Micro-optics

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Exercise 11

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1 Dielectric waveguide design (45)

Assume a symmetric waveguide with a GaAs core ($n_g = 3.35$) and AlGaAs upper and lower cladding ($n_c = n_s = 3.12$).

- Design a 2-mode TE waveguide at $\lambda_0 = 1550\,\text{nm}$ which supports only 3 modes at $\lambda_0 = 850\,\text{nm}$.
- What are N, β and θ at the longer wavelength (at minimum thickness)?

  Hint: Use the characteristic equation for symmetric waveguides, and find either numerical or graphical solutions for N.
- Give a limit for the core thickness at 1550 nm, if the waveguide should only support a single mode.

2 Mode cutoff (15)

Consider a symmetric dielectric slab waveguide with $n_g \approx n_s$. Show that the cutoff wavelength for TE modes with index $m > 1$ is approximately given by

$$\lambda_0^2 \approx \frac{8 n_g \Delta n t^2}{m^2}, \tag{1}$$

where $\Delta n = n_g - n_s$.

3 Parameters of a symmetric waveguide (40)

Light of vacuum wavelength $\lambda_0 = 780\,\text{nm}$ is guided by a planar symmetric waveguide. The core layer has a thickness of $t = 2\,\mu\text{m}$ and a refractive index $n_g = 1.6$. The cladding of the waveguide has a refractive index $n_c = 1.4$. The numerical aperture NA of a waveguide is given by $NA = \sqrt{n_g^2 - n_c^2}$.

3.1 Acceptance angle (25)

The critical angle of the waveguide determines a maximum angle θ_{acc} relevant for coupling light into the waveguide. The surrounding medium of the waveguide has a refractive index n_o. Planar waves incident under angles greater than θ_{acc} onto the end facet of the waveguide will not be guided in the waveguide.

- Provide a *clear, large* sketch of the physical situation of coupling in. Label all relevant quantities (Hint: Points will be subtracted if the sketch is too small and if you do not use a ruler and a sharp pencil!).
- Derive an expression for θ_{acc} in terms of the refractive indices.

3.2 Parameters (15)

Determine the critical angle θ_{crit}, the numerical aperture NA, the acceptance angle of the waveguide in air ($n_o = 1$), and the number of TE modes guided by the waveguide.

Then, the cladding is removed from the waveguide and the core layer without the cladding is suspended in air. Is it possible to use this configuration for waveguiding, too? Repeat the calculation of θ_{crit}, NA, θ_{acc}, and the number of guided modes for this case!