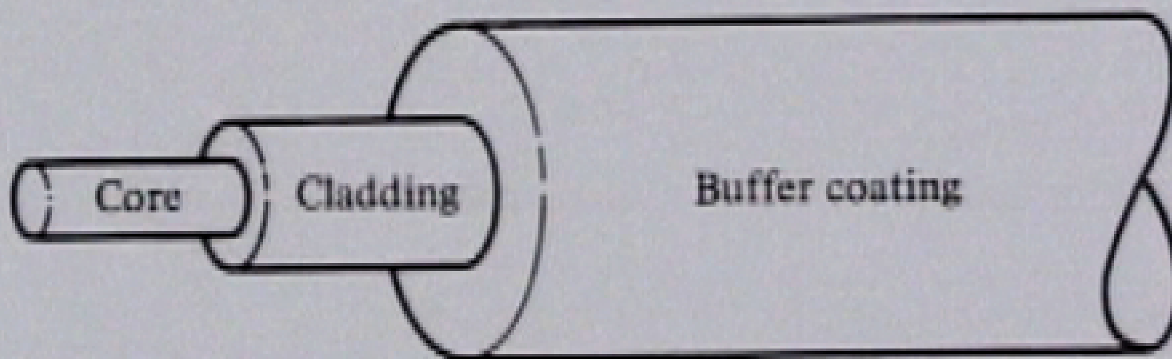
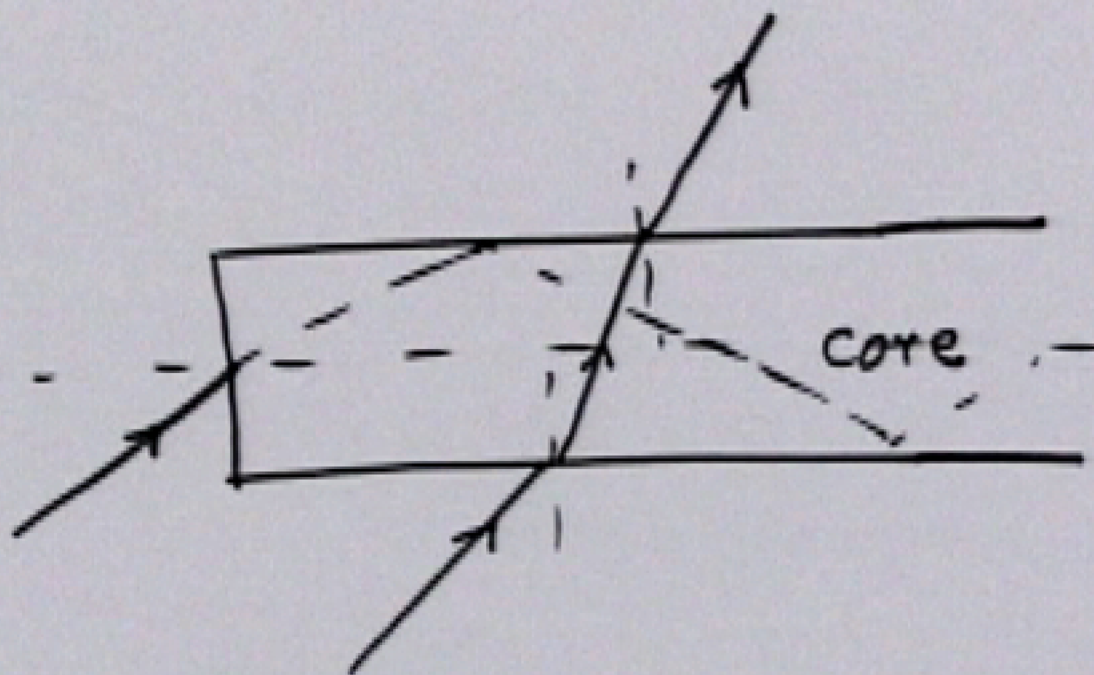
- Ray Model

- Wave Model

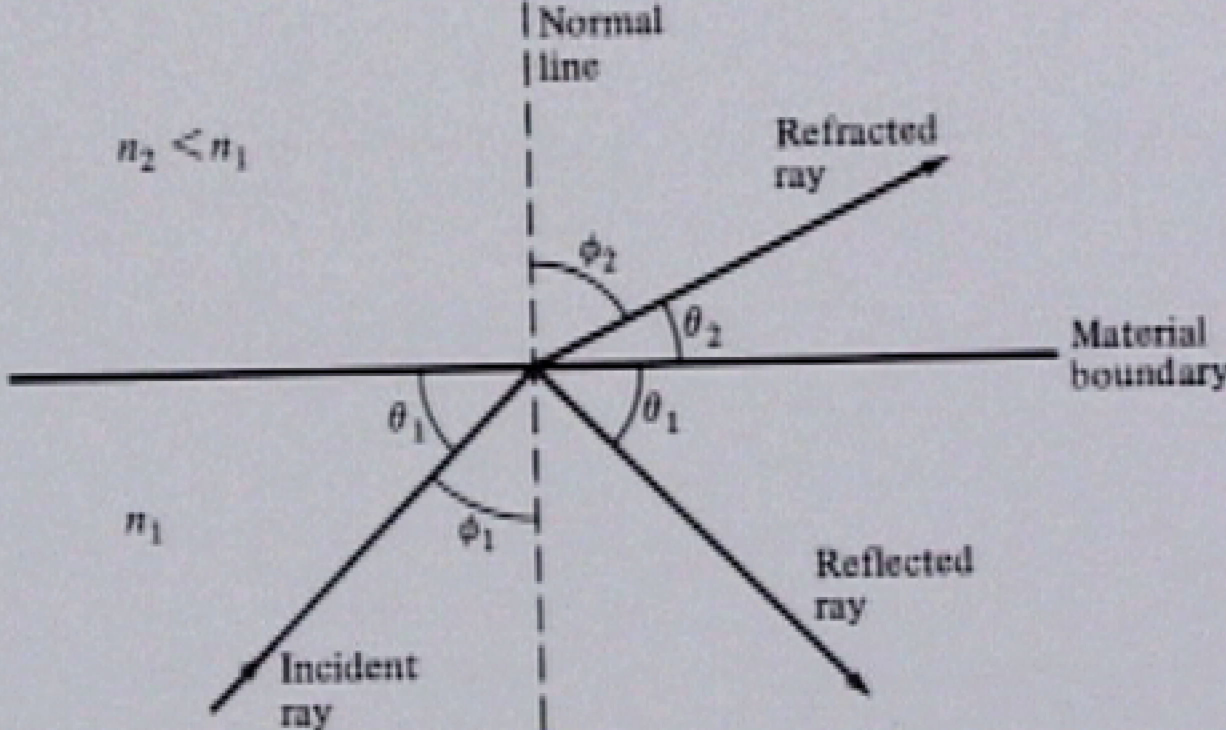
- Quantum Model

Single fiber structure



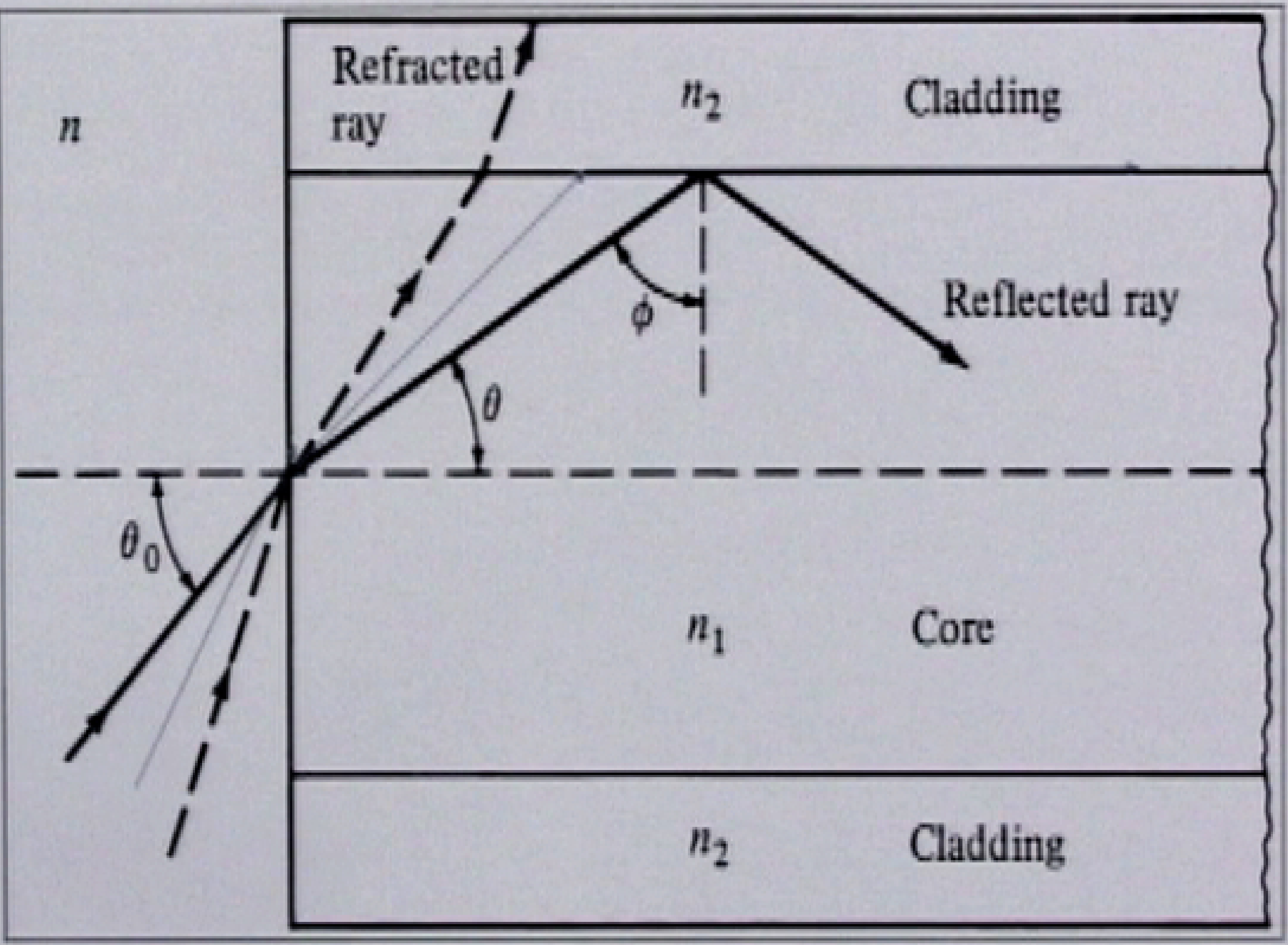

core

Snell's Law

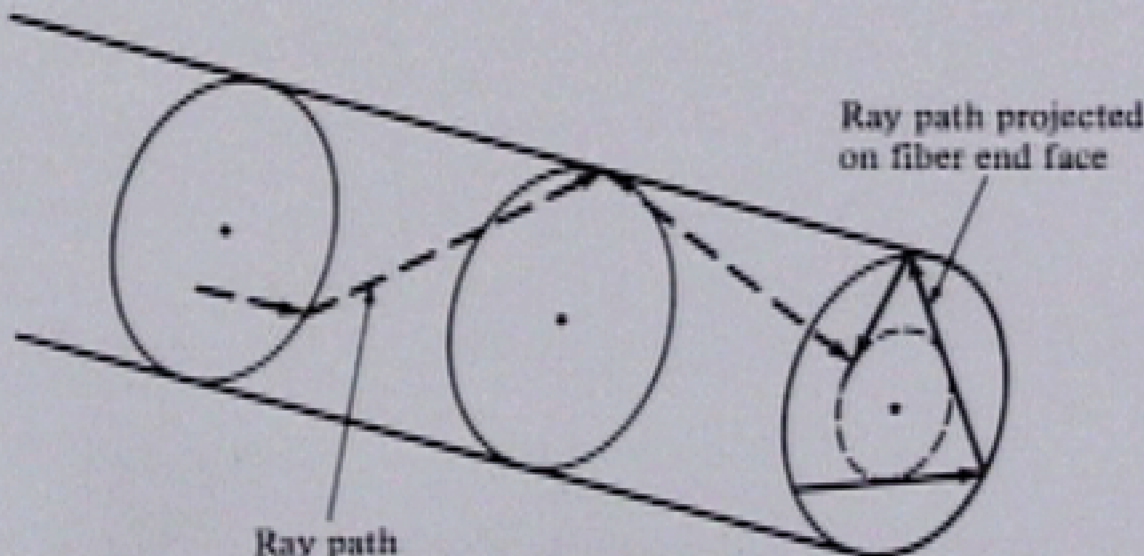


$$n_1 \sin \phi_1 = n_2 \sin \phi_2$$

Meridional ray representation



Skew rays



$$n \sin\theta_0 = n_1 \sin\theta = n_1 \sin\left(\pi/_2 - \phi\right) = n_1 \cos\phi$$

$$n_1 \sin\phi = n_2 \sin \pi/_2 = n_2$$

$$\Rightarrow \sin\phi = \frac{n_2}{n_1} \Rightarrow \cos\phi = \sqrt{1 - \frac{n_2^2}{n_1^2}}$$

$$\sin\theta_{0_{max}} = \frac{n_1 \cos\phi}{n} = \sqrt{\frac{n_1^2 - n_2^2}{n^2}}$$

Numerical Aperture

Sine of the maximum angle accepted by the fiber.

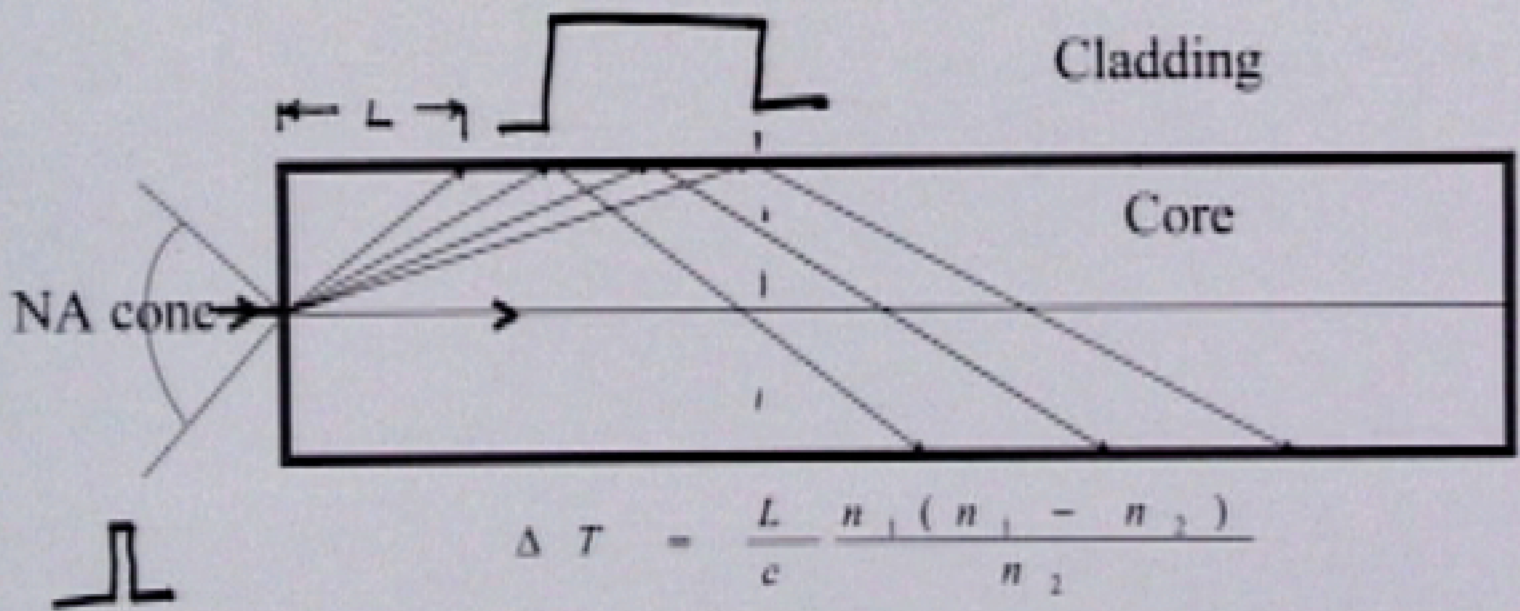
It defines the light launching efficiency

$$NA = \sin\theta_{0\max} = (n_1^2 - n_2^2)^{1/2}$$

For high launching efficiency NA should be as large as possible.

Group delay

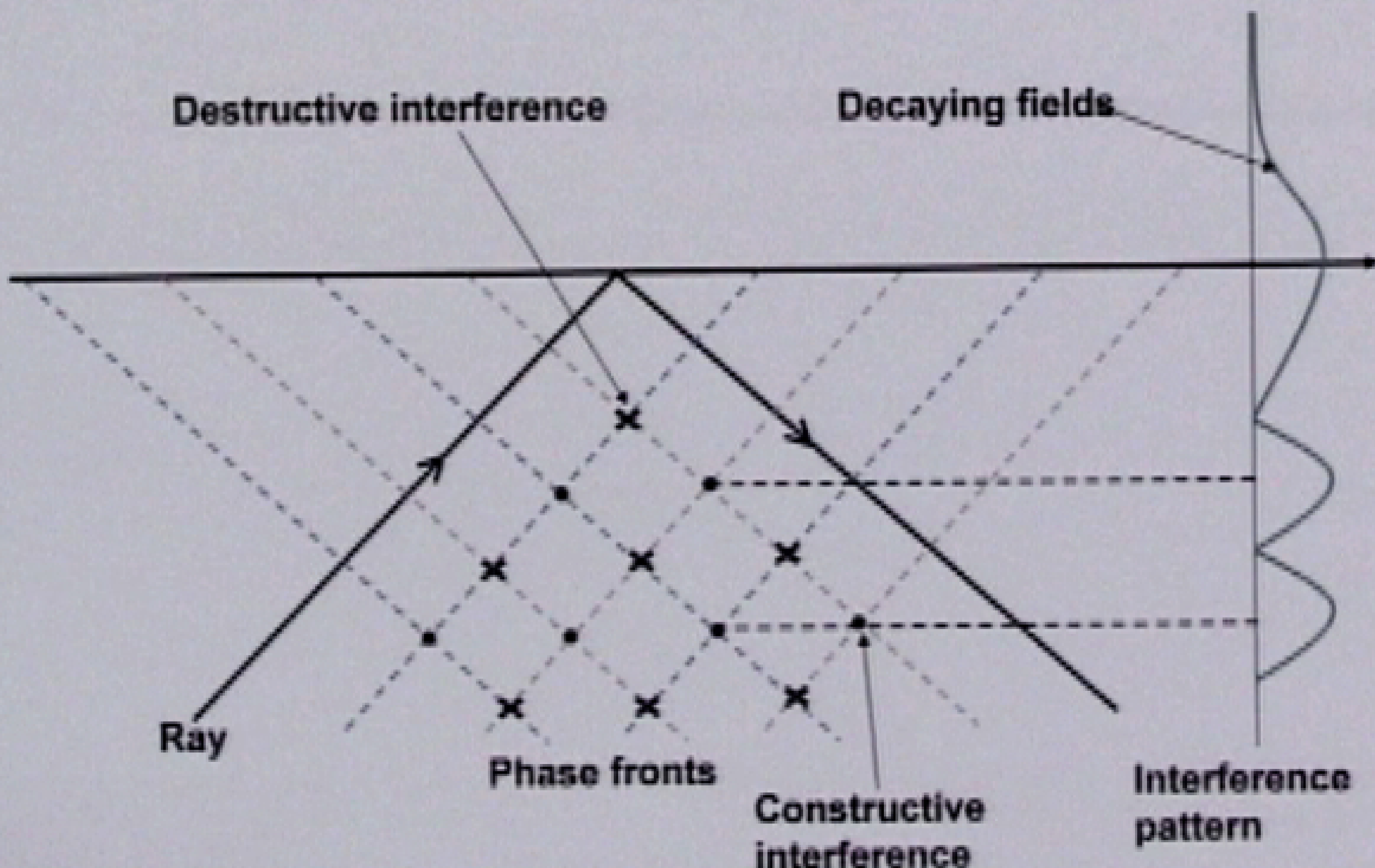
- A pulsed signal travels by multiple paths within the NA cone.



$$\Delta T = \frac{L}{c}\frac{n_1(n_1 - n_2)}{n_2}$$

$$BW = \frac{1}{\Delta T}$$

Total Internal Reflection



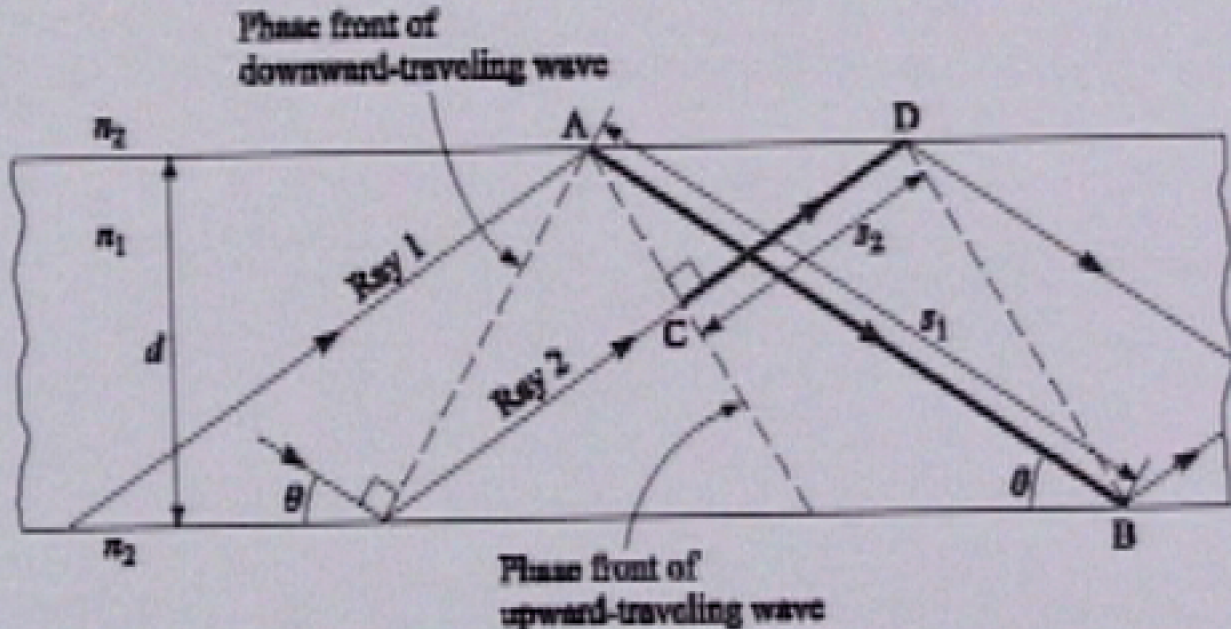
At Total internal reflection, we have

1. Standing wave type of fields in the core.

2. Decaying fields in cladding.

3. The ray undergo the phase change at the reflecting boundary.

Light propagation



1. Rays can survive at discrete angles
2. There are finite number of rays

$$s_1 = d / \sin\theta$$

$$s_2 = AD\cos\theta = (\cos^2\theta - \sin^2\theta) d / \sin\theta$$

$$\frac{2\pi n_1}{\lambda}(s_1 - s_2) + 2\delta = 2\pi m$$

$$\frac{2\pi n_1 d \sin\theta}{\lambda} + \delta = \pi m$$