Simulating a Mach-Zehnder Silicon Photonic Switch

Aditya Wadaskar
Major: Electrical Engineering
Mentor: Takako Hirokawa
Faculty Advisor: Professor Clint Schow
Department: Electrical and Computer Engineering
**Photonics and Electronics: What’s the Difference?**

<table>
<thead>
<tr>
<th>Photonics</th>
<th>Electronics</th>
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<tbody>
<tr>
<td>Study and application of light</td>
<td>Study of flow and control of electricity</td>
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</tbody>
</table>

- ✔ Speed
- ✔ Bandwidth
- ✔ Low Attenuation
- ✔ Immunity
- ✔ Durability
- ✔ Security

### Cables
- **Optical Fibers**
- **Coaxial Copper Cable**
Managing Growth in Data Centers

- Global data traffic expected to increase from 6.2 EB (10^{18} bytes) per month in 2016 to 30.6 EB per month in 2020
- As a result, data centers continue growing in size and complexity

- **Photonic Switch**: Reroutes information transmitted as light of a certain wavelength
- **Used for optical networking**

![4 x 4 Switch Diagram]
Simulating a Mach-Zehnder Photonic Switch: Research Goals

1. Determine bandwidth – Range of frequencies that can be rerouted
2. Simulate loss
3. Optimize switch – Increase efficiency, reduce crosstalk and footprint

Layout of a Mach-Zehnder Block: A Portion of the Photonic Switch
Simulating a Mach-Zehnder Switch: Research Methods

Performance Check

<table>
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<tr>
<th>Calculate Parameters</th>
<th>Determine Bandwidth</th>
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Basic test for performance of switch components at 1310 nm using Lumerical FDTD (Maxwell solver)

A Simple U Bend

Silicon Waveguide

Light Source

Monitors

Intensity along U Bend
Simulating a Mach-Zehnder Switch: Research Methods

Determine different aspects of waveguides in Lumerical MODE using modal and frequency analysis

- Effective refractive index ($n_{eff}$)
- Group index ($n_g$)
- Loss
- Dispersion

Components to test:
- Directional couplers
- 90 degree bends
- S bends
- Straight waveguides

Top left to right: S Bend, U Bend
Bottom: Directional Couplers
Simulating a Mach-Zehnder Switch: Research Methods

| Performance Checks | Calculate Parameters | Determine Bandwidth |

- Switch is assembled in Lumerical INTERCONNECT using parameters from Step 2
- BER (Bit error rate) testing and Eye Diagrams used to analyze switch performance at various frequencies
- Bandwidth determined using cutoff threshold of at most $10^{-9}$ BER.

Assembly of photonic switch and test setup in Lumerical INTERCONNECT
Results: Waveguide Parameters

Refractive Index:
• Silicon (Si): 3.44
• Silicon Dioxide/Silica (SiO₂): 1.43

Effective Index (ratio of propagation constant of light in waveguide to free space propagation constant):
• determined to be ~ 2.22 for waveguides

Loss:
• Straight waveguides: 55.92 dB/cm
• 90 degree bends: 0.028 dB

Overall, calculated parameters are most likely accurate
Ideal Case scenario:

- BER at 1310 nm much less than $10^{-9}$
- Clean and jitter-free eye diagram
Results: BER and Waveguide Bandwidth

BER: 0.024, which is incredibly high
Testing parameters may need to be changed
Future Goals: Optimizing Mach-Zehnder Switch

- Determining bandwidth of switch will help develop test cases for actual chip
- Find ways to increase efficiency and reduce crosstalk of switch
- Photonics is the future

“The 21st century will depend as much on photonics as the 20th century depended on electronics” – IYL2015


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