Exercise 4.1

Consider an x-cut balanced Mach-Zehnder modulator. V_π is defined as the required driving voltage in order to obtain an 180º phase delay between the two arms of the modulator. Knowing that V_π =2 V, answer the following questions:

1) Determine the required amplitude (peak-to-peak) and the DC bias in the modulation signal for an intensity modulation to be generated.
2) Idem to previous question but avoiding the signal inversion.
3) Determine the required amplitude (peak-to-peak) and the DC bias in the modulation signal for a phase modulation to be generated.
4) Assume the intensity modulation case. Imagine that the bias signal (DC level) is unstable. Estimate the maximum allowed deviation if the required extinction ratio (ER) is 10 dB.
5) Imagine now that the bias signal (DC level) is stable but the amplitude is not. Estimate the maximum allowed deviation if the required extinction ratio (ER) is 10 dB.

Exercise 4.2

The input-output function of a Mach-Zehnder modulator can be modeled as follows:

$$\begin{pmatrix} E_{out,1} \\ E_{out,2} \end{pmatrix} = \underbrace{\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & j \\ j & 1 \end{pmatrix}}_{coupler\_out} \underbrace{\begin{pmatrix} e^{j\phi_U} & 0 \\ 0 & e^{j\phi_L} \end{pmatrix}}_{delay} \underbrace{\frac{1}{\sqrt{2}}\begin{pmatrix} \sqrt{1+\varepsilon} & j\sqrt{1-\varepsilon} \\ j\sqrt{1-\varepsilon} & \sqrt{1+\varepsilon} \end{pmatrix}}_{coupler\_in} \begin{pmatrix} E_{in} \\ 0 \end{pmatrix}$$

ε parameter models the imbalance of the input coupler. $E_{in} = E_0 e^{j\omega_c t}$ corresponds to the input optical carrier and ϕ_U and ϕ_L to the phase shifts introduced in the upper al lower arms, respectively.

1) Find the output signals $E_{out,1}$ and $E_{out,2}$.
2) Find the maximum value for ε if the required minimum extinction ratio is $10\ dB$.
3) Explain if a chirpless operation can be achieved using this modulator.