An Optical Wavelength-Division Multiplexed Communication Link

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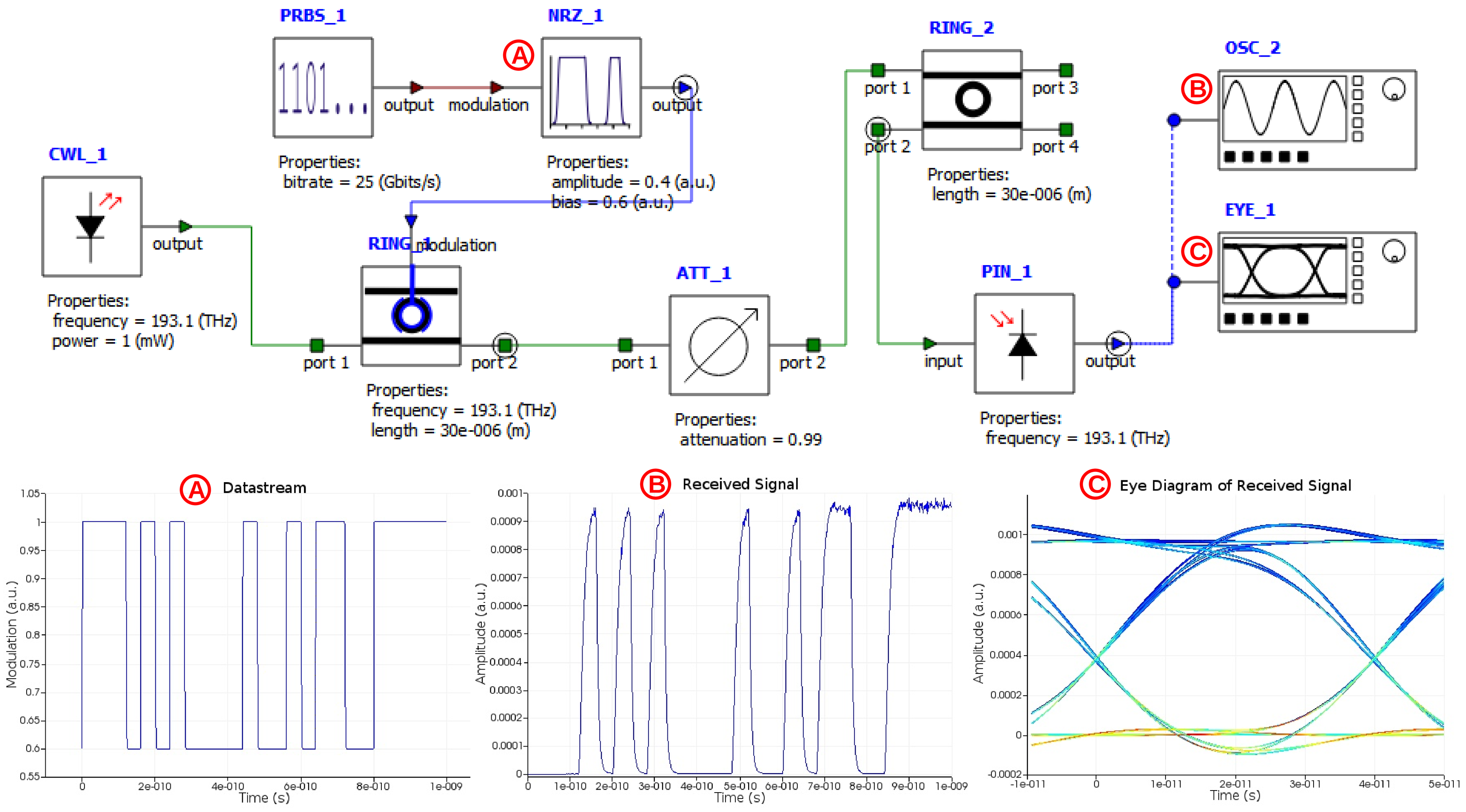
Abstract

Wavelength-division multiplexing (WDM) enables optical interconnects to have high and easily scalable data transmission rates. The key component in an optical WDM system is the micro-ring resonator or modulator. In this work, a 4-channel WDM system based on a ring resonator design from Chrostowski and Hochberg[1] was simulated in Lumerical INTERCONNECT, with optical parameters extracted from a 2.5D finite-difference time-domain (FDTD) analysis of the ring resonator in Lumerical MODE Solutions. Frequency- and time-domain representations of four independent pseudo-random bit sequences modulated onto four frequency channels illustrate the behavior of the optical communication link.

Introduction

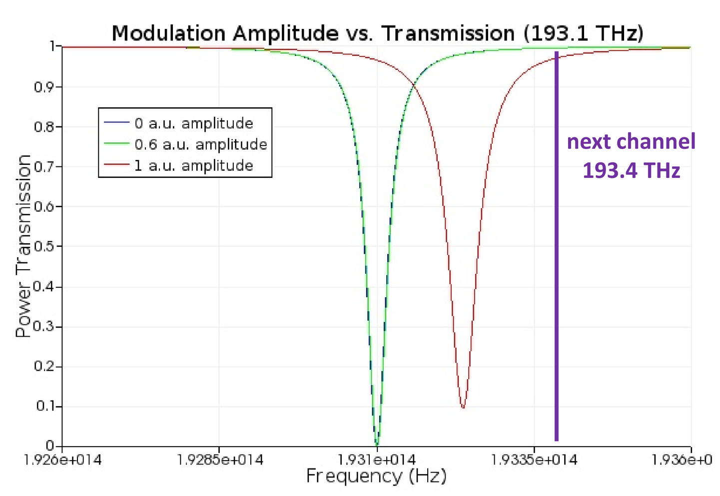
High throughput, WDM-enabled optical interconnects are a favorable alternative to electrical interconnects for applications such as faster chip-level communications. Below, a datastream is transmitted and received at 25 Gbps through a single-channel optical WDM link modeled in Lumerical INTERCONNECT. The data rate scales up to 100 Gbps with a 4-channel optical WDM.

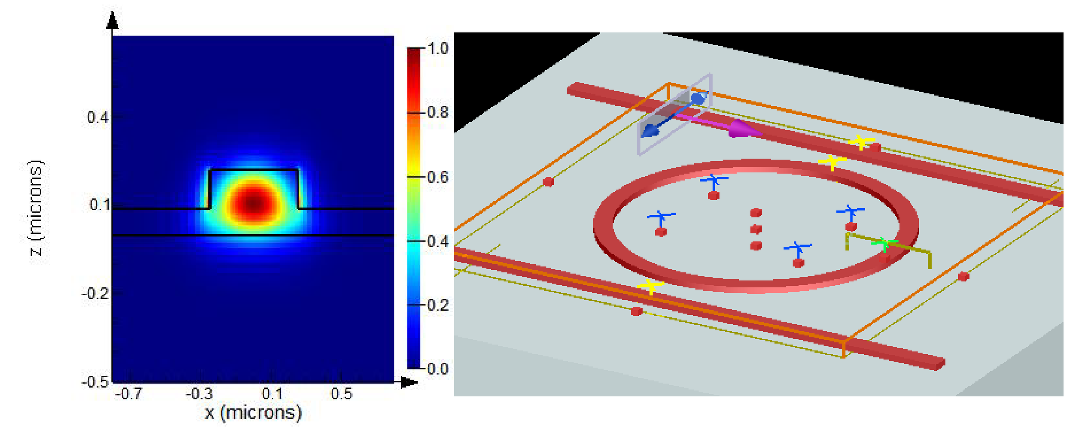


Optical Design and Parameter Extraction

- Loss, group index, dispersion, and coupling coefficient were extracted from 2.5D FDTD simulations of the ring resonator waveguide and coupler in Lumerical MODE Solutions.
- Applying an electric field shifts the resonance curve (electro-optic effect).
- Modulation amplitudes of 0.6 (0/OFF) and 1 (1/ON) were chosen to shift the curve completely off-resonance. This corresponds to a 300 GHz channel spacing.

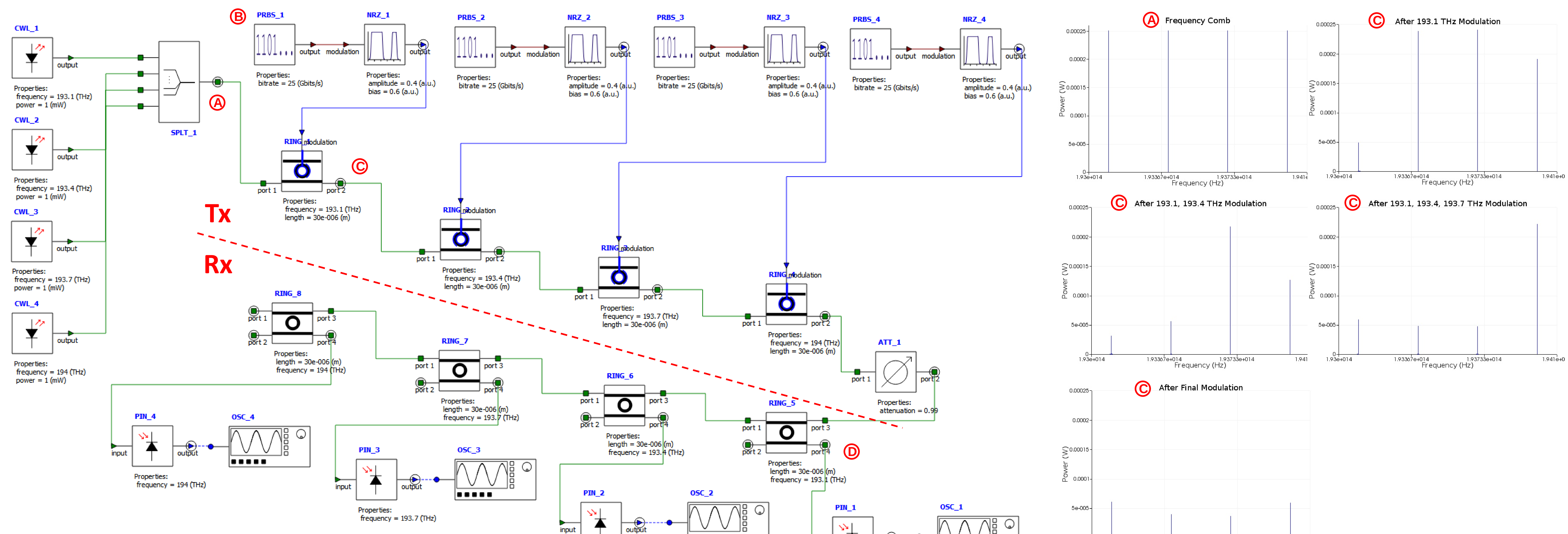
Ring Modulator Parameters	
Resonant Frequencies	193.1, 193.4, 193.7, 194 THz
Circumference	30 μm
Free Spectral Range (FSR)	2.54 THz
Coupling Coefficient	0.046
Loss (at 193.1 THz)	3.45578 dB/m
Group Index (at 193.1 THz)	3.93544
Dispersion (at 193.1 THz)	-1501.5×10^{-6} s/m/m
Modulation Amplitude	0.6 to 1.0 a.u.

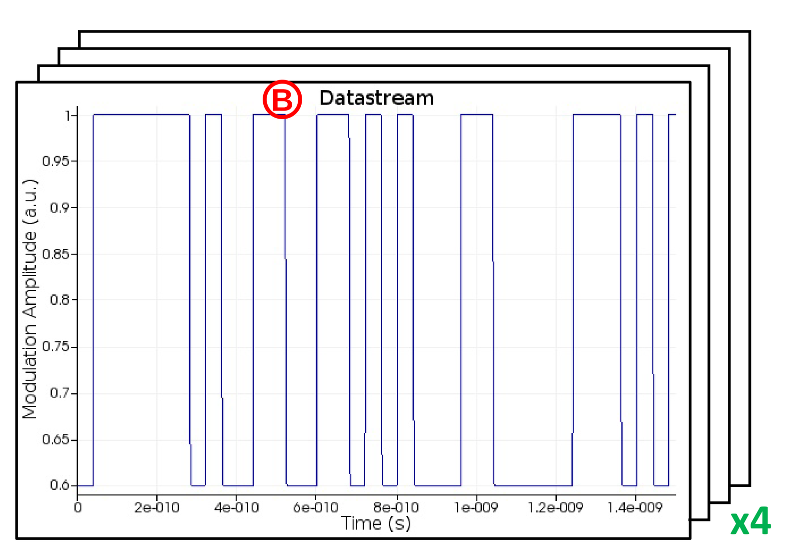




Above Left: Fundamental waveguide TE mode of Chrostowski and Hochberg's design[1] obtained from FDTD.
Above Right: A layout and FDTD setup of a generic ring resonator.

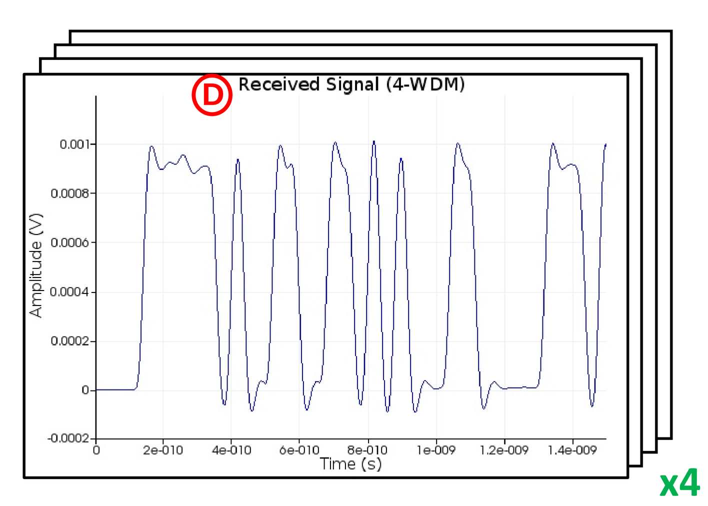
System Design: 4-Channel WDM





Steps

A. A frequency comb is generated from 4 continuous-wave lasers. This is the optical carrier signal.
B. There are 4 datastreams to be transmitted.
C. The datastreams are independently modulated onto 4 frequency channels by applying a voltage to shift the resonance peak of the ring.
D. The signals on each frequency channel are extracted at the receiver using a matched (unmodulated) ring resonator filter bank.



Conclusion

A system-level implementation of WDM using ring modulators and ring resonator filter banks was simulated in Lumerical INTERCONNECT with optical parameter extraction performed in MODE Solutions. Future work to aid the photonic integrated circuit design process will involve the simulation of a ring modulator design from the Integrated Systems Group across the Lumerical DEVICE and MODE Solutions platforms.

References

[1] L. Chrostowski and M. Hochberg, *Silicon Photonics Design: From Devices to Systems*. Cambridge, UK: Cambridge University Press, 2015.

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