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Abstract Abstract

1 Introduction

Silicon photonics is a field of study of manipulating light using silicon-based materials as the optical medium [1]. Most popular choice of material for the optical medium include silicon (Si) and silicon nitride (Si3N4), and the advantage of using silicon-based materials is the compatibility with the already-existing silicon electronics industry. Silicon photonic devices have various applications including optical communications, signal processing and sensing.

This course provides a brief introduction to silicon photonics and some of the basic concepts used in this field. A model circuit was simulated, fabricated and analysed for the purpose of understanding the principles of silicon photonics.

More specifically, in this report, I investigate a Mach-Zehnder interferometer circuit with different path differences. I will be using strip waveguides with 220nm height and 500nm width for quasi-TE modes, and the path difference between

2 Theory

In this study, I will use a Mach-Zehnder interferometer (MZI), which consists of a splitter, waveguides connected to each output, which are later combined. If the lengths of the two waveguides are the same, it's classified as a balanced MZI, otherwise an unbalanced MZI. Here, MZIs with different path length differences will be investigated. It can be shown that the output electric field of an unbalanced MZI is:

$$E_{output} = \frac{E_{input}}{\sqrt{2}} \left(e^{-i\beta L_1} + e^{-i\beta \ L_2} \right),$$

where E_{output} and E_{input} are the output and input electric fields, β is the propagation constant given by $2\pi n/\lambda$, L_1 and L_2 are the lengths of each waveguide arm. Hence, the intensity of light at the output is:

$$I_{output} = \frac{I_i}{4} \left(e^{-i\beta L_1} + e^{-i\beta L_2} \right) = \frac{I_i}{2} \left(1 + \cos\left(\beta \Delta L\right)\right)$$

where ΔL is the path length difference, $L_1 - L_2$. Along with simulation of the waveguides to o

3 Modelling and Simulation

The waveguide parameters used for this study is 220nm height, 500nm width for quasi-TE polarisation. The fundamental TE mode profile is shown in Figure\ref{789066} below, obtained from Lumerical MODE.

The effective index of the waveguide can be approximated by second order Taylor series expansion around the centre wavelength of 1.55 micron, and we call it the compact model for the waveguide. From sweeping the frequency for the waveguide simulations and fitting the waveguide, the following expression was obtained:

$$n_{eff} = 2.45 - 1.1\left(\lambda \ - 1.55\right) - 0.43\left(\lambda - 1.55\right)^2$$

where n_{eff} is the effective refractive index, and λ is the wavelength in microns. The effective index and

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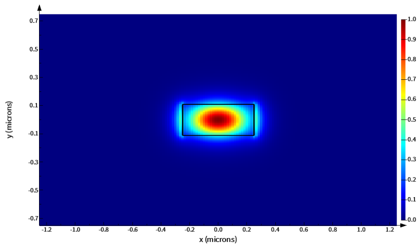

Fig. 1 TE0 mode profile, calculated from Lumerical MODE

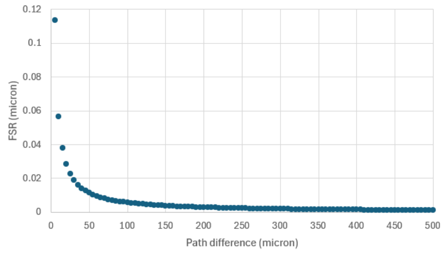

Fig. 4 FSR at different path differences

group index at different wavelengths are shown in Figure \ref{301044} and \ref{442352}.

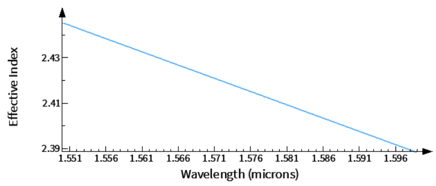

Fig. 2 Effective refractive index at different wavelengths

FSR (nm)	Path difference (micron)
5.67	100
2.83	200
1.89	300
1.42	400
1.13	500

Table 1 FSR at selected path differences

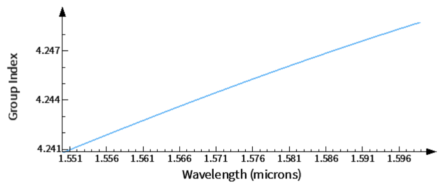

Fig. 3 Group index at different wavelengths

The photonic circuit can be simulated with Lumerical INTERCONNECT. A sample schematic is shown in Figure \ref{713976}, and the resulting spectrum fom the simulation in Figure \ref{708418}.

The free spectral range (FSR) is a parameter that can be used to characterise a MZI, which is given by:

$$FSR = \frac{\lambda^2}{n_g \Delta L}$$

where n_g is the group index. This is also the difference in the neighbouring minima or maxima. By having multiple circuits with different path length differences and comparing with the calculated FSR, we can estimate the group index of the waveguide. This estimated group index can then be compared with the simulated group index from Lumerical MODE. As an example, FSR is plotted against different path differences, with 1.55 micron wavelength and 4.24 group index in Figure \ref{797297}, and some representative values given in Table \ref{787123}.

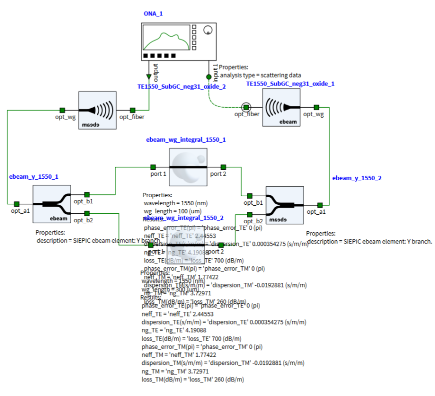

Fig. 5 Lumerical INTERCONNECT schematic

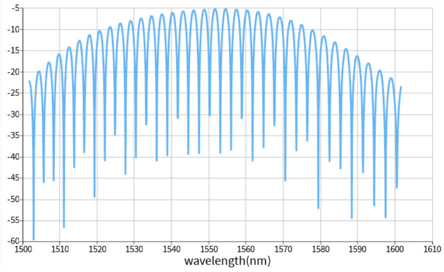

Fig. 6 Lumerical INTERCONNECT simulation spectrum

4 Fabrication

5 Experimental Data

6 Analysis

7 Conclusion

8 Acknowledgements

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References

1. Chrostowski L, Hochberg M (2015) Silicon Photonics Design. Cambridge University Press (CUP)