Lect. 14: Waveguide Devices

Issues for practical waveguides

- Precise control of dimension and refractive index
- Low loss at desired λ
- Mass production possible
- Integration desirable (Integrated Optics)
- Electrical control of refractive index (Electro-Optic effect)

Materials used for waveguides

- Silica ➔ Optical fiber
- Semiconductors: GaAlAs, InGaAsP, Si/SiO_2
- Dielectric materials: $LiNbO_3$ with Ti doping

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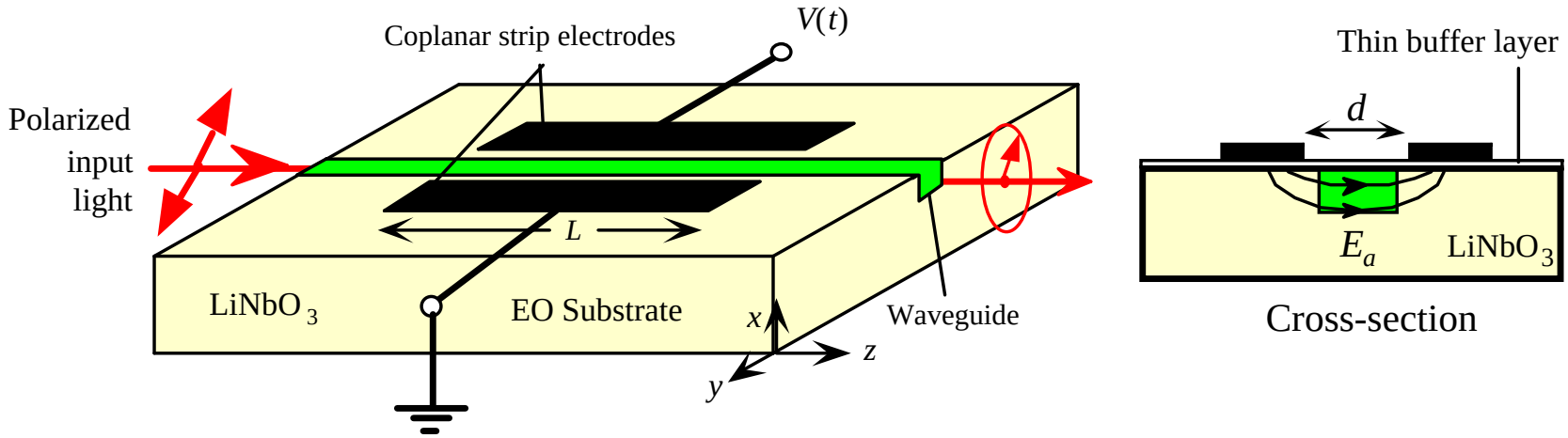
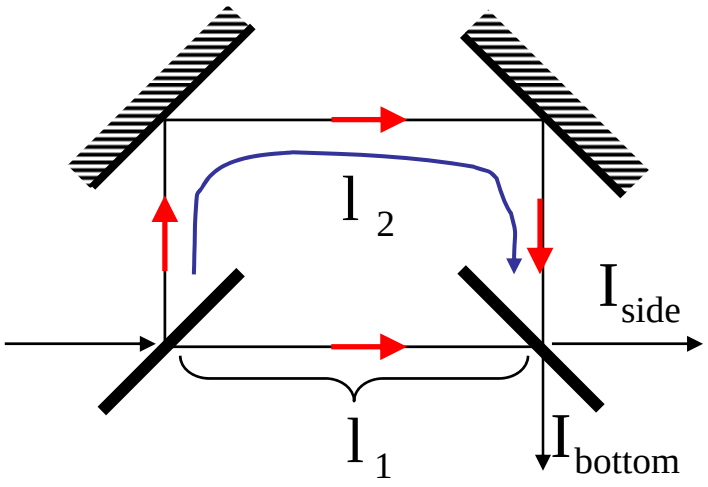
$LiNbO_3$ waveguide



Mach-Zehnder Interferometer:



$$E_{out,side} = \frac{1}{2}\left(e^{-jkl_2} - e^{-j2kl_1}\right) = \frac{1}{2}e^{-jk\frac{l_2+l_1}{2}}\left(e^{-jk\frac{l_2-l_1}{2}} - e^{jk\frac{l_2-l_1}{2}}\right)$$

$$I_{out,side} = \sin^2\left(k\frac{l_1-l_2}{2}\right)$$

$$E_{out,bottom} = \frac{j}{2}\left(e^{-jkl_1} + e^{-jkl_2}\right) = \frac{j}{2}e^{-jk\frac{l_1+l_2}{2}}\left(e^{-jk\frac{l_1-l_2}{2}} + e^{jk\frac{l_1-l_2}{2}}\right)$$

$$I_{out,bottom} = \cos^2\left(k\frac{l_1-l_2}{2}\right)$$

Realize M-Z interferometer with wave devices

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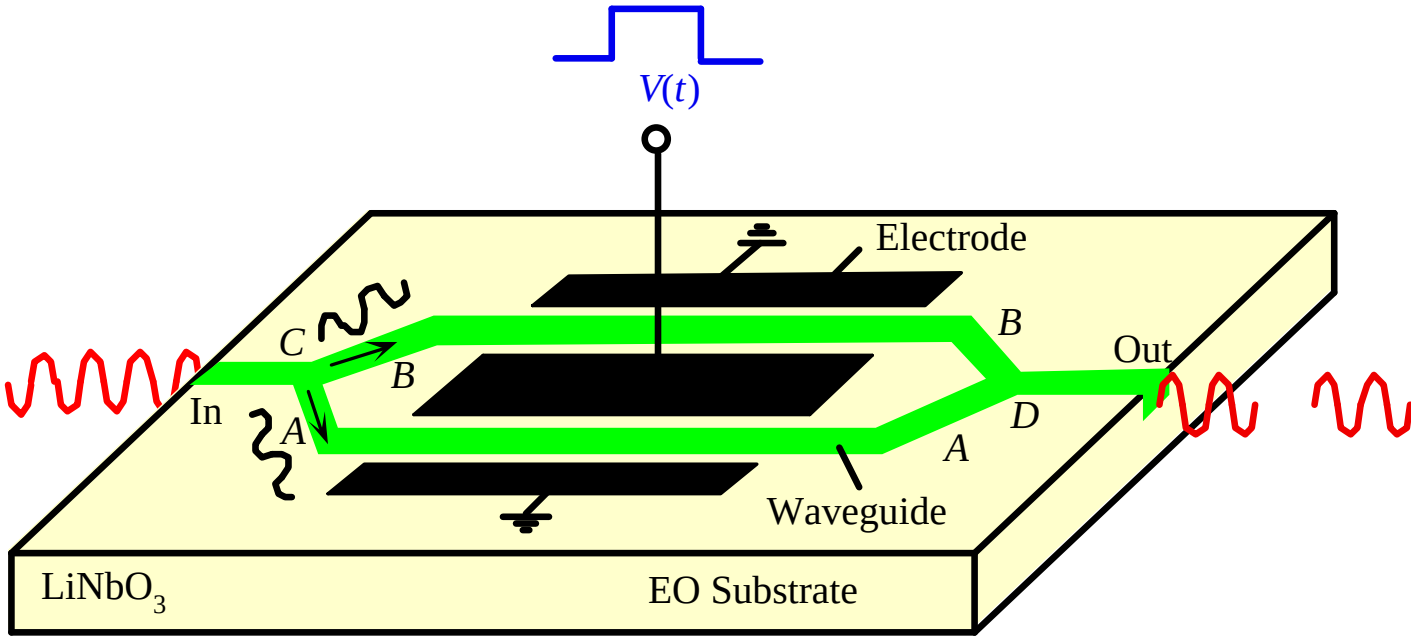
Mach-Zehnder Modulator



Homework: Prob. 3 in 1999 Final
(Assume P_{out} has $\cos^2$ dependence on P_{in})

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Homework: Prob. 3 in 1999 Final
(See the figure next page. Assume P_{out} has $\cos^2$ dependence on P_{in})

Consider a Mach-Zehnder interferometer shown below. The refractive index that $1.5\,\mu m$ light experiences while traveling inside the interferometer is 3.5 when no bias voltage is applied. Due to manufacturing problems, $l_1 = 100\mu m$ and $l_2 = 100.1\mu m$ are not the same.

(a)(10) What is the output power when the input power is $1mW$ at $1.5\,\mu m$ and no bias is applied?

We want to use the interferometer as an optical on/off switch by applying voltage to the upper arm as shown. The refractive index of the upper arm increases 0.001 per 1 volt applied.

(b)(10) What is the voltage with the smallest absolute value that needs to be applied to make the switch on?

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Homework: Prob. 3 in 1999 Final
(Assume P_{out} has $\cos^2$ dependence on P_{in})