Silicon Photonics

Design Report

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Introduction

Problem Statement:

We are required to design a minimum of six Mach-Zehnder Interferometer in a given wafer sizing and parameters being 3 simple MZI designs and 3 unique designs using different configurtations, waveguides lengths, polarization method and addition of bragg gradings. The inspirations were derived from the EdX course which was used as an additional source of understanding of Silicon photonics and the use of KLayout software.

Part A

Introduction:

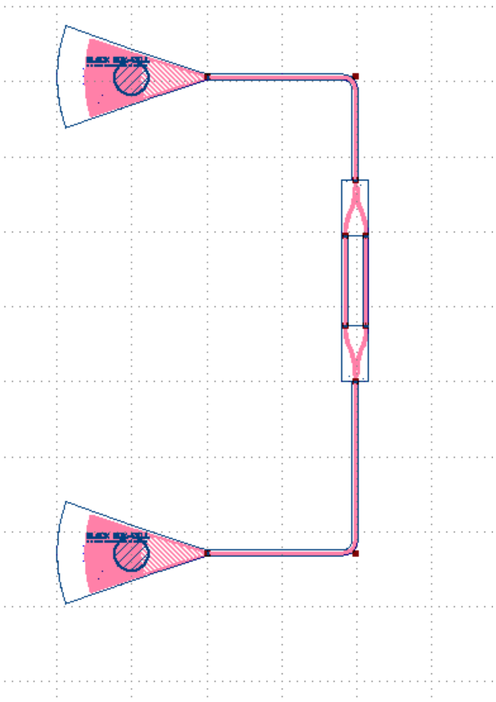
This section of the design consists of 3 MZI designs with different waveguides and Y-splitters.

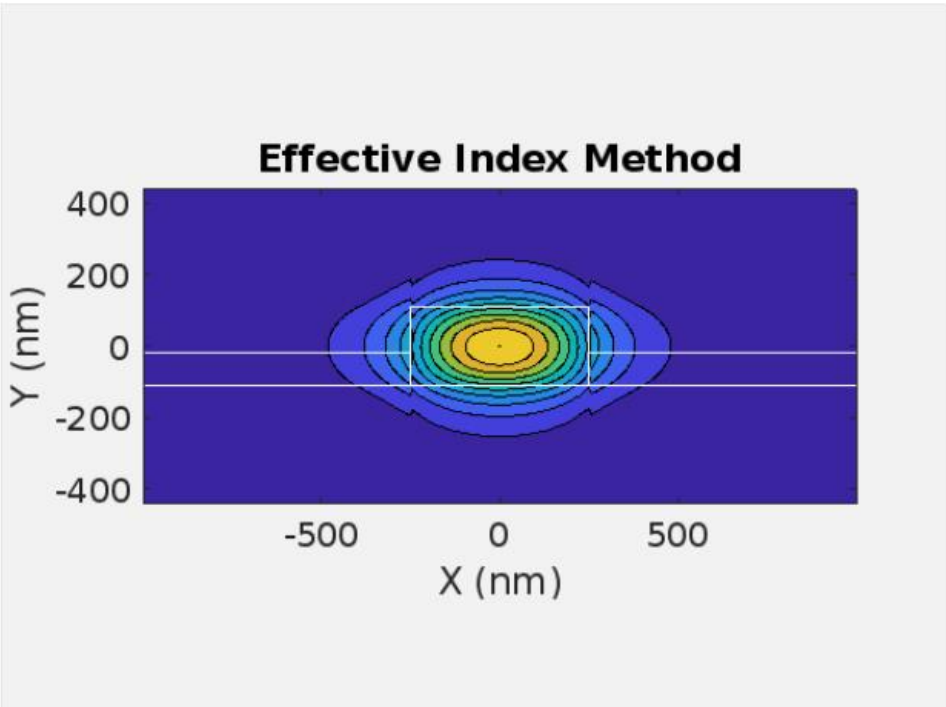
Design details:

- The MZI's designed in part A consistst of TE prolarization waveguides with a base wavelength consideration of 1550nm.
- Waveguide lengths:
  - MZI1 - 155.31nm
  - MZI2 - 328.22nm
  - MZI3 – 223.18nm
- The first and third design were implimented with the Y-splitters.
- The MZI designs were inspired form the EdX course tutorials and the simplicity of using a TE polirization.

Design modelling:

- MZI1:
    - The predicted Ng is 4 from the simulation data.
    - The obtained Ng is 3.76 from the post fabrication data provided.





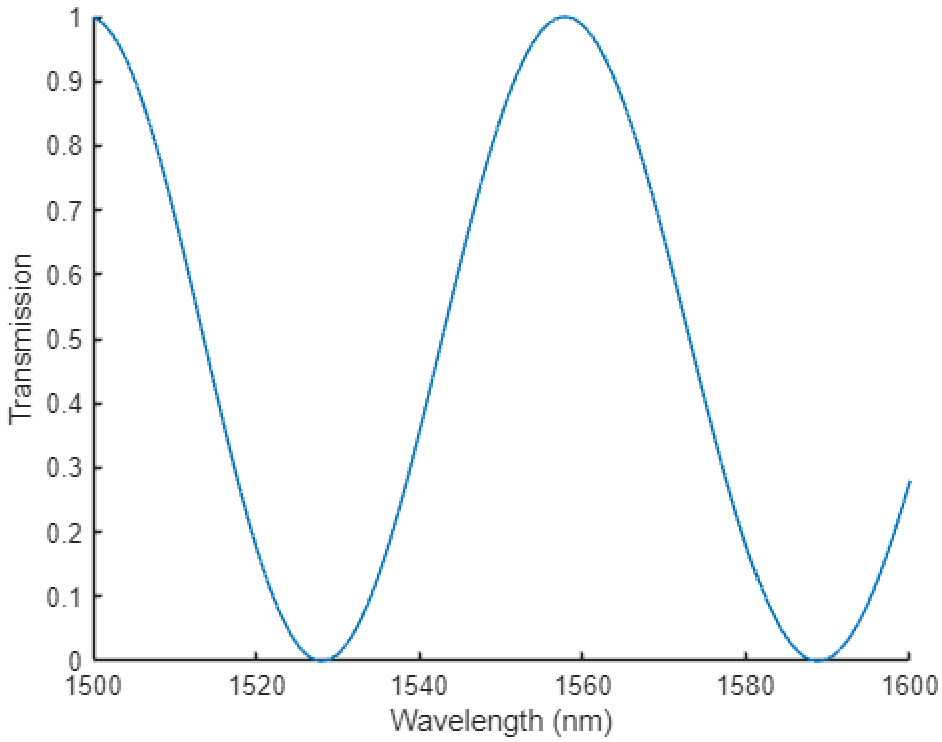
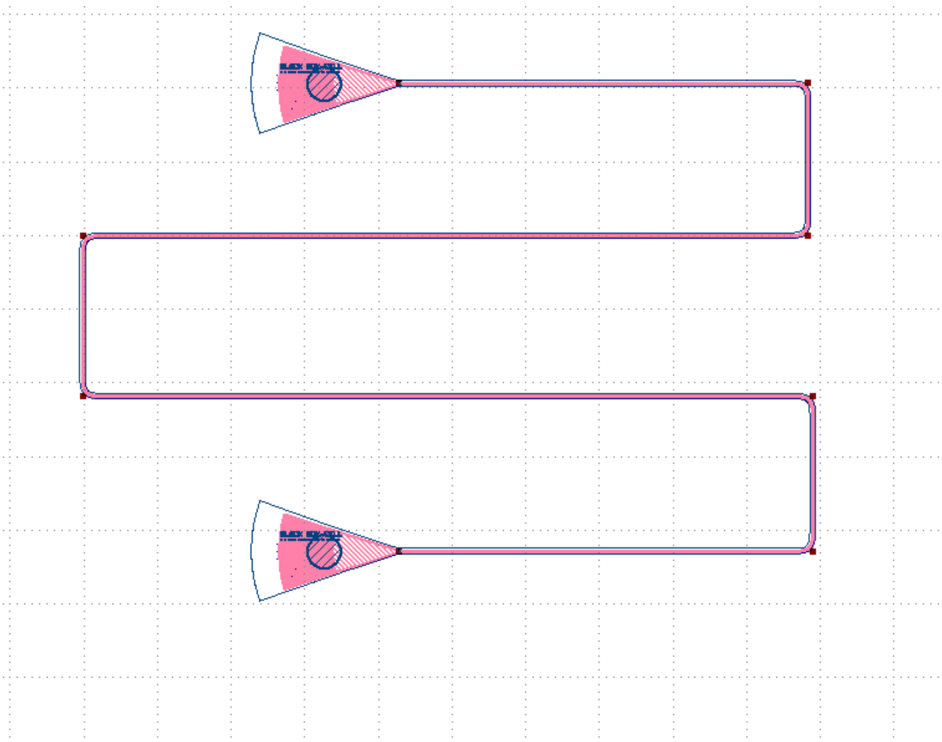
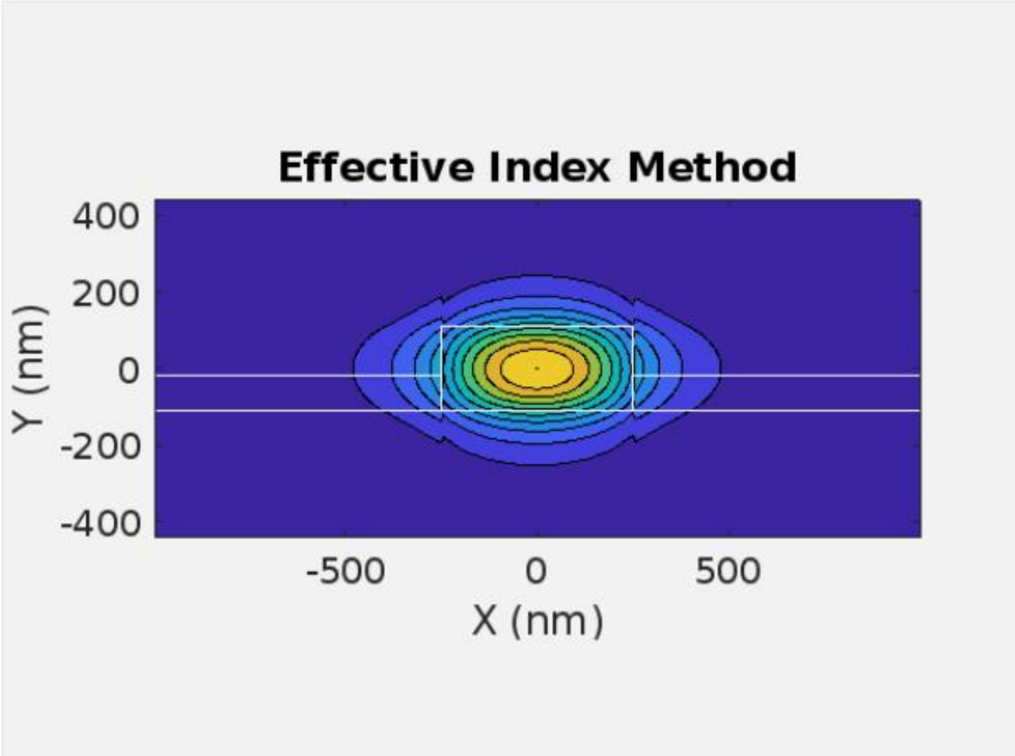


Fig 1: MZI 1 Design, Simulated Ng & MZI Transmission

- MZI2:
    - The predicted Ng is 4 from the simulation data.
    - The obtained Ng is 3.85 from the post fabrication data provided.





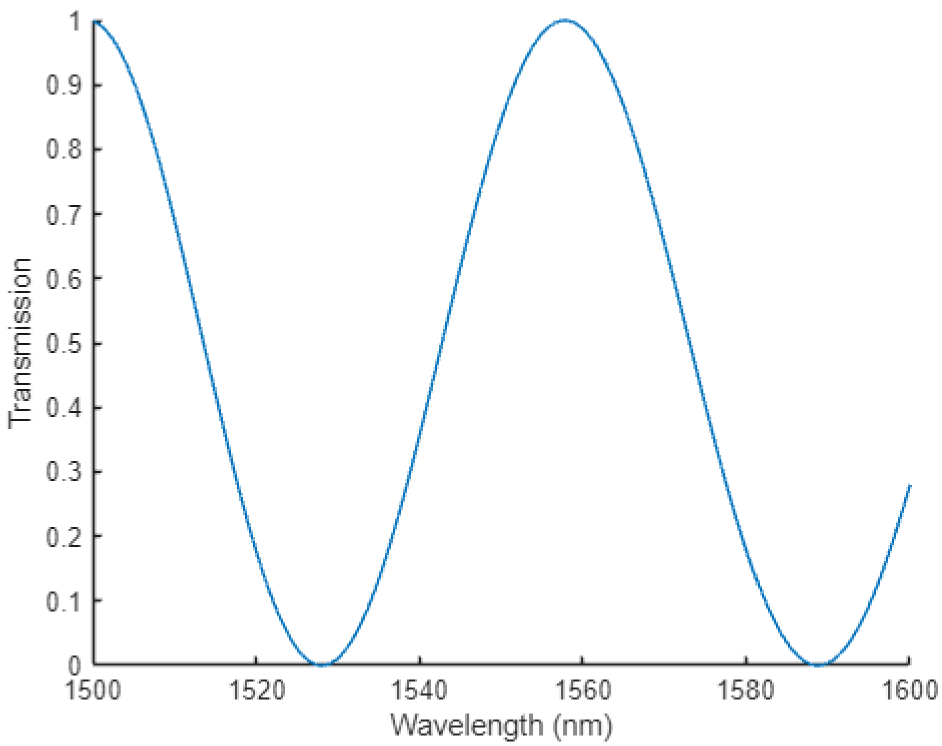
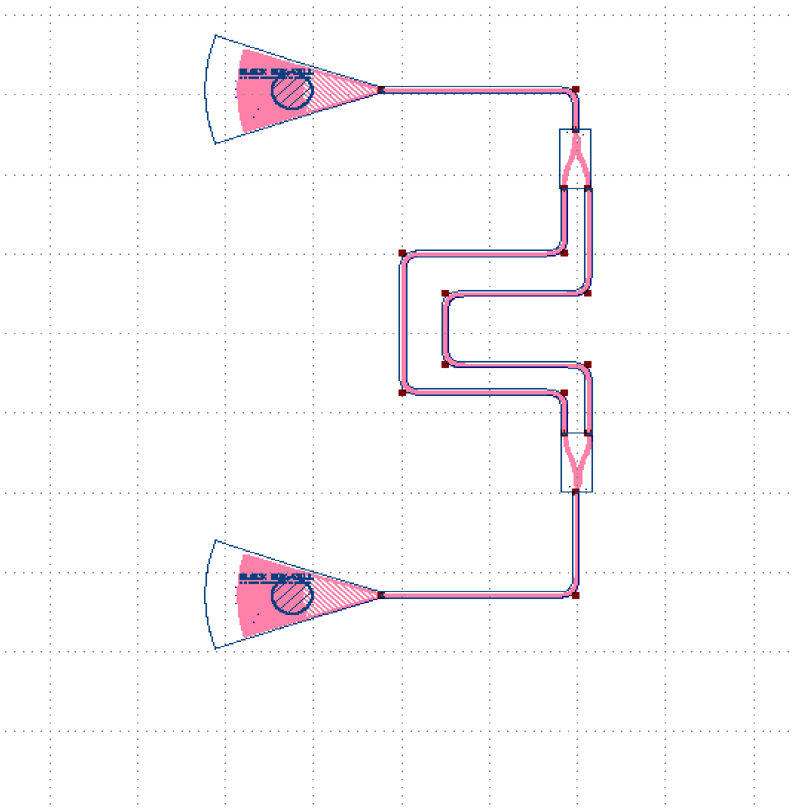
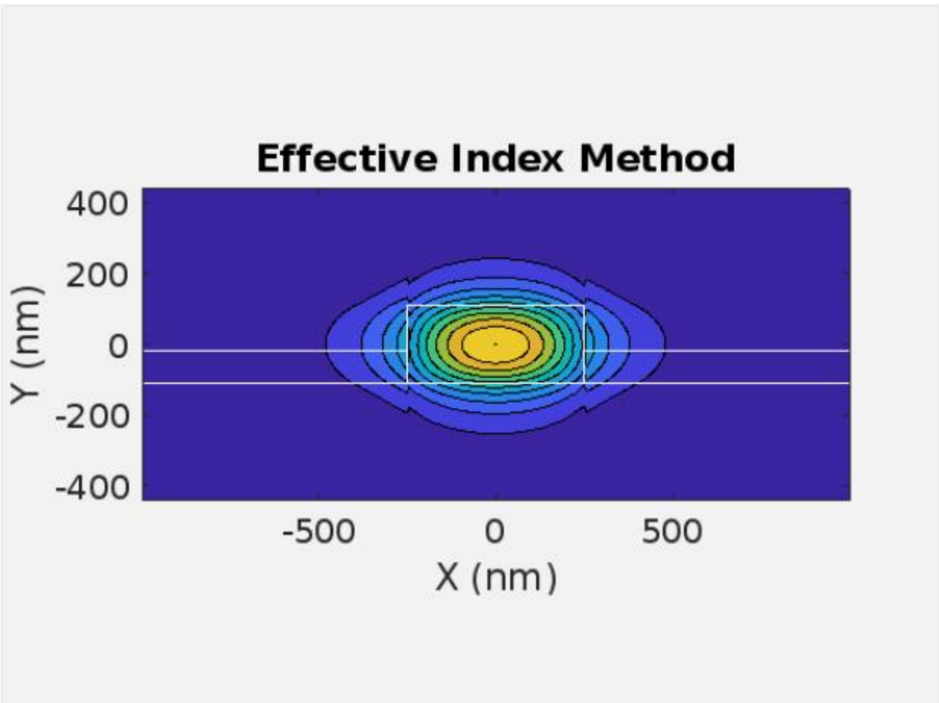


Fig 2: MZI 2 Design, Simulated Ng & MZI Transmission

- MZI3:
  - The predicted Ng is 4 from the simulation data.
  - The obtained Ng is 3.93 from the post fabrication data provided.





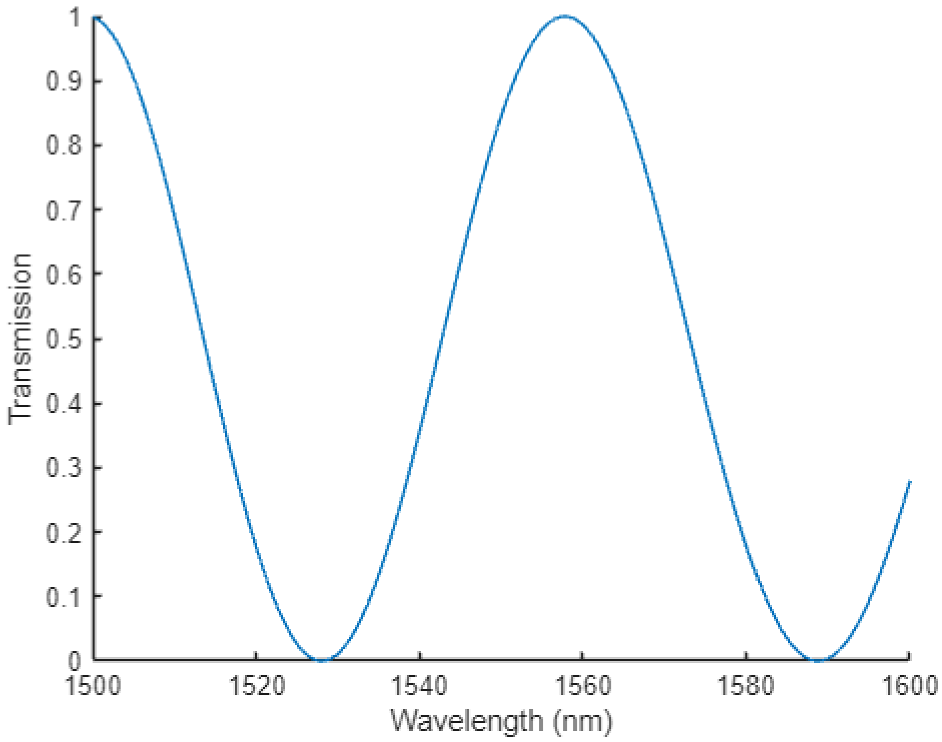


Fig 3: MZI 3 Design, Simulated Ng & MZI Transmission

- The Free Spectral Range(FSR) was calculated using the lumerical MODE software, The distance between two peaks were identitfied from the simulation and that distance was considered as the FSR for that given design.
    - MZI 1:
        - The predicted FSR is 18.39 from the simulation data.
    - MZI 2:
        - The predicted FSR is 17.50 from the simualtion data.
    - MZI 3:
        - The predicted FSR is 15.91 from the simulation data.

Experimental Results:

- MZI Transmission spectra
    - MZI 1: Transmission spectra

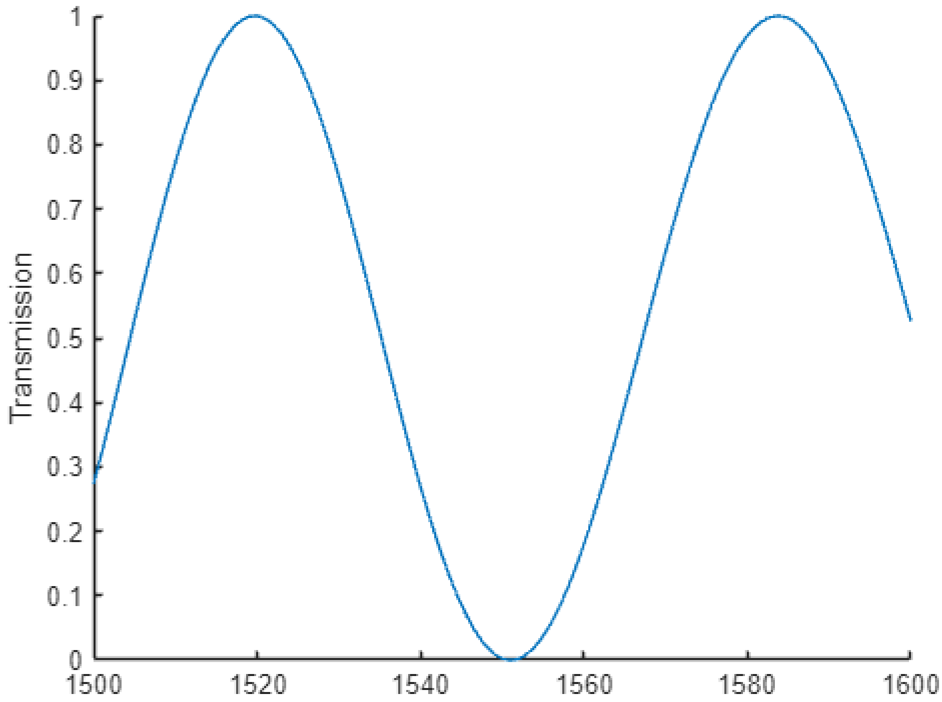


Fig 4: Transmission spectra dB VS NM

- MZI 2: Transmission spectra

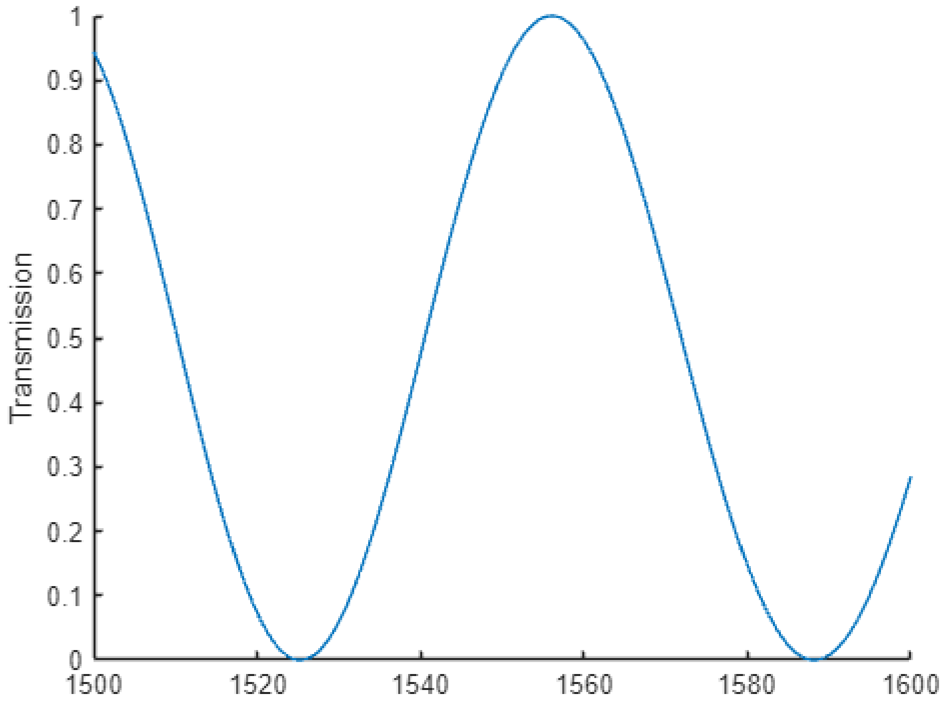


Fig 5: Transmission spectra dB VS NM

- MZI 3: Transmission spectra

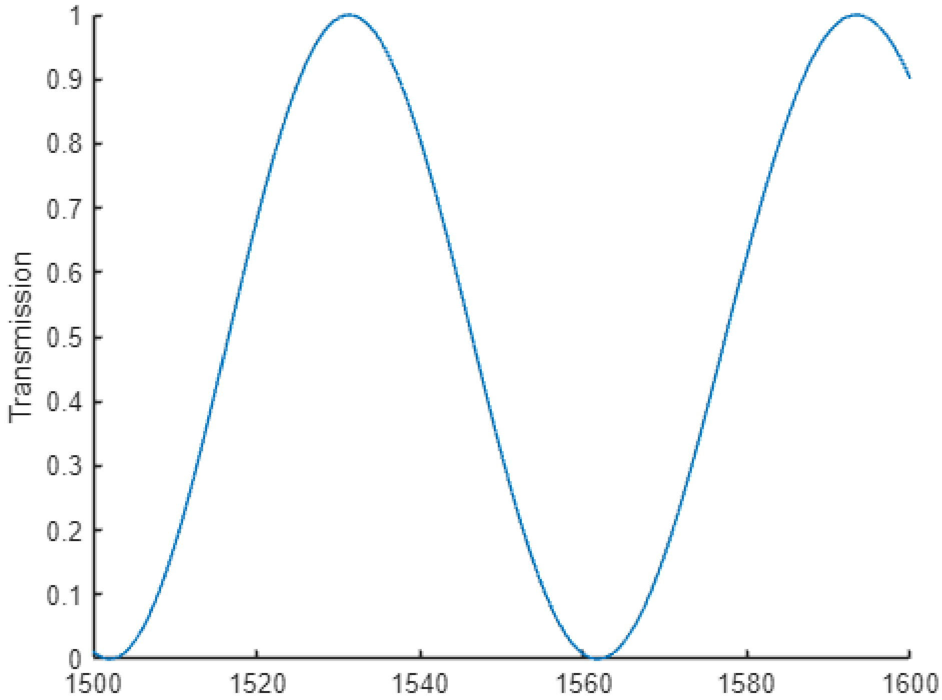


Fig 6: Transmission spectra dB VS NM

- The Free Spectral Range(FSR) was calculated using the data provided from the fabrication process, The distance between two peaks were identitfied from the graph produced from the Channel 3 of the data provided and that distance was considered as the FSR for that given design.

  - MZI 1:

    - The obtained FSR is 18.00 from the post fabrication data provided.

  - MZI 2:

    - The obtained FSR is 17.15 from the post fabrication data provided.

  - MZI 3:

    - The obtained FSR is 15.46 from the post fabrication data provided.

- Extraction and discussion of Group Index
    - Group index obtained for MZI 1 is 3.76 compared to the predicted group index of 4

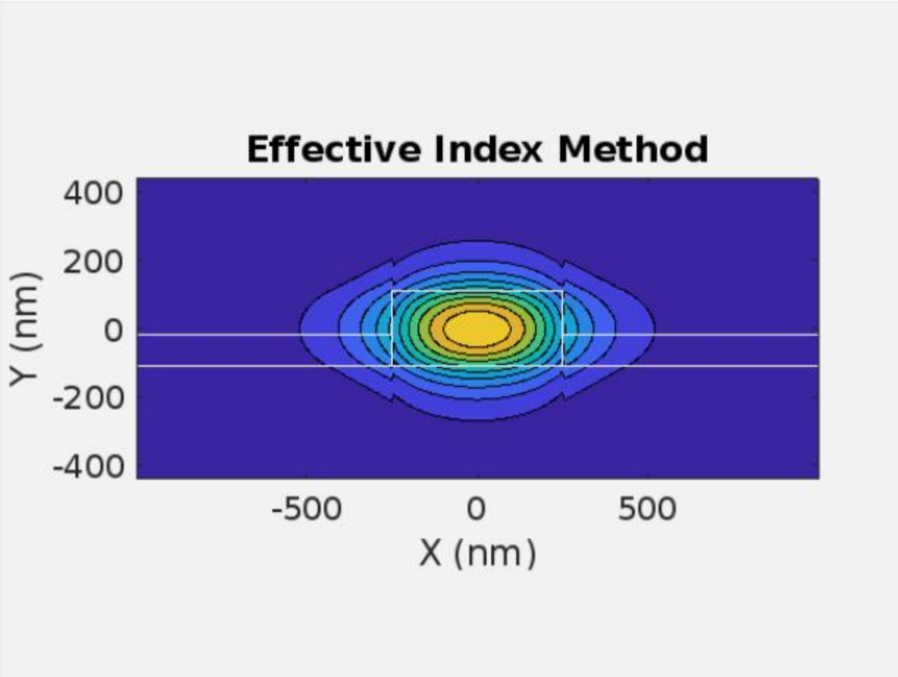


Fig 7: Obtained Ng

    - Group index obtained for MZI 2 is 3.85 compared to the predicted group index of 4

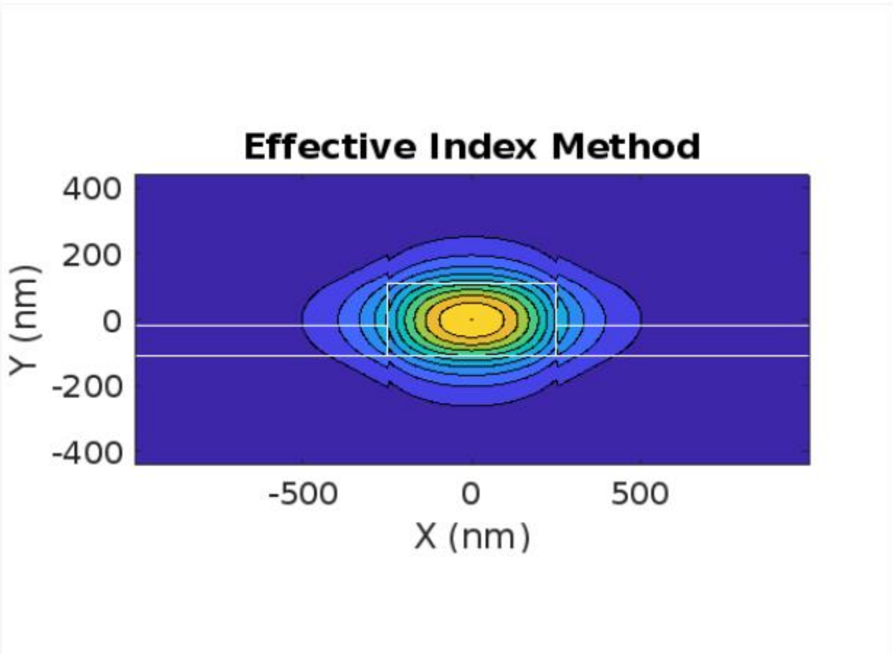


Fig 8: Obtained Ng

- Group index obtained for MZI 3 is 3.93 compared to the predicted group index of 4

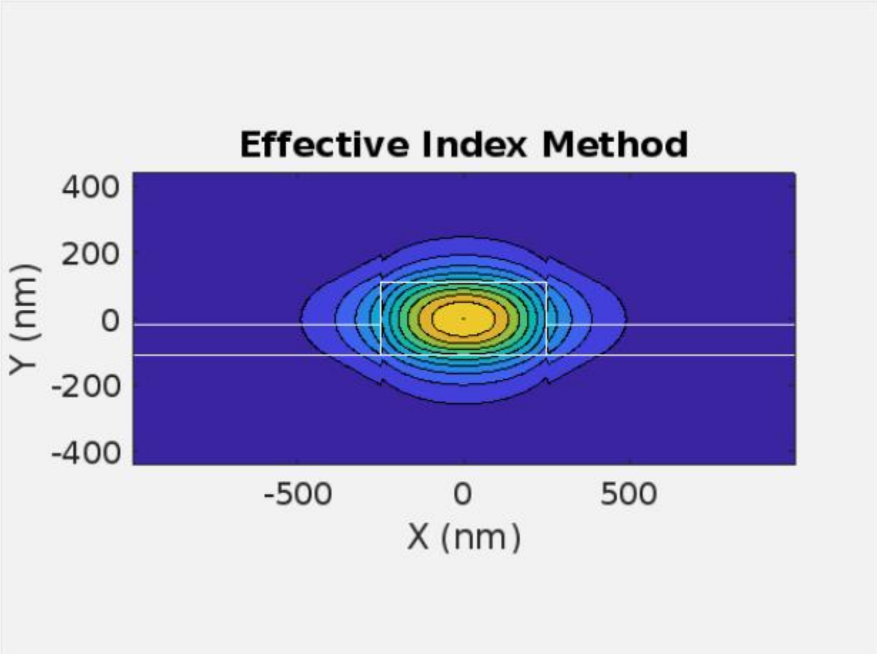


Fig 9: Obtained Ng

Fabrication tolerance analysis:

- The primary limitation to overcome was to efficienty design a minimum of six or more MZI's to fit into the given base sizing parameter with possible buffer spacing betweeen each design to prevent fabrication errors.
- The thinckness variation was considered to be +/- 50nm from the designed specification of 500nm.
- A repetative noise presence was found in each design simulation post fabrication which could be due to the noise floor set during the fabrication process.

Conclusion

- The predicted group index for the three designs were considered to be 4 and the data from the fabrication process show the obtained group index is fairly close to the predicted index.

- The same conclusion can be derived for the MZI's FSR which have stayed within the predicted range of +/- 50 for each design.

- The simplicity in the structure design prevented any sort of discrepancy due to the fabrication process.

Part B

Introduction:

The section B of the design consists of a simple interferometer as it was one of the required parameters, the remaining two designs were implemented with a double Y-splitter as part of the design with variying waveguide lengths with curves introduced to each of them.

The parameters were set to 1550nm as the wavelength and the MZI's were design with TE polarization along with a performance metrics of 0.5dB Bandwidth: +/- 50nm and a Splitting ratio of 50% at given wavelength and this was done to focus on the parameters change and performance change post fabrication in order to study the overall limitations of the process and the possible impacts of the data obtained from the fabrication compared to the simulations.

Design details:

- The design structure was maintained across the 3 MZI designs, The waveguide lengths and the use of Y-splitters were unique to each design.

- The length assigned to MZI 4 was 165.44nm, followed by MZI 5 with 264.37nm and finally MZI 6 with 379.20nm.

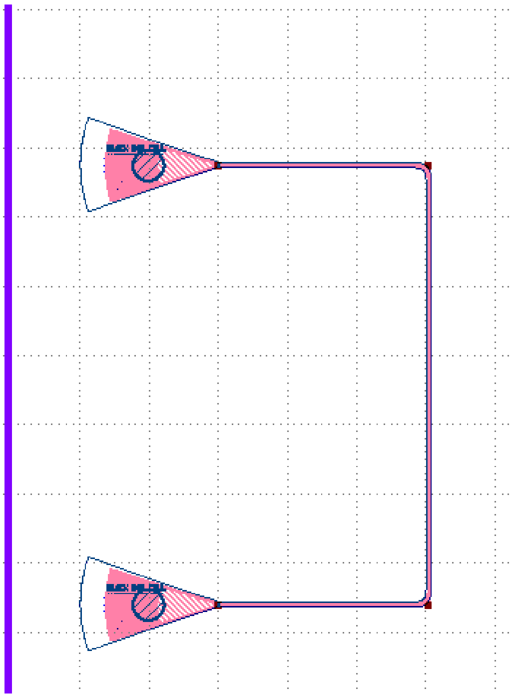
- A Y-splitter was introduced at 67.33nm in MZI 5 with a length of 9.42nm, A double Y-splitter was implimented in MZI 6, the first Y-spliiter was integrated into the design at 59.13nm followed by another Y-splitter at 272.45nm.

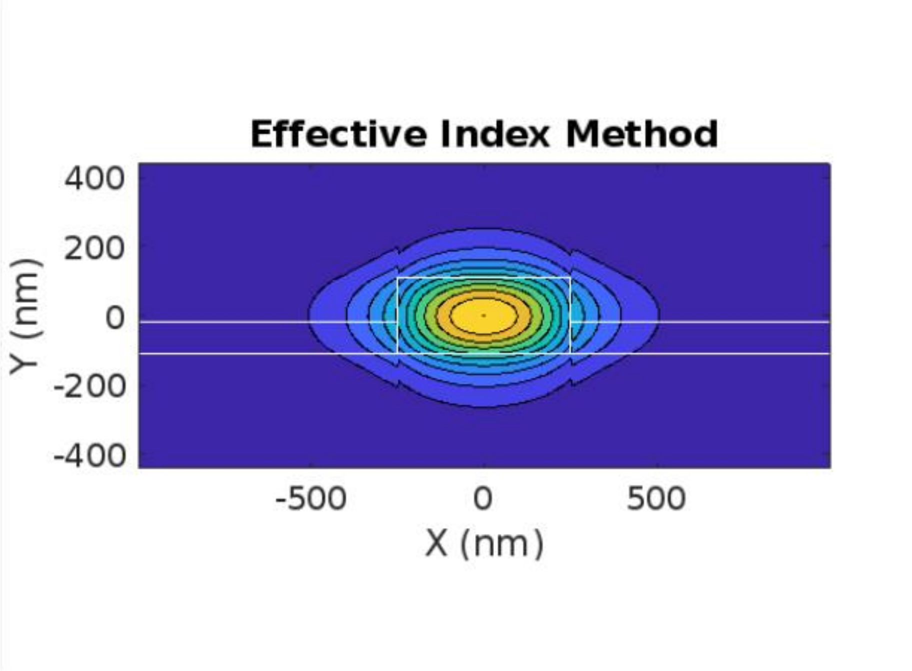
Device modelling:

- The primary step is to design the light input and output, then the length of the waveguide along with the minimum length required to introduce a curve to the waveguide is analysied and implemented into the structure.

- The implimentation of the Y-spliter is used inorder to introduce a phase shift onto the incoming light source like in the fifth and sixth deisgn.

- MZI 4:
    - The predicted Ng is 4 from the simulation data.
    - The obtained Ng is 3.83 from the post fabrication data provided.





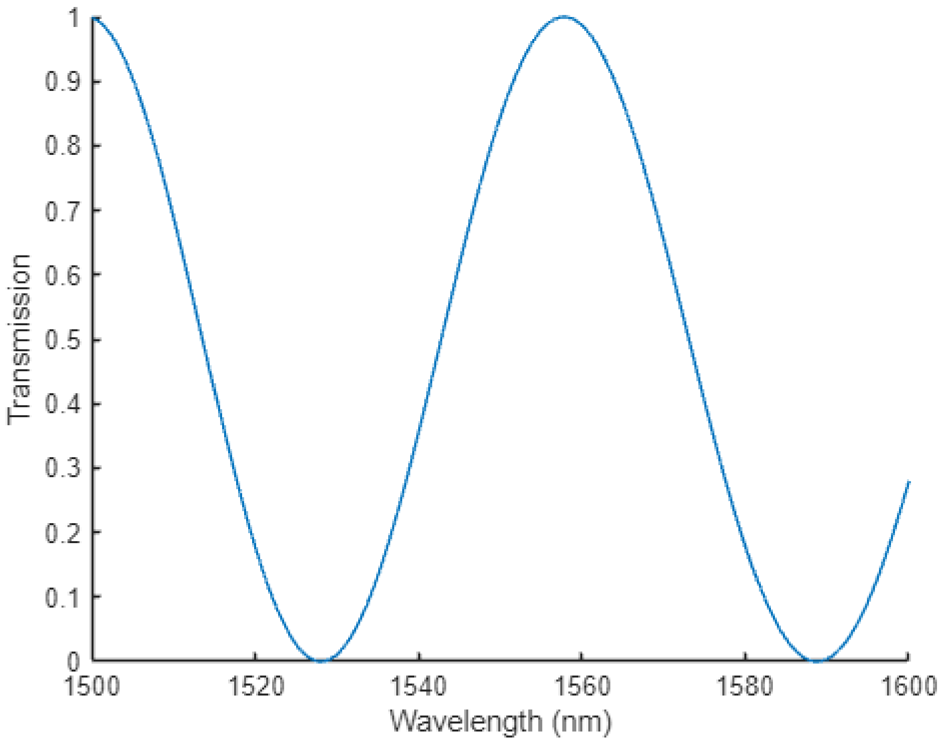
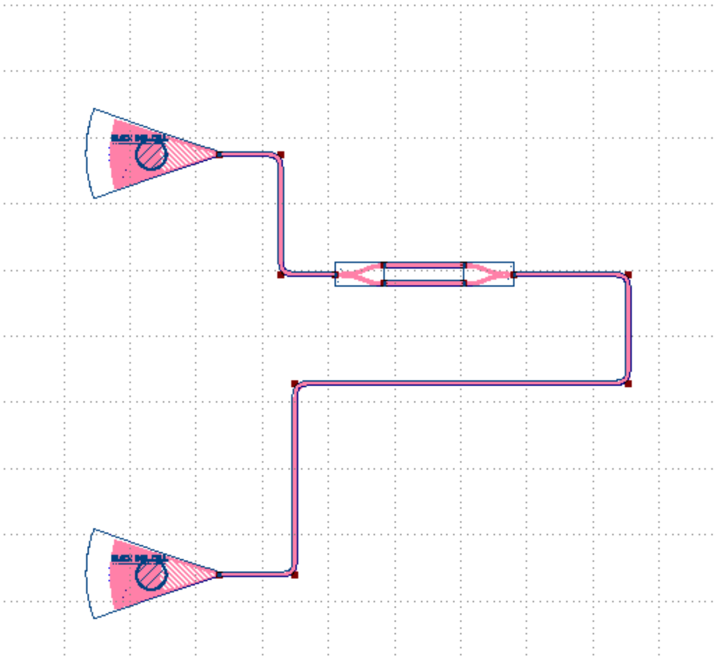
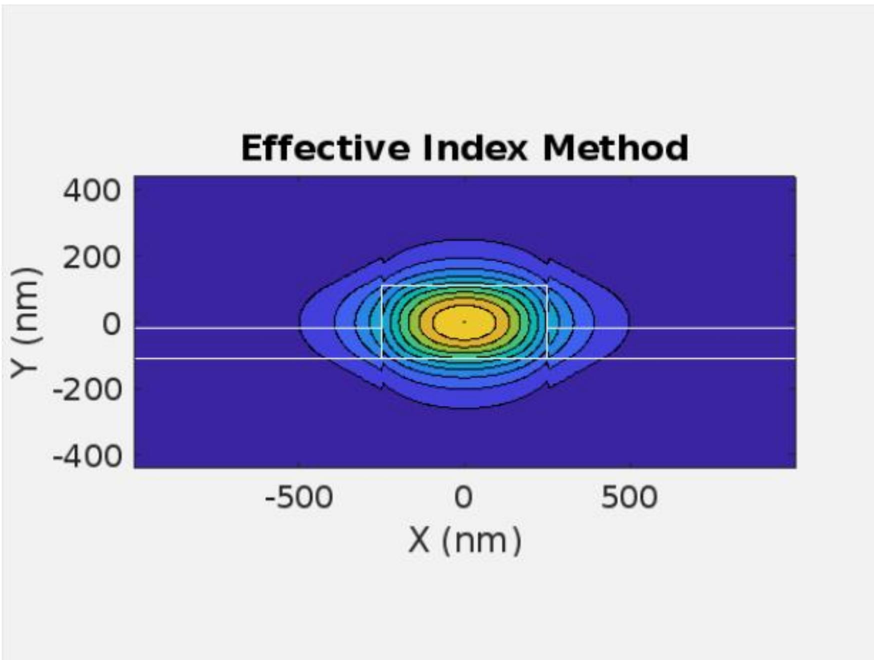


Fig 9: MZI 4 Design, Simulated Ng & MZI Transmission

- MZI 5:
    - The predicted Ng is 4 from the simulation data.
    - The obtained Ng is 3.88 from the post fabrication data provided.





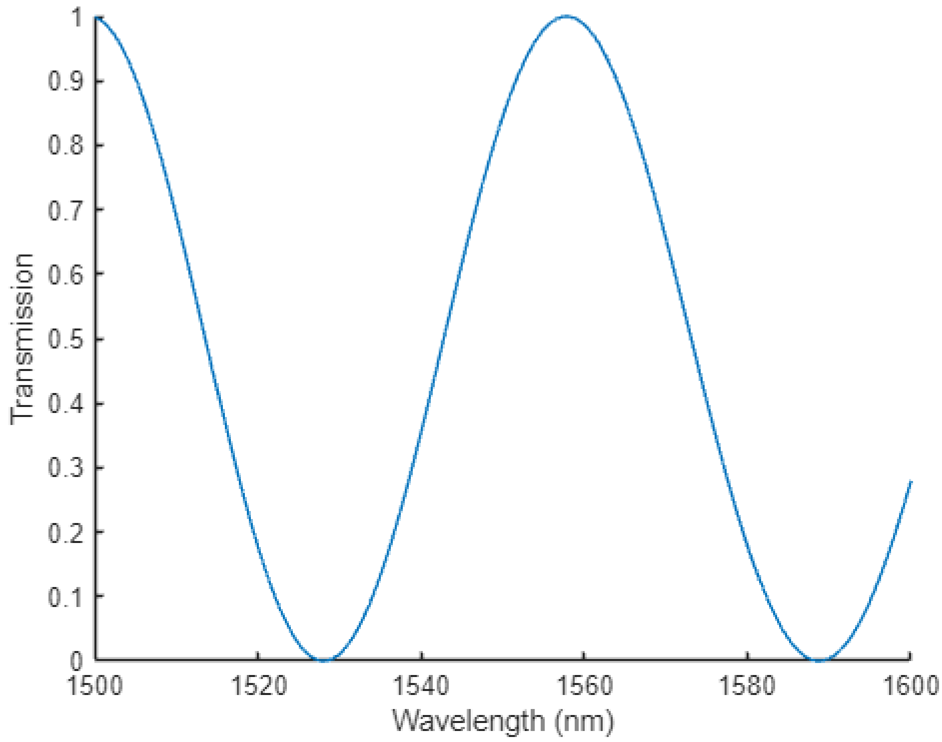
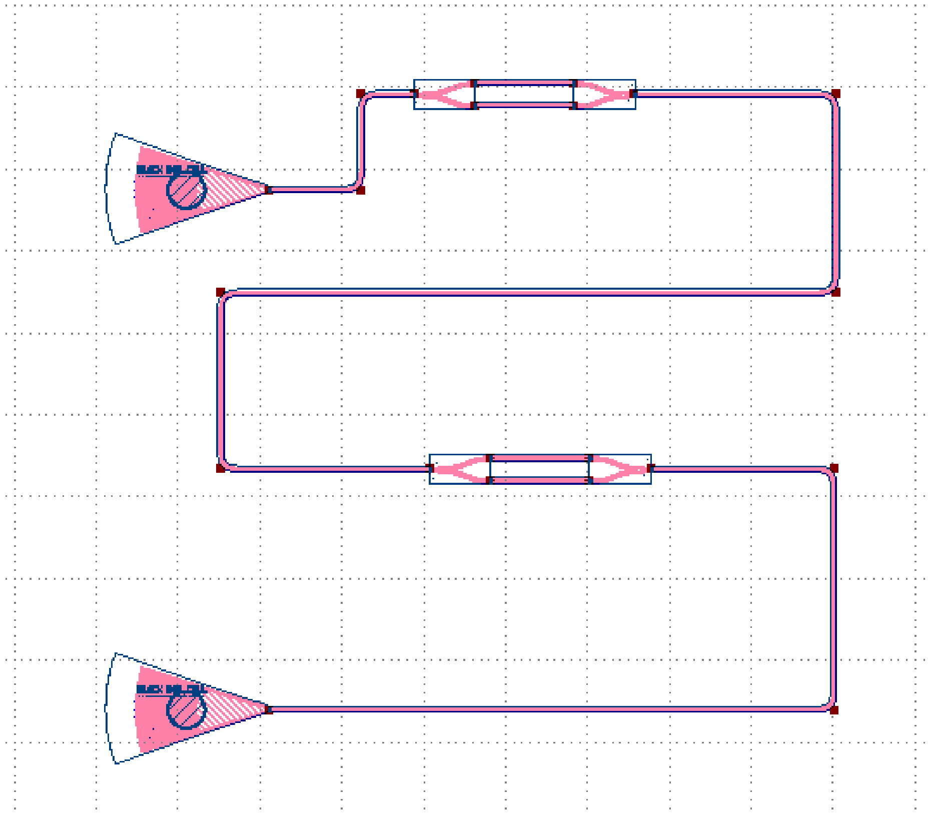
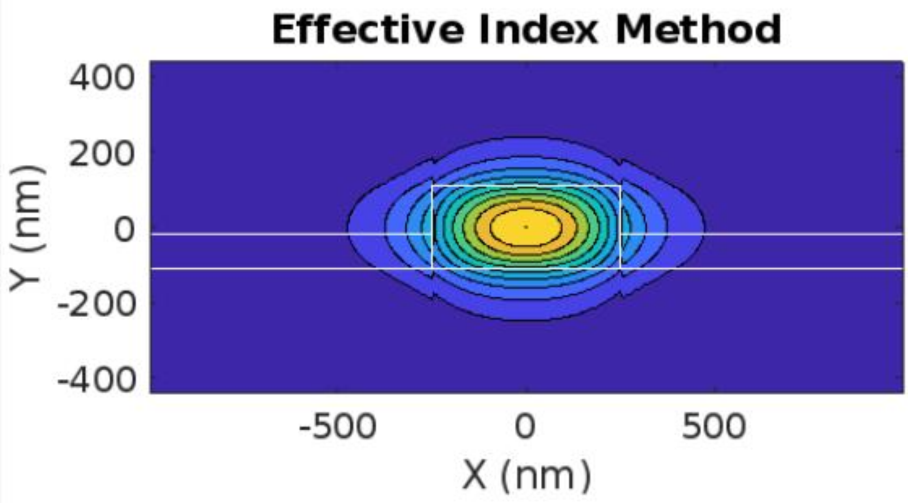


Fig 10: MZI 5 Design, Simulated Ng & MZI Transmission

- MZI 6:
    - The predicted Ng is 4 from the simulation data.
    - The obtained Ng is 4.05 from the post fabrication data provided.





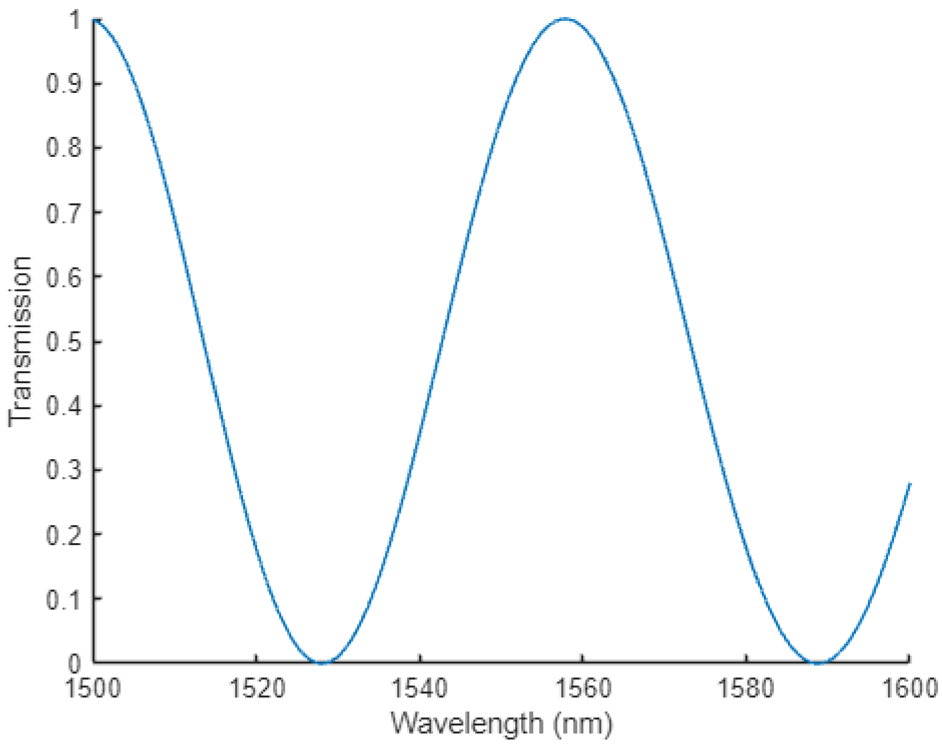


Fig 11: MZI 6 Design, Simulated Ng & MZI Transmission

- The Free Spectral Range(FSR) was calculated using the lumerical MODE software, The distance between two peaks were identitfied from the simulation and that distance was considered as the FSR for that given design.
    - MZI 1:
        - The predicted FSR is 17.94 from the simulation data.
    - MZI 2:
        - The predicted FSR is 18.52 from the simualtion data.
    - MZI 3:
        - The predicted FSR is 19.45 from the simulation data.

- The Free Spectral Range(FSR) was calculated using the data provided from the fabrication process, The distance between two peaks were identitfied from the graph produced from the Channel 3 of the data provided and that distance was considered as the FSR for that given design.
    - MZI 1:
        - The obtained FSR is 17.99 from the post fabrication data provided.
    - MZI 2:
        - The obtained FSR is 18.75 from the post fabrication data provided.
    - MZI 3:
        - The obtained FSR is 19.66 from the post fabrication data provided.

Experimental Results:

- MZI Transmission spectra
    - MZI 4: Transmission spectra

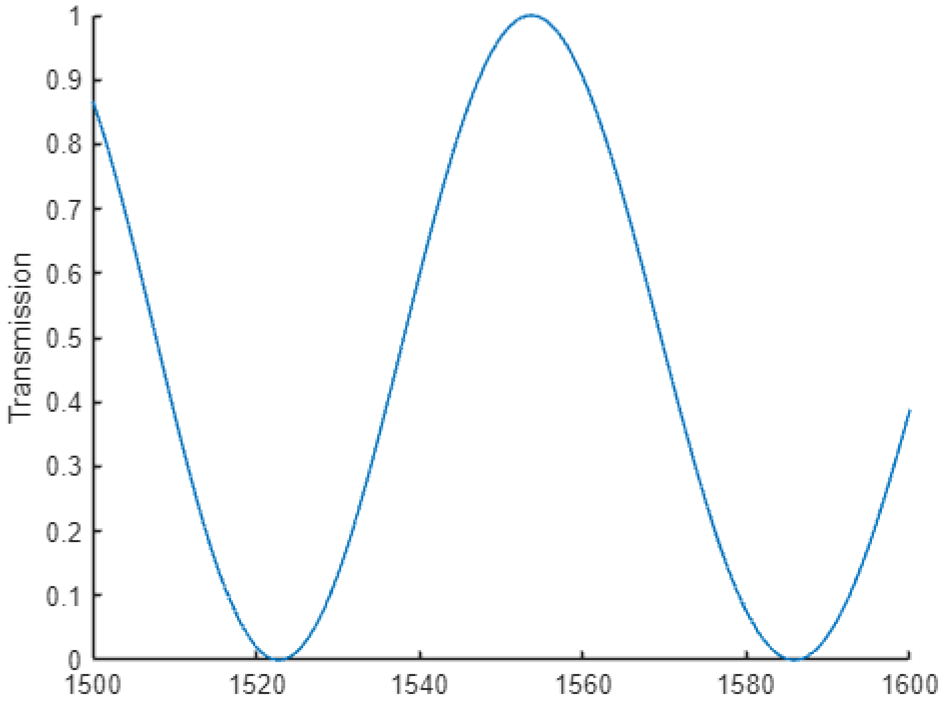


Fig 11: Transmission spectra dB VS NM

- MZI 5: Transmission spectra

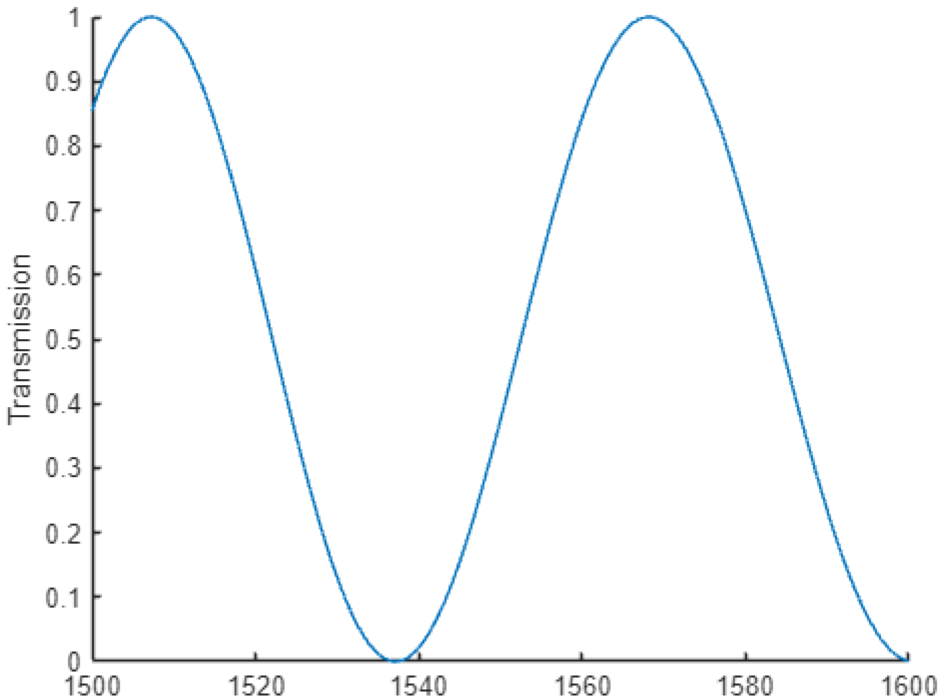


Fig 12: Transmission spectra dB VS NM

- MZI 6: Transmission spectra

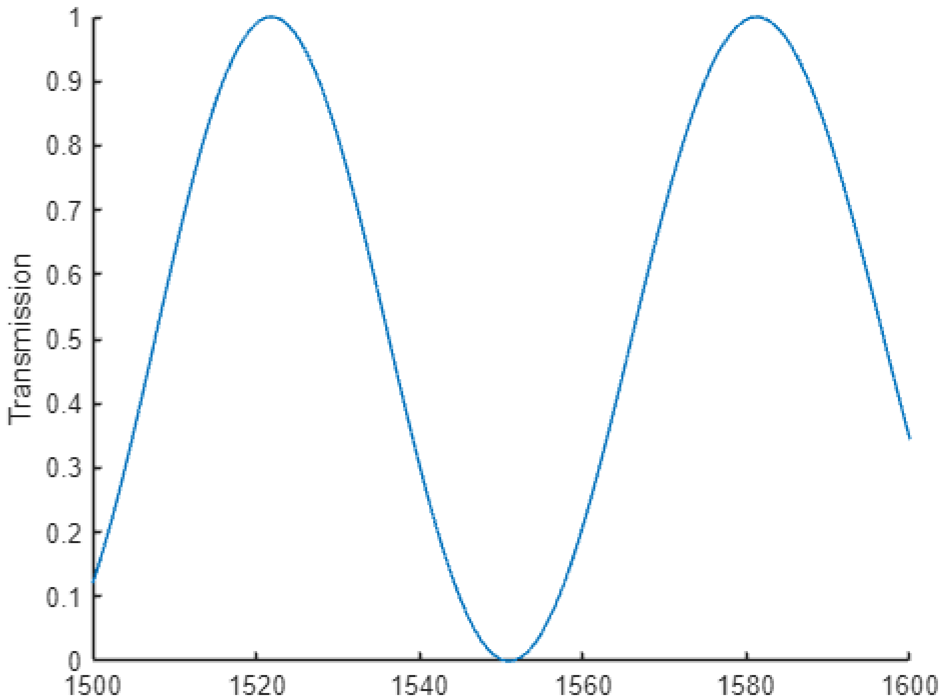


Fig 13: Transmission spectra dB VS NM

- 0.5dB Bandwidth with +/- 50nm was considered for the performance metrics and when the simualted results and the fabrication results are compared the overall bandwith loss was within the predicted range of +/-50nm as in categorised in the range of +/-30nm.

- The unavailability of post fabrication files posed as a major limitation to further analysis of the structures and compare results, All the above data was infered from the given CSV files and the simulation data.

Fabrication tolerance analysis:

MZI 6 was consisdered for the fabrication tolerance analysis, The overall structures integrity was maintained for all six designs due to the space buffer given to the limitation parameters during the structure design phase, A wavelength error buffer of +/- 50nm was expected between the simulation and fabrication data, As expected the fabrication data for the wavelength fell in the error buffer, the overall FSR was observed to be fairly relative to the simulation FRS obtained. The 0.5dB bandwidth performance metric which was implimented in this design was calculated to be +/-30nm in the fabrication whereas the data was +/-50nm for the simulation. The calculated group index was found to be Ng = 4.05 compared to the group inxed of 4 which was considered for all the designs.

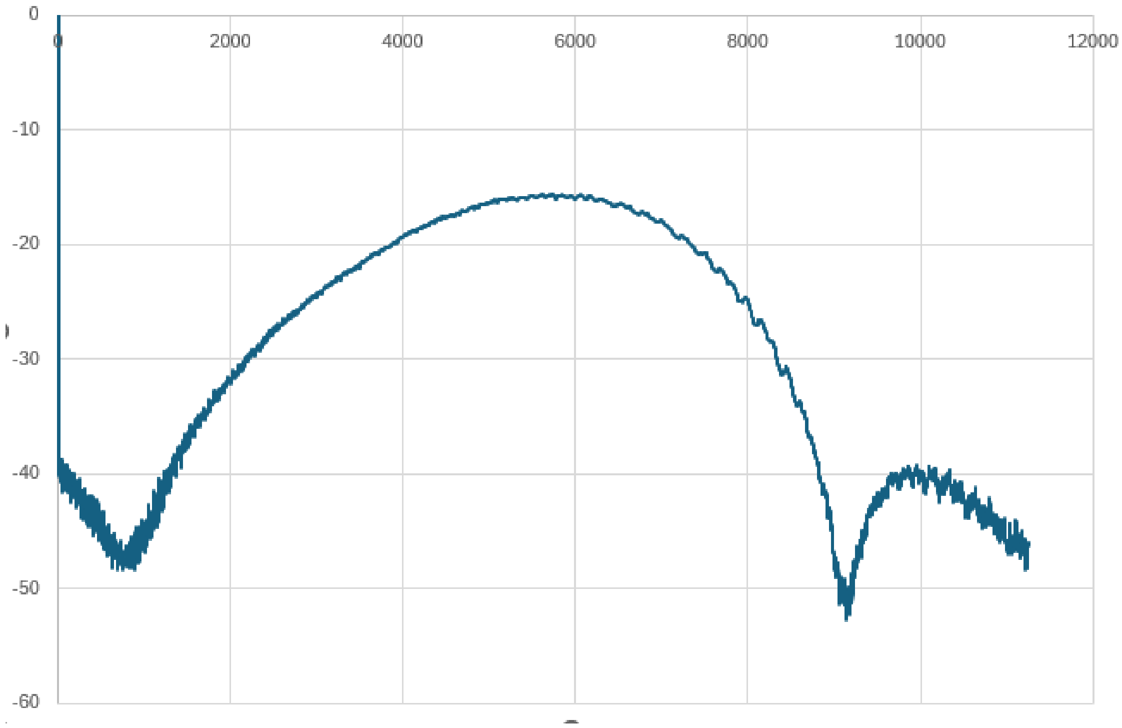


Fig 14: MZI 6 Comparison between Wavelength(nm) (X-axis) VS Channel 3(nm) (Y-axis)

One of the major factors to be considered during fabrication was the noise floor set for the fabrication device, This factor let to a lot of noise detection in the graphs calculated from the fabrication data which could have been avoided.

Conclusion:

The overall experiment results were closer to the predicted data through the simulations than they were anticipated to be, The general expectations from the simulatied data and fabrication data was satisfactory.

A possible implimentation for future designs would include more advanced and complex designs to compare the FSR and Ng of the simulations and the fabrication data, Noise filters using matlab could be implimented into the post fabrication data calculation to reduce the noise detection of the noise floor of the fabricator during calculations of graphs.

Finally, I would like to thank Dr.Judson Ryckman for providing me with the opportunity to gain knowledge in the Silicon photonics industry along with the invaluable hands on experience with designing interferormeter structures using the KLayout software and its fabrication.