Design Proposal: Study of Imbalance Effects on

Performance of Mach-Zehnder Interferometer

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Design 2 Link:
https://github.com/SiEPIC/UBC-ELEC413-2025/blob/4eb085ced2257f2575dfc7668795d7756ec68eb6/submissions/ELEC413_JiahaoYan_withinput.gds

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DESIGN OBJECTIVE

The goal is to design an optical multiplexer and demultiplexer to handle two lasers, each separated by a 25 GHz channel spacing, into a single output and vice versa for separating optical signals. **Wavelength of Operation**: Between 1270 nm and 1330 nm (O Band, centered at 1.31 μm). **Channel Spacing**: 25 GHz. **Design Features**: **Multiplexer**: Combine two optical signals into a single output. **Demultiplexer**: Separate a combined signal into distinct outputs.

I.INTRODUCTION

This is a draft for project 1. Additional explanation will later on.

II. THEORY

A. Wave guide:

Light is guided by Total Internal Reflection(TIR)

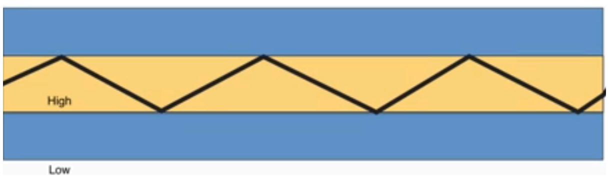


Fig1 . Wave guide TIR

High index of refraction(Si)

Low index of refraction(SiO2)

Plane wave can be expressed as

$$E = E_0 e^{i(wt-\beta z)} \qquad (1)$$

Propagation constant

$$\beta = \frac{2\pi n}{\lambda} \qquad (2)$$

Group index, n_g, related to group velocity, the velocity at which overall shapes wave.

$$n_g = n - \lambda \frac{dn}{d\lambda} \qquad (3)$$

The group index can be calculated from the relationship between wavelength and index.

For n_p It represents the wave's phase velocity. When different phase velocity waves are added, dispersion will happen, where the wave is sharp at one moment of time, but it is suddenly dispersed at another moment in time.

However, if different waves in the same phase velocity are added together, their phase velocity will be equal to group velocity.

TE_polarized:

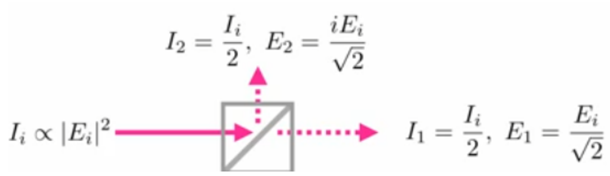
Light's electric field is transverse/parallel to the wafer.

TM_Polarized:

Light's magnetic field is transverse/parallel to the wafer.

In my design requirements, the thickness is 220 nm, which is below 240 nm, there is only one solution—TE and TM mode.

B. Y-Branch



(3)

A **Y-branch** is a simple optical splitter that divides an i
optical signal into two separate paths. Unlike a beam sp
which introduces phase shifts due to reflection and tran
a Y-branch operates through waveguide branching, ensu
nearly equal power distribution between the two output
commonly used in integrated photonics for power splitt
combining, playing a fundamental role in optical comm
systems and interferometers.

For two inputs E1, E2 into Y branch the electric field output : $\frac{E1 + E2}{\sqrt{2}}$ (4)

C. MZI

MZI

A Mach-Zehnder Interferometer (MZI) is an optical device that splits a beam of light into two paths using a beam splitter, introduces a phase difference between them, and then recombines them using another beam splitter. The interference of the two beams at the output determines the intensity distribution, depending on the relative phase shift. MZIs are widely used in optical communication, sensing, and quantum computing for precise phase control and signal modulation.

Mach Zehnder Interferometer has following functions:

$$\frac{I_o}{I_i} = \frac{1}{2}[1 + \cos(\beta_1 L_1 - \beta_2 L_2)] \quad (5)$$

$$E_{o1} = E_1 e^{-i\beta_1 L_1 - \frac{\alpha_1}{2} L_1} = \frac{E_i}{\sqrt{2}} e^{-i\beta_1 L_1 - \frac{\alpha_1}{2} L_1} \quad (6)$$

Transfer function:

$$n_{\mathrm{eff}}(\lambda) = n_1 + n_2(\lambda - \lambda_0) + n_3(\lambda - \lambda_0)^2 \quad (7)$$

III. WAVEGUIDE MODELLING

Lumerical Mode:

350 nm x 220 nm @1310nm (width x thickness)

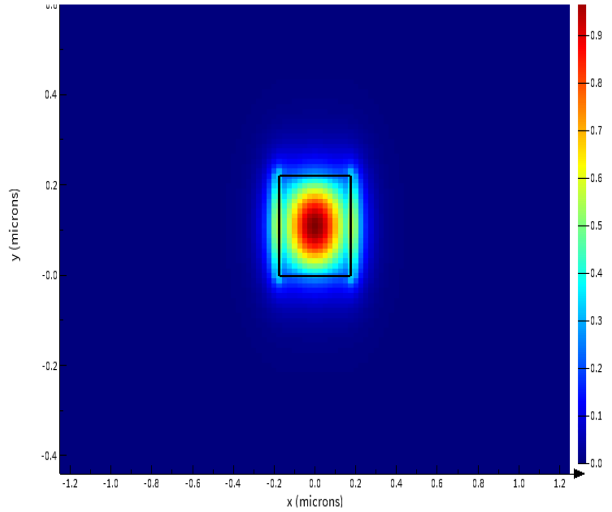


Fig.2 First TE Mode Electric Field Intensity for strip Waveguide (1310nm)

I chose to use Lumerical to perform the curve fitting since the transcript is provided in the tutorial as another option. The effective index versus wavelength is given.

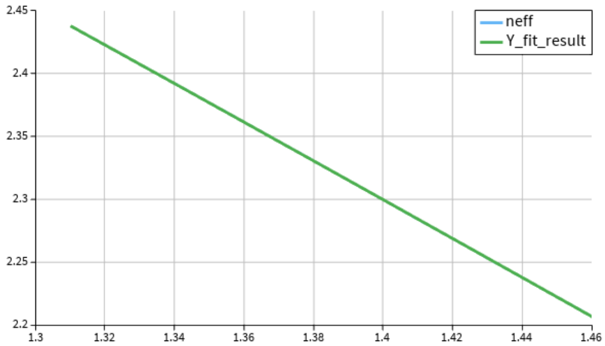


Figure 4: Effective index of waveguide versus wavelength(microns)

The result outputs three indexes: n1 = 2.43768, n2 = -1.5278, n3 = -0.0773793 for

$$n_{eff}(\lambda) = n_1 + n_2(\lambda - \lambda_0) + n_3(\lambda - \lambda_0)^2$$

rest simulations are to be added