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Mach-Zehnder Interferometer Design Proposal

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Abstract Nick Barclift nick@nickbarclift.com
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1 Introduction

Photonics is a growing field of technology, which offers many promising applications. Some of these include ultra fast data transmission, quantum computing, biosensing, and optics. As of 2026, silicon is often used in photonic chip manufacture because there is an existing infrastructure and methodology for the manufacture of silicon chips, and because a layer of silicon encased in an insulating layer of cladding, such as silicon dioxide, allows for a useful level of light information transmission. Light has different polarization modes, and TE and TM modes are useful in different applications.

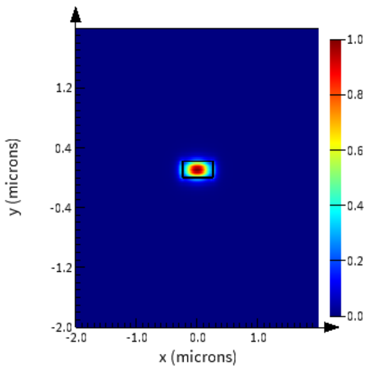

Fig. 1 Electric field intensity for the TE mode in a basic slab waveguide

1.1

2 Theory

This project will begin with simple photonic circuit designs, and increase complexity with subsequent design drafts. One of the simplest photonic circuits is the Mach-Zehnder interferometer (MZI). This type of circuit is useful in signal modulation because it utilizes the ability of light waves to create constructive and destructive interference.

By splitting a beam of light into two paths with a variation in length (delta L), an MZI can achieve a strong sinusoidal variation in light transmission that is correlated with the wavelength of light used (see image below).

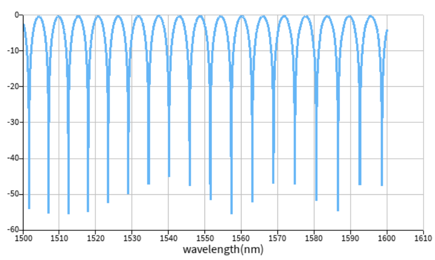

Fig. 2 Wavelength vs Gain in a simulated inteferometer

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3 Modelling and Simulation

The first draft of layout designs was created with the software Klayout, and consists of two TE mode MZIs, consisting of two gratings, two Y branch beam-splitters, and two waveguide paths of varying lengths. The waveguide paths have a width of 500 nm. The first waveguide has path lengths of 1,800 and 2,800 nm, for a delta L of 1,000 nm. The second waveguide has path lengths of 1,800 and 3,800 nm, for a delta L of 2,000 nm. The transfer function for these devices is TMZI(λ) = 1/2 [1+cos(βdeltaL)] where β = 2πn/ λ and n is the effective index of the material.

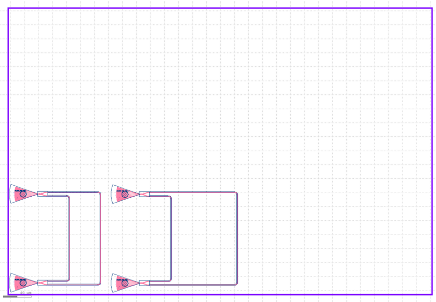

Fig. 3 First design draft 2/2/2026

The following two figures demonstrate how the difference in delta L changes the transmission vs wavelength pattern between the two interferometer designs.

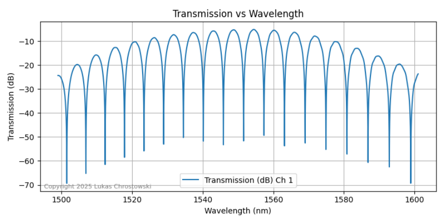

Fig. 4 Transmission vs Wavelength for 1000 nm [?]L

The following figure shows that greater wavelengths of light lead to a lower effective index, which results in a higher phase velocity for the light due to the equation β = 2πn/ λ

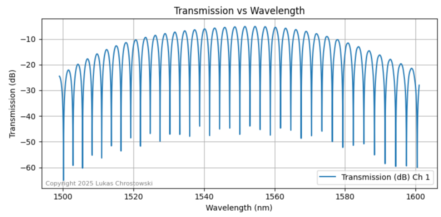

Fig. 5 Transmission vs Wavelength for 2000 nm [?]L

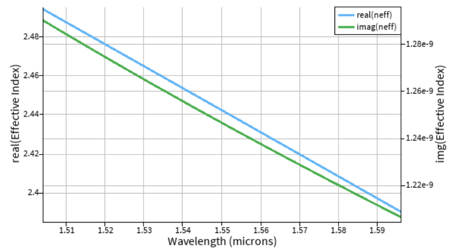

Fig. 6 neff vs wavelength

4 4 Conclusion

Both this report and the circuit designs will greatly improve with subsequent drafts. Later drafts of the circuit designs should include some TM mode designs as well as greater variations in path length and more modulating elements. With great luck, they may include other types of circuits than MZIs. Later drafts of this report should include better integration of mathematical equations, citations of included information, and analysis of data from the results of the designs.