

MASSACHUSETTS INSTITUTE of TECHNOLOGY  
Department of Electrical Engineering and Computer Science

Problem Set No. 8  
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*6.637 Optical Signals, Devices and Systems*

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## **Reading recommendation:** 6.637 Class Notes

### Problem 8.1

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 it is operated in air. 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 8.2

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  $n_2$ .

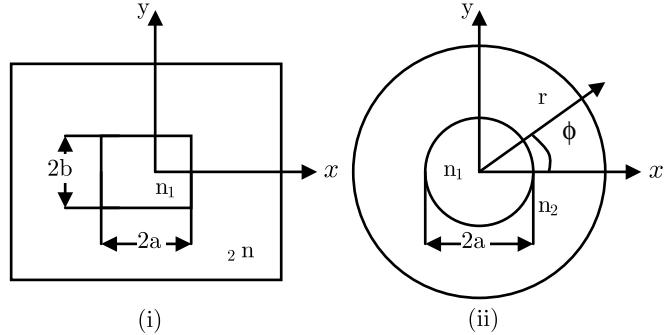


Figure 1: Cross-sectional view of (i) a dielectric rectangular waveguide and (ii) a cylindrical dielectric waveguide.

- Assume for the rectangular dielectric waveguide that  $a \gtrsim b$  ( $a$  is greater than  $b$ , but almost equal). This waveguide is excited with an external convergent unpolarized monochromatic light source. Sketch qualitatively the first six mode (intensity) distributions inside the dielectric rectangular waveguide shown in (i).
- Assume for the circular waveguide that it is excited with a linearly-polarized monochromatic light source. Sketch the first three E-field mode distributions inside fiber (ii).
- For fiber (i), what is the maximum curvature by which you can bend the fiber (give the radius of the arc) such that light in the  $m$ th mode does not escape the core? Assume the cladding is VERY thick. In which direction do we bend the fiber to achieve this?

### **Problem 8.3**

Following the wave-optics approach in the Appendix of the notes on optical waveguides, and using the same notation:

- (a) Write basic forms of the components of the electric and magnetic fields inside and outside the dielectric slab waveguide for the even TM modes.
- (b) Force your postulated solution in (a) to satisfy both the boundary conditions and the wave equation so as to determine the unknown propagation constants in part (a) (graphical solution is acceptable).
- (c) What is the longest possible wavelength for the even TM modes that can propagate inside this waveguide (i.e., waveguide cutoff)?
- (d) Repeat (a), (b) and (c) for odd TM modes.
- (e) Now that you have all 4 solutions for the dielectric slab waveguide, compare the 4 types of modal propagation by making a list or a table of the similarities, differences, key features, etc.