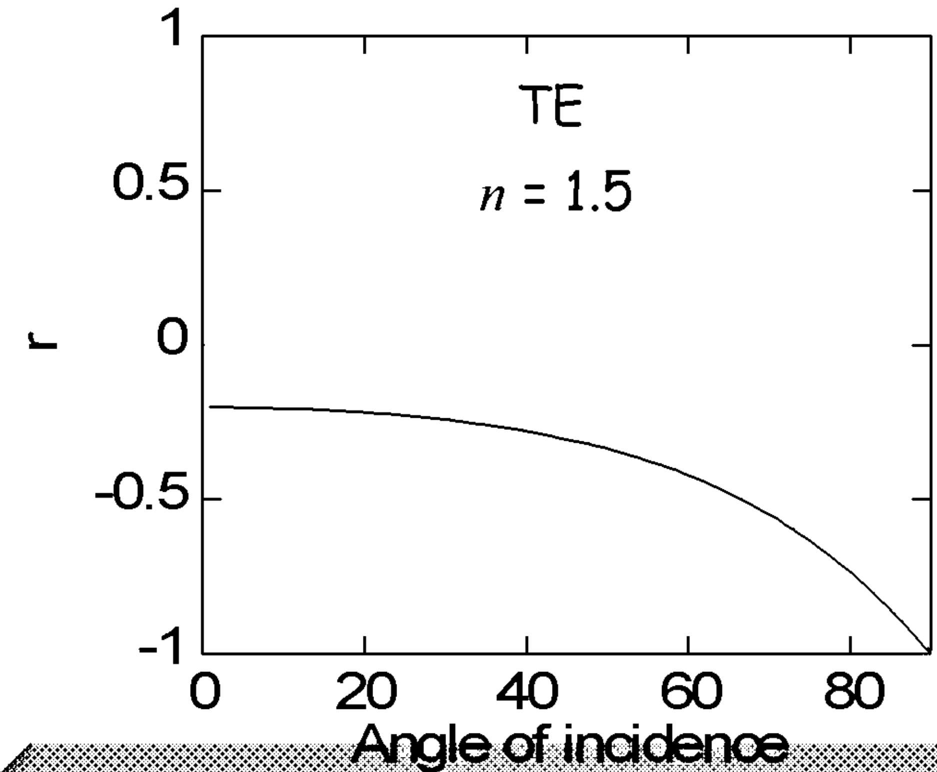


TE
n = 1.5
r
1
0.5
0
-0.5
-1
0
20
40
60
80
Angle of incidence

r_{TE} being negative means a π phase shift.

In the previous calculations we could think of E_i E_r E_t as representing complex amplitude and phase:

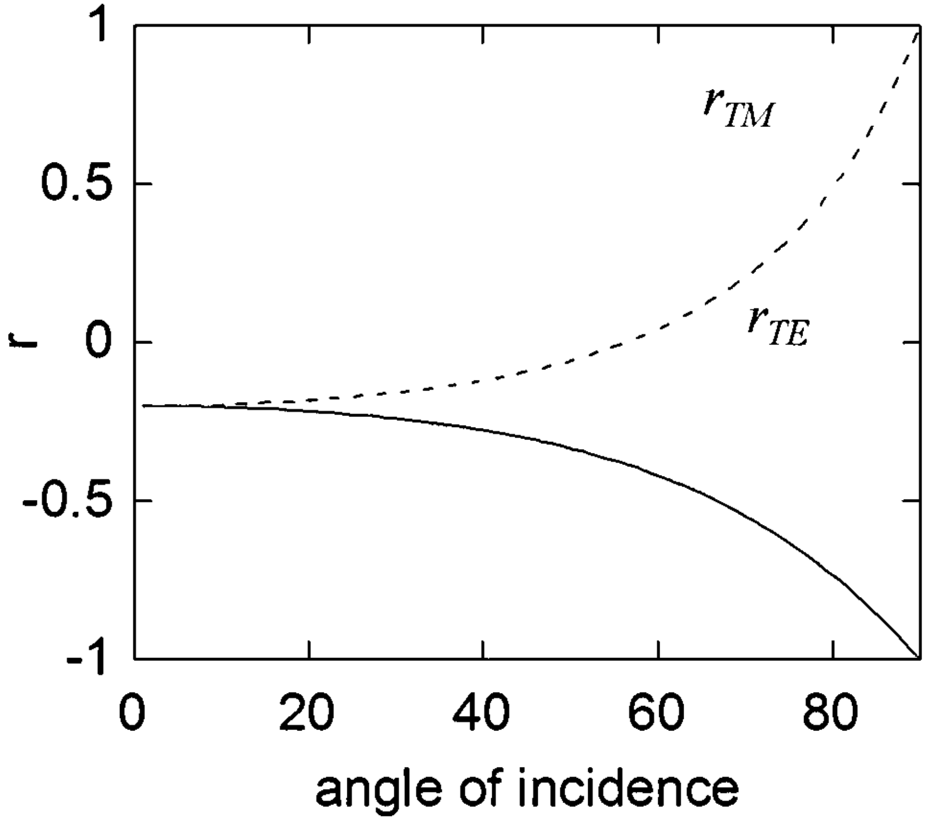
$$E_{oi}e^{j\varphi_i} \qquad E_{or}e^{j\varphi_r} \qquad E_{ot}e^{j\varphi_t}$$

$$r_{TE} = \frac{E_{or}e^{j\varphi_r}}{E_{oi}e^{j\varphi_i}} = \frac{E_{or}}{E_{oi}} e^{j(\varphi_r - \varphi_i)}$$

Since amplitudes are only positive, a negative value for r_{TE} is due to a phase difference. As long as r_{TE} is real, there will only be 0 and π phase shifts.

SIMILAR DERIVATION FOR r_{TM}

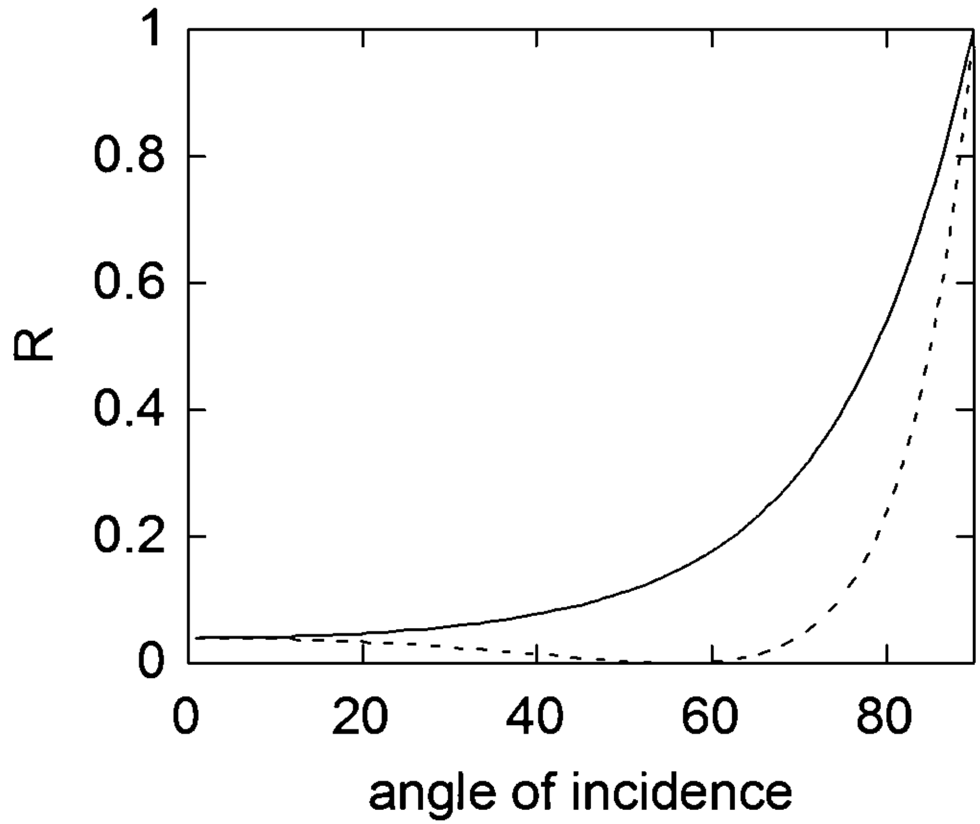
$$r_{TM} = \frac{-n^2\cos\theta_i + \sqrt{n^2 - \sin^2\theta_i}}{n^2\cos\theta_i + \sqrt{n^2 - \sin^2\theta_i}}$$



1
0.5
0
-0.5
-1
r
0
20
40
60
80
angle of incidence
r_{TM}
r_{TE}

What is observed? Irradiance (W/m^2) not the E field, so define:

Reflectance: $$R = \frac{E_{e-ref}}{E_{e-inc}} = \left(\frac{E_r}{E_i}\right)^2 = r^2$$



Transmission? We could do all that again, or:

$$t_{TE} = \frac{E_t}{E_i}$$

$$E_i + E_r = E_t$$

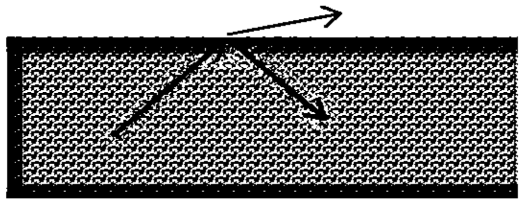
$$1 + \frac{E_r}{E_i} = \frac{E_t}{E_i}$$

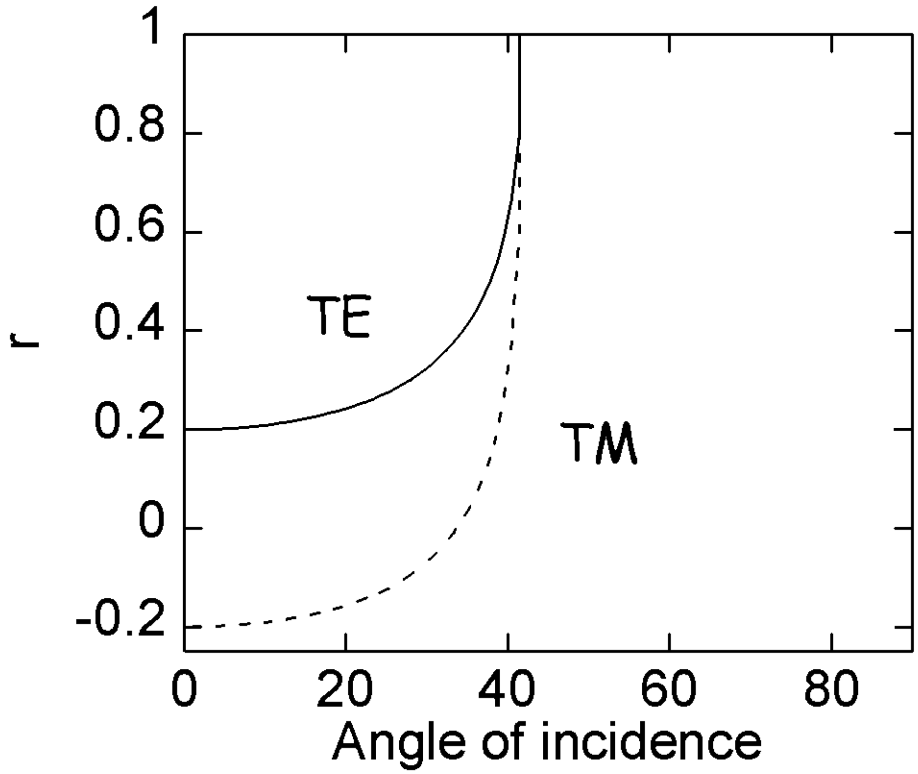
$$1 + r_{TE} = t_{TE}$$

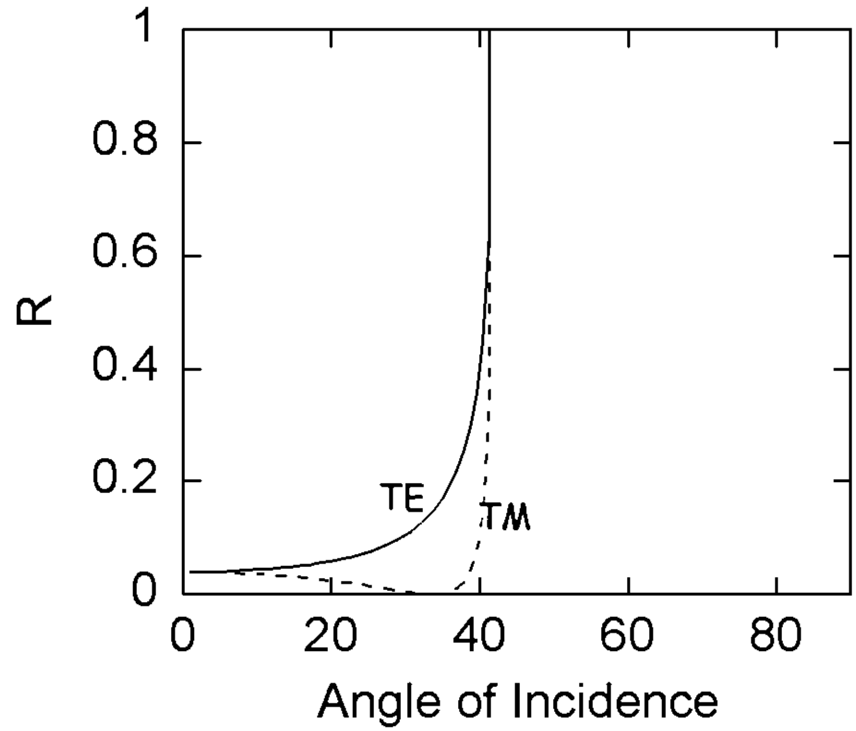
…get transmission coefficients from the reflection coefficients already derived.

This is NOT a conservation law! There is no law of conservation of the E field!

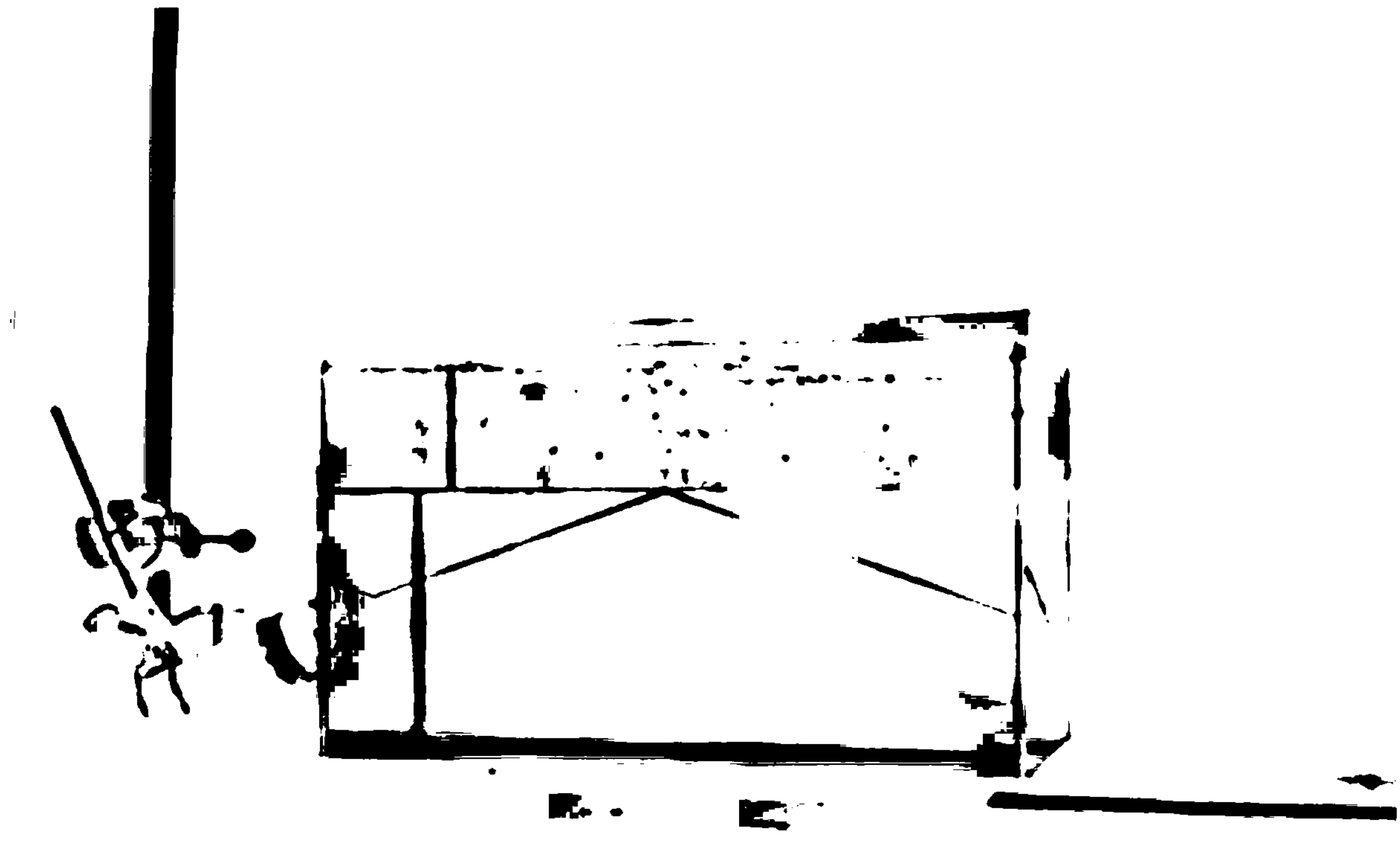
internal reflection: light incident in a high index travelling into a low index, $n = n_2 / n_1 = 0.667$





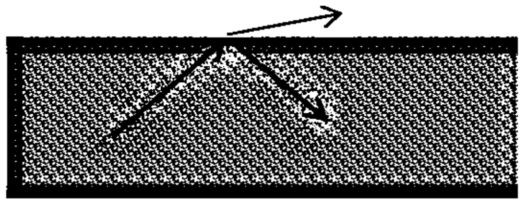


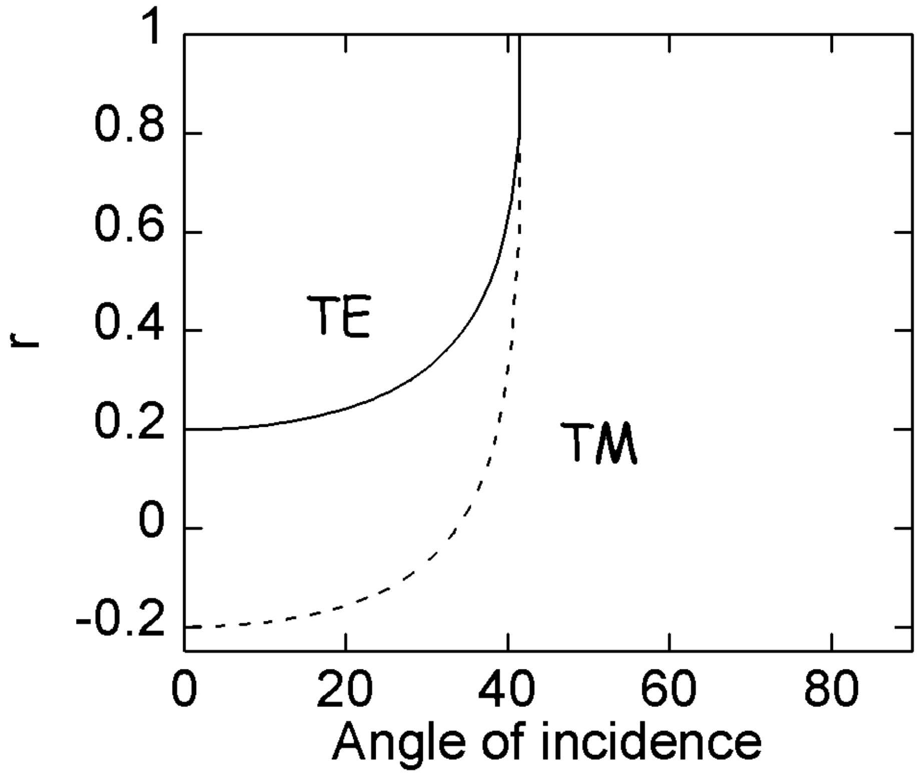
The Milky Fishtank!

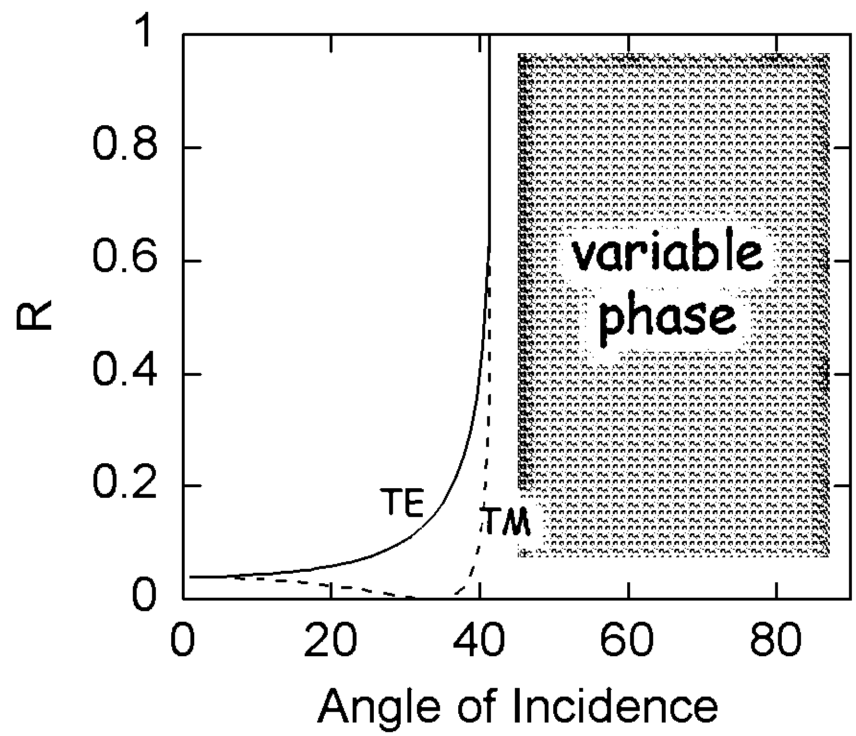



HY-110

internal reflection: light incident in a high index travelling into a low index, $n = n_2 / n_1 = 0.667$







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?

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

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

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

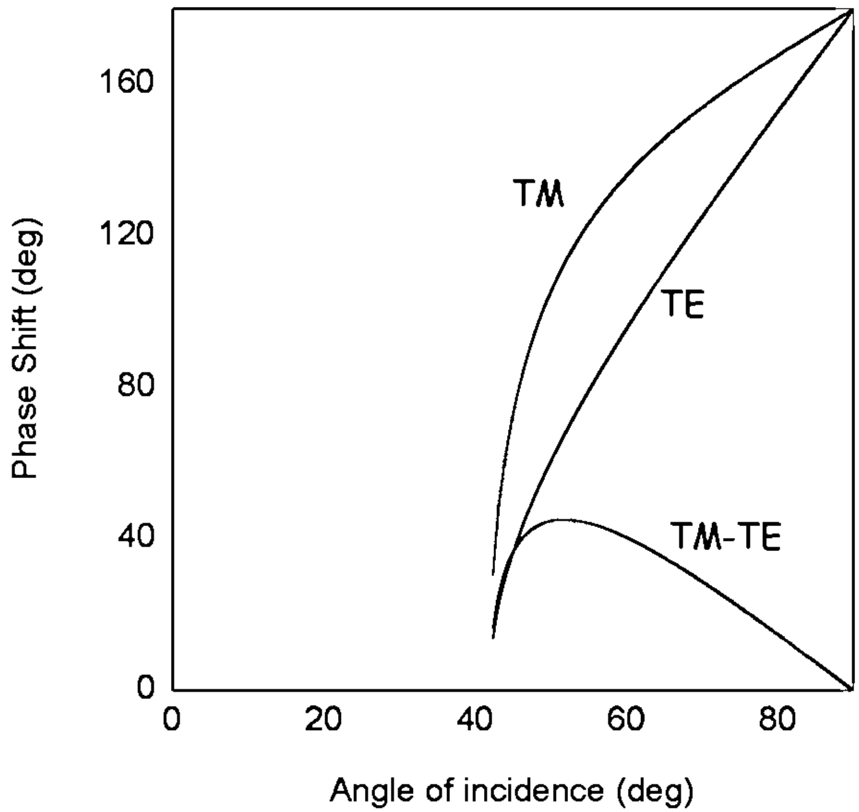
TE: $\cos(\alpha) = \cos\theta_i$ $\sin(\alpha) = \sqrt{\sin^2\theta_i - n^2}$

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

Phase shift upon total internal reflection (ϕ):

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!