UNIVERSITY OF CALIFORNIA SANTA BARBARA
ELECTRICAL AND COMPUTER ENGINEERING

Optical Switches with Microring Resonators

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AIM photonics
AMERICAN INSTITUTE for MANUFACTURING INTEGRATED PHOTONICS

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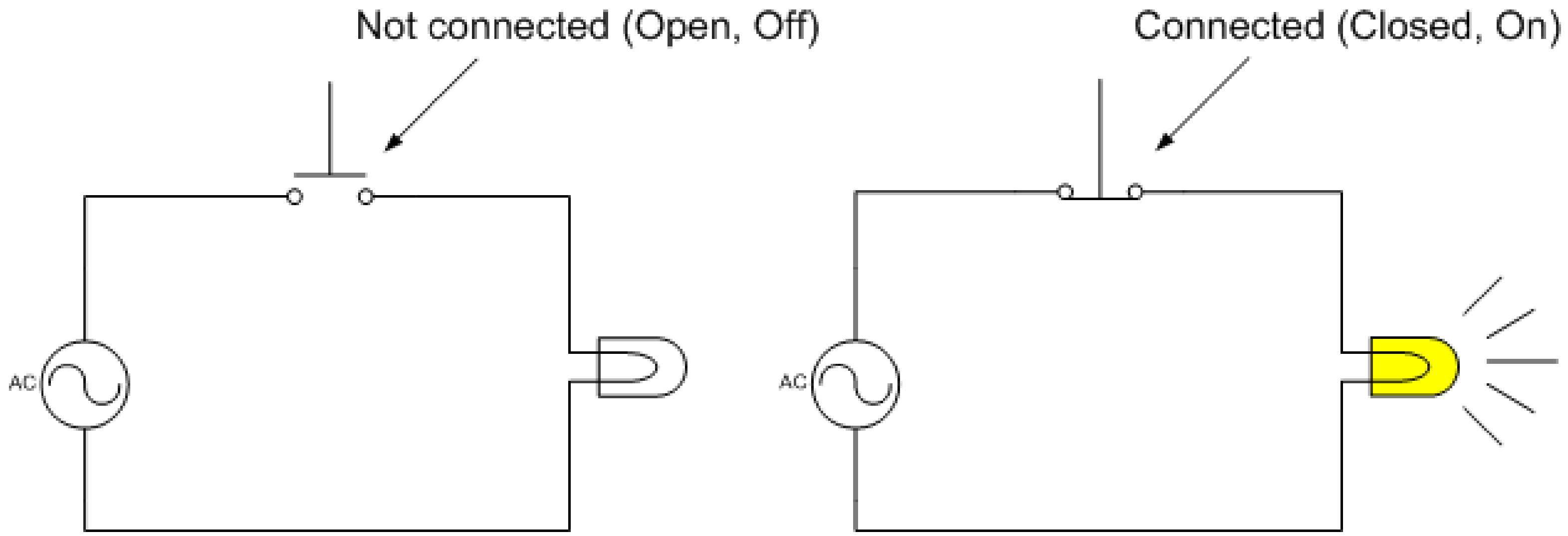
- Coaxial cable used today is 100 Mbps.
  - Optical fibers transfer data at 15 Tbps (150k faster)
  - Transceivers are too expensive & inefficient

What is a Microring Resonator?

- What is a switch?
  - Creation, transition or termination of connections



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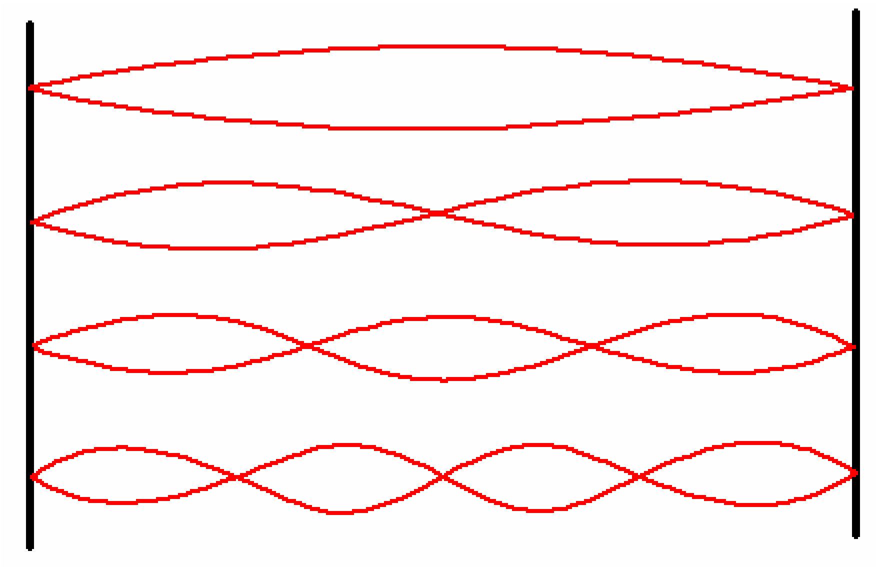

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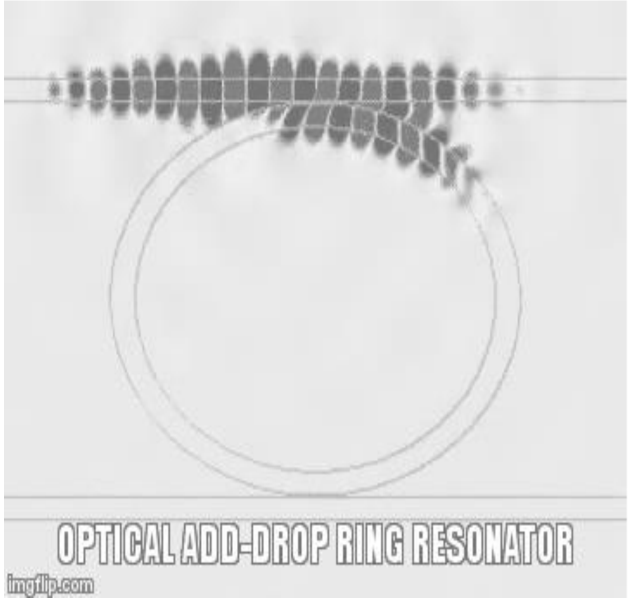
  - Reinforces a frequency of a waveform like light or sound
- What is optical coupling?
  - Light leak from one waveguide to another

What is a Microring Resonator?



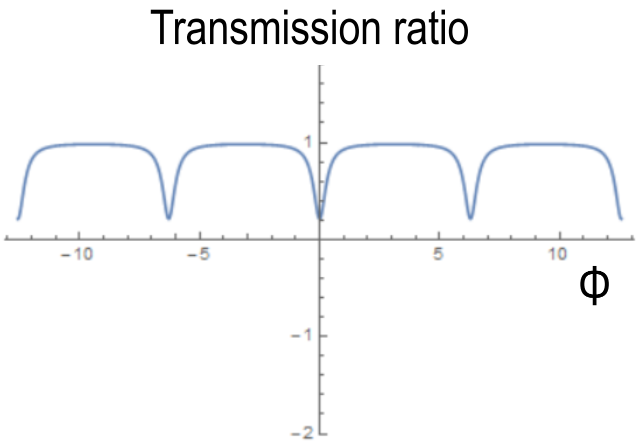
- All three of these concepts create an optical ring resonator
  - Can redirect light
  - Specific frequencies get redirected => filters them
  - Size changes with thermal expansion

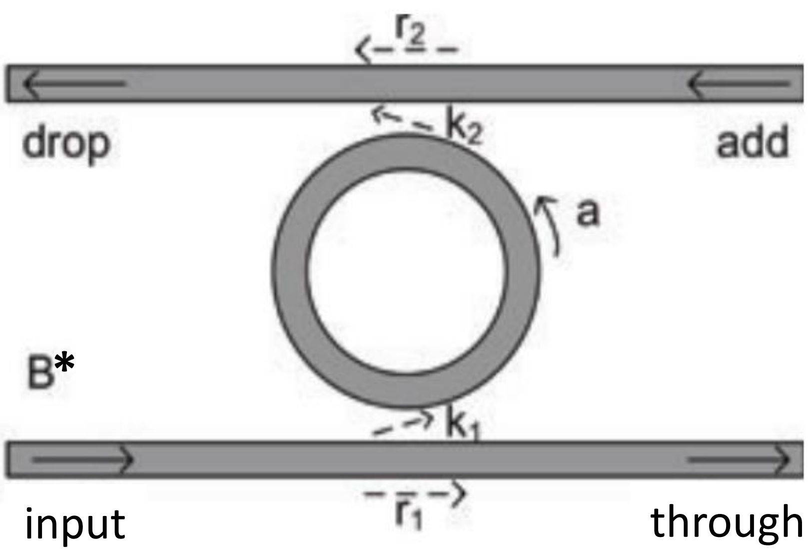
Graphs of Transmission vs Wavelength

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

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

$$\mathrm{r}^2 = \frac{\mathrm{P}_{\text{pass}}}{\mathrm{P}_{\text{input}}} = \text{self-coupling coefficient}$$



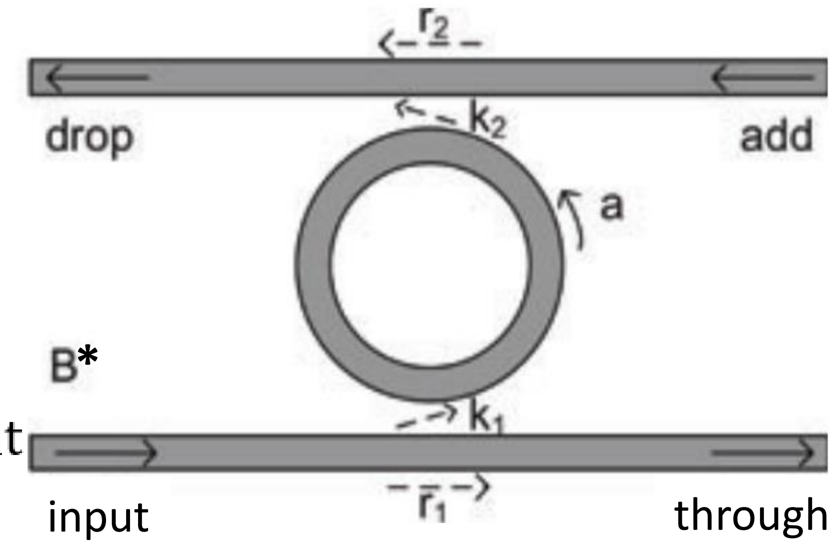


* Figure B: Add-drop Ring Resonator from Bogaerts, Wim, et al. "Silicon microring resonators." *Laser & Photonics Reviews* 6.1 (2012): 47-73.

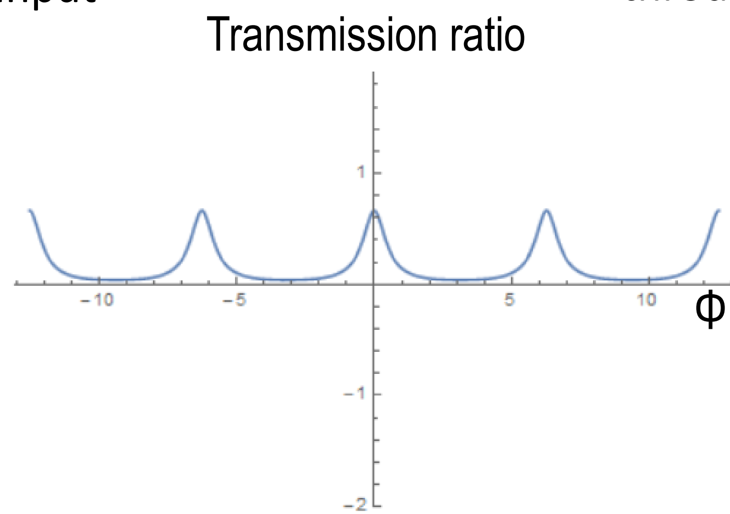
Graphs of Transmission vs Wavelength

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

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



- **Transmission of Drop over Input vs. wavelength (µm)**



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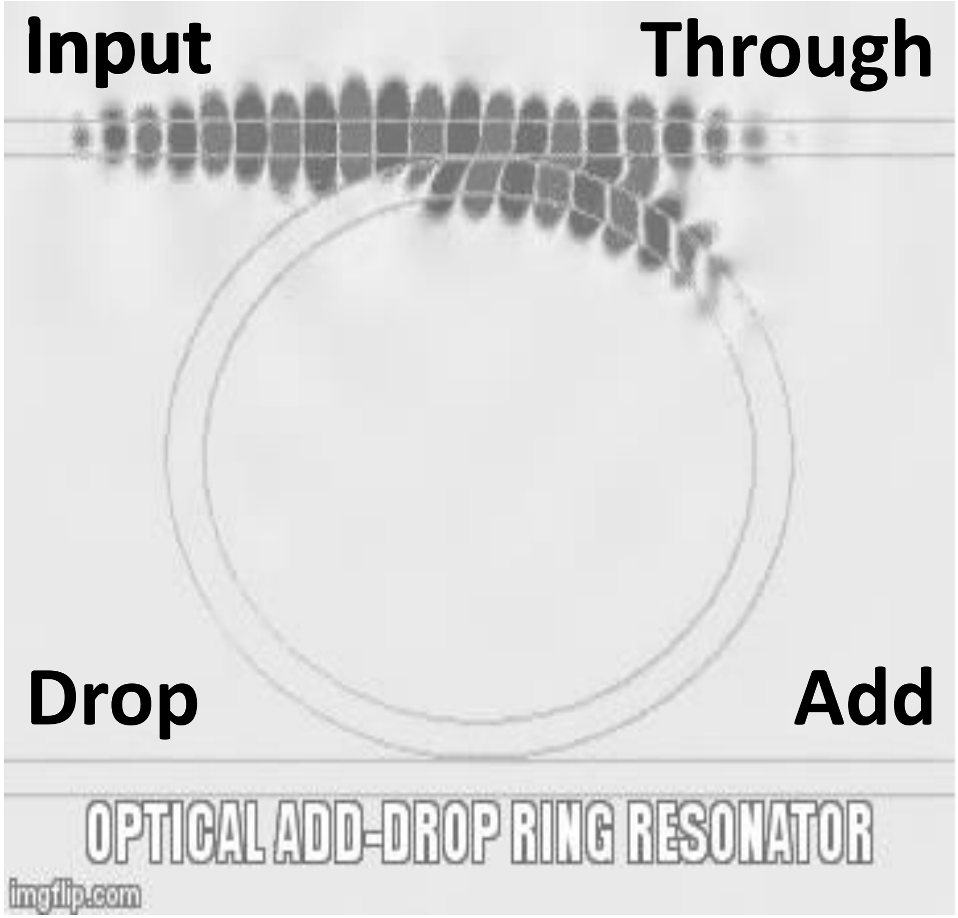
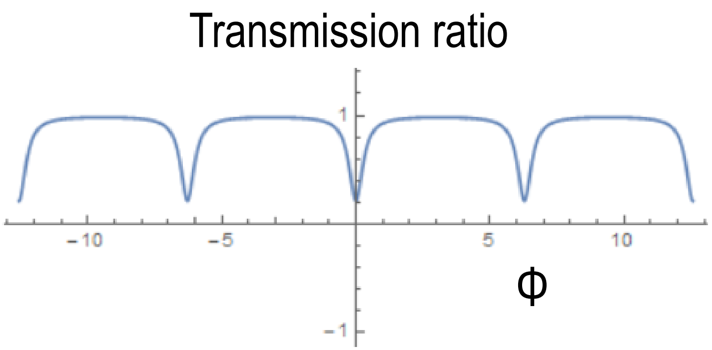
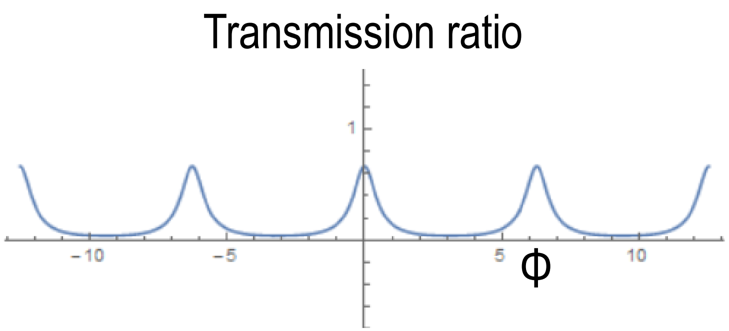




Transmission of Through over Input vs. wavelength (μm)



Transmission of Drop over Input vs. wavelength (μm)

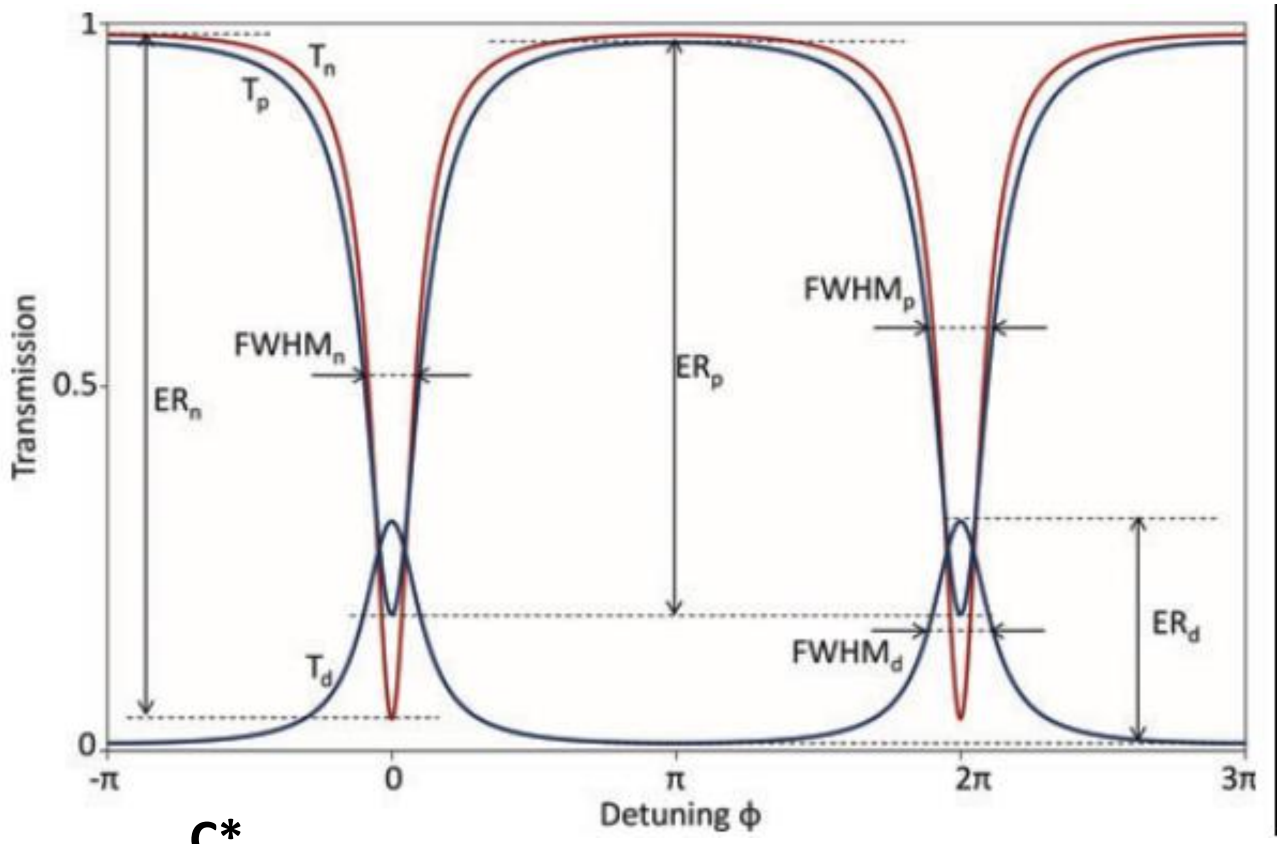
Transmission graphs of add/drop resonator

$$\phi = \beta L$$

$$\beta = \frac{2\pi n_{\text{eff}}}{\lambda}$$

$$\lambda_{\text{res}} = \frac{n_{\text{eff}} L}{m},$$

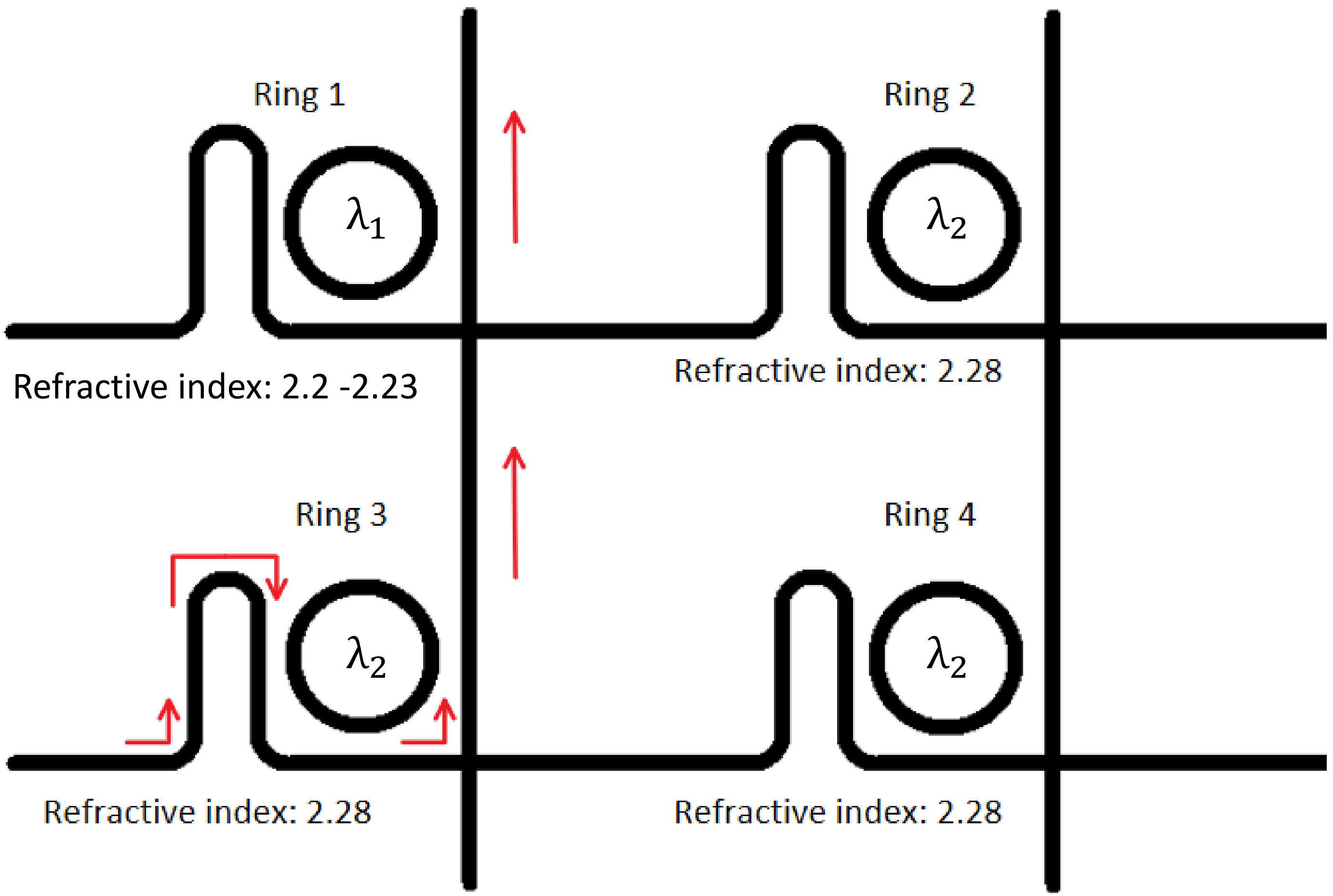
$$m = 1, 2, 3 \ldots .$$



C*

* Figure C: Transmission graph from Bogaerts, Wim, et al. "Silicon microring resonators." *Laser & Photonics Reviews* 6.1 (2012): 47-73.

Optical crossbar switches

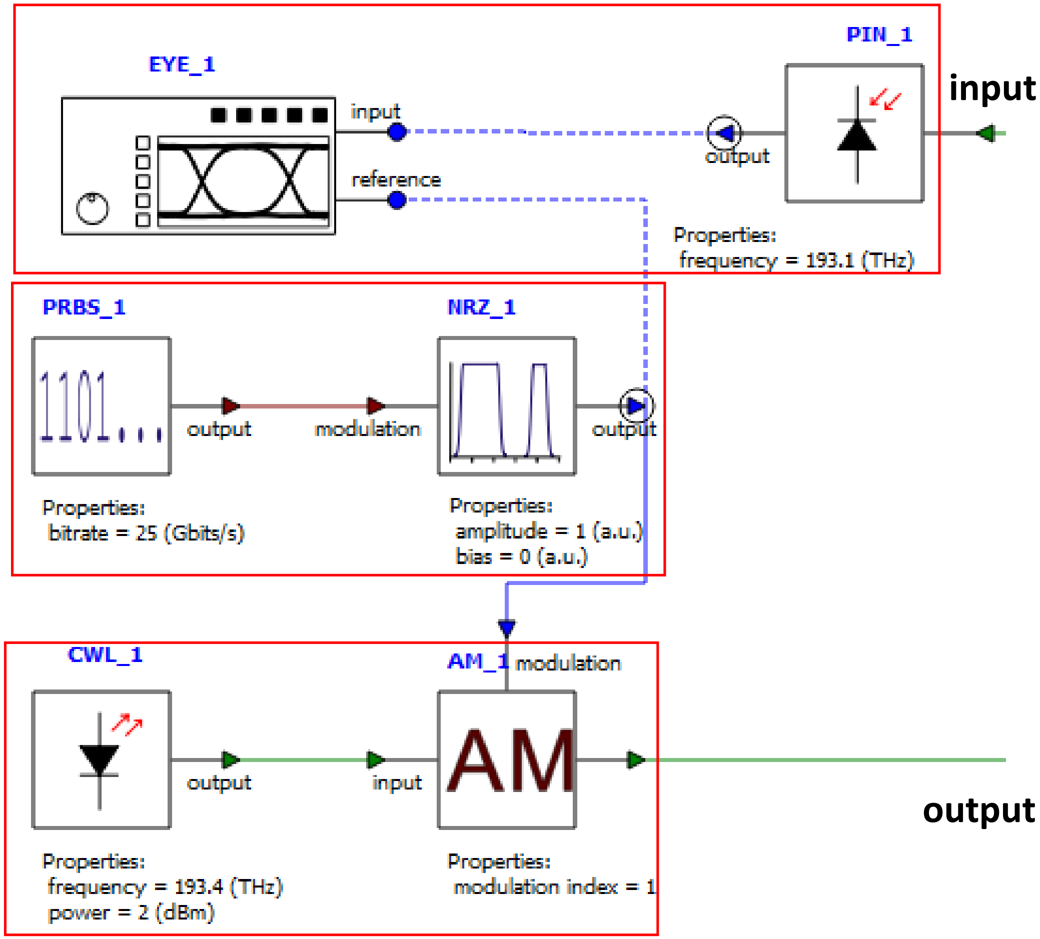


Optical crossbar switches

3) Compares reference input to real input to generate BER

1) Simulates real data

2) Converts electrical data to optical



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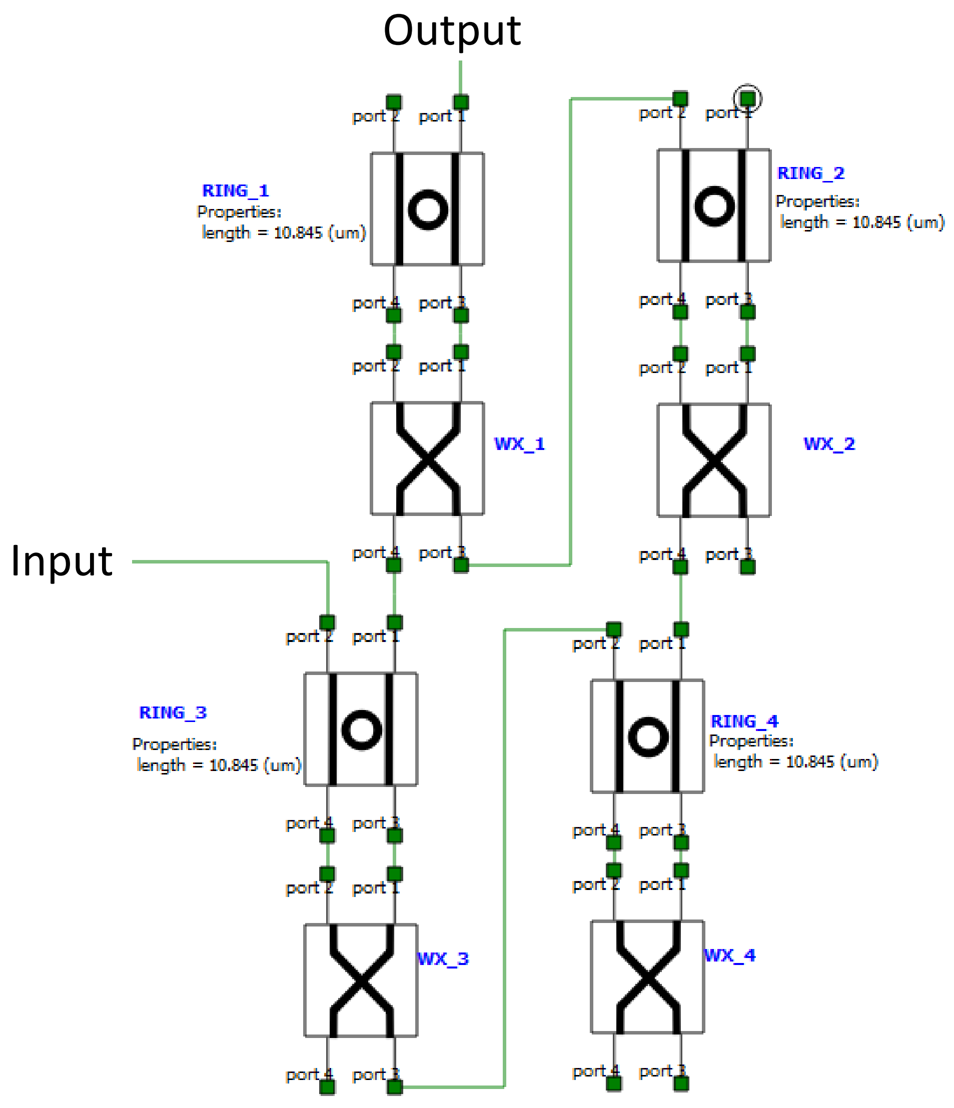

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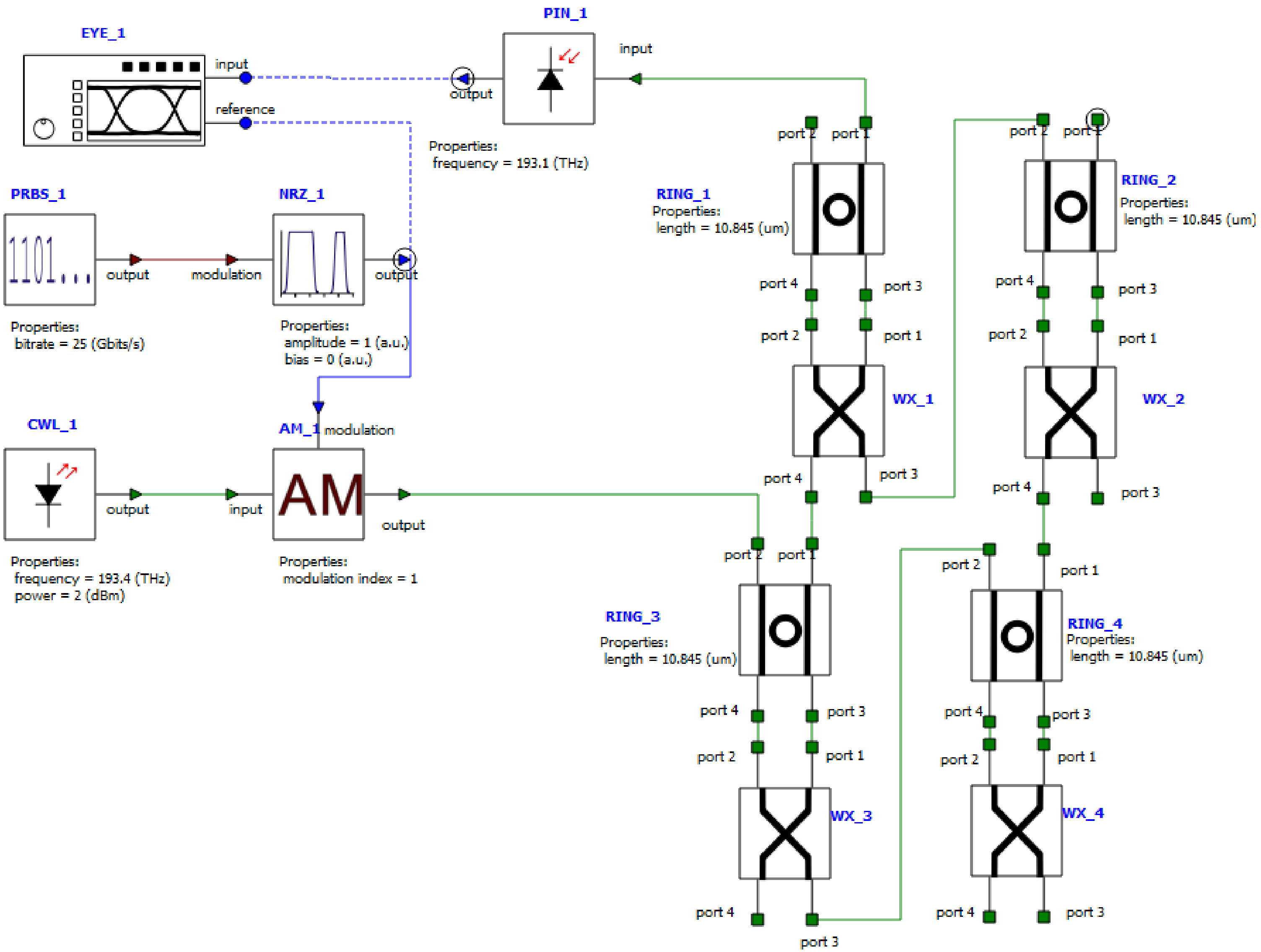
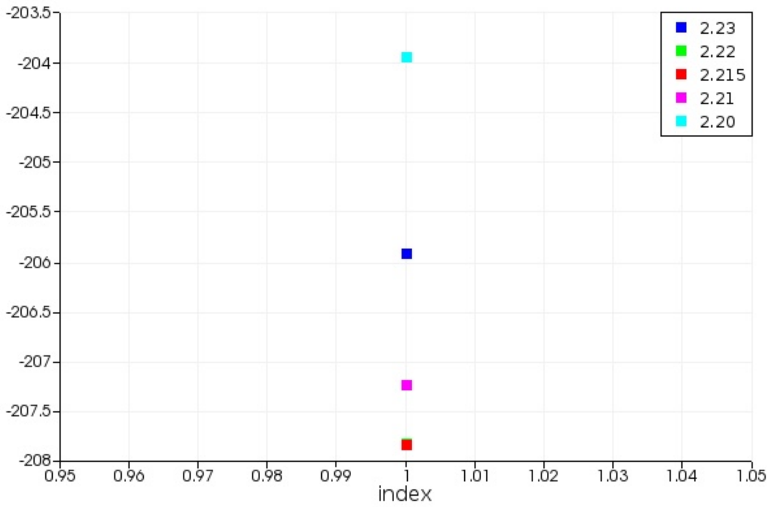


BER (Bit Error Rate)

- **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**



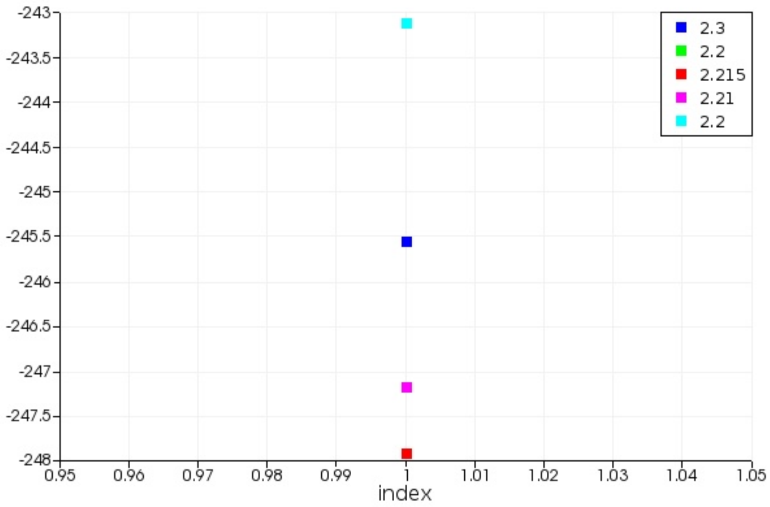
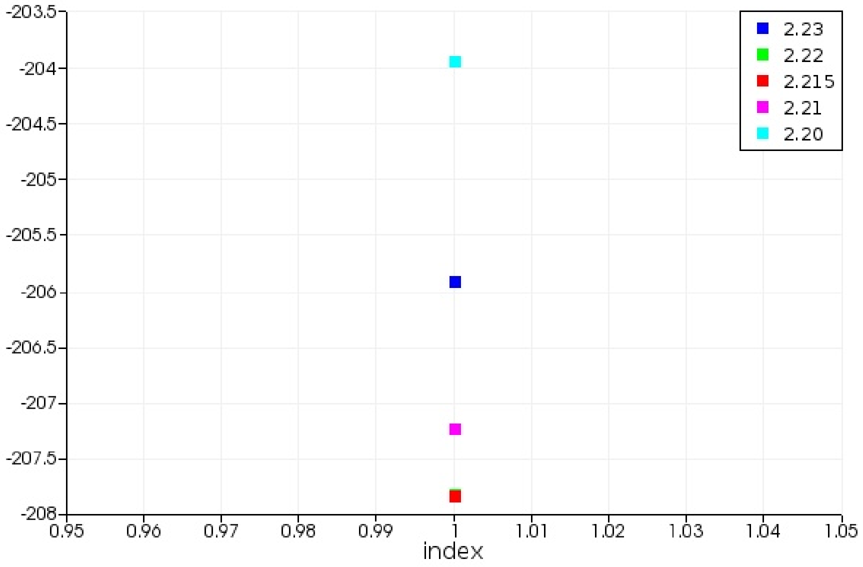


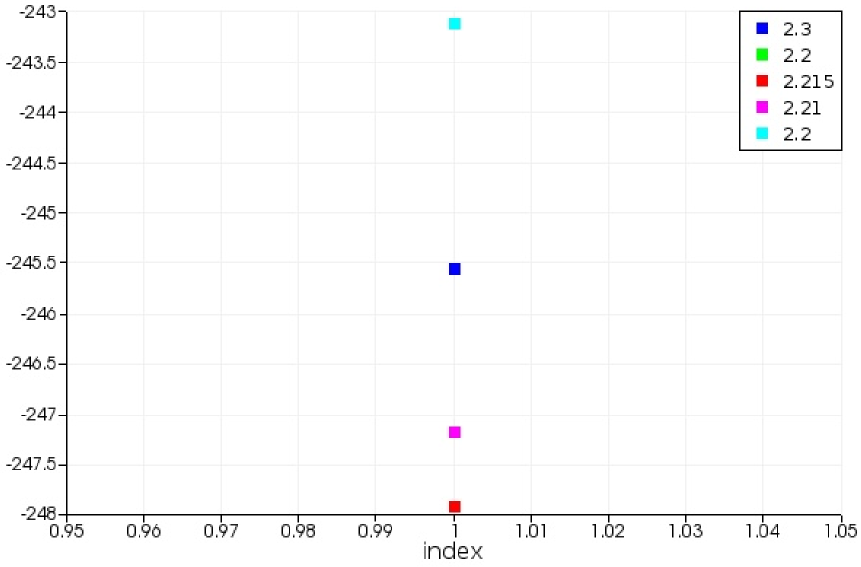
Figure Source: M. Nakazawa, H. Kubota, K. Suzuki, E. Yamada, and A. Sahara, IEEE J. Sei. Topics Quantum Electron. 6, 36 3 (2000).

Conclusion: BER (Bit Error Rate)

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

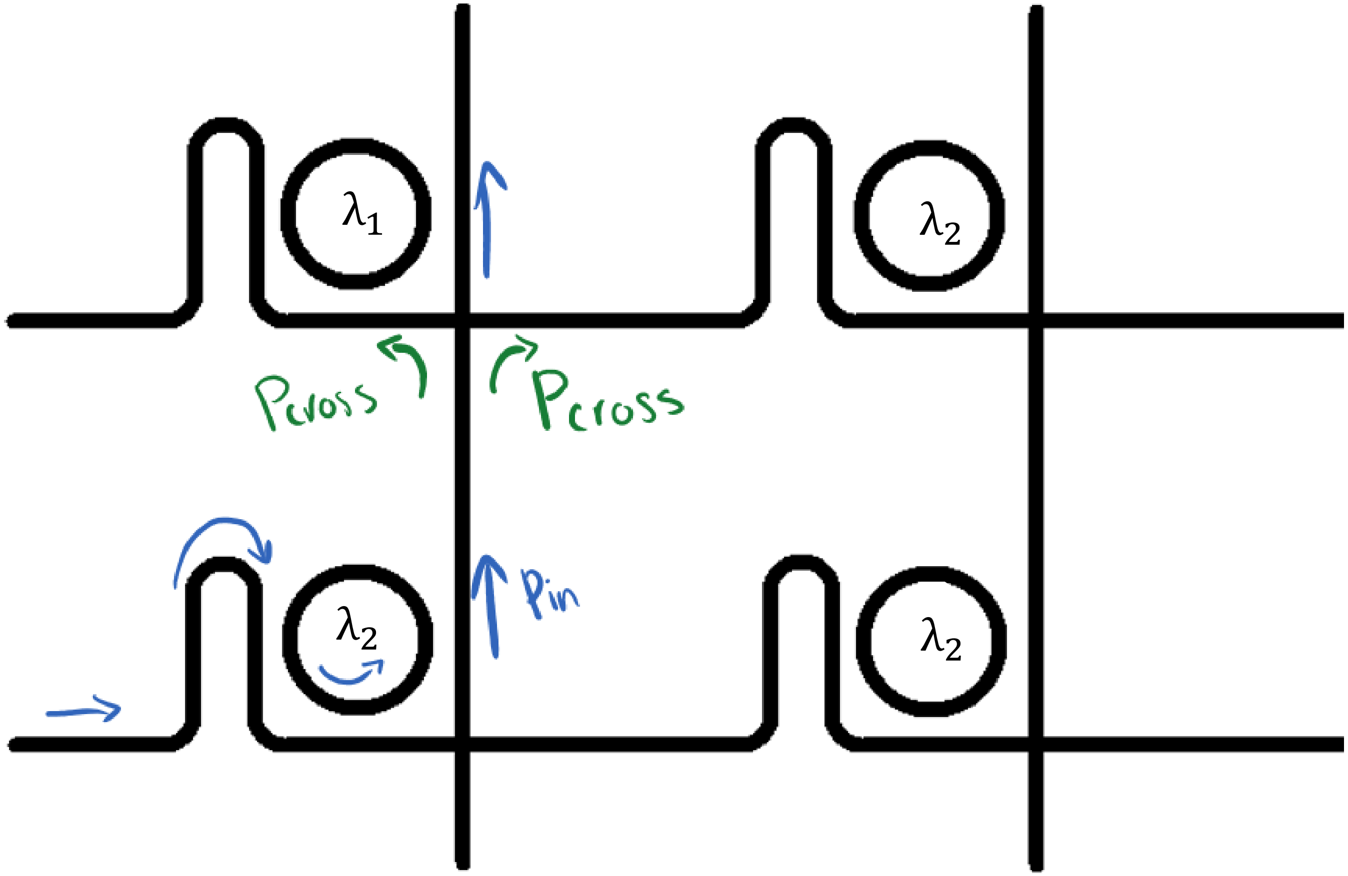


BER with Power at 2 dBm vs
the change in refractive index



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

Future Goal: Calculate Crosstalk



$$10\log\left(\frac{P_{cross}}{P_{in}}\right) = crosstalk\ (dB)$$

Acknowledgements

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