Introduction to Fiber Optic

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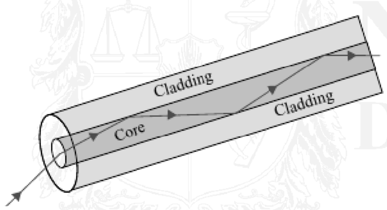
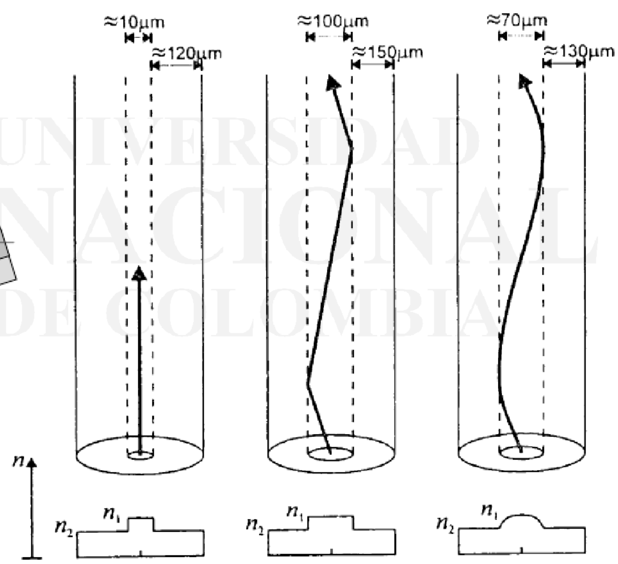
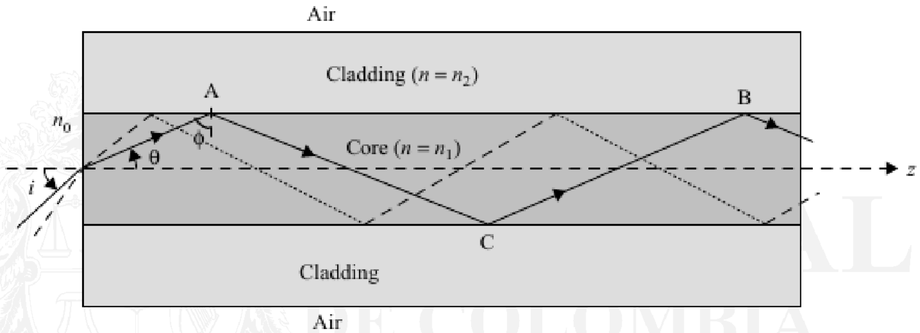
Physical construction



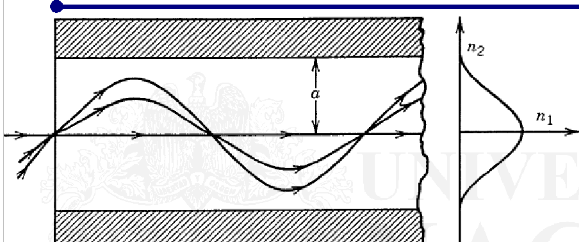


High Frequency Analysis (Step-Index Fiber)

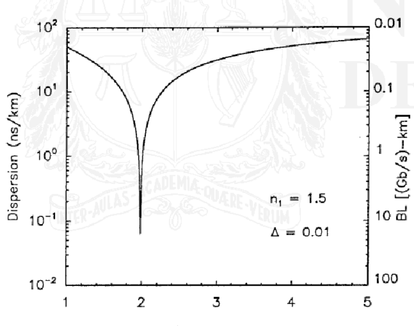


- Refraction Index
- Fractional Index change
- Numerical Aperture
- Modal Dispersion/Multipath Dispersion
- Bitrate-distance product

Graded-Index Fiber



$$n_1[1-\Delta(\rho/a)^{\alpha}]$$



- Rarely used for long-haul links.
- Their wide core aids in coupling efficiency
- BL product for plastic fibers exceeds 2GB/s-km, useful in short distances.

Field Analysis of Step-Index Optic Fiber

$$\frac{\partial^2 E_z}{\partial \rho^2}+\frac{1}{\rho}\frac{\partial E_z}{\partial \rho}+\frac{1}{\rho^2}\frac{\partial^2 E_z}{\partial \phi^2}+\frac{\partial^2 E_z}{\partial z^2}+n^2k_0^2E_z=0$$

$$n=\begin{cases} n_1; & \rho\le a\\ n_2; & \rho>a\end{cases}$$

$$E_z(\rho,\phi,z)=F(\rho)\Phi(\phi)Z(z)$$

$$\begin{aligned} d^2Z/dz^2+\beta^2Z&=0\\ d^2\Phi/d\phi^2+m^2\Phi&=0\\ \frac{d^2F}{d\rho^2}+\frac{1}{\rho}\frac{dF}{d\rho}+\left(n^2k_0^2-\beta^2-\frac{m^2}{\rho^2}\right)F&=0\end{aligned}$$

Field Analysis of Step-Index Optic Fiber (2)

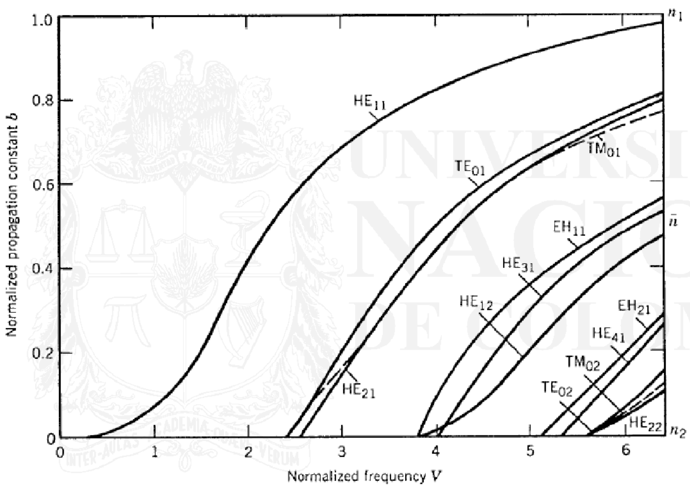
$$F(\rho)=\begin{cases} AJ_m(p\rho)+A'Y_m(p\rho); & \rho\le a\\ CK_m(q\rho)+C'I_m(q\rho); & \rho>a\end{cases}$$

$$\begin{aligned} p^2&=n_1^2k_0^2-\beta^2\\ q^2&=\beta^2-n_2^2k_0^2\end{aligned}$$

$$E_z=\begin{cases} AJ_m(p\rho)\exp(im\phi)\exp(i\beta z)\,; & \rho\le a\\ CK_m(q\rho)\exp(im\phi)\exp(i\beta z); & \rho>a\end{cases}$$

$$\left[\frac{J_m'(pa)}{pJ_m(pa)}+\frac{K_m'(qa)}{qK_m(qa)}\right]\quad\left[\frac{J_m'(pa)}{pJ_m(pa)}+\frac{n_2^2}{n_1^2}\frac{K_m'(qa)}{qK_m(qa)}\right]$$
$$=\frac{m^2}{a^2}\left(\frac{1}{p^2}+\frac{1}{q^2}\right)\left(\frac{1}{p^2}+\frac{n_2^2}{n_1^2}\frac{1}{q^2}\right)$$

Dispersion Relation Propagation Modes

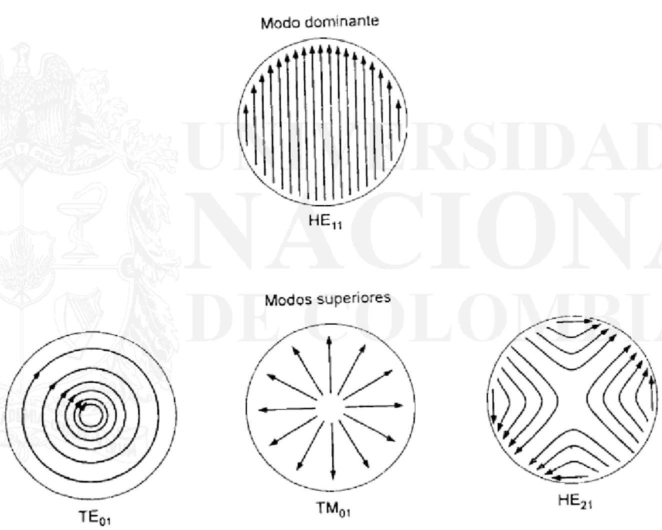


$$V = k_0 a (n_1^2 - n_2^2)^{1/2} \approx (2\pi/\lambda) a n_1 \sqrt{2\Delta}$$

$$b = \frac{\beta/k_0 - n_2}{n_1 - n_2} = \frac{\bar{n} - n_2}{n_1 - n_2}$$

Fundamental mode propagates downto DC!
Mono-mode operation results for V<2.405

Low-Order Propagation Modes in Fiber Optic



References

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[3] Rodolfo Neri Vela, “Lineas de Transmision”, McGraw-Hill, 1999.