UBCxPhot1x: Silicon Photonics Design, Fabrication and Data Analysis

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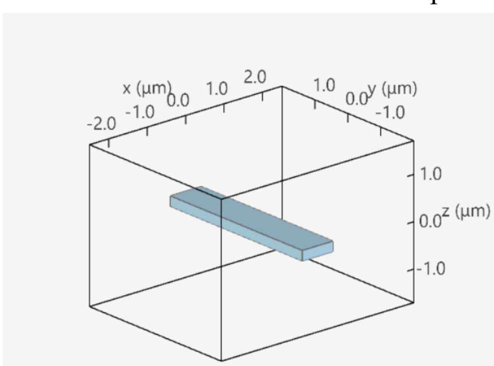
Mach Zehnder Interferometer Design Document Draft

I. Introduction

Mach Zehnder Interferometers have various use cases in optical communication, quantum mechanics, and biosensors. This report will cover the design and analysis of a Mach Zehnder Interferometer. If both paths of the interferometer are equal, we anticipate constructive interference at the output. If we have a 180-Degree phase shift, we anticipate destructive interference (essentially, there isn't enough light for propagation within our fundamental wave guide mode. The light instead goes towards the radiation mode and 2nd order modes.

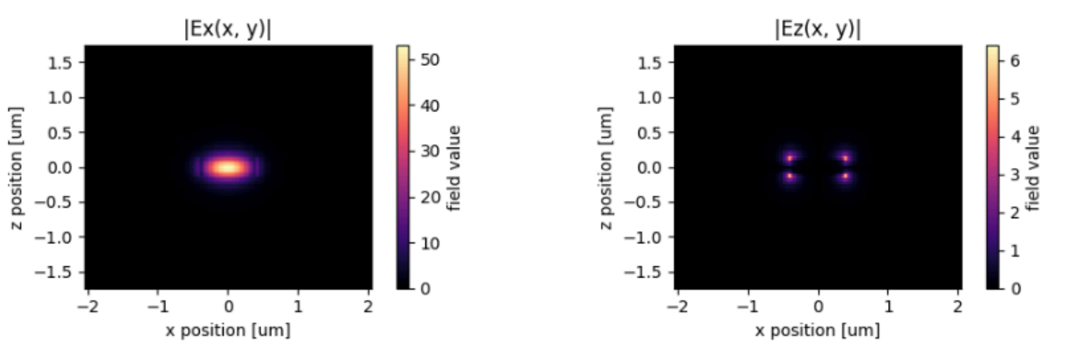
II. Modeling and Simulation

Simulated Waveguide Mode Profile from Tidy3D
Simulation of a 220nm x 500 nm strip waveguide.

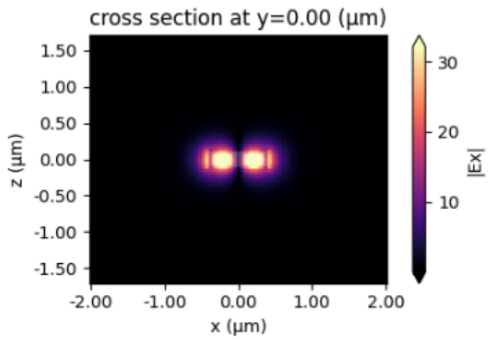


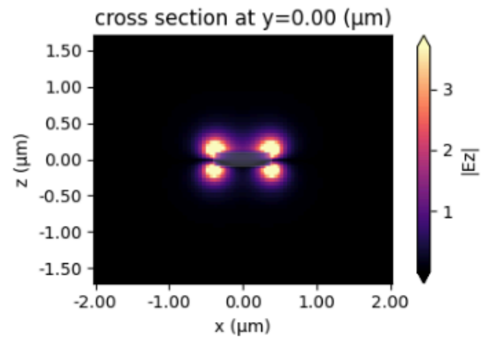
The simulated waveguide mode profile (images from Tidy3D):

Fundamental Mode:

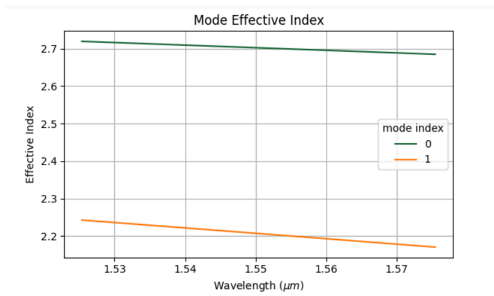


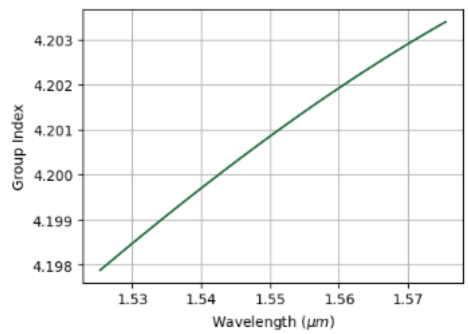
Second Mode





A plot of effective and group index of the waveguide, versus wavelength (Graphs from MATLAB and/or Lumerical MODE Solutions):





Compact model for the waveguide (polynomial expression)

$$n_{eff} = 1.767 + (\lambda - 1.246)(\lambda - 1.55) + 1.818(\lambda - 1.55)^2$$

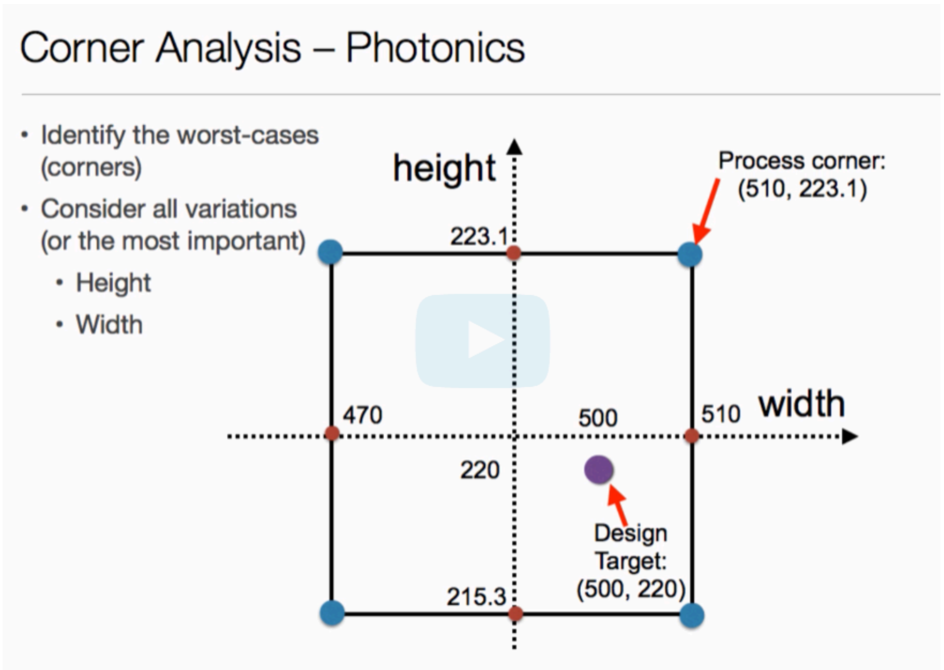
A table listing your parameter variations (e.g., different values for path length difference ΔL, waveguide width, etc.), and expected performance for each (e.g., FSR). Below has the path length difference for each device.

```
%<X-coord>,<Y-coord>,<Polarization>,<wavelength>,<type>,<deviceID>,<comment=waveguide length difference>
907.5,2794.6,TE,1550,device,MakennaNoel_MZI1,145.3
906.6,3266.7,TE,1550,device,MakennaNoel_MZI2,156.6
779.2,291.1,TE,1550,device,MakennaNoel_RingRes,31.4
779.3,3021.5,TE,1550,device,MakennaNoel_RingRes2,62.8
779.3,3144.8,TE,1550,device,MakennaNoel_RingRes3,94.2
```

Analysis

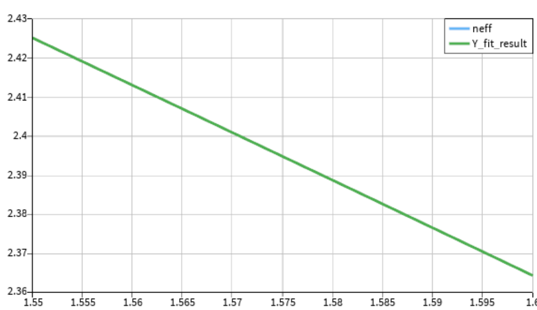
Corner Analysis

- Perform 5 Simulations in Lumerical MODE with for loops using example scripts

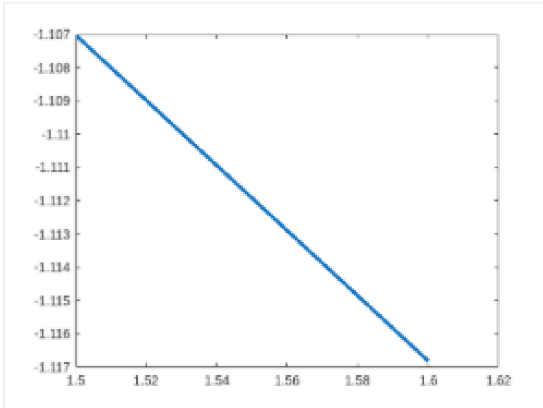


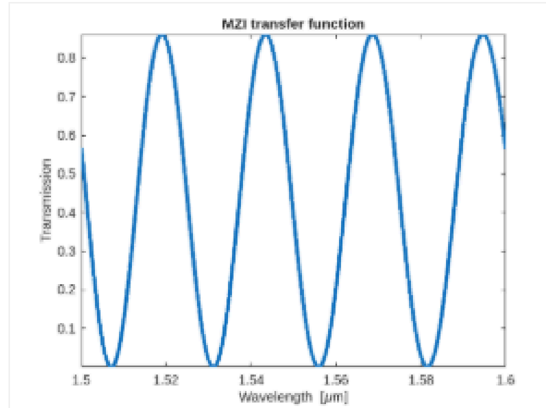
I performed a frequency sweep and followed it with the following simulations utilizing the fitting script provided in the lecture:

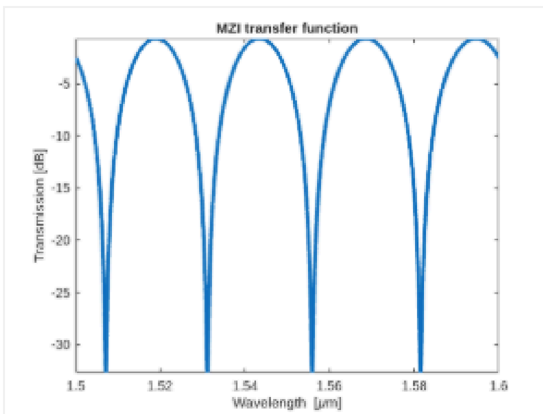
Simulation 0 (500, 220):



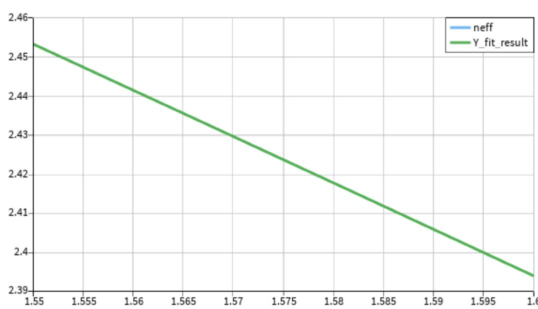
2.42511
-1.21112
-0.110847







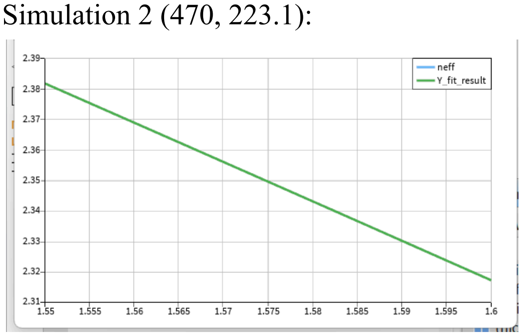
Simulation 1 (510, 223.1):



2.45323
-1.18094
-0.111182

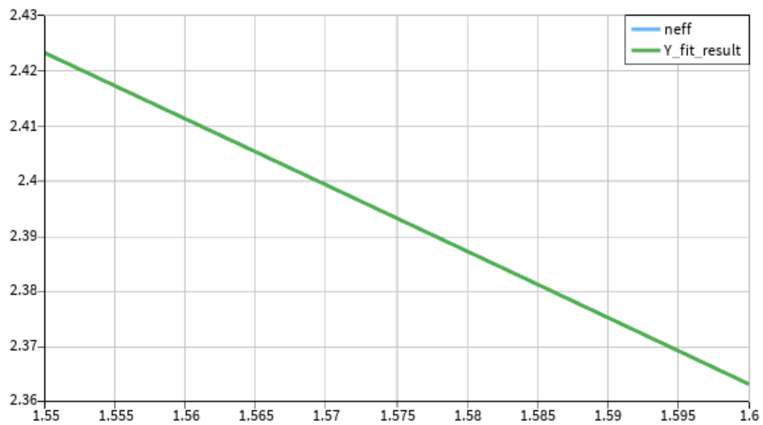
Neff = [4,1]

Simulation 2 (470, 223.1):



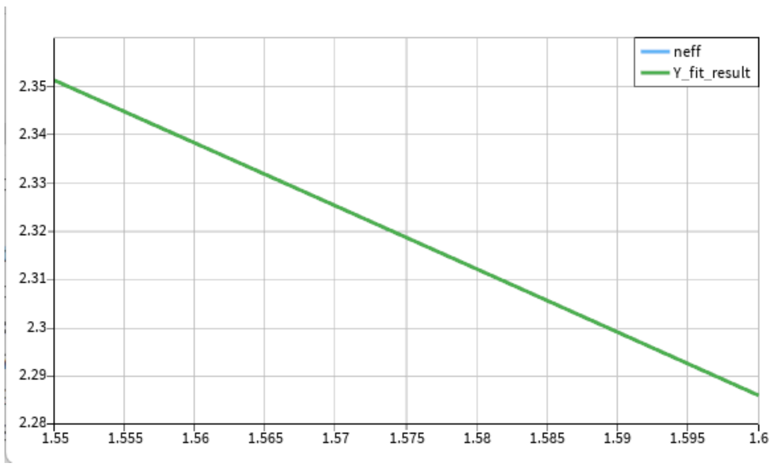
2.38177
-1.28494
-0.127081

Simulation 3 (510, 215.3):



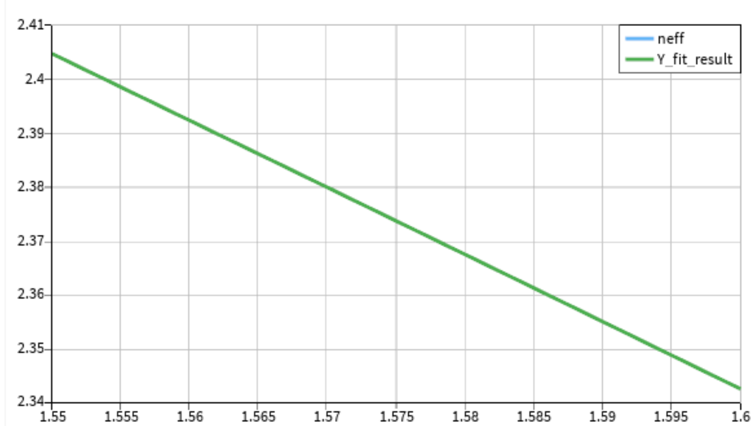
2.42317
-1.19685
-0.0978312

Simulation 4 (470, 215.3):



2.35119
-1.30066
-0.107777

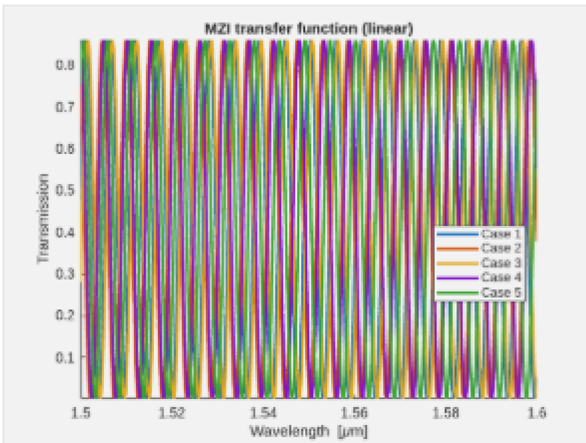
Simulation 5 (490, 219.2):

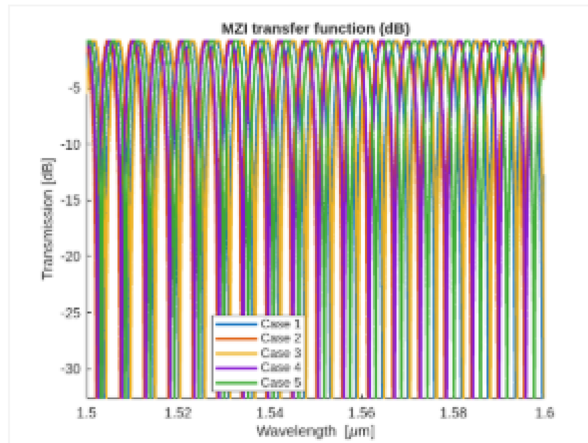


2.40471
-1.23803
-0.113334

- Generate 5 compact models for the waveguides (curve fitting), and save all data as a matrix in mode to perform both eigenmode simulations and compact model generation

```
coeff = [ 2.45 -1.18   -0.111;   % example nomi
          2.38  -1.28   -0.127;   % corner 1
          2.42  -1.197  -0.097;   % corner 2
          2.35  -1.30   -0.1078;   % corner 3
          2.40  -1.24   -0.113 ]; % corner 4
```





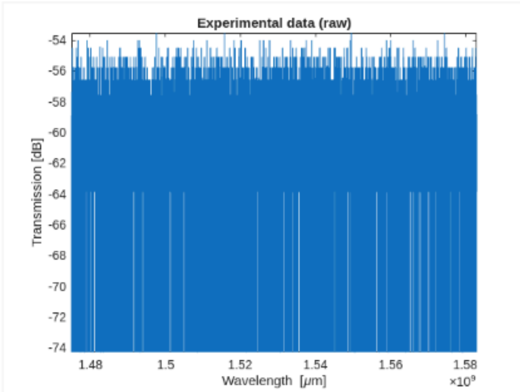
The min and max group index:

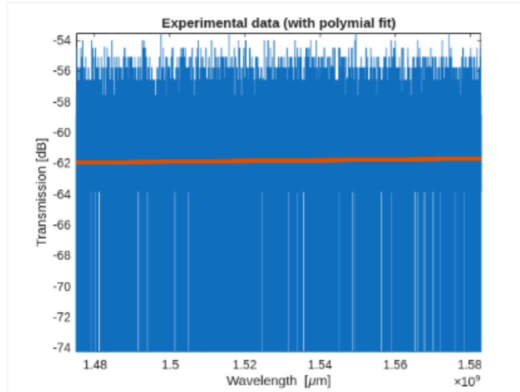
```
ng_min = 3.7850
ng_max = 4.1150
```

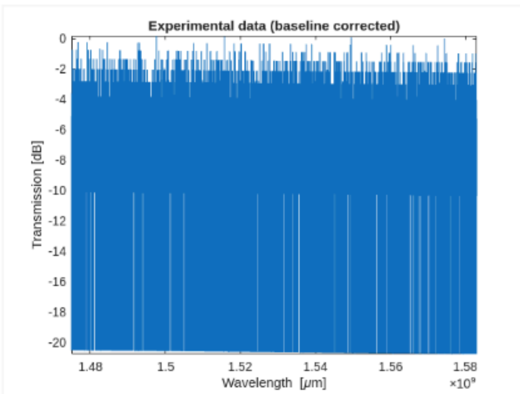
Measurement Analysis

While trying to complete the baseline correction, none of the poly_orders I tried gave me a polynomial with a good fit.

Output







Both Corner Analysis and Monte Carlo methods gave me errors, unfortunately. Still working to compare measurement data and analysis data, meaning the analysis will have to be fully completed after the course completion.

III. References:

1. Lukas Chrostowski, Michael Hochberg. Silicon Photonics Design. Cambridge University Press (CUP), 2015. Link
2. Lukas Chrostowski, Michael Hochberg. Testing and packaging. 381–405 In Silicon Photonics Design. Cambridge University Press (CUP) Link
3. Yun Wang, Xu Wang, Jonas Flueckiger, Han Yun, Wei Shi, Richard Bojko, Nicolas A. F. Jaeger, Lukas Chrostowski. Focusing sub-wavelength grating couplers with low back reflections for rapid prototyping of silicon photonic circuits. Opt. Express 22, 20652 The Optical Society, 2014. Link

Frequency Sweep Code:

```
# Get the data from the MODE frequency sweep
lambda=c/getdata("FDE::data::frequencysweep","f")*1e6; #
lambda in [microns]

neff=abs(getdata("FDE::data::frequencysweep","neff"));
lambda0 = 1.55;  # central wavelength

# Polynomial fitting.
x_fit = lambda-lambda0; # X vector
y_fit = neff;           # Y vector
n_fit = 2;              # order of the polynomial

# Next 3 lines do polyfit. Inputs: x_fit, y_fit, n_fit.
Outputs: a_fit.
# Based on a linear algebra approach
X_fit = matrix(length(x_fit),n_fit+1);
for(i_fit=0:n_fit){ X_fit(1:length(x_fit),i_fit+1) =
x_fit^i_fit; }
a_fit =
mult(mult(inv(mult(transpose(X_fit),X_fit)),transpose(X_f
it)),y_fit);

# Display the fit polynomial coefficients
?a_fit;
```

```
# This is the polynomial equation:
Y_fit_result = a_fit(1) + a_fit(2)*(lambda-lambda0) +
a_fit(3)*(lambda-lambda0)^2;


plot (lambda, neff, Y_fit_result);  # plot the result
```