Integrated Photonic Device

Homework 3
2007, Spring

Waveguide Coupler

8.1 A dual-channel-coupler type of modulator has been designed so that

$$\kappa L = \frac{\pi}{2} + m\pi , \qquad m = 0, 1, 2, \dots ,$$

where κ is the coupling coefficient and L is the length. Thus, complete transfer of light will occur from channel 0 to channel 1. If we now apply a voltage to produce a $\Delta\beta = \beta_0 - \beta_1$, the condition for complete cancellation of the transfer is

$$gL = \pi + m\pi , \qquad m = 0, 1, 2, \dots ,$$

where

$$g^2 = \kappa^2 + \left(\frac{\Delta\beta}{2}\right)^2 .$$

Derive an expression for $\Delta\beta$ required to produce this complete cancellation in terms of the length L.

8.4 If two dual-channel waveguide directional couplers of identical channel geometry and spacing are formed in the same substrate material, except that coupler A has an index of refraction n_A in the channels and coupler B has an index of refraction n_B in the channels, which coupler has the larger coupling coefficient κ if $n_A > n_B$?

8.5 A dual-channel directional coupler has $\kappa = 4\,\text{cm}^{-1}$, $\alpha = 0.6\,\text{cm}^{-1}$, and $\Delta\beta = 0$. What length should it be to produce a 3 dB power divider? If that length is doubled, what fraction of the input power is in each channel at the output?

I/O Coupler

7.5 A grating situated on a planar waveguide can act as a 180° reflector for the waves within the guide. If the propagation constant of the guided mode is $\beta = 1.582\,k$ and $\lambda_0 = 0.6328\,\mu\text{m}$, find the smallest grating spacing Λ that will cause the mode to be reflected.

7.6 A rutile prism ($n_p = 2.50$) is used to couple light of vacuum wavelength $\lambda_0 = 0.9050\,\mu\text{m}$ to the fundamental mode in a waveguide which has a refractive index $n_g = 2.09$. Given that the phase constant of the fundamental mode is $\beta_0 = 1.44 \times 10^5\,\text{cm}^{-1}$ what angle γ must the input face of the prism make with the waveguide surface and what angle ϕ must the optical beam within the prism make with the waveguide surface in order to obtain the most efficient coupling.

7.7 A grating with spacing $\Lambda = 0.4\,\mu\text{m}$, situated on a GaAs planar waveguide, is to be used for coupling a beam of light from a He-Ne laser ($\lambda_0 = 1.15\,\mu\text{m}$) into the waveguide. If the propagation constant for the lowest-order mode in the guide is $\beta_0 = 3.6\,k$, what angle must the laser beam make with the surface of the waveguide in order to couple to this mode? Assume first-order coupling, i.e. $|\nu| = 1$.

7.8 A thin film waveguide has $n_1 = 1$, $n_2 = 1.5$ and $n_3 = 1.462$. The waveguide thickness is $0.9\,\mu\text{m}$. Light from a He-Ne laser ($\lambda_0 = 6328$ Å) is being guided in the (fundamental) TE_0 mode, for which the effective refractive index of the guide is $n_{\text{eff}} = 1.481$, If a 45°–45°–90° prism with index $n_{\text{p}} = 2.25$ is used as an output coupler, what angle will the exiting beam make with the surface of the waveguide?

7.9 A prism coupler with index $n_{\text{p}} = 2.2$ is used to observe the modes of a waveguide as shown below. The light source is a He-Ne laser with $\lambda_0 = 6328$ Å. If the light from a particular mode is seen at an angle of 26.43° with the normal to the prism surface, what is the propagation constant β for that mode?