Learning Outcome: Identify the fundamental principles of photon optics & quantify photon properties

* Light as electromagnetic waves

 - satisfy Maxwell's equ.

$$\nabla \cdot \vec{D} = \rho_v$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{H} = \vec{J}_c + \frac{\partial \vec{D}}{\partial t}$$

$\vec{D} = \epsilon \vec{E}$

$\vec{B} = \mu \vec{H}$

For a plane EM wave propagating in +z direction - represented by wave equ.

$$\vec{E} = (\hat{a}_x E_x + \hat{a}_y E_y e^{j\phi}) e^{-jkz}$$

$$\nabla^2 \vec{E} + k^2 \vec{E} = 0 \qquad \nabla^2 \vec{H} + k^2 \vec{H} = 0$$

If $\phi = 0 \Rightarrow$ linear polarization

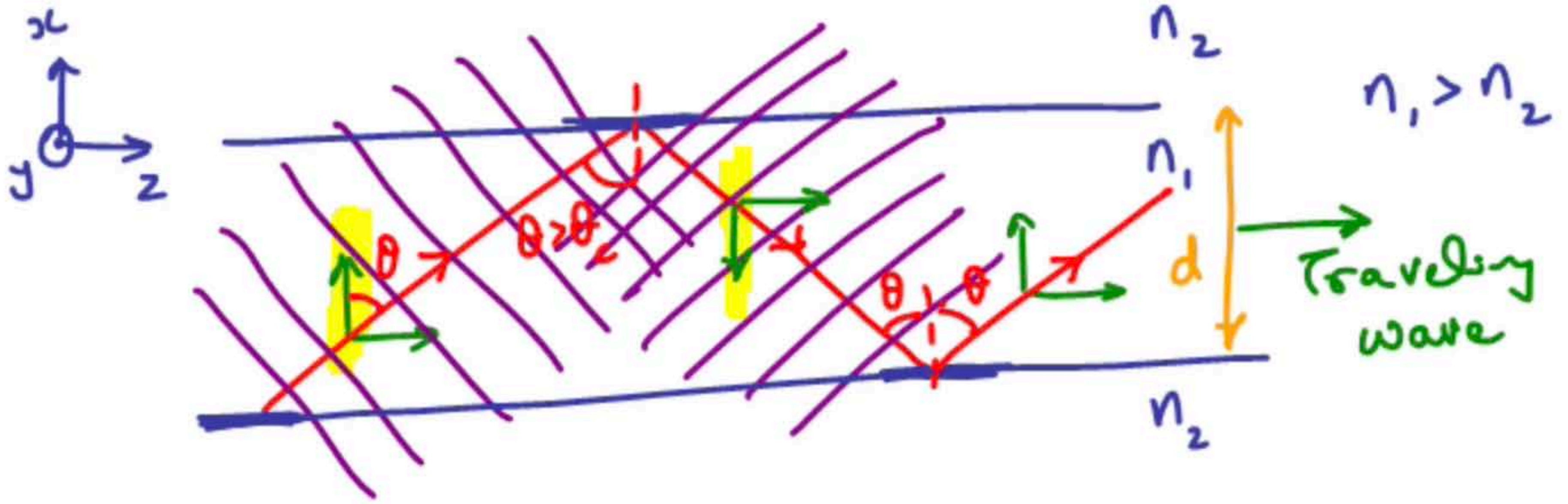
If $\phi = \pm \pi/2 \Rightarrow$ circular polarization
$E_x = E_y$

Any other $\Rightarrow$ Elliptical polarization

* For a given structure, only specific field configurations are allowed

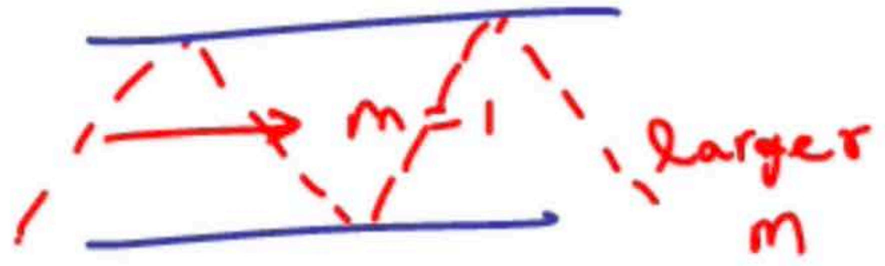
$\Rightarrow$ Eigenmodes or Modes of the structure

Example: Optical Fiber



Does any angle $\theta > \theta_c$ survive in the waveguide?

neglecting $\phi_{boundaries} + k_x \cdot 2d = 2\pi m$



$k\cos\theta \cdot 2d = 2\pi m$

$\frac{\cancel{2\pi}}{\lambda} n_1 2d \cos\theta = \cancel{2\pi} m$

$\theta_c < \theta_m < \pi/2$

For $m=1$, θ_m is highest ($\pi/2$)

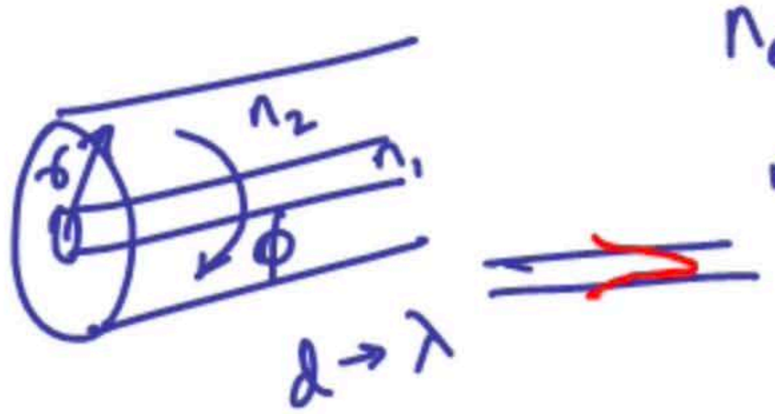
# of modes supported, depends on λ/d

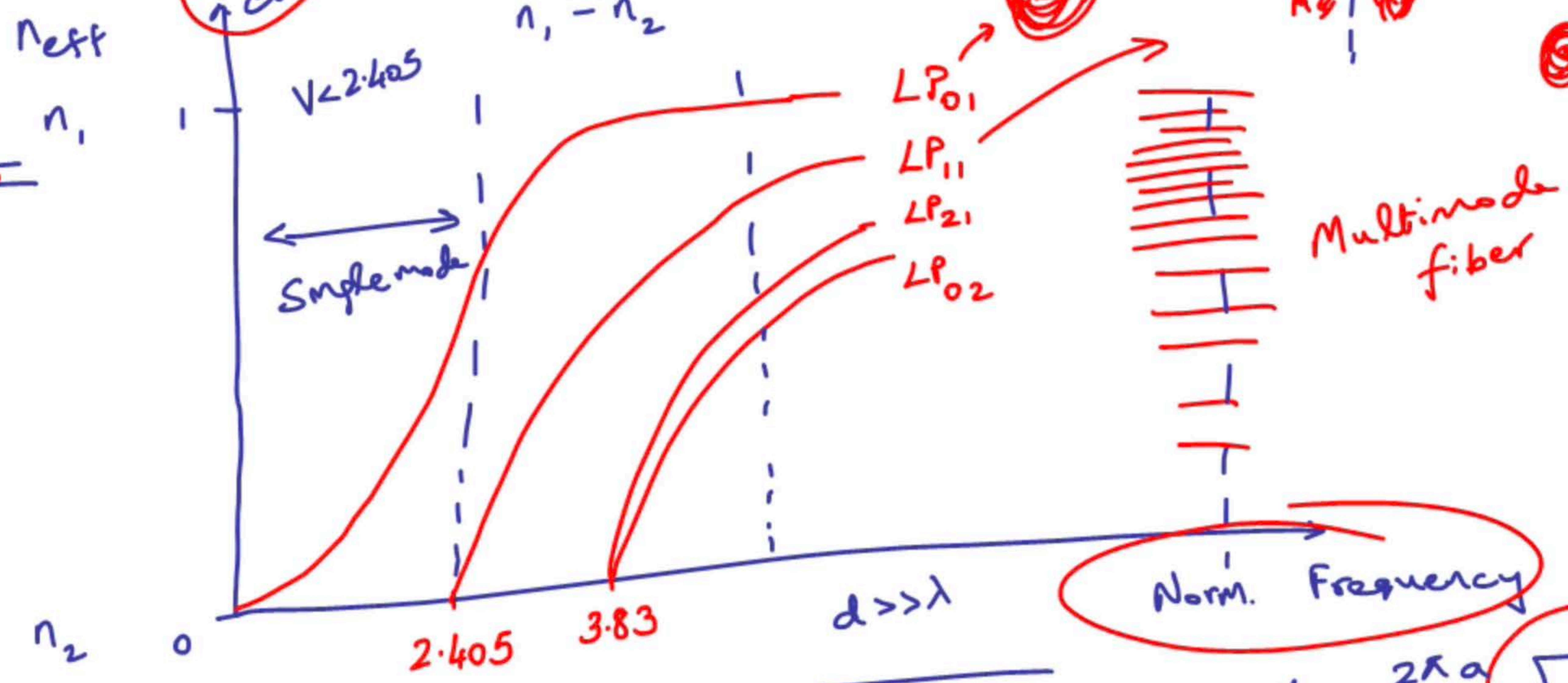
$$\boxed{\cos\theta_m = \frac{m\lambda}{2n_1 d}}$$

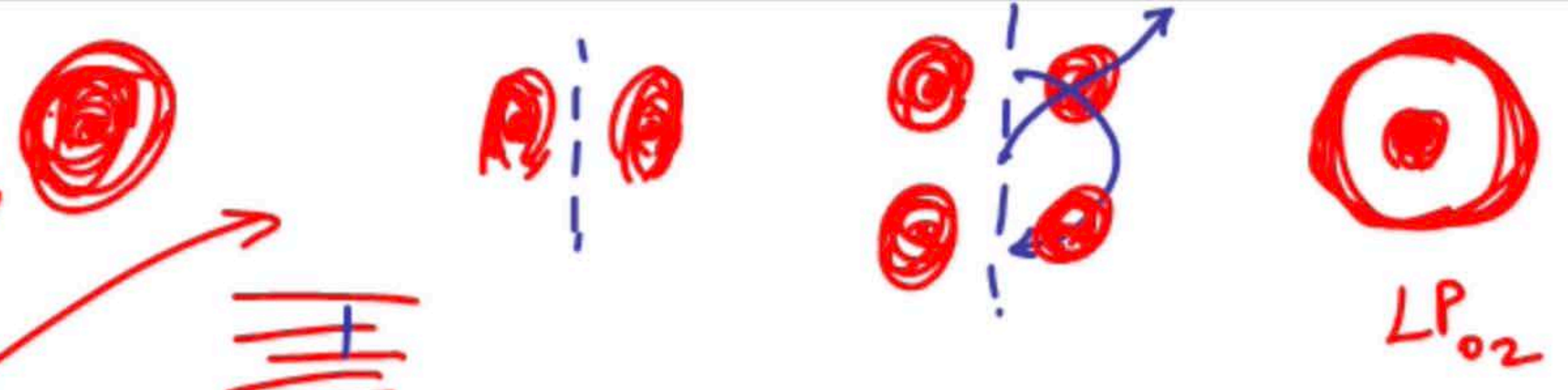
$d \to \lambda \Rightarrow$ fundamental mode

If $d >> \lambda \Rightarrow$ larger # of modes (multimode)

Prop. const. $b = \dfrac{n_{eff} - n_2}{n_1 - n_2}$

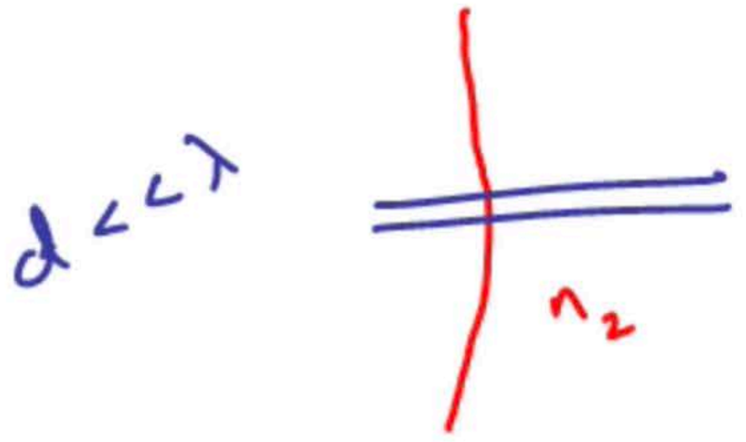


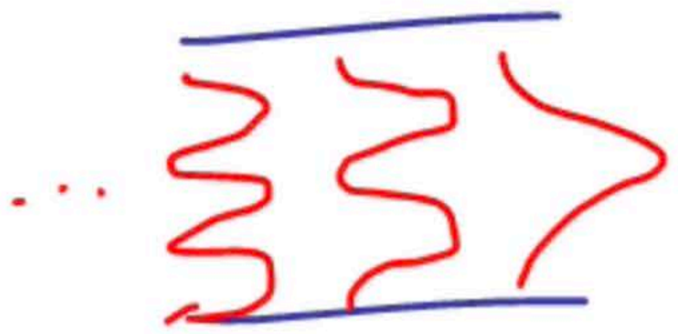




$$V = \frac{2\pi a}{\lambda} \sqrt{n_1^2 - n_2^2}$$

NA





LP_{mn}

$\swarrow$ # of maxima in ϕ-dir

$\searrow$ # of maxima in r-dir

A given fiber cannot be classified as singlemode/multimode

$\to$ depends of λ (λ/d)

Example:

$\lambda_c = 1200\,nm \quad , \quad NA = 0.12$

$$V = 2.405 = \frac{2\pi a}{\lambda} \times NA \Rightarrow 2a \cong \underline{8\ \mu m}$$

$$V_{1.5\mu m} = V_{1.2\mu m} \times \frac{1.2 \times 10^{-6}}{1.5 \times 10^{-6}} = 2.405 \times \frac{4}{5} = 1.92$$