

2-18. (a) From Eqs. (2-59) and (2-61) we have

$$M \approx \frac{2\pi^2 a^2}{\lambda^2} (n_1^2 - n_2^2) = \frac{2\pi^2 a^2}{\lambda^2} (\text{NA})^2$$

$$a = \left( \frac{M}{2\pi} \right)^{1/2} \frac{\lambda}{\text{NA}} = \left( \frac{1000}{2} \right)^{1/2} \frac{0.85 \mu\text{m}}{0.2\pi} = 30.25 \mu\text{m}$$

Therefore,  $D = 2a = 60.5 \mu\text{m}$

$$(b) M = \frac{2\pi^2 (30.25 \mu\text{m})^2}{(1.32 \mu\text{m})^2} (0.2)^2 = 414$$

(c) At 1550 nm,  $M = 300$

2-20 (a) At 1320 nm we have from Eqs. (2-23) and (2-57) that  $V = 25$  and  $M = 312$ .

(b) From Eq. (2-72) the power flow in the cladding is 7.5%.

3-13. (a) From Fig. 3-13,  $\frac{d\tau}{d\lambda} \approx 80 \text{ ps}/(\text{nm}\cdot\text{km})$  at 850 nm. Therefore, for the LED we have from Eq. (3-20)

$$\frac{\sigma_{\text{mat}}}{L} = \frac{d\tau}{d\lambda} \sigma_{\lambda} = [80 \text{ ps}/(\text{nm}\cdot\text{km})](45 \text{ nm}) = 3.6 \text{ ns}/\text{km}$$

For a laser diode,

$$\frac{\sigma_{\text{mat}}}{L} = [80 \text{ ps}/(\text{nm}\cdot\text{km})](2 \text{ nm}) = 0.16 \text{ ns}/\text{km}$$

(b) From Fig. 3-13,  $\frac{d\tau_{\text{mat}}}{d\lambda} = 22 \text{ ps}/(\text{nm}\cdot\text{km})$

Therefore,  $D_{\text{mat}}(\lambda) = [22 \text{ ps}/(\text{nm}\cdot\text{km})](75 \text{ nm}) = 1.65 \text{ ns}/\text{km}$

3-17. Since  $n_2 = n_1(1 - \Delta)$ , we can rewrite the equation as

$$\frac{\sigma_{\text{mod}}}{L} = \frac{n_1 \Delta}{c} \left( 1 - \frac{\pi}{V} \right)$$

where the first term is Equation (3-30). The difference is then given by the factor

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

$$\text{At 1300 nm this factor is } 1 - \frac{\pi(1.3)}{2(62.5)1.48\sqrt{2(0.015)}} = 1 - 0.127 = 0.873$$

3-26. (a)  $D = (\lambda - \lambda_0)S_0 = -50(0.07) = -3.5 \text{ ps}/(\text{nm} - \text{km})$

(b)  $D = \frac{1500(0.09)}{4} \left[ 1 - \left( \frac{1310}{1500} \right)^4 \right] = 14.1 \text{ ps}/(\text{nm} - \text{km})$

3-28. (a) From Eq. (3-29)

$$\sigma_{\text{mod}} = T_{\text{max}} - T_{\text{min}} = \frac{n_1 \Delta L}{c} = \frac{(1.49)(0.01)(5 \times 10^3 \text{ m})}{3 \times 10^8 \text{ m/s}} = 248 \text{ ns}$$

(b) From Eq. (3-48)

$$\sigma_{\text{step}} = \frac{n_1 \Delta L}{2\sqrt{3} c} = \frac{248}{2\sqrt{3}} = 71.7 \text{ ns}$$

(c)  $B_T = \frac{0.2}{\sigma_{\text{step}}} = 2.8 \text{ Mb/s}$

(d)  $B_T \cdot L = (2.8 \text{ MHz})(5 \text{ km}) = 13.9 \text{ MHz} \cdot \text{km}$