

1. If an electric field E_0 is applied in the $[0,1,0]$ direction inside ADP, find the principal axis. Is it dependent on the magnitude of the electric field E_0 ? If yes, find the principle axis at $E_0=10^4$ V/m. Use $\lambda=633\text{nm}$. What is the propagation direction for maximum birefringence and the value of the birefringence?

2. A bulk cube of KD*P is placed in one arm of a Mach-Zehnder interferometer to create a modulator. To couple light through the cube the width of the cube must be greater than 10mm. Use the following parameters: $\lambda=546\text{nm}$, $r_{41}=8.8\text{E-}12\text{m/V}$, $r_{63}=26.8\text{E-}12\text{m/V}$, $n_o=1.5079$, $n_e=1.4683$.
 - a. Design a modulator using the KD*P cube to have the lowest voltage for 100% extinction. What is the required voltage?
 - b. An integrated MZ modulator is fabricated from the same material. The length is still $L=10\text{mm}$ but the thickness is now $d=1\mu\text{m}$. Design the modulator and calculate the voltage for 100% extinction. (An integrated modulator has to operate with the voltage applied perpendicular to the propagation direction.)

3. A bulk modulator is designed to modulate a CO_2 laser, which has a wavelength of $\lambda=10.6\mu\text{m}$. The modulator is designed to use polarization filtering and uses a cube of material with dimensions larger than or equal to 5mm. Design the modulator and determine the best cube orientation, and the required voltage range for entire extinction. Looking at Table 14.4 the materials that have EO coefficients measured at this wavelength are in the cubic crystal group. Choose the material best material for your design.

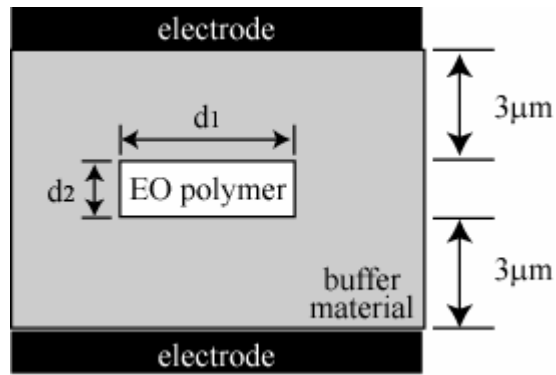


Figure 1: Cross-section of integrated optical waveguide.

4. An integrated optical waveguide is constructed with a poled EO nonlinear polymer in which the EO coefficients are measured to be $r_{33}=7\text{pm/V}$ and $r_{13}=1/3*r_{33}$ and the index of refraction with no applied field is $n=1.6$. In order to create an integrated optical waveguide with reasonable loss the metallic electrode must be separated from the EO polymer by a buffer material that has an index of refraction of $n=1.59$. Figure 1 shows an illustration of the waveguide cross-section. Assume that if the electric field is oriented in the horizontal direction (x-direction) the normalized frequency and normalized propagation constant are respectively $V_x = \frac{2\pi}{\lambda} d_1 \sqrt{n_1^2 - n_2^2}$ and

$$b_x(V_x) = \left(1.1428 - \frac{0.996}{V_x} \right)^2 ; \text{ and if the electric field is in the vertical direction (z-}$$

$$\text{direction) then } V_z = \frac{2\pi}{\lambda} d_2 \sqrt{n_1^2 - n_2^2} \text{ and } b_z(V_z) = \left(1.1428 - \frac{0.996}{V_z} \right)^2 . \text{ Assume that}$$

the wavelength is $\lambda=1550\text{nm}$.

- What are the waveguide dimensions such that $V_x=1.5$ and $V_z=2.3$?
- Design the waveguide in a polarization filtering configuration. Use a waveguide length close to 1cm. Design the modulator such that with no applied voltage the transmission is zero (complete extinction).
- What is the required applied voltage to turn the modulator on (complete transmission)?

5. If the linear electro-optic tensor is given by $r = \begin{bmatrix} 0 & 0 & r_{13} \\ 0 & 0 & r_{13} \\ 0 & 0 & r_{33} \\ 0 & r_{13} & 0 \\ r_{13} & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$ and the applied electric

field is $E = \begin{bmatrix} 1 \\ 0 \\ 2 \end{bmatrix} E_o$, what the indices of refraction (n_x , n_y , and n_z)?