Noname manuscript No.
(will be inserted by the editor)

edx Phot1x report template (2016/11)

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Abstract The abstract goes here.

1 Introduction

The objective is to design an unbalanced MZI to extract waveguide group index through Free Spectral Range (FSR), which is the spacing in optical frequency or wavelength between the peaks of 2 beams. The device will be fabricated on 220nm SOI, TE polarized, using a 500nm strip waveguide.

2 Theory

2.1 Waveguide dispersion

Light propagation in a single-mode waveguide is characterized by the effective index $n_{\text{eff}}(\lambda)$. The group index, which determines the delay of optical signals and the interference fringe spacing, is

$$n_g(\lambda) = n_{\text{eff}}(\lambda) - \lambda \frac{dn_{\text{eff}}}{d\lambda}. \tag{1}$$

The effective index will be obtained from eigenmode simulations and fitted with a low-order polynomial to enable analytic evaluation of n_g.

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2.2 Mach–Zehnder interferometer

An unbalanced Mach–Zehnder interferometer (MZI) with path length difference $\Delta L = L_2 - L_1$ introduces a wavelength-dependent phase difference

$$\Delta\phi(\lambda) = \frac{2\pi n_g(\lambda)\,\Delta L}{\lambda}. \tag{2}$$

Assuming ideal 50:50 splitting and negligible loss, the normalized transmission is

$$T(\lambda) = \frac{1}{2}\left[1 + \cos(\Delta\phi(\lambda))\right]. \tag{3}$$

2.3 Free spectral range

Constructive interference occurs when $\Delta\phi = 2\pi m$. The wavelength spacing between adjacent maxima, the free spectral range (FSR), is

$$\text{FSR} \approx \frac{\lambda^2}{n_g\,\Delta L}. \tag{4}$$

2.4 Extraction of group index

From measured transmission spectra, the group index can be obtained directly as

$$n_g(\lambda) = \frac{\lambda^2}{\text{FSR} \cdot \Delta L}. \tag{5}$$

This equation forms the basis of the experiment: by fabricating MZIs with known ΔL and measuring the fringe spacing, the waveguide group index can be extracted and compared with simulated values.

Short description of the theory relevant to your project. e.g., Waveguide compact model, MZI transfer function.

3 Modelling and Simulation

3.1 Simulation results

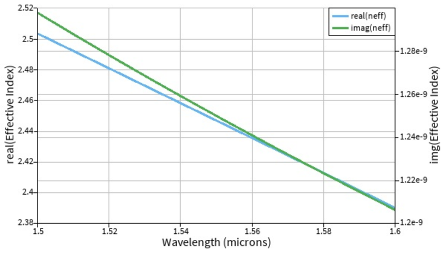

Fig. 1 Effective index

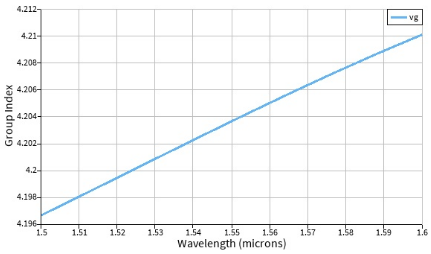

Fig. 2 Group index

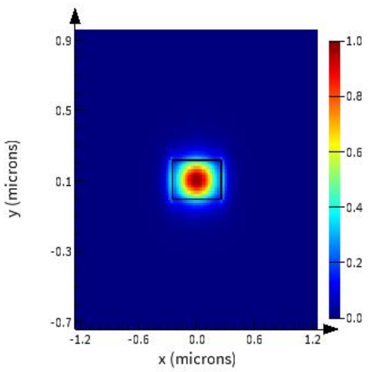

Fig. 3 TE mode electric field intensity

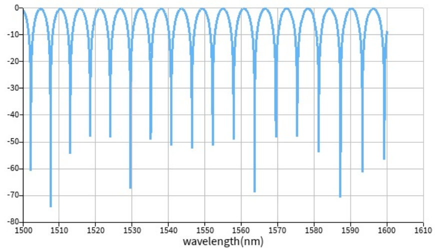

Fig. 4 Transfer function, delta L 100um

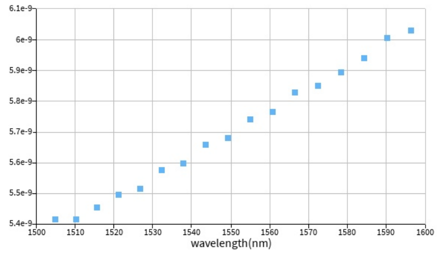

Fig. 5 FSR delta L 100um

3.2 Compact waveguide model

The effective index is represented by a polynomial around $\lambda_0 = 1550$ nm,

$$n_{\text{eff}}(\lambda) = a_0 + a_1(\lambda - \lambda_0) + a_2(\lambda - \lambda_0)^2, \tag{6}$$

with group index

$$n_g(\lambda) = n_{\text{eff}} - \lambda \frac{dn_{\text{eff}}}{d\lambda}. \tag{7}$$

Coefficients a_i will be obtained from eigenmode simulation of the 500 nm $\times$ 220 nm strip waveguide (quasi-TE).

3.3 Interferometer model

The MZI transmission is

$$T(\lambda) = \tfrac{1}{2}\left[1 + \cos\left(\frac{2\pi n_g(\lambda)\mathit{\Delta} L}{\lambda}\right)\right]. \tag{8}$$

The expected free spectral range is

$$\text{FSR} = \frac{\lambda^2}{n_g \mathit{\Delta} L}. \tag{9}$$

ΔL (μm)	Expected FSR (nm)
20	30
40	15
60	10
80	7.5
100	6

3.4 Design sweep

3.5 Planned simulations

- MODE: mode profile and $n_{\text{eff}}(\lambda)$
- Polynomial fit $\rightarrow n_g(\lambda)$
- INTERCONNECT: MZI spectra and FSR extraction

3.6 Manufacturing variability

Width $\pm$20 nm corner study and Monte-Carlo $\sigma = 5$ nm to estimate impact on n_g and FSR.

I/We acknowledge the edX UBCx Phot1x Silicon Photonics Design, Fabrication and Data Analysis course, which is supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) Silicon Electronic-Photonic Integrated Circuits (SiEPIC) Program. The devices were fabricated by Richard Bojko at the University of Washington Washington Nanofabrication Facility, part of the National Science Foundation's National Nanotechnology Infrastructure Network (NNIN), and Cameron Horvath at Applied Nanotools, Inc. Enxiao Luan performed the measurements at The University of British Columbia. We acknowledge Lumerical Solutions, Inc., Mathworks, Mentor Graphics, Python, and KLayout for the design software.