Optical Switches with Microring Resonators

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Benefits of Optical Fibers

• No electromagnetic interference/noise
  • Light data instead of electrical

• Require very little real estate
  • 50-125 microns in diameter (hair ~ 100 microns)

• Energy efficient
  • Data is transmitted via light = very little heat dissipation

• Coaxial cable used today is 50 Mbps.

• Optical fibers transfer data at 15 Tbps (300k faster)

• Transceivers are too expensive & inefficient
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- Coaxial cable used today is 100 Mbps.
  - Optical fibers transfer data at 15 Tbps (150k faster)
  - Transceivers are too expensive & inefficient
What is a switch?
• Creation, transition or termination of connections

What is a resonator?
• Reinforces a frequency of a waveform like light or sound

What is optical coupling?
• Light leak from one waveguide to another

All three of these concepts create an optical ring resonator
• Can redirect light
• Specific frequencies get redirected => filters them
• Size changes with thermal expansion
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Graphs of Transmission vs Wavelength

- Transmission of Through over Input vs. wavelength (μm)

\[ T_p = \frac{I_{\text{pass}}}{I_{\text{input}}} = \frac{r_2^2 a^2 - 2r_1 r_2 a \cos \phi + r_1^2}{1 - 2r_1 r_2 a \cos \phi + (r_1 r_2 a)^2} \]

\[ r^2 = \frac{P_{\text{pass}}}{P_{\text{input}}} = \text{self-coupling coefficient} \]

Graphs of Transmission vs Wavelength

\[ T_d = \frac{I_{\text{drop}}}{I_{\text{input}}} = \frac{(1 - r_1^2)(1 - r_2^2)a}{1 - 2r_1r_2a \cos \phi + (r_1r_2a)^2} \]

\[ r_1^2 = \frac{P_{\text{pass}}}{P_{\text{input}}} = \text{self-coupling coefficient} \]

- Transmission of Drop over Input vs. wavelength (\( \mu \text{m} \))

Graphs of Transmission vs Wavelength

Transmission of Drop over Input vs. wavelength (μm)

Transmission of Through over Input vs. wavelength (μm)
\[ \phi = \beta L \]
\[ \beta = \frac{2\pi n_{\text{eff}}}{\lambda} \]
\[ \lambda_{\text{res}} = \frac{n_{\text{eff}} L}{m}, \]
\[ m = 1, 2, 3, \ldots. \]

Optical crossbar switches

Refractive index: 2.2 - 2.23

Refractive index: 2.28
3) Compares reference input to real input to generate BER

1) Simulates real data

2) Converts electrical data to optical
Optical crossbar switches
• Bit Error Rate = amount of error in the bits per amount of data transmitted
  • Example: A BER of $10^{-9}$ means one error per billion bits sent.
  • Generally, staying under $10^{-9}$ is the standard

Figure Source: M. Nakazawa, H. Kubota, K. Suzuki, E. Yamada, and A. Sahara, IEEE J. Sei. Topics Quantum Electron. 6, 36 3 (2000).
Conclusion: BER (Bit Error Rate)

Data shows that as power is increased, the BER decreases.

BER with Power at 1 dBm vs the change in refractive index

BER with Power at 2 dBm vs the change in refractive index
Future Goal: Calculate Crosstalk

\[ 10 \log\left(\frac{P_{\text{cross}}}{P_{\text{in}}}\right) = \text{crosstalk (dB)} \]
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Faculty advisor: Professor John Bowers
CSEP: Wendy Ibsen & Jens-Uwe Kuhn
Others: Fellow research interns