Design Proposal for Mach-Zehnder Interferometer

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Abstract

Photonic integrated circuits (PICs) are playing an increasingly significant role in optical communication and signal processing applications. This draft report presents the design and preliminary analysis of a ***Mach-Zehnder Interferometer (MZI)*** *fabricated using the* ***silicon-on-insulator (SOI) platform****. The device consists of* ***oxide-cladded waveguides*** *and utilizes standard components from the* ***EBeam Library on KLayout****, including* ***grating couplers, waveguides, and splitters****. The design process involves numerical simulations using* ***Lumerical MODE and INTERCONNECT****, as well as compact modeling in* ***MATLAB and Python*** *to analyze waveguide parameters such as effective index, group index, and propagation loss. The fabricated device will be tested for transmission characteristics, filter performance, and process variations. This draft serves as an initial submission, outlining the theoretical background, modeling methodology, and expected outcomes of the design.*

I. Introduction

The rapid advancement of integrated photonics has enabled the development of compact and efficient optical devices that leverage silicon-based fabrication techniques. Among these, the Mach-Zehnder Interferometer (MZI) is widely used in optical filtering, sensing, and communication due to its ability to manipulate and measure phase differences in light propagation.

This project focuses on designing and fabricating an oxide-cladded MZI using Applied Nanotools Inc. as the fabrication foundry. The layout is implemented in KLayout using standard components from the EBeam Library, with a particular emphasis on waveguide and splitter design for TE-polarized light at 1310 nm. The simulation and modeling process will incorporate Lumerical MODE and INTERCONNECT to validate optical performance, while additional analyses in MATLAB and Python will provide insights into the waveguide's compact model.

The final goal is to fabricate a functional MZI device with a 25 GHz free spectral range filter, accounting for fabrication process variations such as thickness and width deviations. The project is subject to strict deadlines, as the external foundry has a firm submission schedule. This report presents a draft design, including theoretical background, initial modeling results, and the proposed fabrication process.

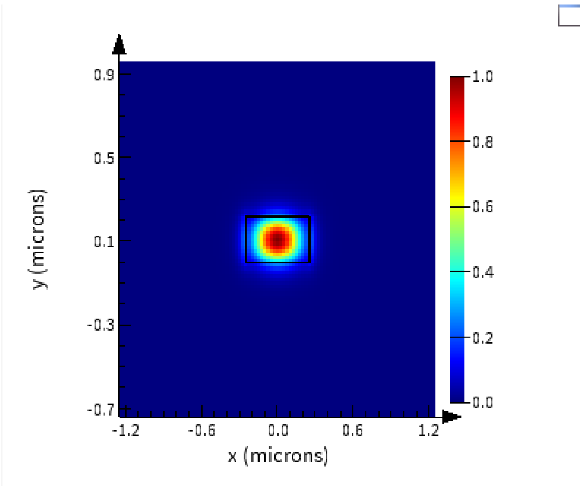
II. Theoretical Background

- Explanation of key concepts relevant to your design.
- Mathematical formulations and equations.
- Reference to prior research or related work.

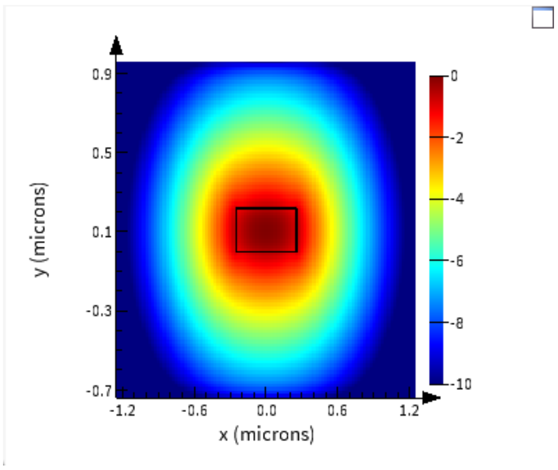
III. Modeling and Simulation

A. Waveguide Modelling

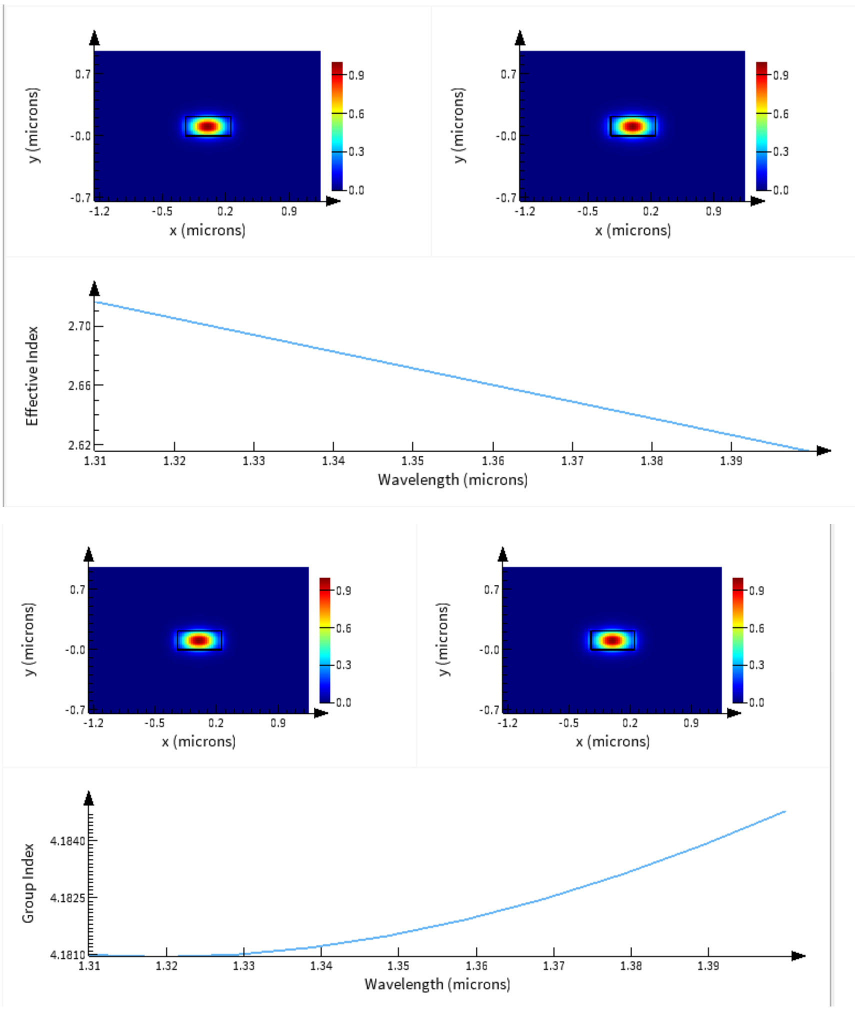
Fundamental modes of the SOI waveguide in Lumerical MODE (220 nm*350 nm)



Linear Scale E Intensity Plot

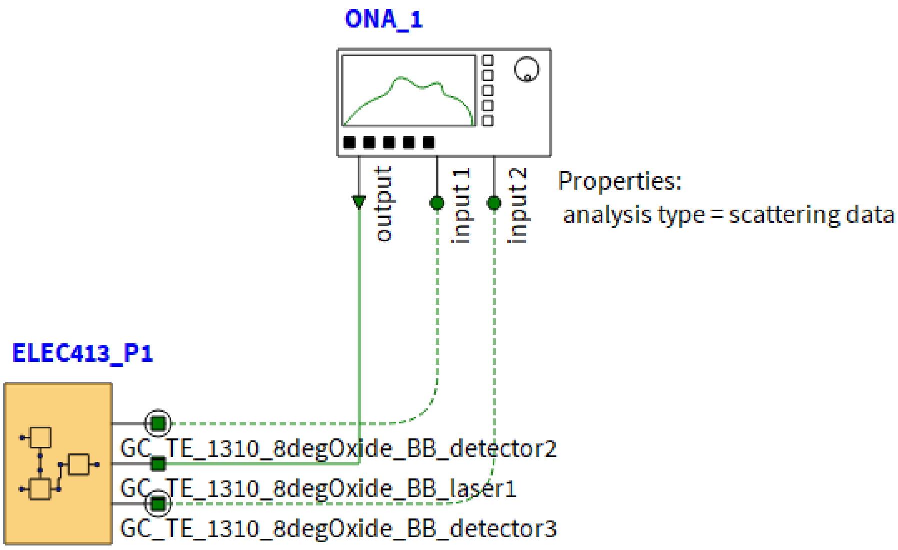


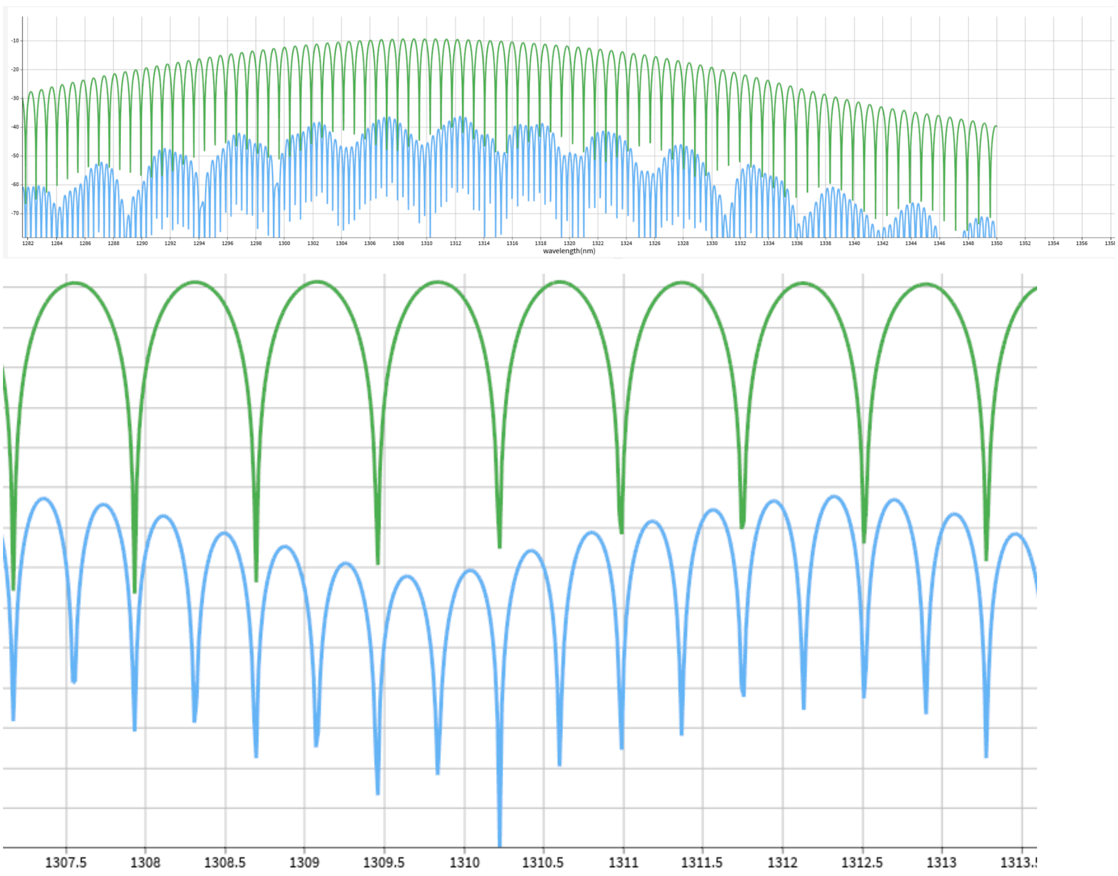
Log Scale E Intensity Plot



Effective Index and Group Index Plot With Wavelength Sweep Starting at 1310nm

C. Circuit/Device Simulation

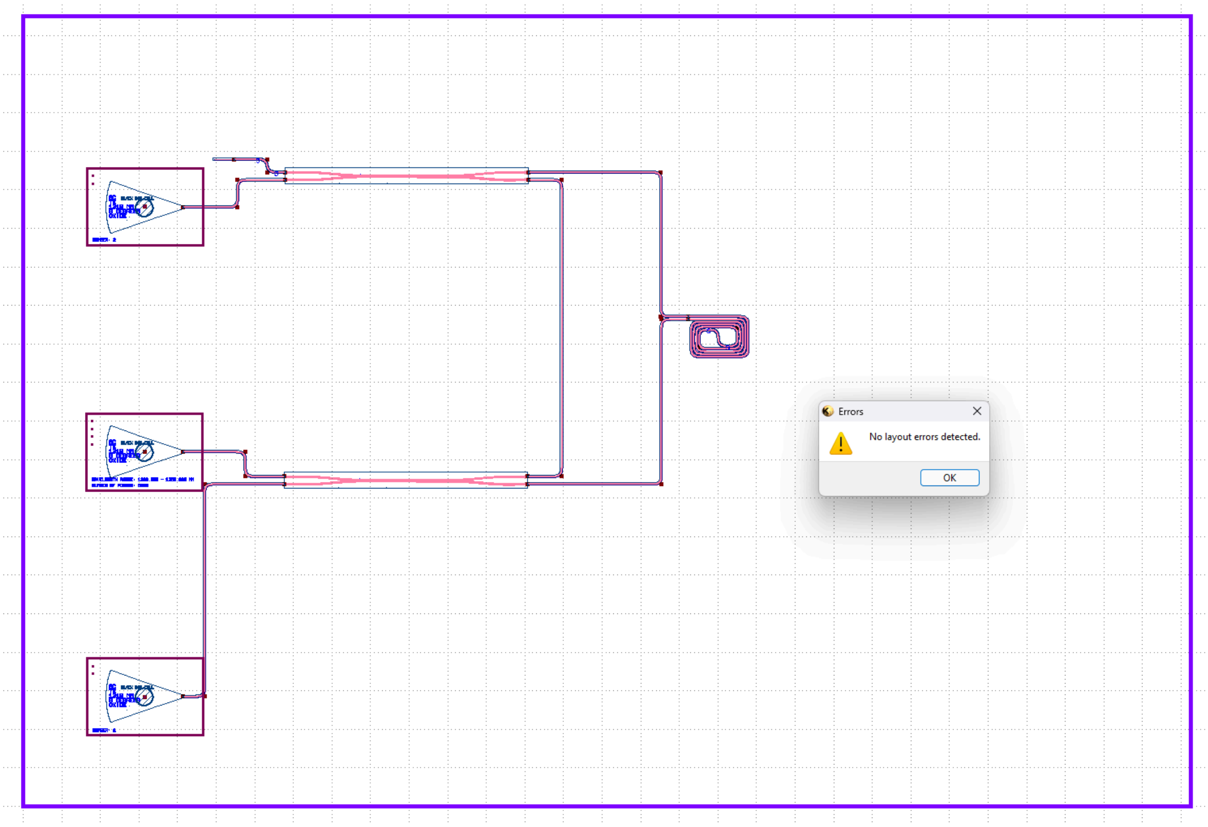




Transmission Spectra of my MZI circuit

V. Design and Fabrication Considerations

Proposed design layout and fabrication details.



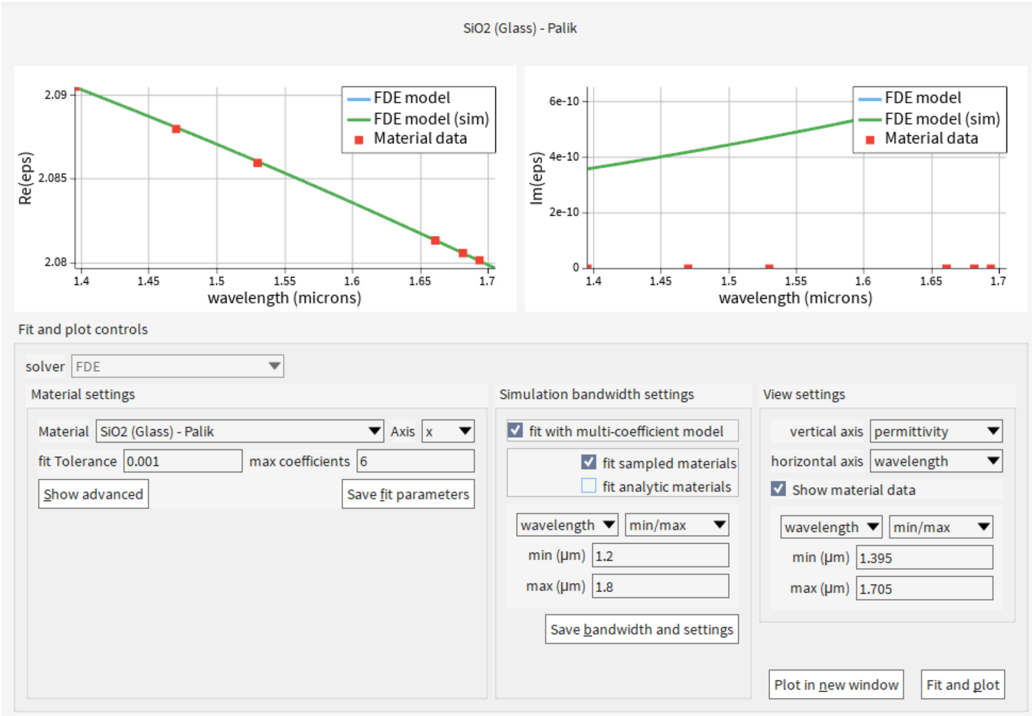
VI. Conclusion and Future Work

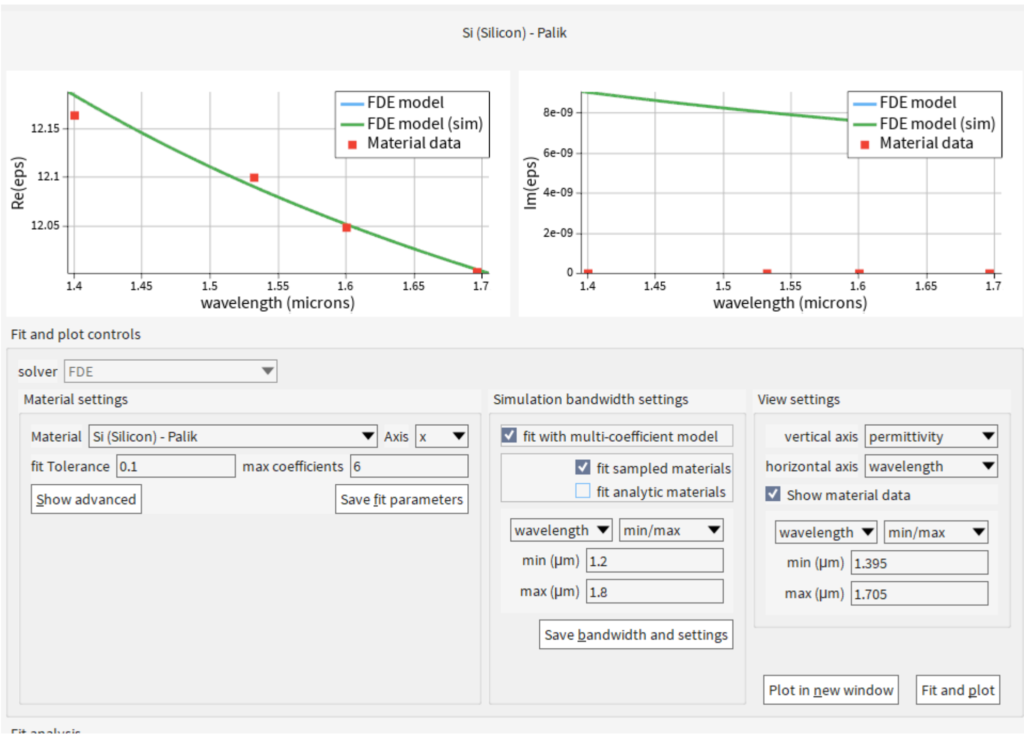
This report presents the initial design and layout verification of a Mach-Zehnder Interferometer (MZI) using the silicon-on-insulator (SOI) platform with oxide-cladded waveguides. The design has been implemented in KLayout utilizing components from the EBeam Library, and preliminary checks indicate that no layout errors have been detected.

However, further work is required to refine and optimize the design. The next steps involve conducting detailed simulations in Lumerical MODE and INTERCONNECT to evaluate waveguide performance, effective refractive index variations, and propagation loss. Additionally, post-layout simulations need to be performed to validate the circuit's behavior under realistic fabrication variations. Only after these verifications will the design be ready for submission to fabrication.

This draft serves as a foundational step, and further refinement, validation, and optimization are essential before finalizing the fabrication submission.

References


SiO2 (Glass) - Palik
Re(eps)
2.09
2.085
2.08
1.4
1.45
1.5
1.55
1.6
1.65
1.7
wavelength (microns)
FDE model
FDE model (sim)
Material data
Im(eps)
6e-10
4e-10
2e-10
0
wavelength (microns)
Fit and plot controls
solver
FDE
Material settings
Material
SiO2 (Glass) - Palik
Axis
x
fit Tolerance
0.001
max coefficients
6
Show advanced
Save fit parameters
Simulation bandwidth settings
fit with multi-coefficient model
fit sampled materials
fit analytic materials
wavelength
min/max
min (µm)
1.2
max (µm)
1.8
Save bandwidth and settings
View settings
vertical axis
permittivity
horizontal axis
wavelength
Show material data
min (µm)
1.395
max (µm)
1.705
Plot in new window
Fit and plot


Si (Silicon) - Palik
Re(eps)
12.15
12.1
12.05
1.4
1.45
1.5
1.55
1.6
1.65
1.7
wavelength (microns)
FDE model
FDE model (sim)
Material data
Im(eps)
8e-09
6e-09
4e-09
2e-09
0
wavelength (microns)
Fit and plot controls
solver
FDE
Material settings
Material
Si (Silicon) - Palik
Axis
x
fit Tolerance
0.1
max coefficients
6
Show advanced
Save fit parameters
Simulation bandwidth settings
fit with multi-coefficient model
fit sampled materials
fit analytic materials
wavelength
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min (µm)
1.2
max (µm)
1.8
Save bandwidth and settings
View settings
vertical axis
permittivity
horizontal axis
wavelength
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Plot in new window
Fit and plot