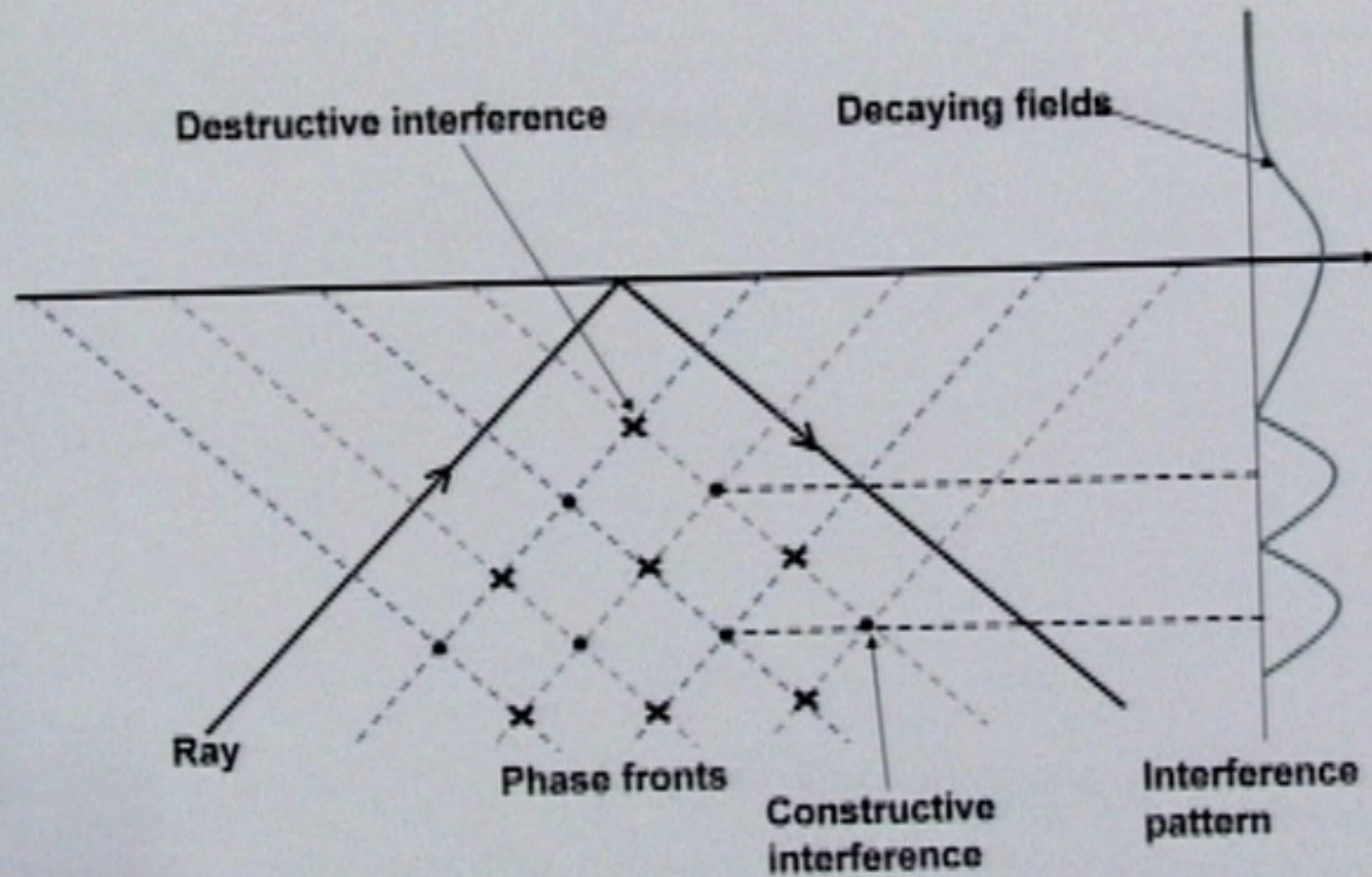
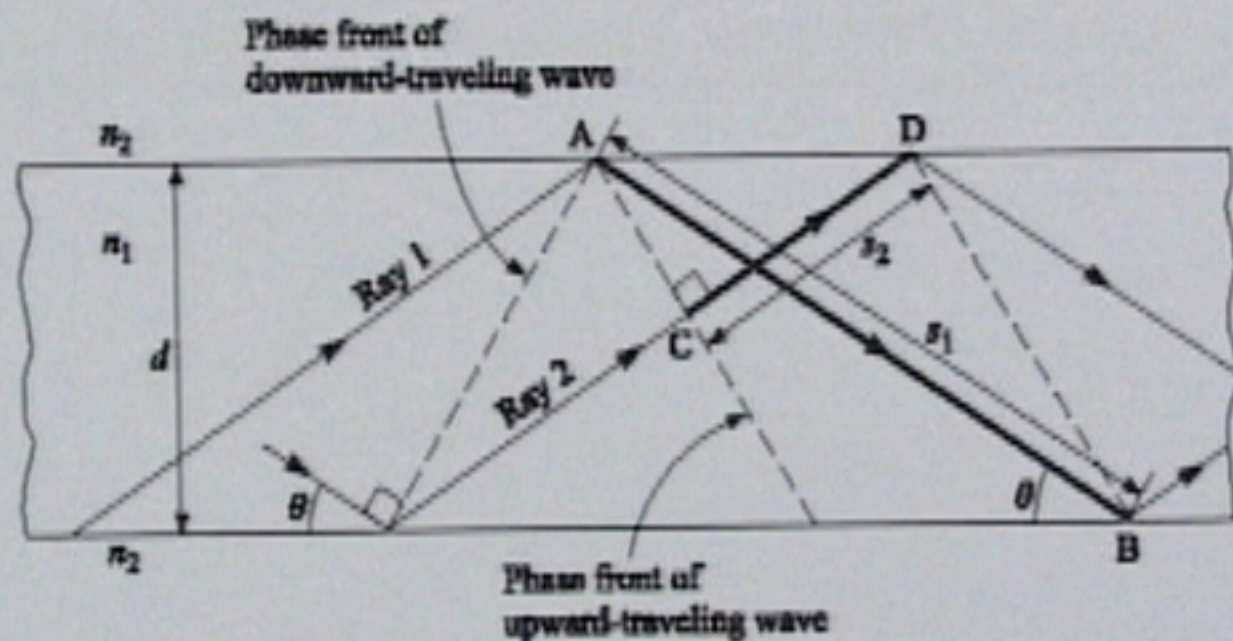


Total Internal Reflection



Light propagation



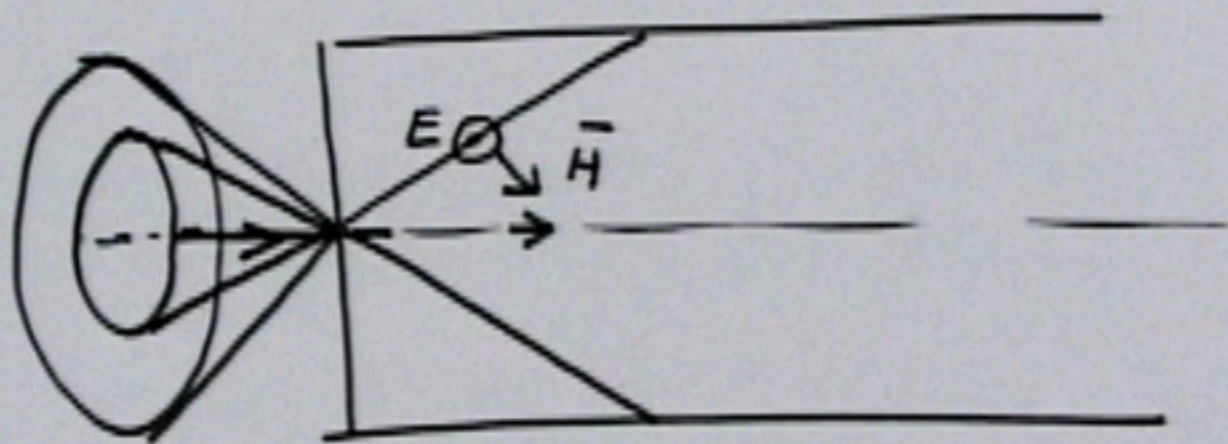
1. Rays can survive at discrete angles
2. There are finite number of rays

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

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

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

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



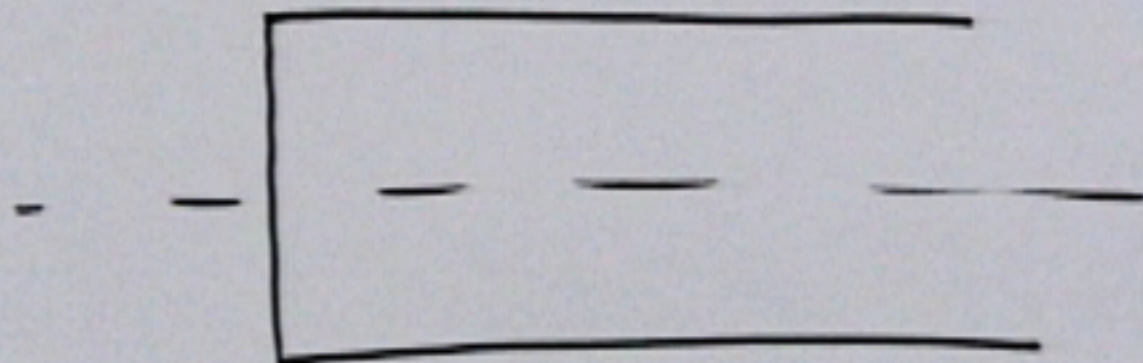
Transverse Electric mode

TE

Transverse Magnetic mode

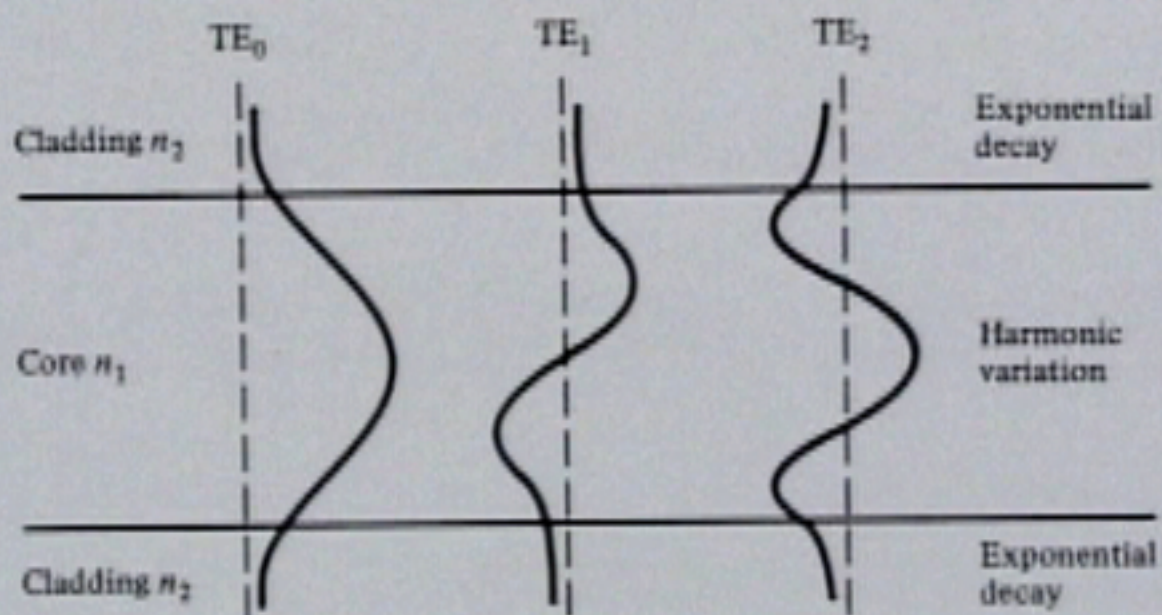
TM

Skew Rays.



Hybrid Modes.

Low-order-mode fields



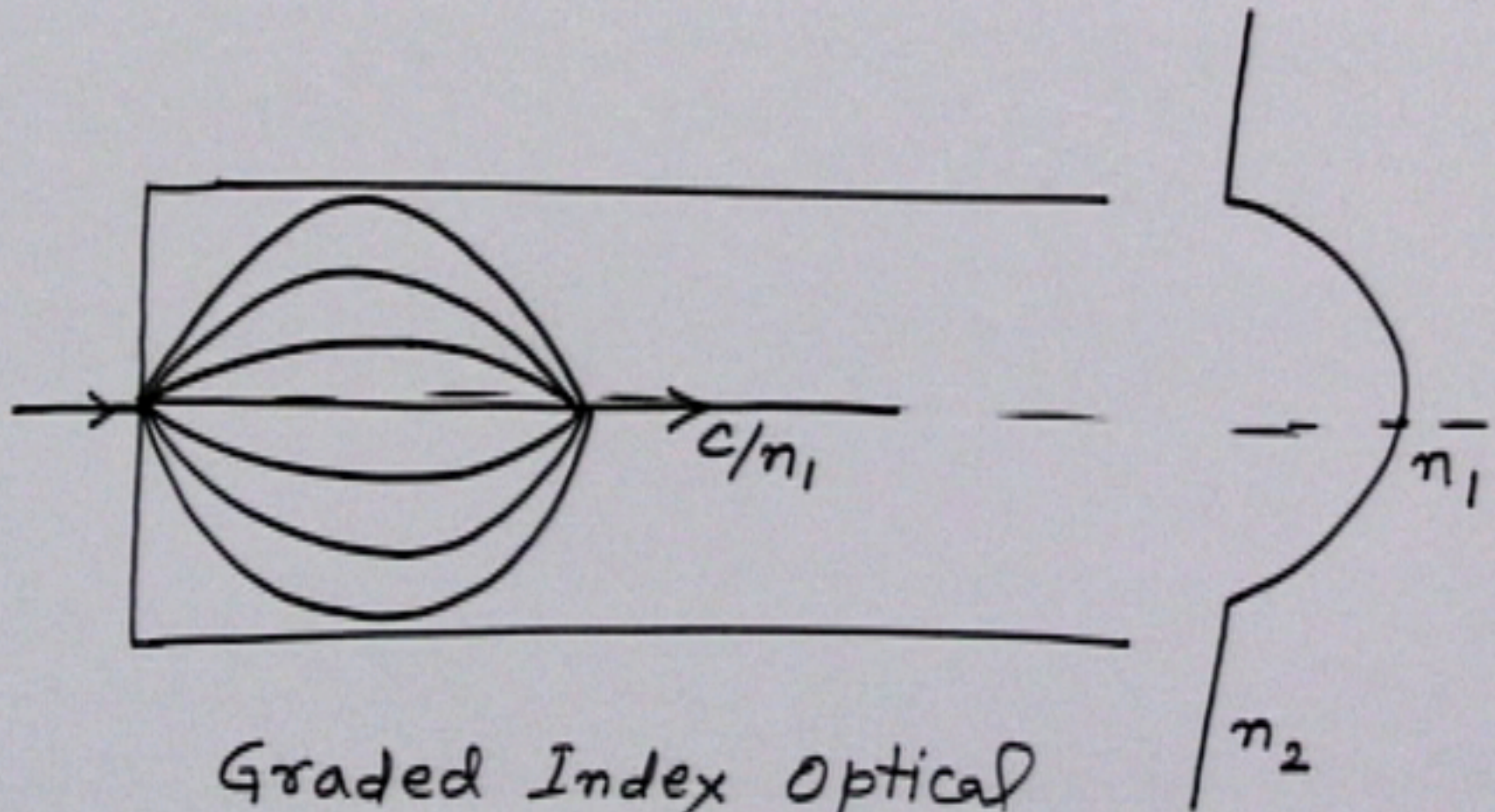
Multimode fiber
(MM)

$d \sim 50-100 \mu\text{m}$

Single mode fiber
(SM)

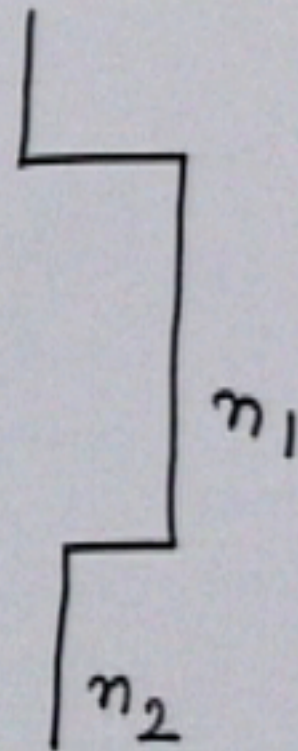
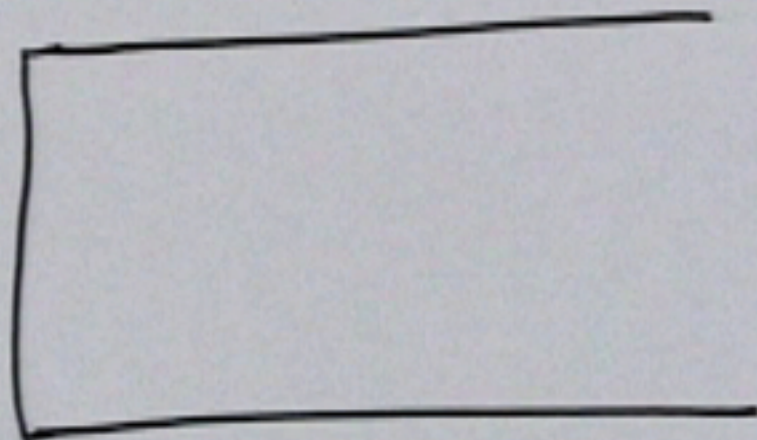
$d \sim 6-8 \mu\text{m}$

cladding diameter = $125 \mu\text{m}$.



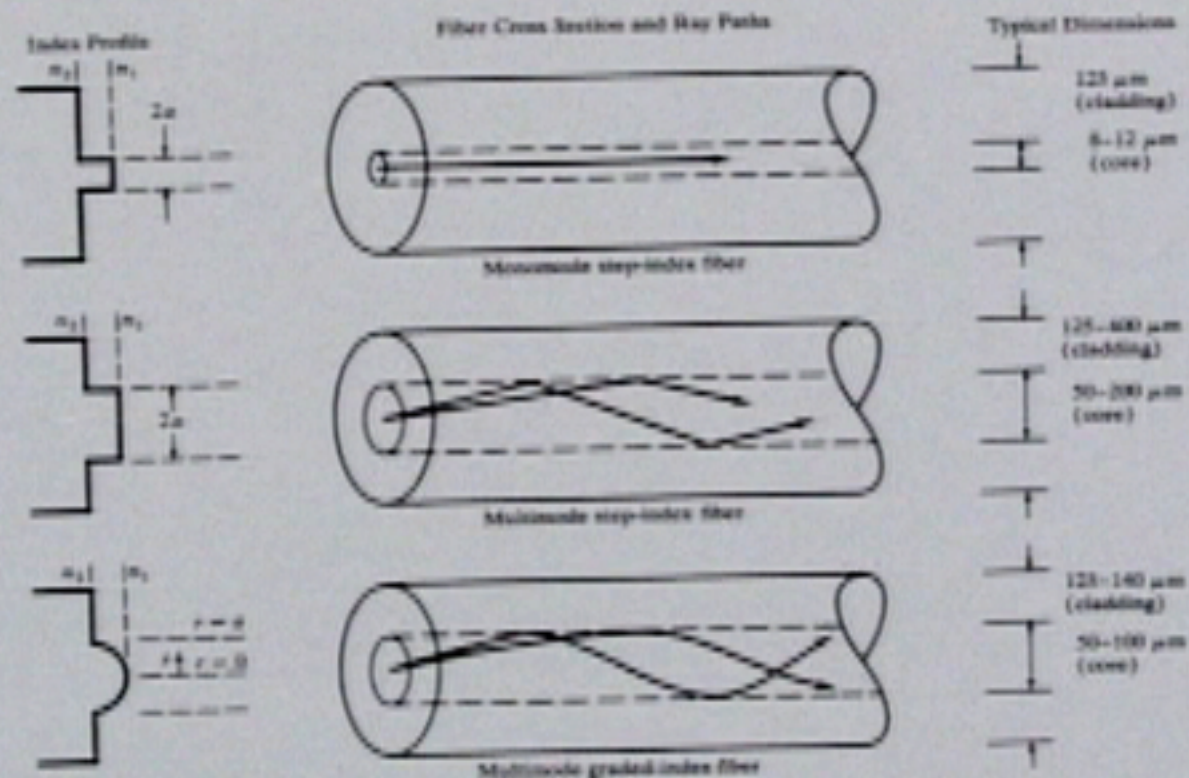
Graded Index Optical
Fiber.

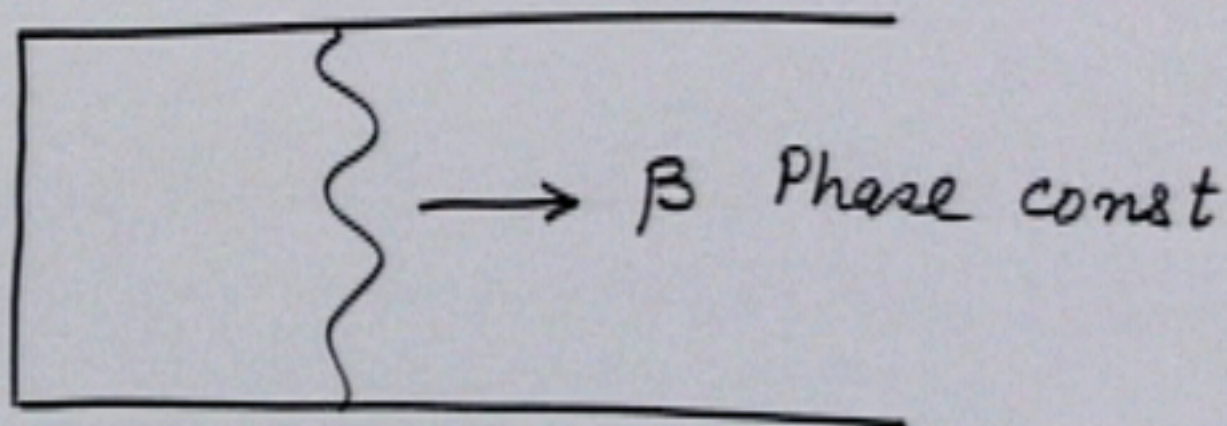
MM



step-index

Comparison of fiber structures





$\beta - \omega$ relation.

$$V_p = \text{Phase velocity} = \omega / \beta$$

$$V_g = \text{Group velocity} = \partial \omega / \partial \beta$$