Fundamentals of Photonics (2nd Edition)

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Chapter 2.2, Problem 1E   1 Bookmark   Show all steps: ON

Step-by-step solution

Step 1 of 3

Validity of the Fresnel Approximation:

The validation criterion for a spherical wave to be approximated by a paraboidal wave within a circle of radius a and it is originated at a distance z away from the given axis.

Write the validation condition of the radius of the circle.

$$a^4 << 4z^3\lambda \text{ .... (1)}$$

Here, a is the radius of the circle, z is the distance from the axis and λ is the wavelength.

Comment

Step 2 of 3

Calculate the maximum possible radius of the circle.

Substitute 633 nm for λ and 1 m for z in equation (1).

$$a^4 << 4(1 \text{ m})^3 (633 \text{ nm})\left(\frac{10^{-9} \text{ m}}{1 \text{ nm}}\right)$$

$$a << 0.0398 \text{ m}$$

Thus, the radius of the circle is $\boxed{0.0398 \text{ m}}$.

Write the equation for the maximum angle.

$$\theta_m = \frac{a}{z}$$

Here, θ_m is the maximum angle.

Substitute 0.0398 m for a and 1 m for z.

$$\theta_m = \frac{0.0398 \text{ m}}{1 \text{ m}} = 0.0398 \text{ rad}$$

Thus, the required angle is $\boxed{0.0398 \text{ rad}}$.

Comment

Step 3 of 3

Write the equation for the Fresnel number.

$$N_F = \frac{a^2}{\lambda z}$$

Here, N_F is the Fresnel number.

Substitute 0.0398 m for a, 1 m for z and 633 nm for λ.

$$N_F = \frac{(0.0398 \text{ m})^2}{(633 \text{ nm})\left(\frac{10^{-9} \text{ m}}{1 \text{ nm}}\right)(1 \text{ m})} = 2513.7 \approx 2514$$

Thus, the Fresnel number is $\boxed{2514}$.

Comment

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