

**Reading recommendation:** Class Notes Chapter 9. Be neat in your work!

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**Problem 8.1**

A fiber has an attenuation of 5 dB/km and it is operated at a wavelength of 1.5  $\mu\text{m}$ .

- (a) What is the ratio of output power to input power for a 10-km length of this fiber?
- (b) If the input power is -3 dBm, what is the output power in mW?
- (c) How many photons are detected at the output in 1 ns?

**Problem 8.2**

A step-index dielectric slab waveguide has a core with a refractive index of 1.52 and a thickness of 100  $\mu\text{m}$ . The refractive index of the cladding is 1.50, and the waveguide is excited with light of  $\lambda = 0.89 \mu\text{m}$ .

- (a) Calculate the maximum cone angle,  $2\psi$ , of rays of wavelength  $\lambda = 0.89 \mu\text{m}$  that can be coupled into the waveguide, and give the numerical aperture of the waveguide.
- (b) Estimate the maximum number of modes for light of wavelength 0.89  $\mu\text{m}$  that can be excited in the waveguide.
- (c) Estimate the pulse spreading in ns/km that occurs due to modal dispersion in the waveguide.
- (d) If single mode TE operation is desired, what is the maximum allowed thickness of the core.

**Problem 8.3**

A cylindrical step-index fiber has a core index of 1.5, a core radius of 5  $\mu\text{m}$ , and  $V = 2$  at  $\lambda = 1.5 \mu\text{m}$ .

- (a) What is the numerical aperture of this fiber?
- (b) What is the refractive index of the cladding at 1.5  $\mu\text{m}$ ?
- (c) At what wavelength does this fiber cease to be a single-mode fiber?
- (d) How many modes exist for: (1) a wavelength of 1.5  $\mu\text{m}$ , (2) a wavelength of 1  $\mu\text{m}$ ?
- (e) List each mode in part (d) and its cutoff condition.

### Problem 8.4

Below are diagrams of the cross sections of two optical fibers. Each fiber has a core of index  $n_1$  and a cladding of lower index  $n_2$ .

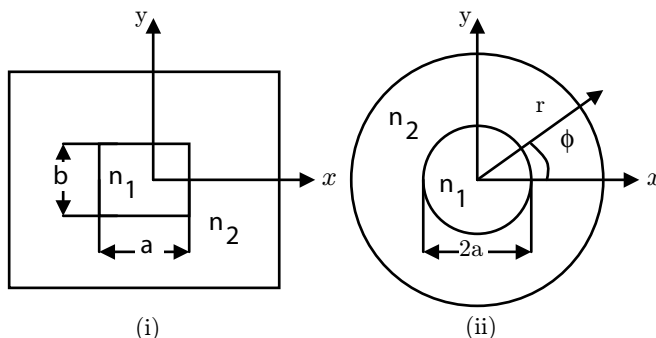


Figure 1: Cross-sectional view of (i) a dielectric rectangular waveguide and (ii) a cylindrical dielectric waveguide.

- What is the condition that determines when a particular mode (mode number  $(m,n)$ ) becomes cut off?
- Assume that for the rectangular dielectric waveguide  $a \gtrsim b$  ( $a$  is greater than  $b$ , but almost equal). This waveguide is excited with an external, non-collimated, unpolarized monochromatic light source. Using the condition derived in part (a), graphically sketch the first **six** E-field mode distributions inside the dielectric rectangular waveguide shown in (i), in the order of their appearance, as the frequency of the input light is increased. To do this, for each case, redraw the core and cladding, plot  $E(x)$  and  $E(y)$  outside the diagram, and shade the inner region of the core to illustrate the corresponding intensity pattern.
- If one of your goals was to tap (extract) a portion of the signal flowing in this fiber by bending it as little as possible, along which direction would you bend this fiber?
- Assume for the circular waveguide shown in (ii) that it is excited with a linearly-polarized monochromatic light source. Graphically sketch the first **four** (LP) E-field mode distributions inside this fiber, and shade the core to illustrate the corresponding intensity distribution.