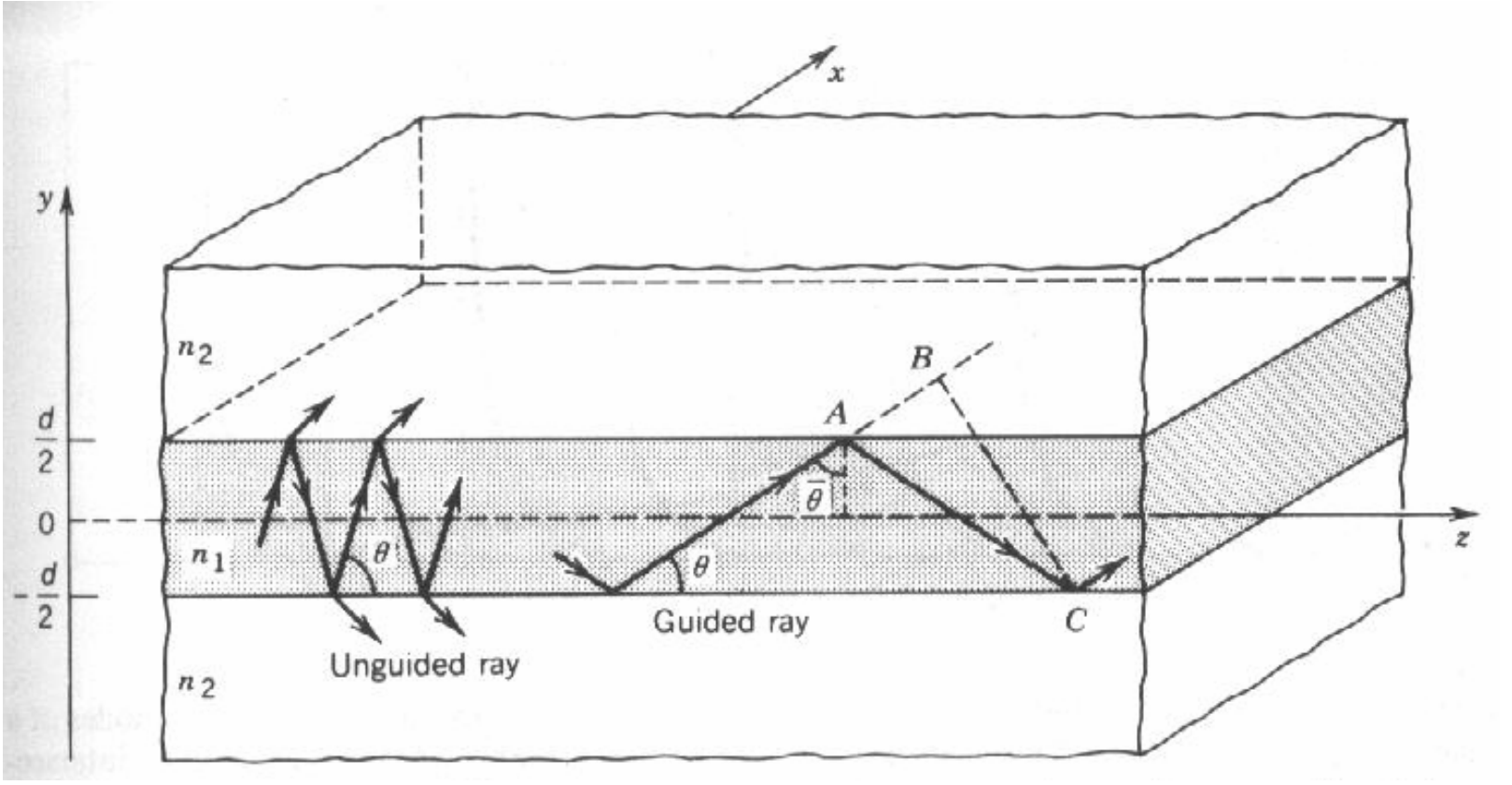
分極と電場の関係

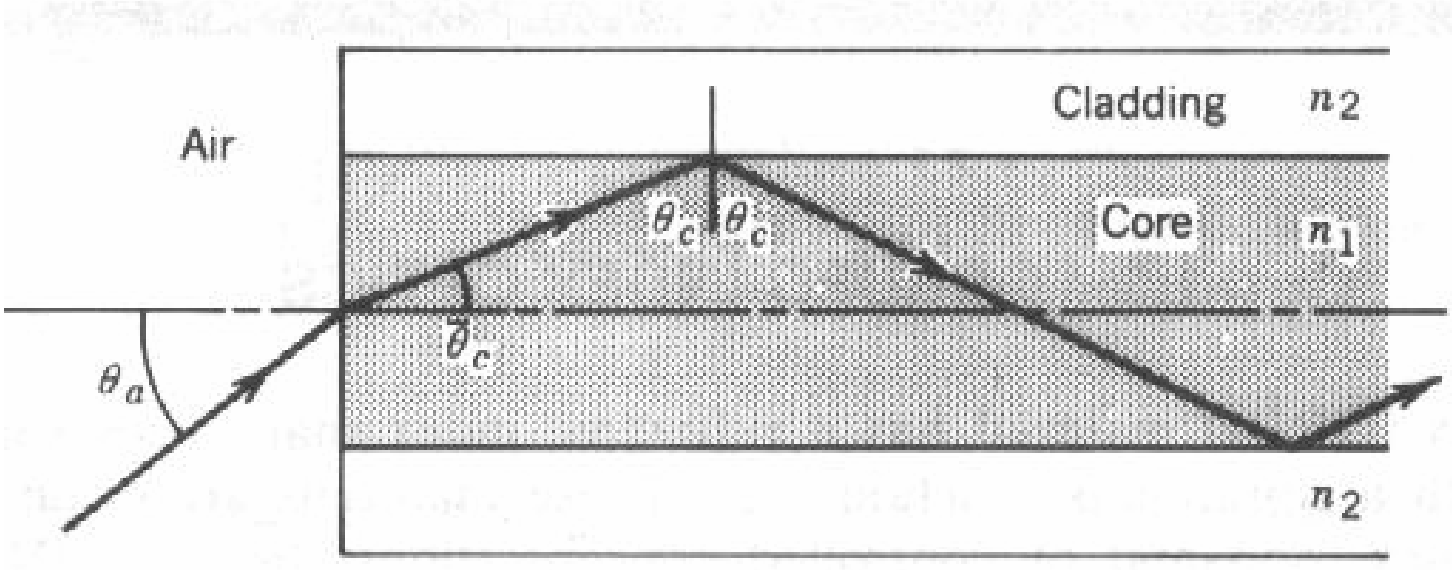
空間依存性	空間対称性	波長依存性	線形性
均一 Homogeneous	**等方的** Isotropic	**非分散的** Nondispersive	**線形** Linear
不均一 Inhomogeneous **(ファイバー)**	**非等方的** anisotropic **(複屈折性)**	**分散的** Dispersive **(吸収と分散)**	**非線形** Nonlinear (SHGなど)

(誘電体) 薄膜導波路



全反射を繰返して進むTEM波

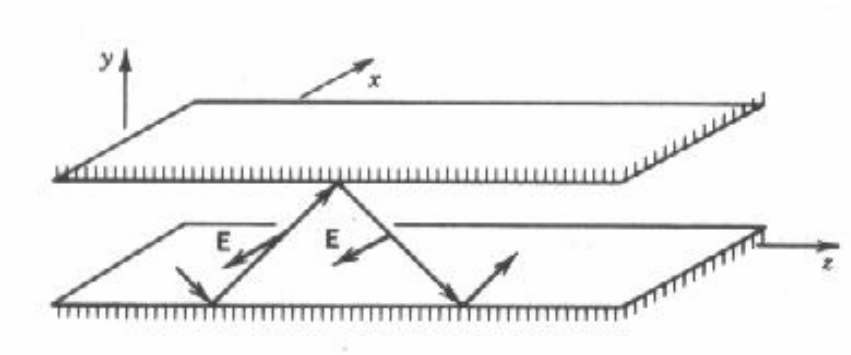
入射角の条件と開口数 (NA)



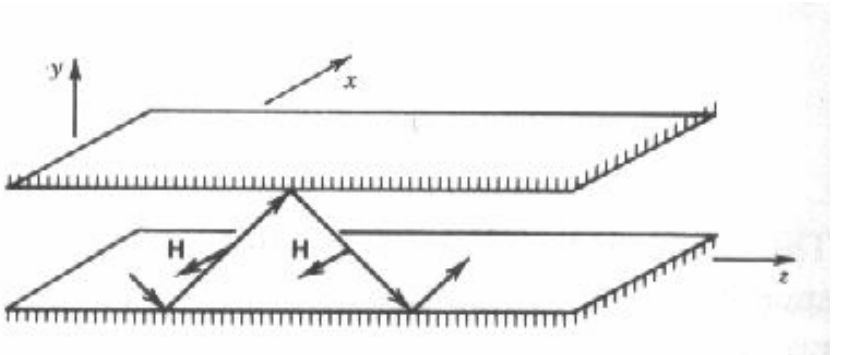
$$\mathrm{NA} \equiv \sin\theta_a \equiv \left(n_1^2 - n_2^2\right)^{1/2}$$

$$\sin\theta_{\text{入射}} < \sin\theta_a \qquad \theta_a : \text{acceptance angle}$$

TE波とTM波



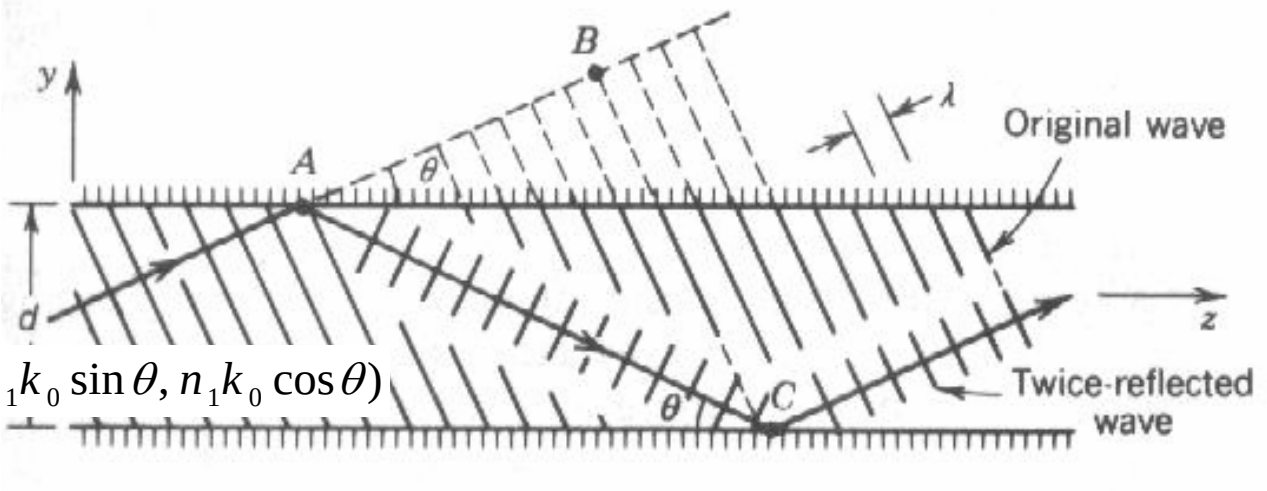
TE (Transverse Electric)波



TM (Transverse Magnetic)波

固有モードの条件

2回反射した波ともとの波の位相が等しい
→定在波（固有モード）

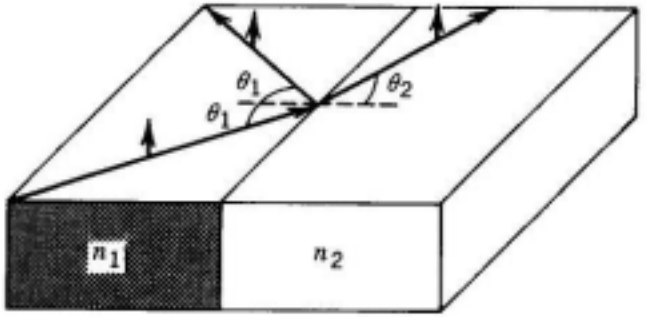


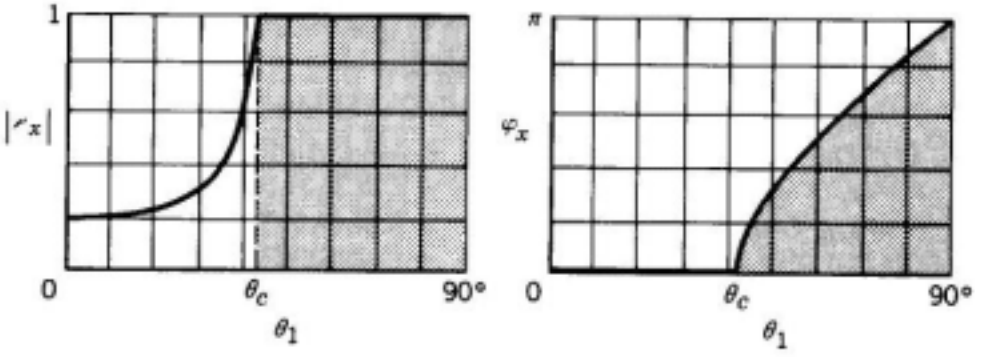
$\boldsymbol{k} = (0, n_1 k_0 \sin\theta, n_1 k_0 \cos\theta)$

$$2\pi \frac{2d\sin\theta}{\lambda} - 2\varphi_r = 2m\pi \quad (m = 0, 1, 2, \ldots)$$

$$\left(2k_y d - 2\varphi_r = 2m\pi\right)$$

復習：TE波の全反射





$$\tan\frac{\varphi_r}{2}=\frac{\left(\sin^2\theta_1-\sin^2\theta_c\right)^{1/2}}{\cos\theta_1}$$

全反射による位相シフト： $\tan\frac{\varphi_r}{2}=\left(\frac{\sin^2\bar{\theta}_c}{\sin^2\theta}-1\right)^{1/2}$

$$\left(\theta_1=\pi/2-\theta,\ \theta_c=\pi/2-\bar{\theta}_c\right)$$

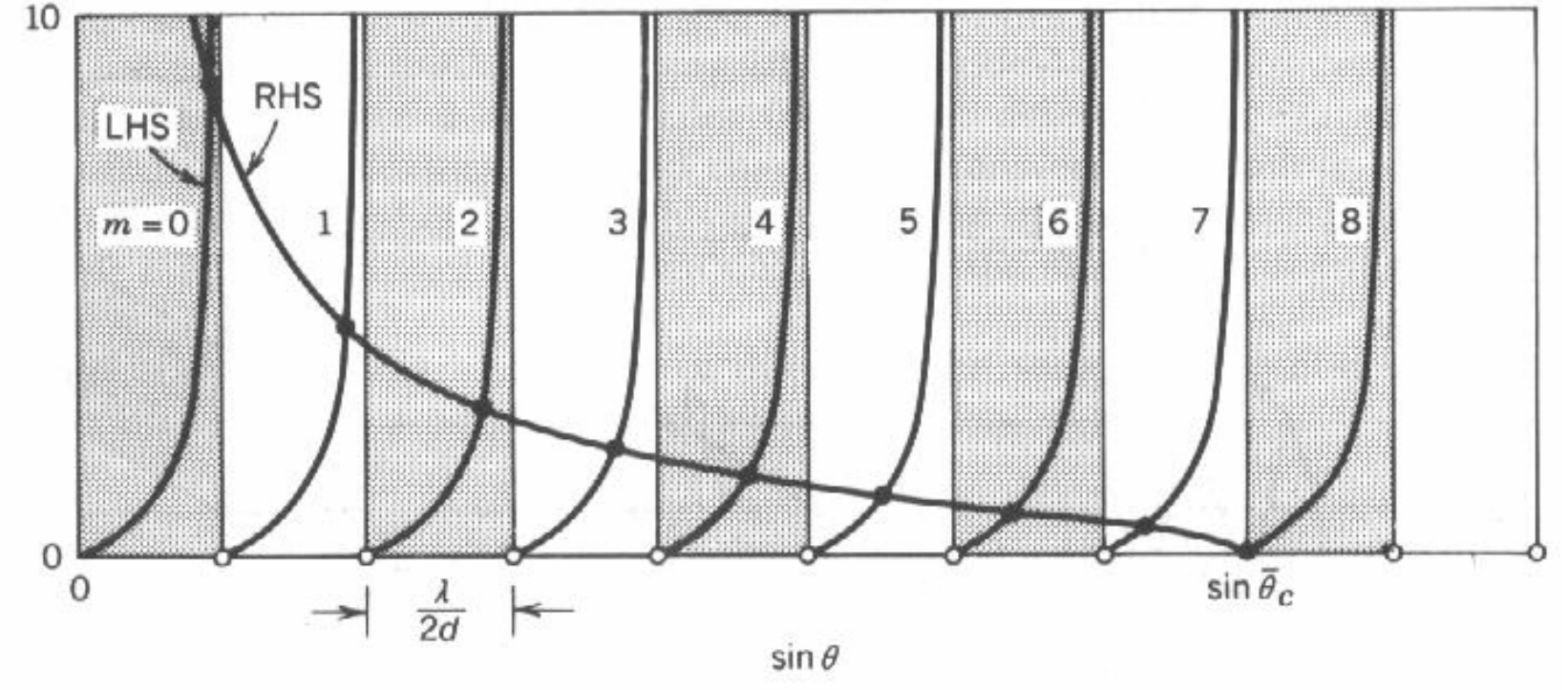
定在波（固有モード）の条件：

$$2\pi\frac{2d\sin\theta}{\lambda}-2\varphi_r=2m\pi\rightarrow\tan\left(\pi\frac{d}{\lambda}\sin\theta-\frac{\pi}{2}m\right)=\tan\frac{\varphi_r}{2}$$

以上より、

$$\tan\left(\pi\frac{d}{\lambda}\sin\theta-\frac{\pi}{2}m\right)=\left(\frac{\sin^2\bar{\theta}_c}{\sin^2\theta}-1\right)^{1/2}$$

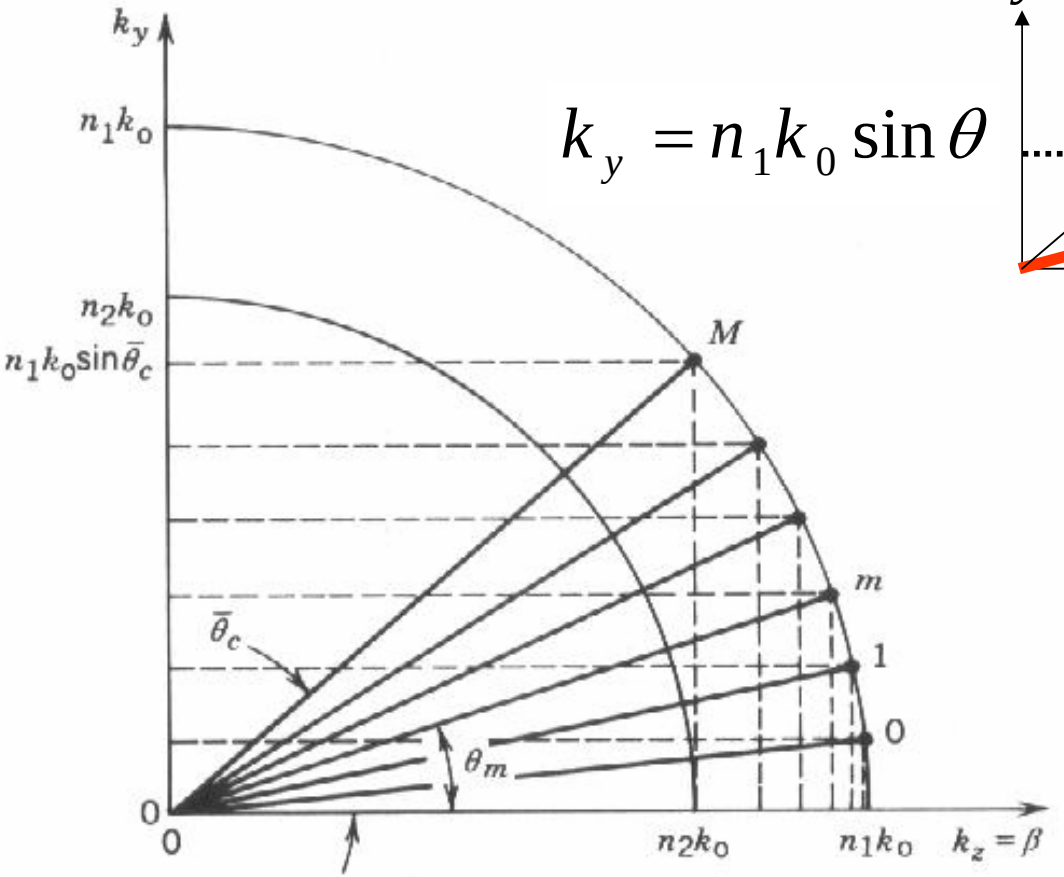
可能な$\sin\theta$の値



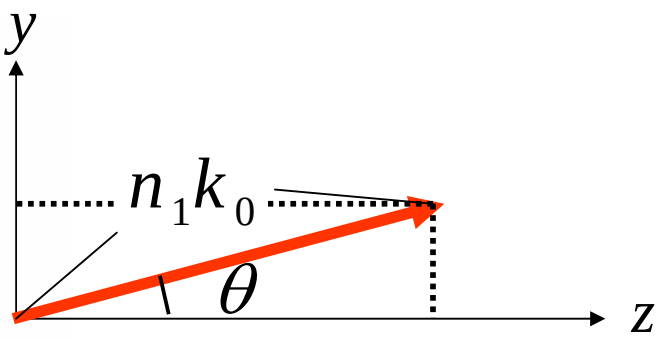
$$\tan\left(\pi\frac{d}{\lambda}\sin\theta-\frac{\pi}{2}m\right)=\left(\frac{\sin^2\bar{\theta}_c}{\sin^2\theta}-1\right)^{1/2}$$

固有モードの波数ベクトル

$$\boldsymbol{k} = (0, n_1 k_0 \sin\theta, n_1 k_0 \cos\theta)$$



$$k_y = n_1 k_0 \sin\theta$$



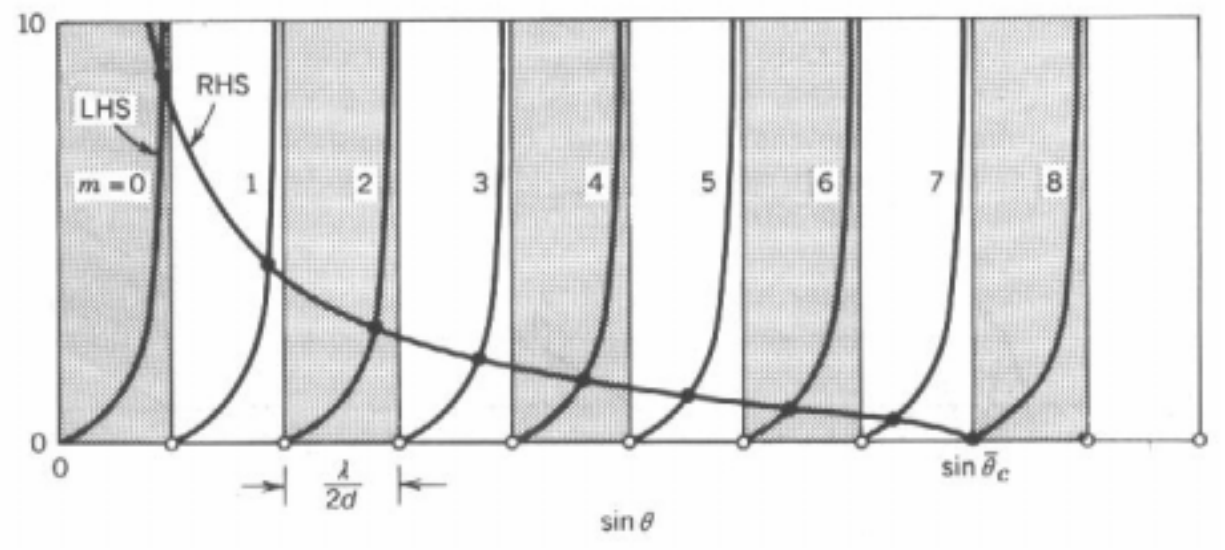
$$k_z = n_1 k_0 \cos\theta \equiv \beta$$

$$\beta_m \equiv n_1 k_0 \cos\theta_m$$

Propagation constatnts

(**伝播係数**)

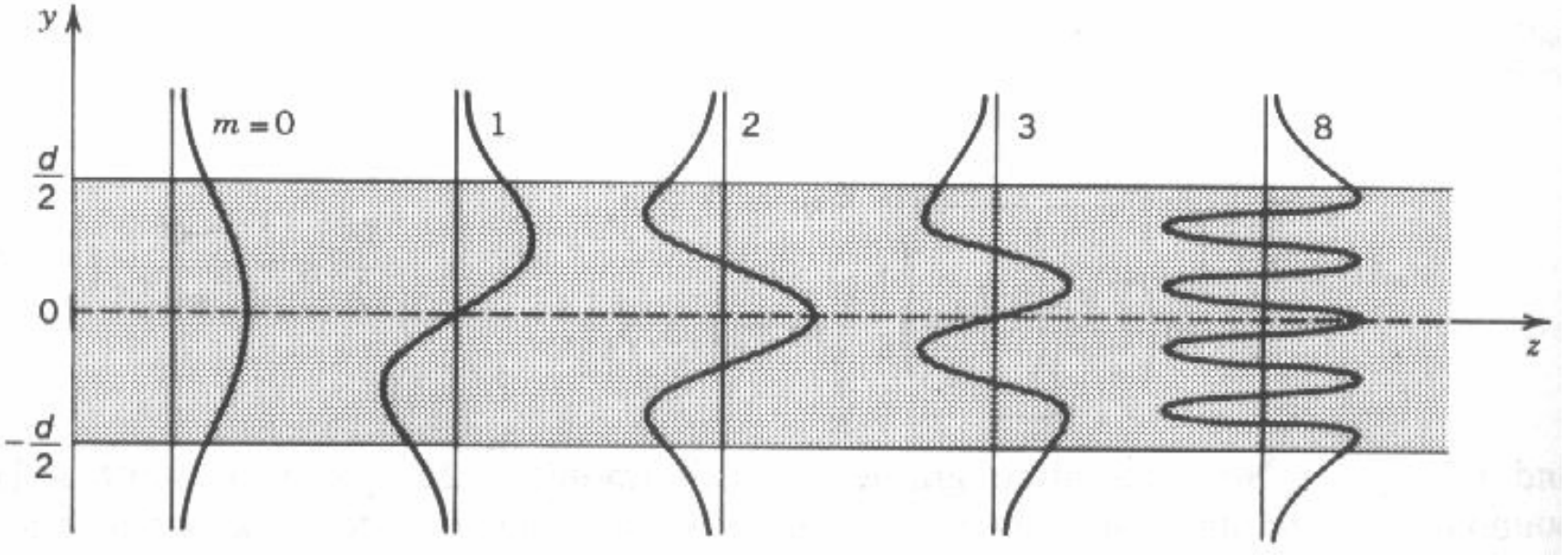
モードの数



$$M \approx \frac{\sin\bar{\theta}_c}{\lambda/2d} = 2\frac{d}{\lambda_0}\mathrm{NA}$$

$$\mathrm{NA} \equiv \sin\theta_a \equiv \left(n_1^2 - n_2^2\right)^{1/2}$$

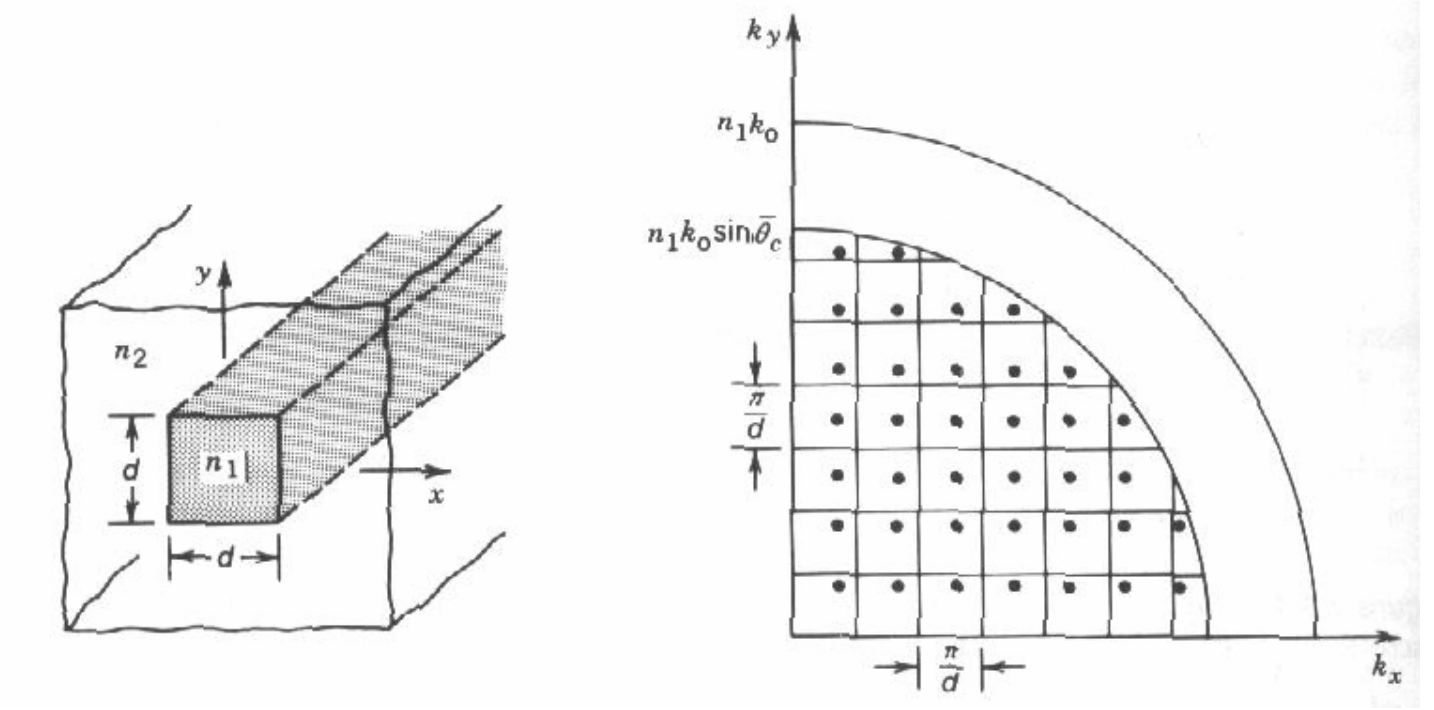
固有モード (TE波) の空間パターン



$$-\frac{d}{2} \le y \le \frac{d}{2} \qquad u_m(y) \propto \begin{cases} \cos\left(n_1 k_0 \sin\theta_m y\right), & m = 0, 2, 4, \ldots \\ \sin\left(n_1 k_0 \sin\theta_m y\right), & m = 0, 2, 4, \ldots \end{cases}$$

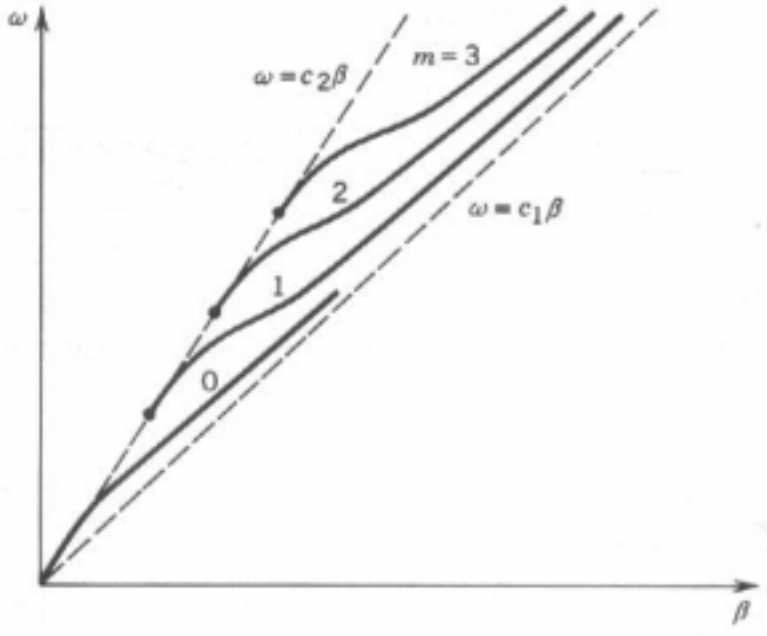
$$|y| \ge \frac{d}{2} \qquad u_m(y) \propto \exp\left(-\gamma_m |y|\right) \qquad \left(\gamma_m^2 = \beta_m^2 - n_2^2 k_0^2\right)$$

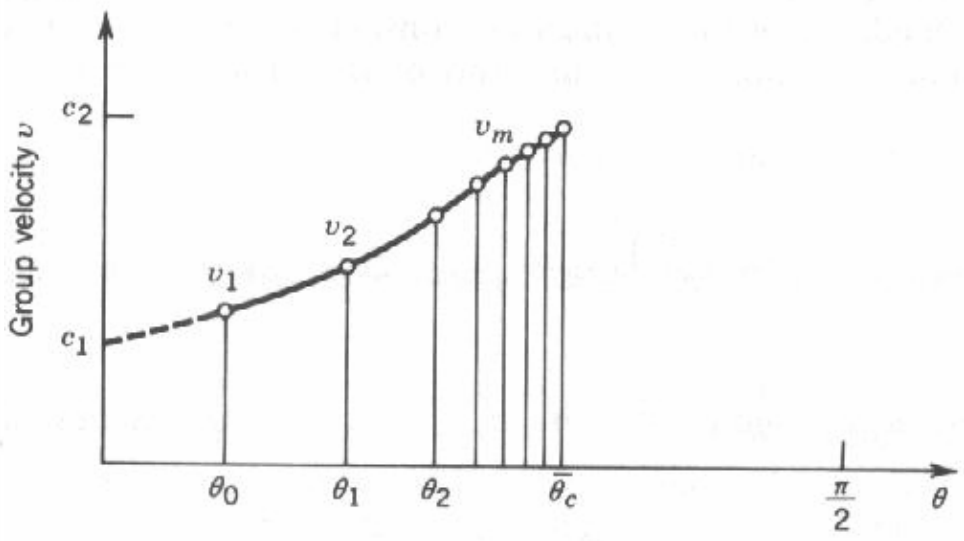
二次元導波路



$$M \approx \frac{\pi}{4}\left(\frac{2d}{\lambda_0}\right)^2 \mathrm{NA}^2$$

導波路内の群速度

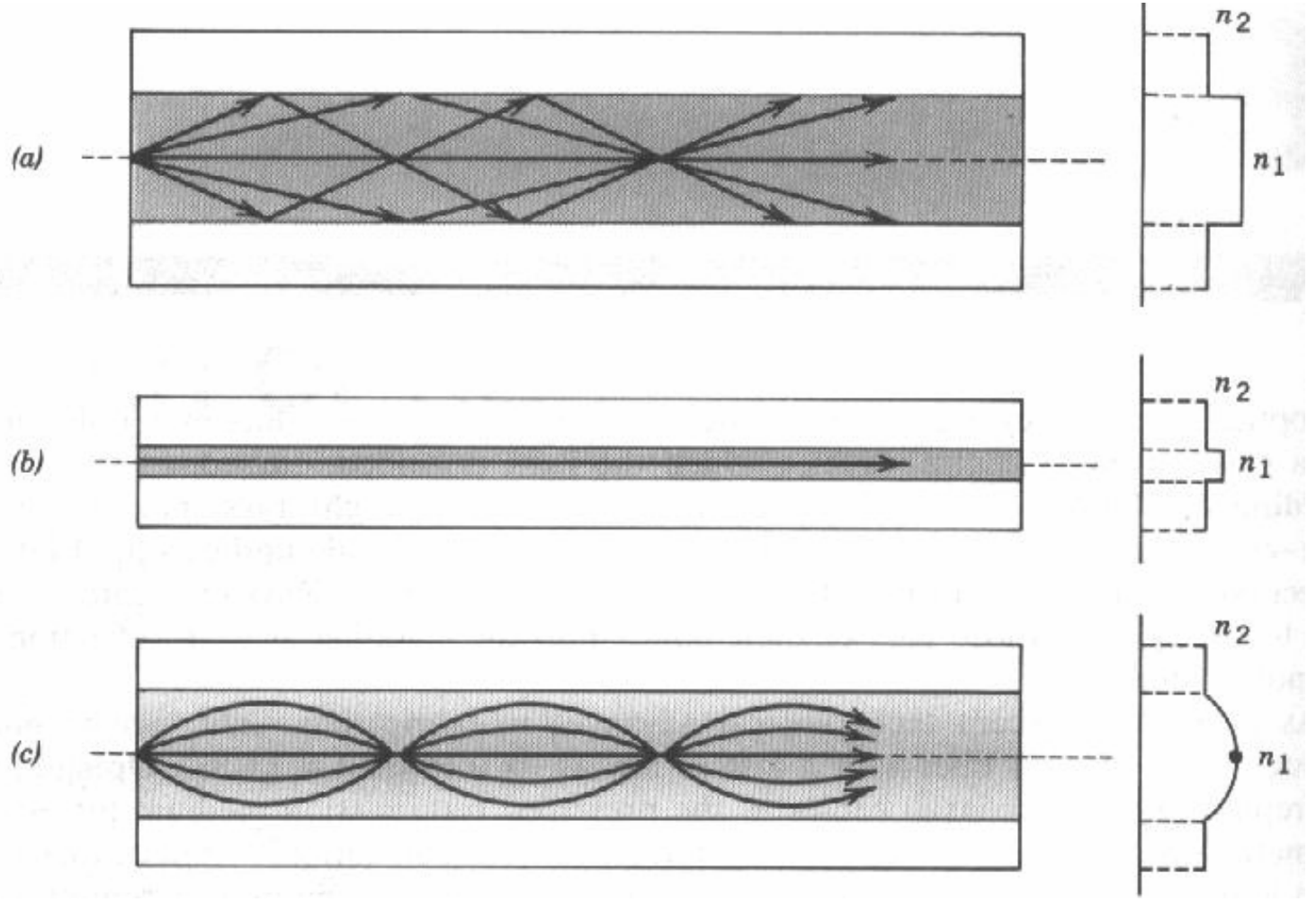




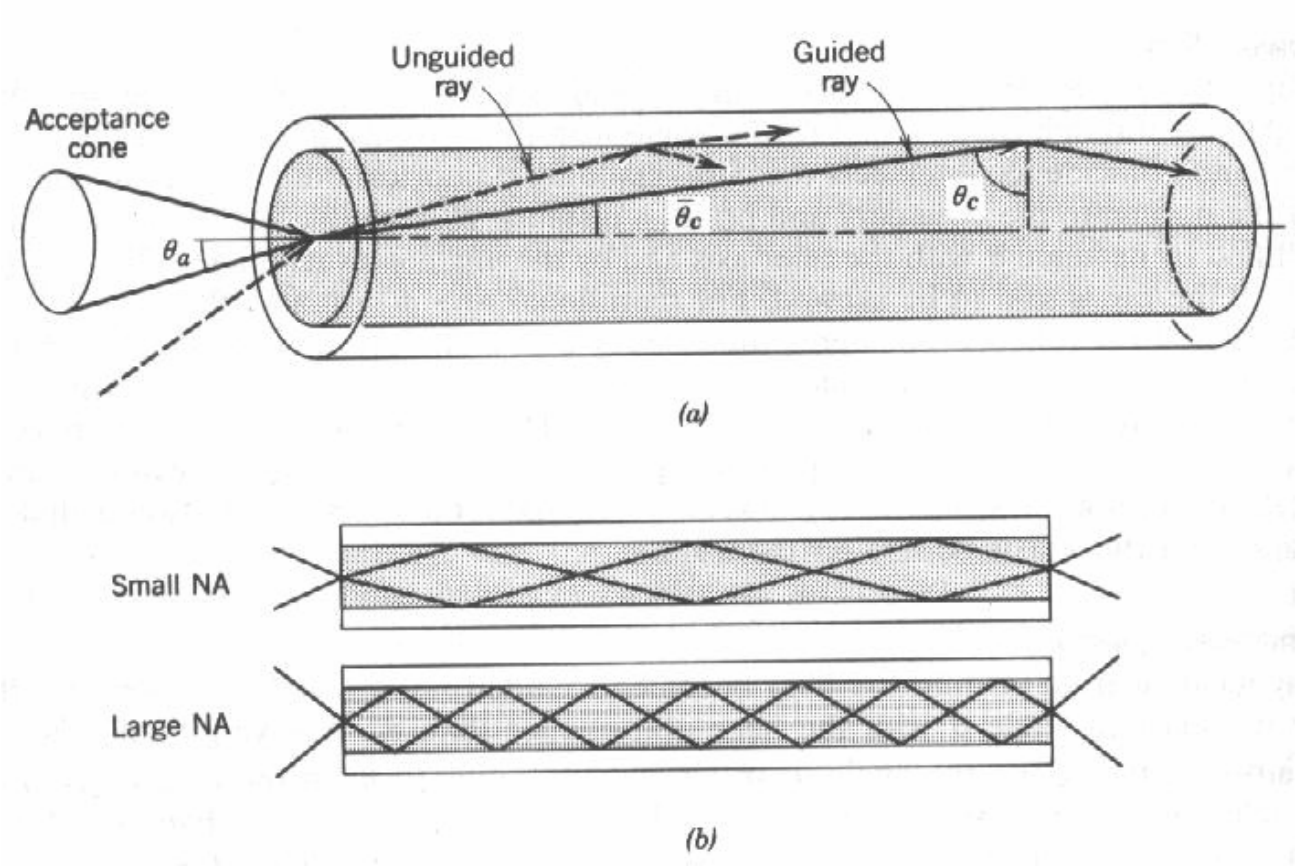
$$k_y^2 = \left(\omega / c_1\right)^2 - \beta^2$$

$$v_g \equiv \frac{\partial \omega}{\partial \beta}$$

色々なファイバー

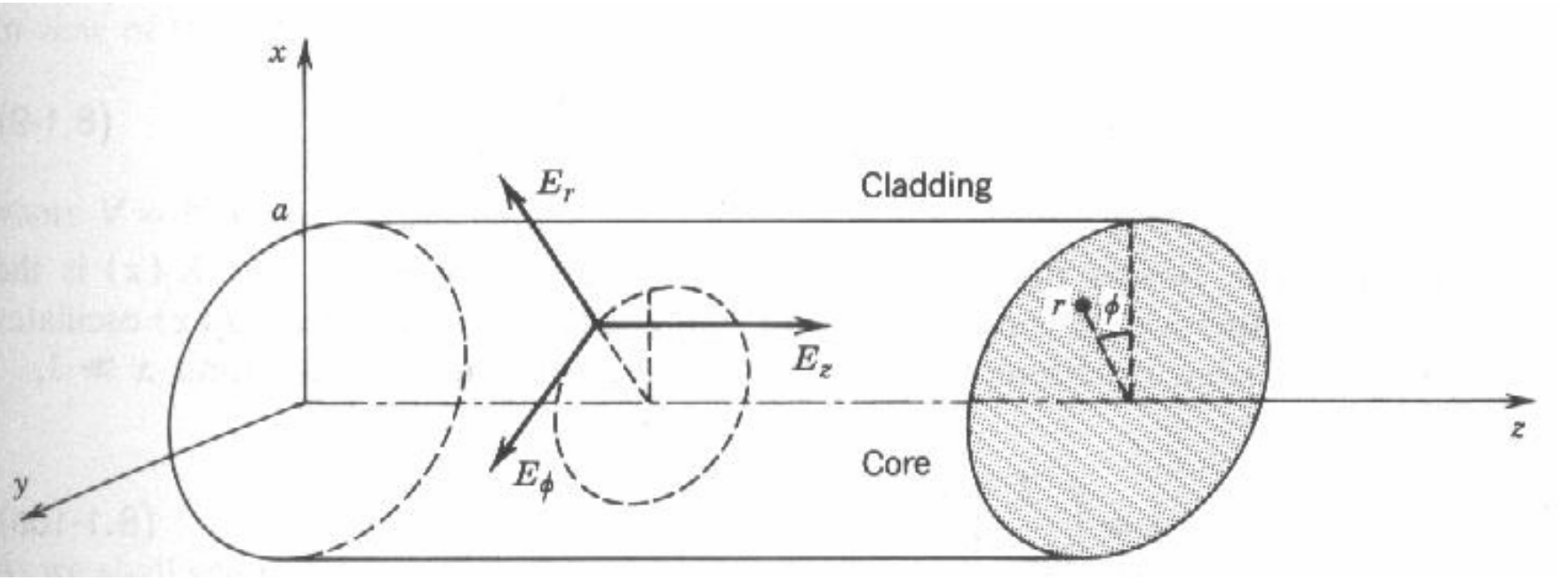


入射角の条件と開口数 (NA)



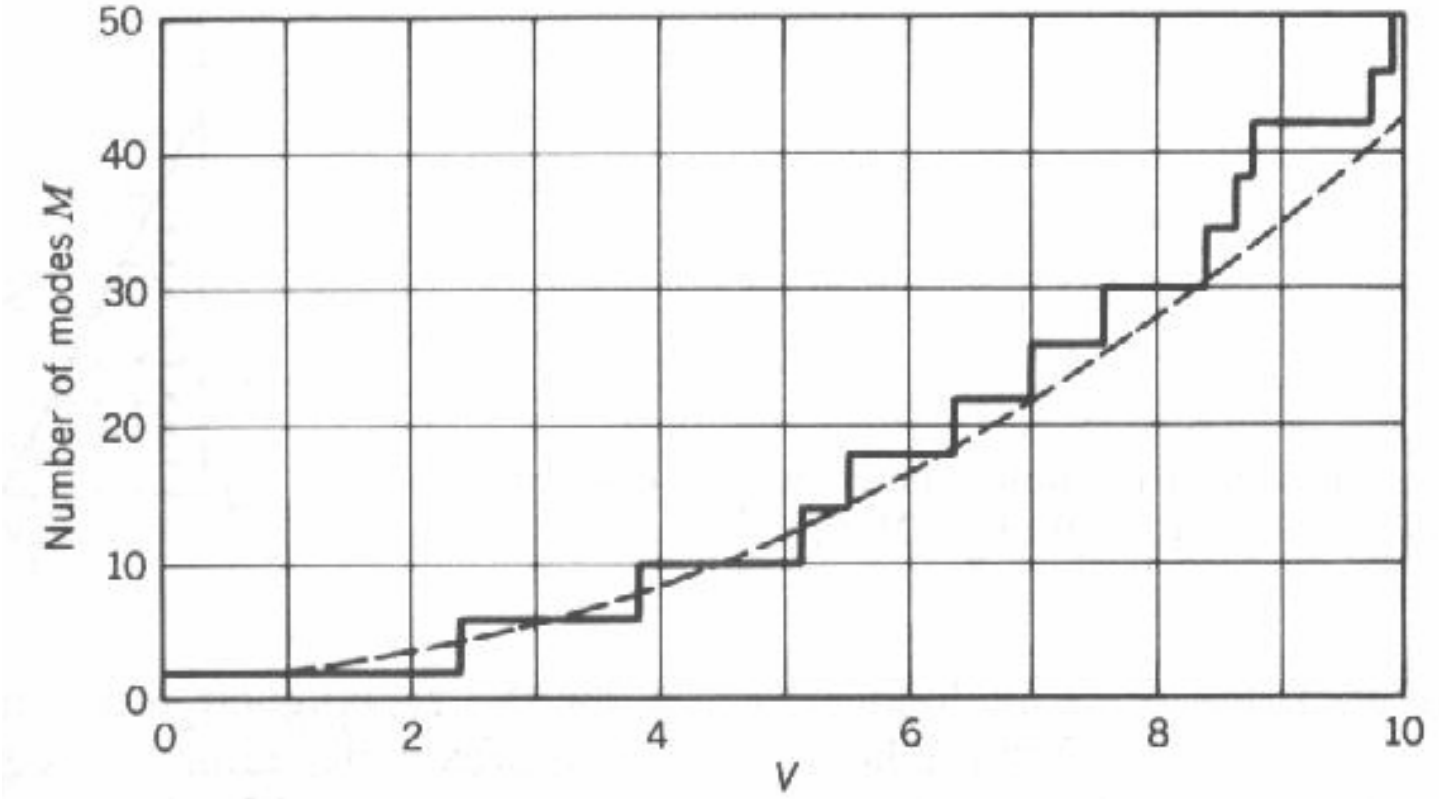
$$\mathrm{NA} \equiv \sin\theta_a \equiv \left(n_1^2 - n_2^2\right)^{1/2}$$

円筒座標系における
ヘルムホルツ方程式



$$\Delta u + n^2 k_0^2 u = 0 \Leftrightarrow \frac{\partial^2 u}{\partial r^2} + \frac{1}{r}\frac{\partial u}{\partial r} + \frac{1}{r^2}\frac{\partial^2 u}{\partial \phi^2} + \frac{\partial^2 u}{\partial z^2} + n^2 k_0^2 = 0$$

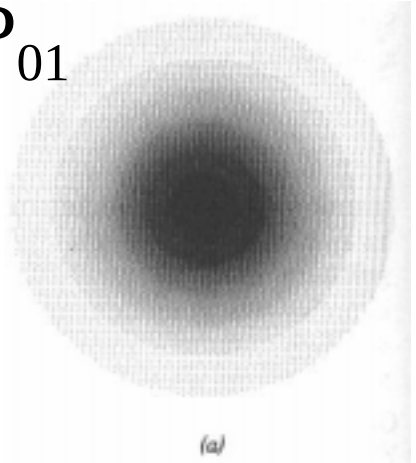
固有モードの数



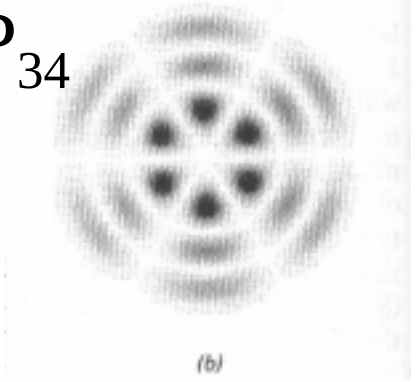
$$V = 2\pi \frac{a}{\lambda_0} \mathrm{NA}$$

ファイバ中の固有モード

LP_{01}



LP_{34}



$$U(r,\phi,z) = u(r)e^{il\phi}e^{i\beta z}$$

$$u_m(y) \propto \begin{cases} J_l(k_T r), & r < a \\ K_l(\gamma_T r), & r > a \end{cases}$$

$J_l(x)$: l**次の第一種ベッセル関数**

$K_l(x)$: l**次の第二種ベッセル関数**

LP_{lm}：**直線偏光モード**

ファイバーのカタログ

Single Mode Fiber: 780-970nm

- Shipped from stock
- No minimums
- Acrylate Jacket
- Exceptional uniformity
- Exceptional core/clad concentricity specifications
- 780HP offers tight second mode cut-off tolerances
- 780HP offers a tight bend radius for applications in miniaturized fiber optic packages

PRICE SCHEDULE-Call For Quantities Over 250m

ITEM #	PRICE/m	$	£	€	¥
780HP	1 to 9m	$ 9.50	£ 6.65	€ 9,50	¥ 1,615
	10 to 49m	$ 6.70	£ 4.69	€ 6,70	¥ 1,139
	50 to 249m	$ 5.70	£ 3.99	€ 5,70	¥ 969
SM800-5.6-125	1 to 9m	$ 5.00	£ 3.50	€ 5,00	¥ 850
	10 to 49m	$ 3.50	£ 2.45	€ 3,50	¥ 595
	50 to 249m	$ 3.00	£ 2.10	€ 3,00	¥ 510

ITEM #	OPERATING WAVELENGTH	MODE FIELD DIAMETER	CLADDING	COATING	CUT-OFF WAVELENGTH	SHORT TERM BEND RADIUS	ATTENUATION MAXIMUM	NA	VENDOR
780HP	780-970nm	5.0±0.5µm@850nm	125±1.5µm	245±15µm	730±30nm	≥6mm	<3.5dB/km@850nm	0.13	Nufern
SM800-5.6-125	830nm[1]	5.6µm[2]	125±1µm	245±5%	730±70nm	–	<5dB/km@830nm	0.12[3]	Fibercore

[1] Operating wavelength range is typically 200nm above the cutoff wavelength.
[2] MFD is a nominal, calculated value, estimated at the operating wavelength(s) using a typical value of NA & cutoff wavelength.
[3] 0.10≤NA≤0.14

Sales: 973-579-7227

THORLABS