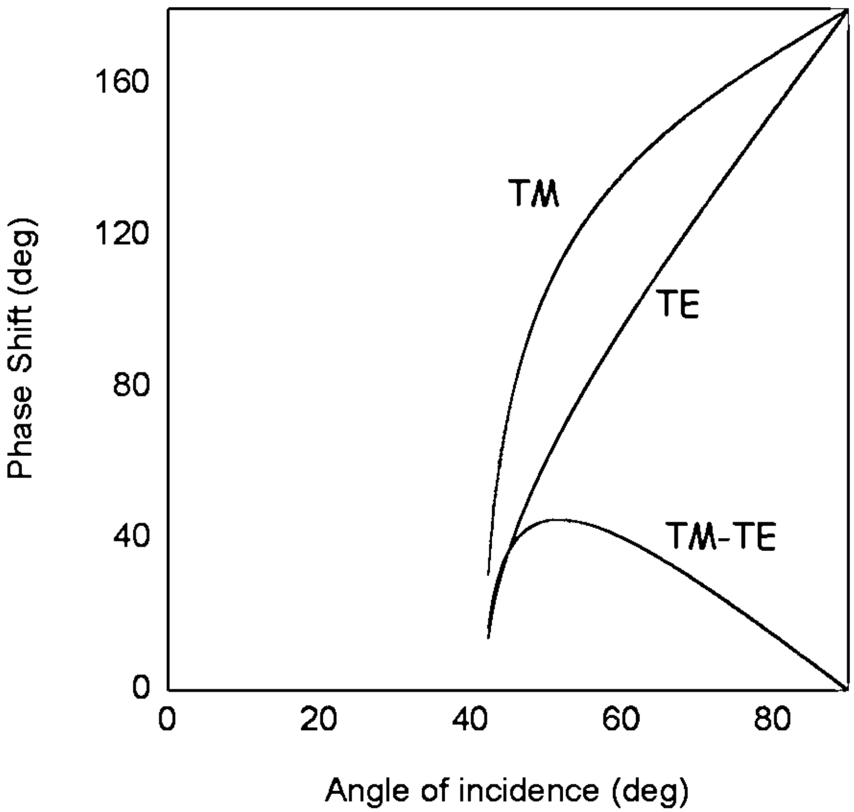
Phase shift upon total internal reflection:

TM

$$\tan\left(\frac{\phi}{2}\right) = \frac{\sqrt{\sin^2\theta_i - n^2}}{n^2\cos\theta_i}$$

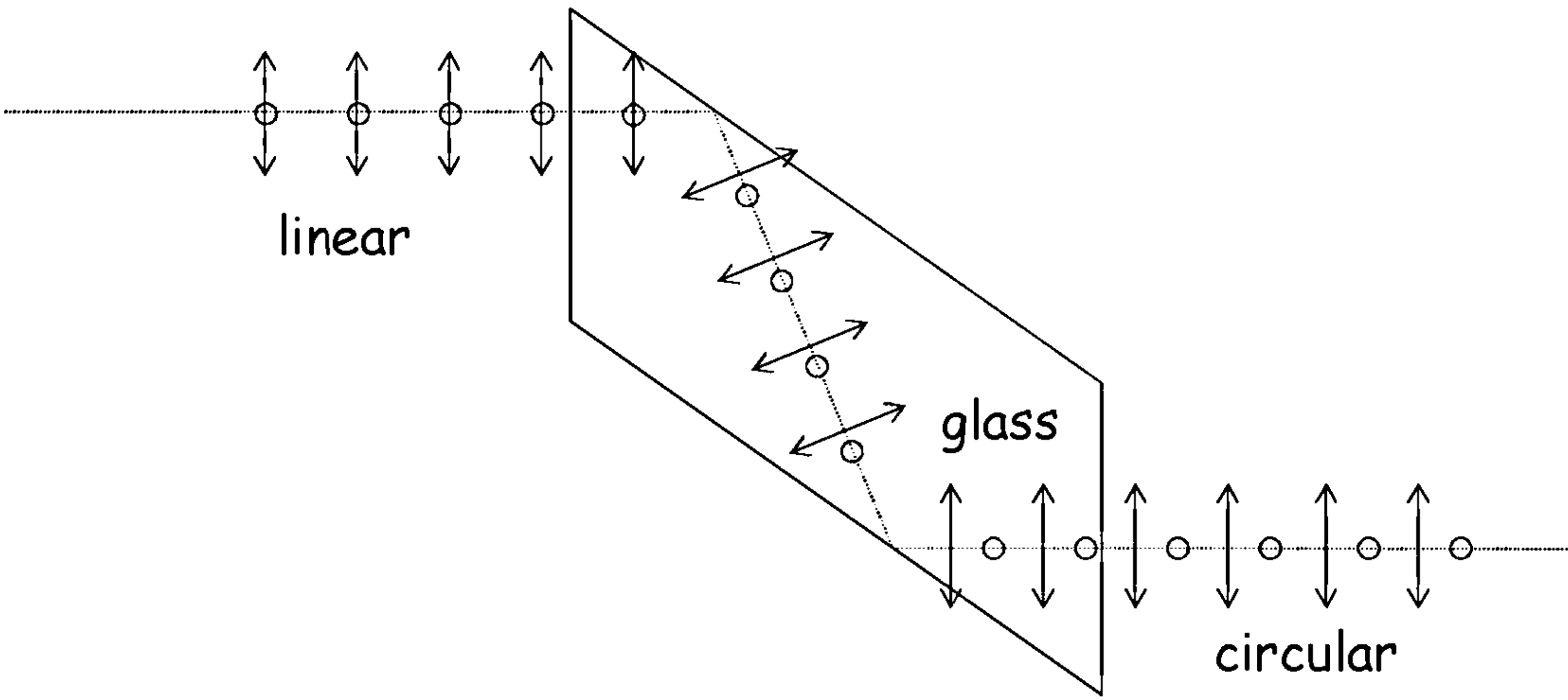
TE

$$\tan\left(\frac{\phi}{2}\right) = \frac{\sqrt{\sin^2\theta_i - n^2}}{\cos\theta_i}$$

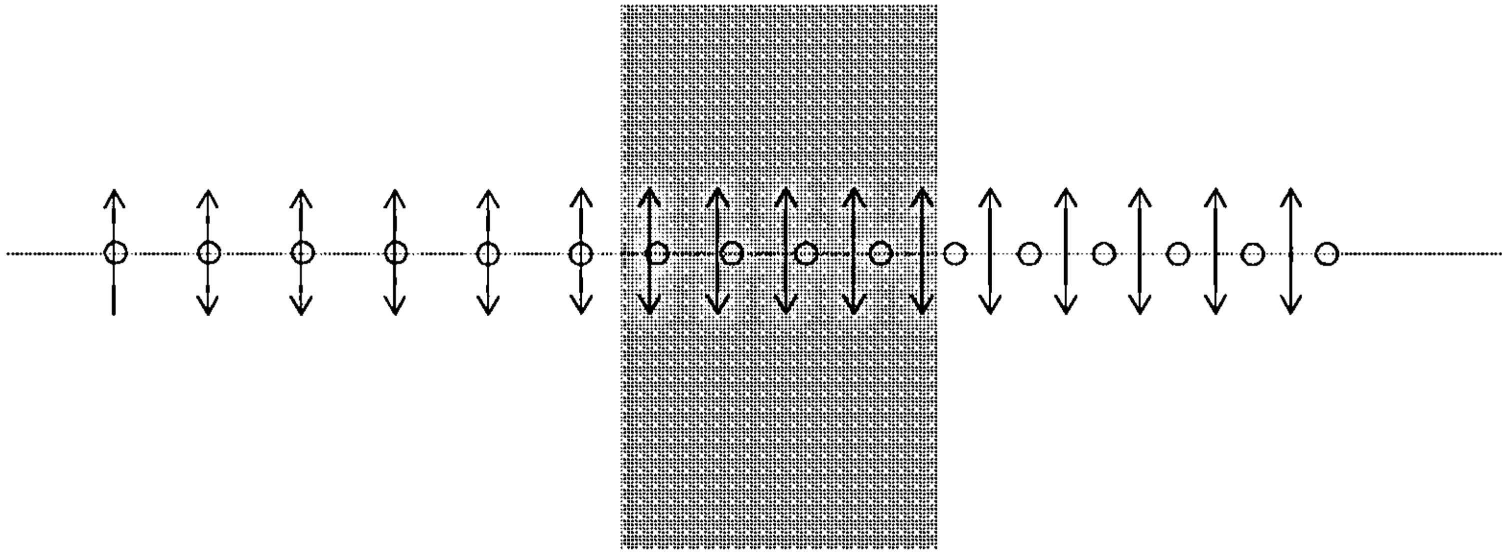


Tunable phase lag based only on dielectric reflections!

The Fresnel Rhomb:



Phase Retarder



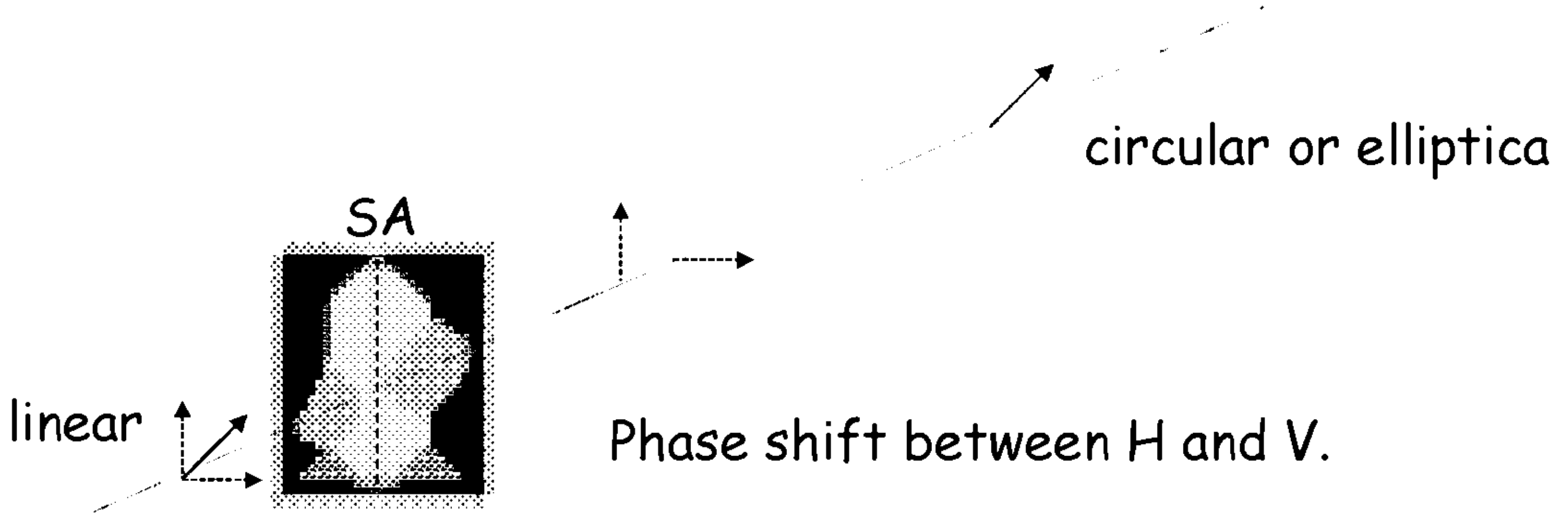
"birefringence"

A dependence of the index of refraction on polarization (anisotropy in n).

$$\Delta\phi = \frac{2\pi}{\lambda_o} d\left(\left|n_e - n_o\right|\right)$$

Jones: $\begin{bmatrix} e^{j\varepsilon_x} & 0 \\ 0 & e^{j\varepsilon_y} \end{bmatrix}$

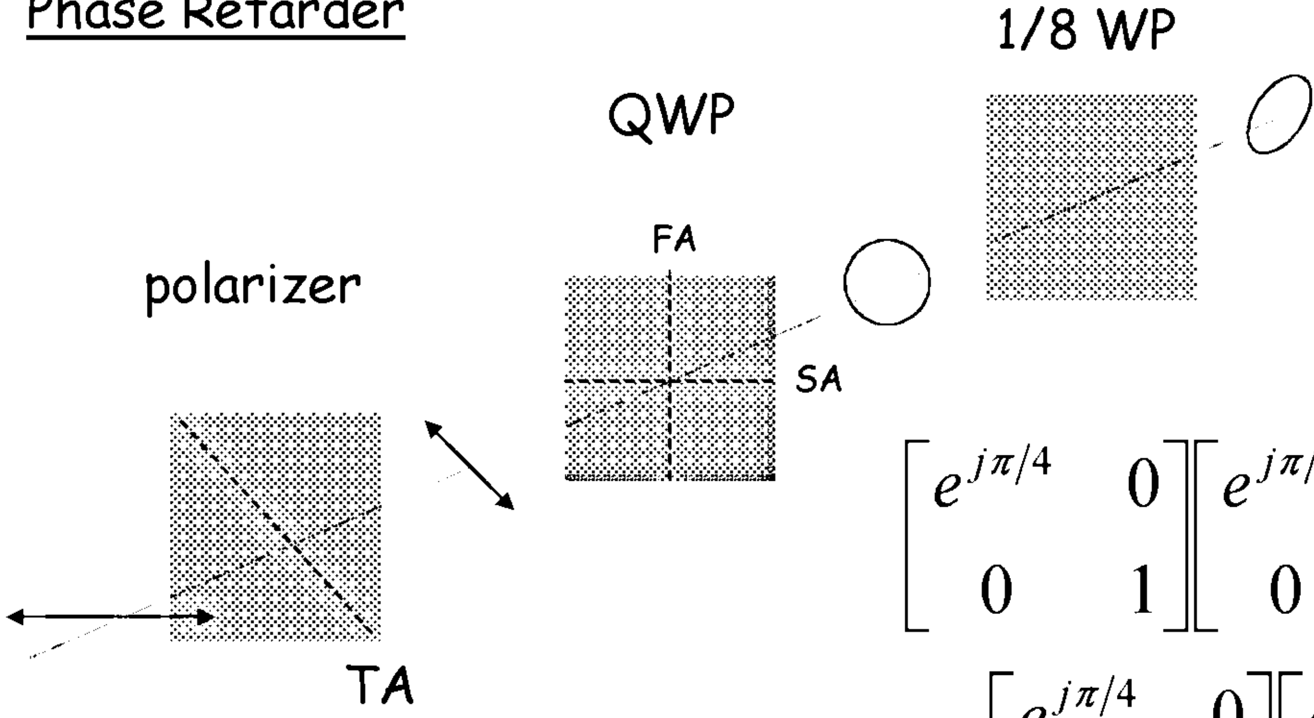
Phase Retarder



Phase shift between H and V.

Jones matrix: $\begin{bmatrix} e^{j\varepsilon_x} & 0 \\ 0 & e^{j\varepsilon_y} \end{bmatrix}$

Phase Retarder

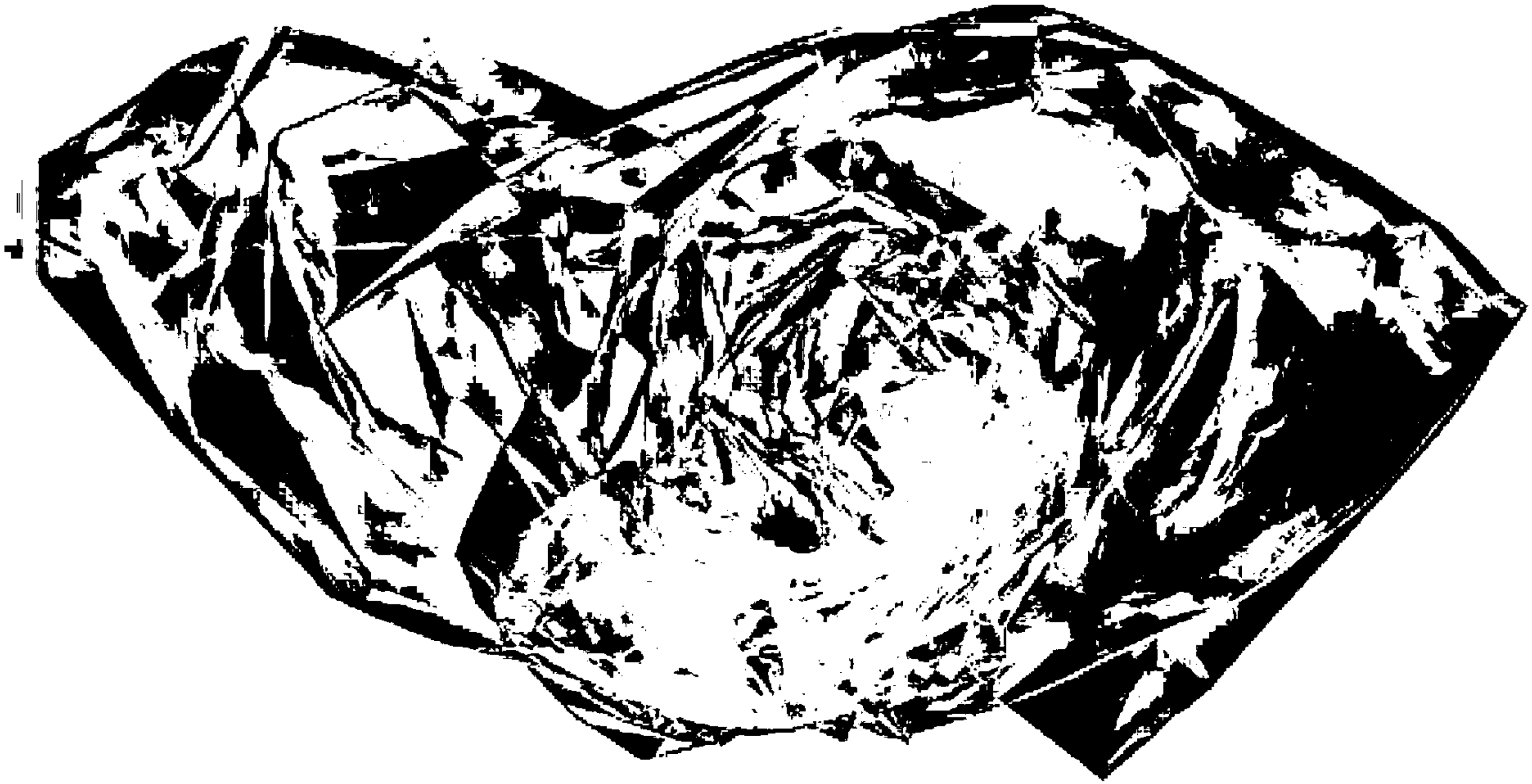


$$\begin{bmatrix} e^{j\pi/4} & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} e^{j\pi/2} & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} \frac{1}{2} & \frac{1}{2} \\ \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

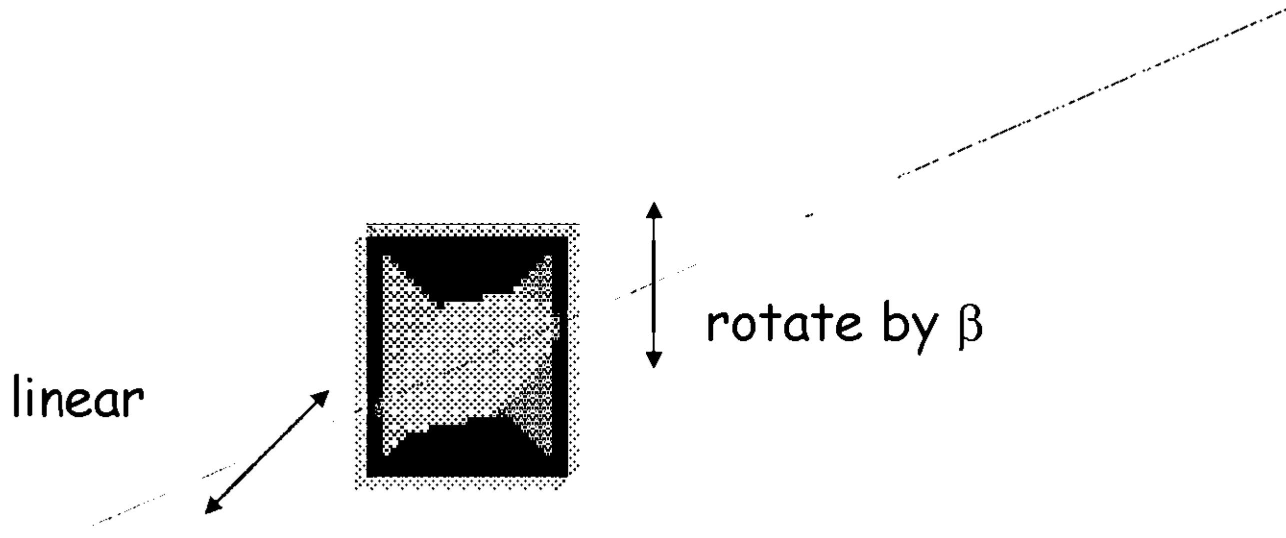
$$\begin{bmatrix} e^{j\pi/4} & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} e^{j\pi/2} & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} \frac{1}{2} \\ \frac{1}{2} \end{bmatrix}$$

$$\begin{bmatrix} e^{j\pi/4} & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} \frac{1}{2}e^{j\pi/2} \\ \frac{1}{2} \end{bmatrix}$$

$$\begin{bmatrix} \frac{1}{2}e^{j\pi/2+j\pi/4} \\ \frac{1}{2} \end{bmatrix}$$



Rotator

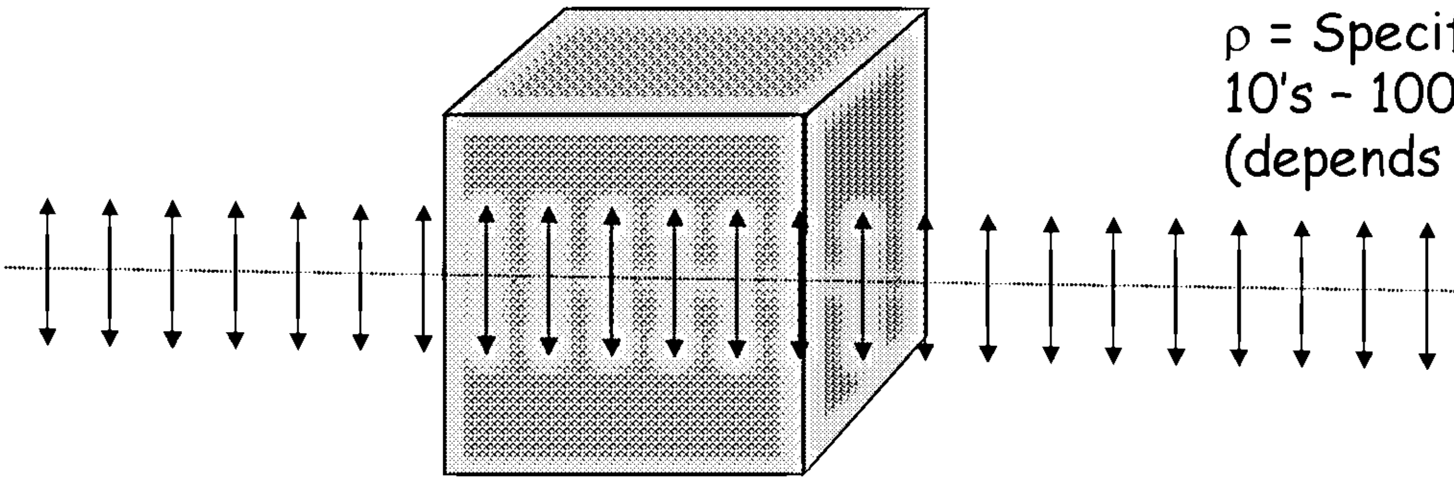


"optical activity"

Rotation of linearly polarized light as it travels through a material.

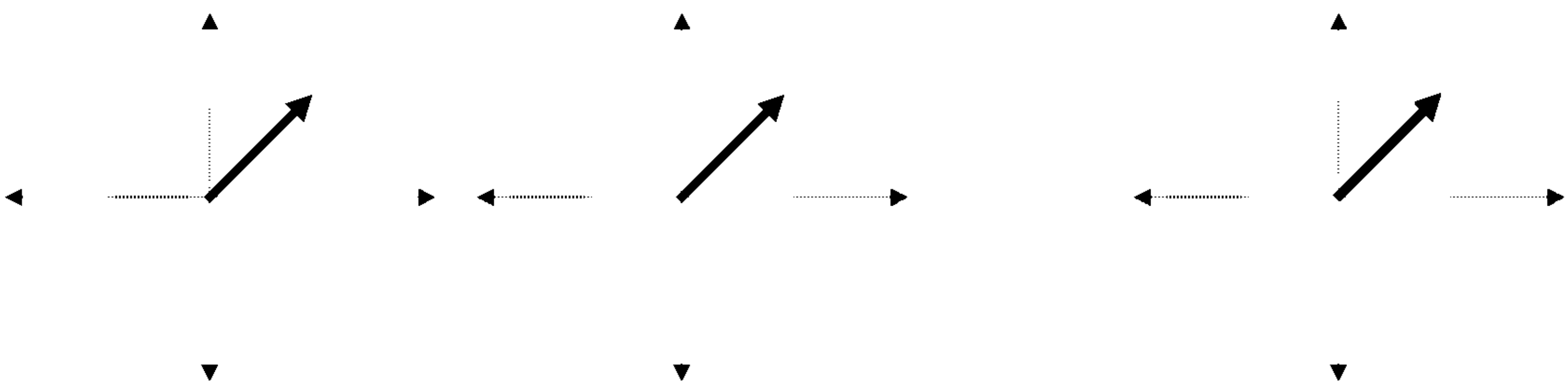
Jones Matrix: $$\begin{bmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{bmatrix}$$

"optical activity"



ρ = Specific rotation:
10's – 100's degree/mm
(depends on wavelength)

RCP + LCP = linear



$n_{\mathcal{L}} > n_{\mathcal{R}}$

Optical activity can be thought of as the result of **circular birefringence**!

Manipulating Polarization:

	Dichroism	Birefringence
Linear	$\begin{bmatrix} \cos^2\theta & \sin\theta\cos\theta \\ \sin\theta\cos\theta & \sin^2\theta \end{bmatrix}$	$\begin{bmatrix} e^{j\varepsilon_x} & 0 \\ 0 & e^{j\varepsilon_y} \end{bmatrix}$
Circular		$\begin{bmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{bmatrix}$