INTERNATIONAL EDITION

Optoelectronics and Photonics

Principles and Practices

SECOND EDITION

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ALWAYS LEARNING

PEARSON

Selected definitions and basic equations

Photon energy

$$E_{\text{ph}} = h\upsilon = \hbar\omega;\ \omega = 2\pi\upsilon$$

Photon momentum

$$p_{\text{ph}} = \frac{h}{\lambda} = \hbar k$$

Photon flux Φ_{ph} and irradiance (intensity)

$$\Phi_{\text{ph}} = \frac{\text{Photons crossing area } A \text{ in time } \Delta t}{A\Delta t} = \frac{\Delta N_{\text{ph}}}{A\Delta t}$$

$$I = h\upsilon\Phi_{\text{ph}}$$

Propagation constant (wave vector)

$$k = \frac{2\pi}{\lambda}$$

Phase velocity

$$\mathsf{v} = \lambda\upsilon = \frac{\omega}{k};\quad \mathsf{v} = \frac{c}{n} = \frac{c}{\sqrt{\varepsilon_r}}$$

Changes in wavelength and frequency

$$\frac{\delta\lambda}{\lambda} = -\frac{\delta\upsilon}{\upsilon};\quad \delta\lambda = -\frac{\lambda^2}{c}\delta\upsilon = -\frac{c}{\upsilon^2}\delta\upsilon$$

Group velocity

$$\mathsf{v}_g = \frac{d\omega}{dk}$$

Group index

$$\mathsf{v}_g(\text{medium}) = \frac{c}{N_g};\quad N_g = n - \lambda_o\frac{dn}{d\lambda_o}$$

Electric and magnetic fields

$$E_x = \mathsf{v}B_y = \frac{c}{n}B_y$$

Poynting vector and irradiance

$$\mathbf{S} = \mathsf{v}^2\varepsilon_o\varepsilon_r\mathbf{E}\times\mathbf{B};\quad I = S_{\text{average}} = \frac{1}{2}\mathsf{v}\varepsilon_o\varepsilon_r E_o^2$$

Snell's law and the Brewster angle

$$n_1\sin\theta_i = n_2\sin\theta_t; \sin\theta_c = \frac{n_2}{n_1}; \tan\theta_p = \frac{n_2}{n_1}$$

Phase change in total internal reflection (TIR)

$$\tan\left(\tfrac{1}{2}\phi_\perp\right) = \frac{[\sin^2\theta_i - n^2]^{1/2}}{\cos\theta_i}; n = \frac{n_2}{n_1}$$

$$\tan\left(\tfrac{1}{2}(\phi_{//} + \pi)\right) = \frac{[\sin^2\theta_i - n^2]^{1/2}}{n^2\cos\theta_i}$$

Attenuation in second medium in TIR

$$\alpha_2 = \frac{2\pi n_2}{\lambda_o}\left[\left(\frac{n_1}{n_2}\right)^2\sin^2\theta_i - 1\right]^{1/2}$$

Reflectance, transmittance (normal incidence)

$$R = R_\perp = R_{//} = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2;$$

$$T = T_\perp = T_{//} = \frac{4n_1n_2}{(n_1 + n_2)^2}$$

Fabry–Perot cavity

$$\upsilon_m = m\left(\frac{c}{2L}\right) = m\upsilon_f,\quad m = 1, 2, 3, \ldots$$

$$\delta\upsilon_m = \frac{\upsilon_f}{F};\quad F = \frac{\pi R^{1/2}}{1 - R}$$

Single slit diffraction

$$I(\theta) = I(0)\text{sinc}^2(\beta);\quad \beta = \frac{1}{2}(ka\sin\theta)$$

Airy disk, angular radius, divergence

$$\sin\theta_o = 1.22\frac{\lambda}{D}$$

$$\text{Divergence} = 2\theta_o \approx 2\times 1.22\frac{\lambda}{D}$$

Diffraction grating

$$d(\sin\theta_m - \sin\theta_i) = m\lambda;\quad m = 0, \pm 1, \pm 2, \ldots$$

V-number, normalized frequency

$$V = \frac{2\pi a}{\lambda}(n_1^2 - n_2^2)^{1/2}; V = \frac{2\pi a}{\lambda}\text{NA}$$

Normalized index difference

$$\Delta = (n_1 - n_2)/n_1$$

Acceptance angle and numerical aperture (NA)

$$2\alpha_{\max}; \sin\alpha_{\max} = \frac{(n_1^2 - n_2^2)^{1/2}}{n_0}; \sin\alpha_{\max} = \frac{\text{NA}}{n_0}$$

Normalized propagation constant

$$b = \frac{(\beta/k)^2 - n_2^2}{n_1^2 - n_2^2} \approx \frac{(\beta/k) - n_2}{n_1 - n_2}$$

$$b \approx \left(1.1428 - \frac{0.996}{V}\right)^2 \text{ for } 1.5 < V < 2.5$$

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