System Design Examples

Outline

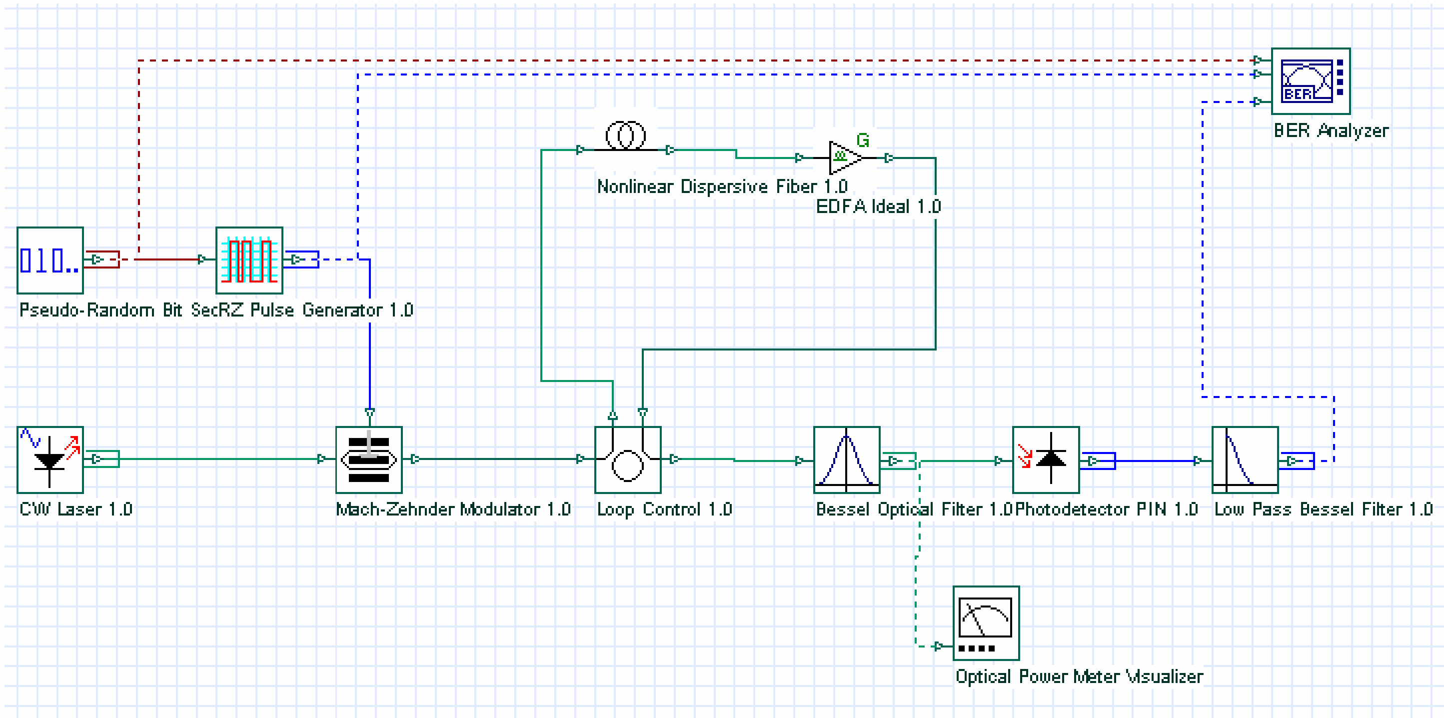
- Considering modulation formats
  - Comparison of Return to Zero and Non-Return to Zero modulation formats
- Fiber nonlinearities and dispersion
  - Single channel
  - Multi-channel
- Dispersion compensation schemes
  - Post-compensation
  - Pre-compensation
  - Symmetrical compensation
- Designing a basic ring network
  - Using Ring Control component to create a ring network
  - Investigating effects of node element imperfections to system performance
- Implementing alternative network architectures
  - Dual fiber protected ring architecture

Comparison of RZ and NRZ

- In this example, we investigate the effects of modulation format to system performance
- Due to higher peak power, NRZ may suffer more from nonlinearities
- Due to shorter pulse width, RZ may suffer more from dispersion
- Studies show that 10 Gbps WDM systems, in general, operate better by using RZ modulation in high power regime
- It is hard to go give any specific guideline due to complex interaction between dispersion and nonlinear effects
- Loss, periodic amplification with ASE noise is considered
- Standard single mode fiber is used
  - D = 16 (ps/nm/km)
  - Loss = 0.2 (dB/km)
  - Nonlinear coefficient = 1.31 (1/km/W)

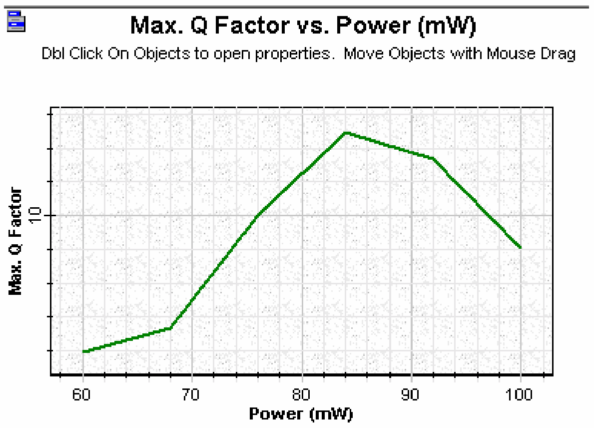
K. Ennser and K. Petermann, IEEE Photon. Technol. Lett., vol. 8, pp.443-445, 1996.
M.I. Hayee and A.E. Willner, IEEE Photon. Technol. Lett., vol. 11, pp.991-993, 1999.

RZ modulation format

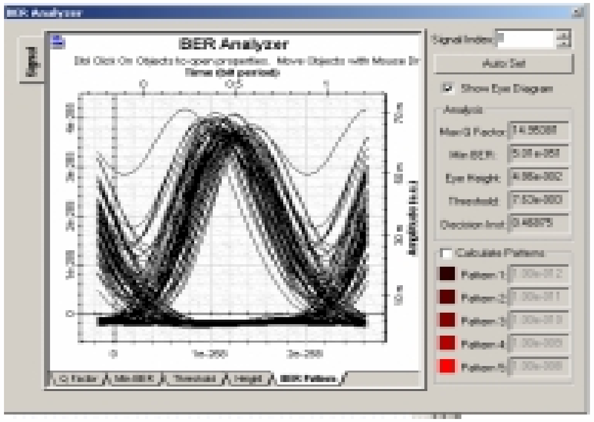


- 200 km of propagation
- 10 Gbps transmission rate
- Duty cycle is 0.5 bit

Simulation results

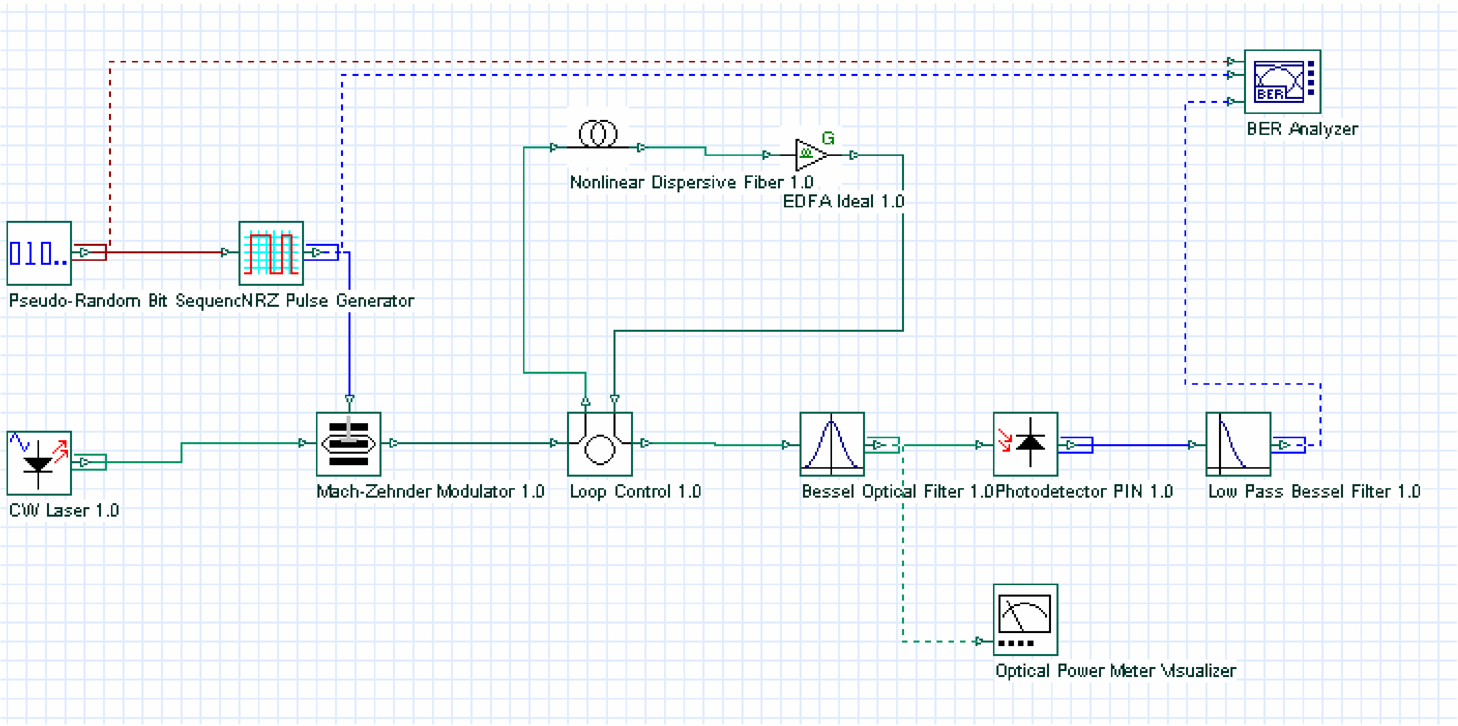


- Max Q factor vs. laser power



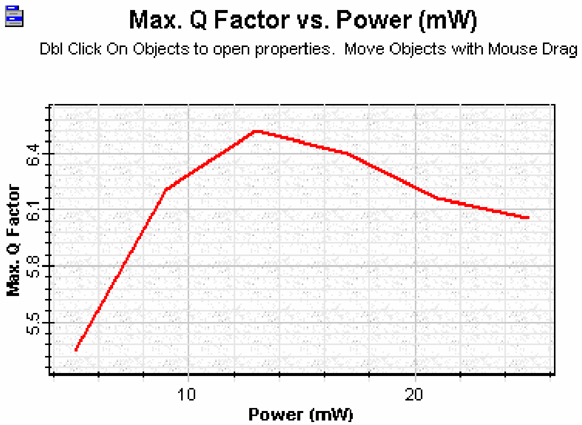
- Eye diagram when the laser power is about 84 mW

NRZ modulation format

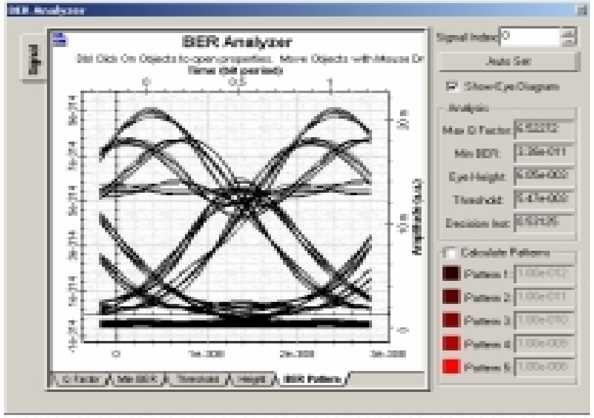


- 100 km of propagation
- 10 Gbps transmission rate

Simulation results



- Max Q factor vs. laser power



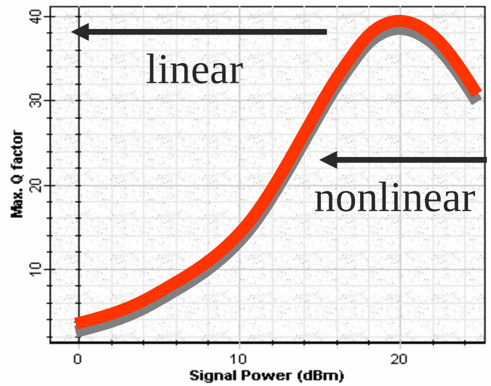
- Eye diagram when the laser power is about 13 mW

Fiber nonlinearities and dispersion

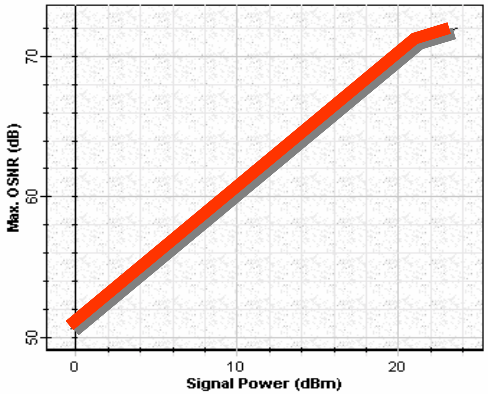
- In this example, we consider the effects of dispersion on system performance in high power regime where nonlinearities are active
- Dispersion plays a key role in reducing the effects of nonlinearities
- On the other hand, dispersion itself can cause inter-symbol interference
- We can engineer systems with zero total dispersion but with some local dispersion
- Single and multi-channel systems are simulated for two different cases
  - Zero accumulated dispersion
  - Some accumulated dispersion

Fiber nonlinearities and dispersion

	Single channel	Multi channel
Refractive index related	Self phase modulation (SPM)	Cross phase modulation (XPM) Four wave mixing (FWM)
Scattering related	Stimulated Brillouin scattering (SBS)	Stimulated Raman scattering (SRS)

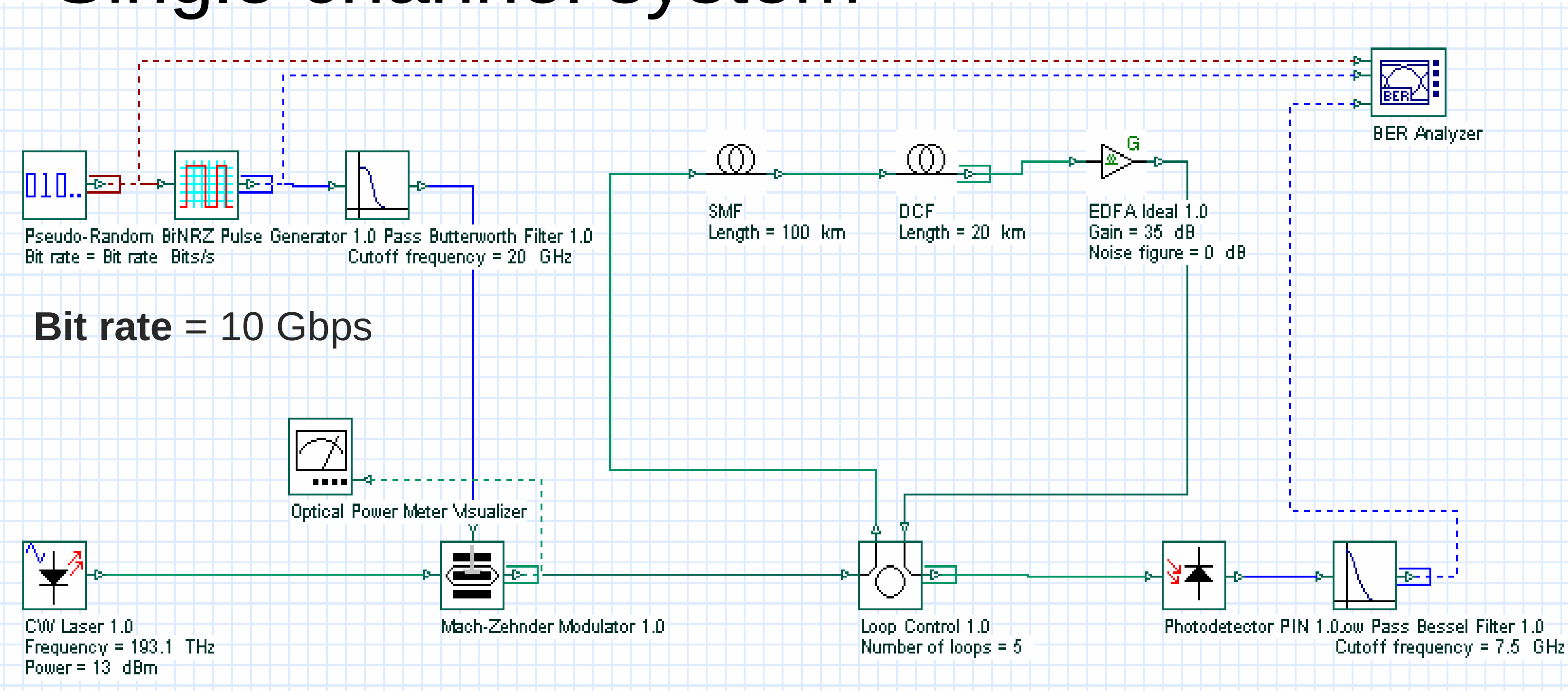


Q factor verses launch power



SNR verses launch power

Single channel system



Bit rate = 10 Gbps

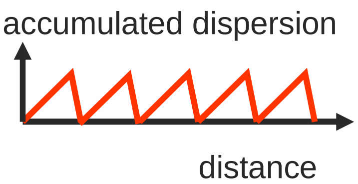
SMF
100 km
L = 0.25 dB/km
D = 16 ps/nm/km
Aeff = 72 micron-square

DCF
20 km
L = 0.5 dB/km
D = -80 or -72 ps/nm/km
Aeff = 30 micron-square

EDFA
G = 35 dB
NF= 0 dB

Simulation results

Signal power

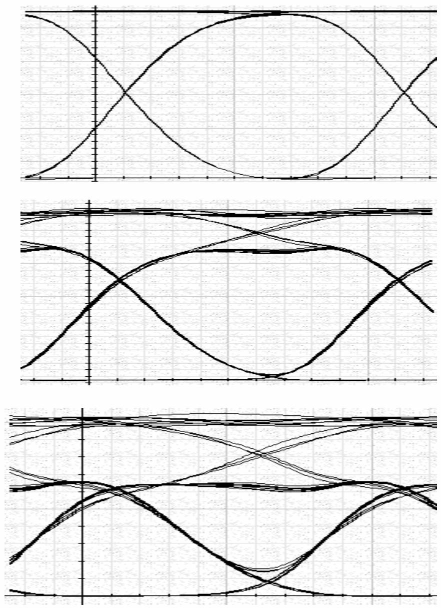


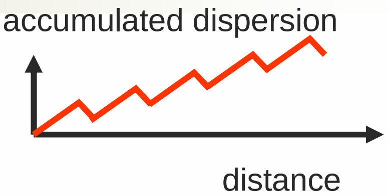
Total dispersion = 0

0 dBm

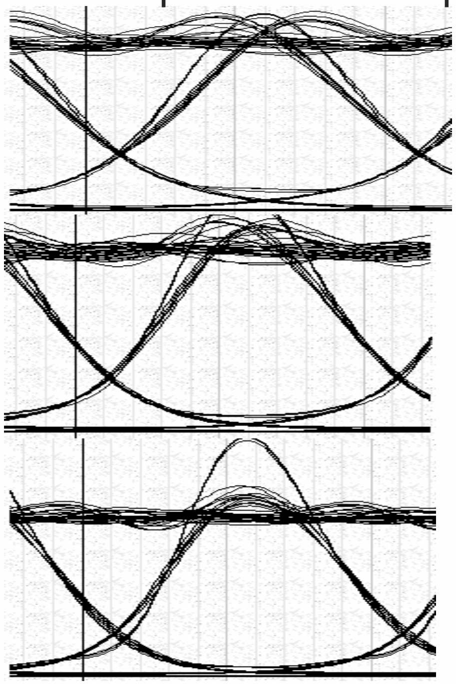
10 dBm

13 dBm



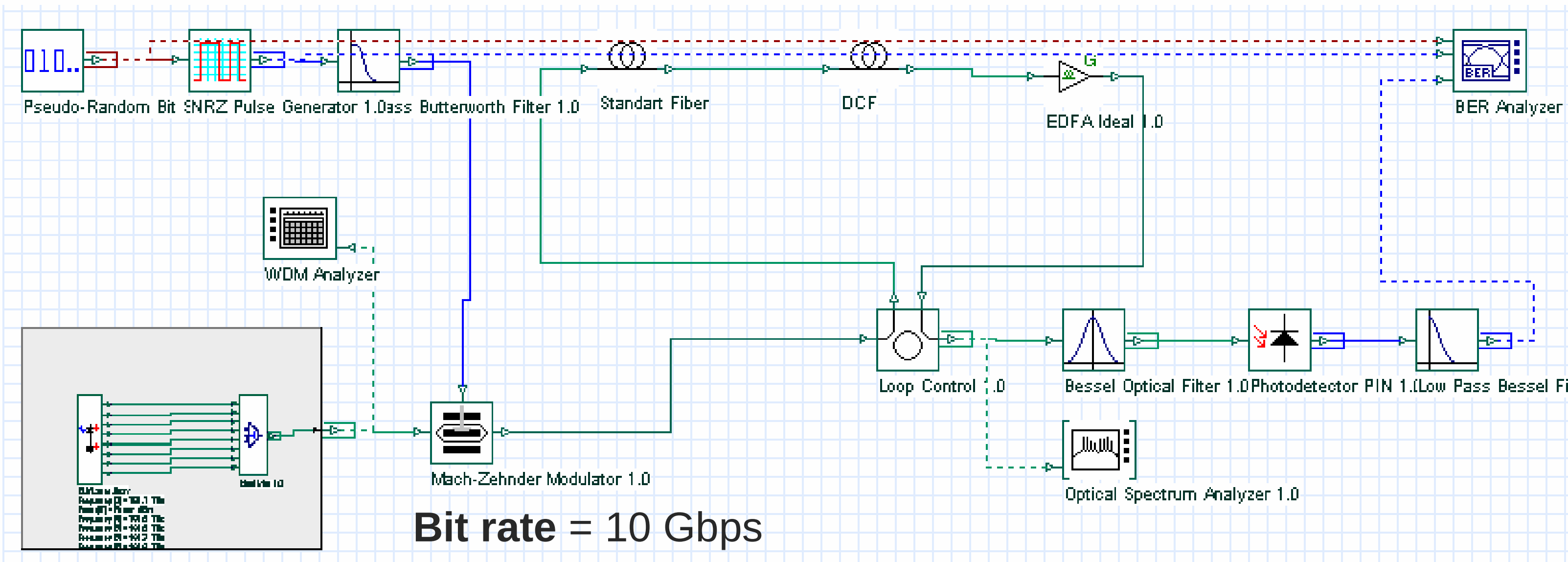


Residual dispersion = 800 ps/nm



G. Bellotti et. al., “Dependence of self-phase modulation impairments on residual dispersion in 10 Gb/s based terrestrial transmission using standart fiber”, IEEE Poton. Tech. Lett. 11, pp. 824, 1999.

Multi-channel system



SMF
100 km
L = 0.25 dB/km
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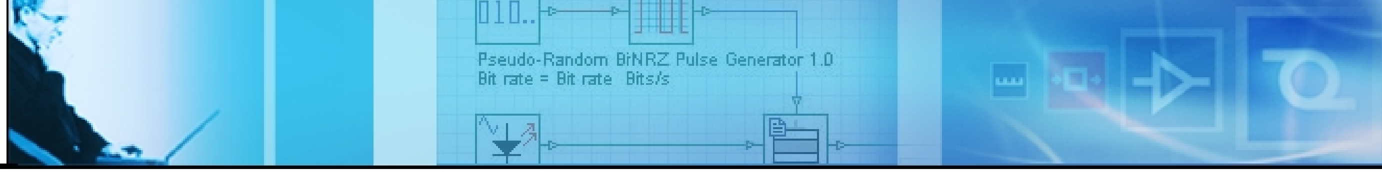
Aeff = 72 micron-square

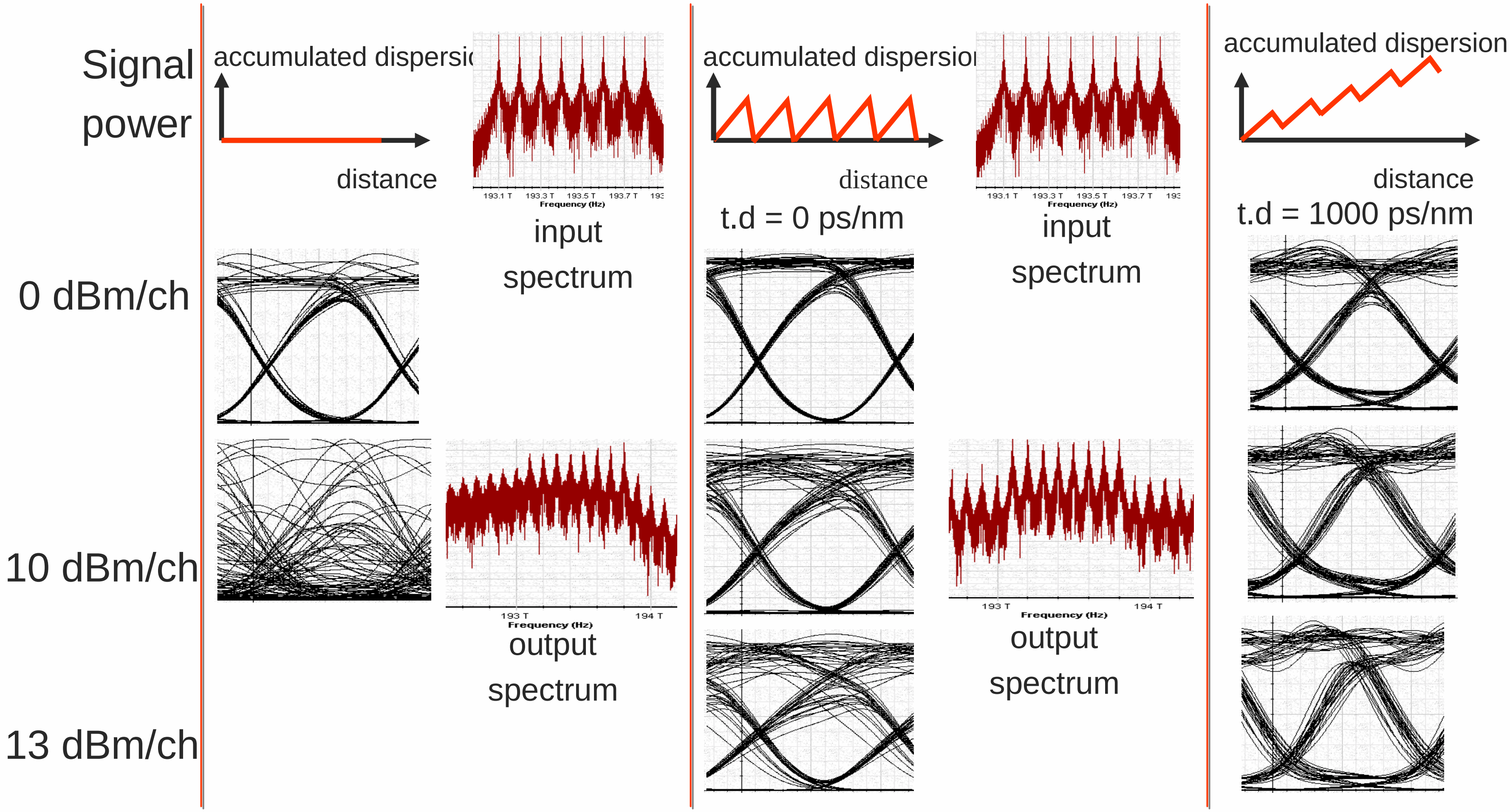
DCF
20 km
L = 0.5 dB/km
D = -80 or -72 ps/nm/km
Aeff = 30 micron-square

EDFA
G = 35 dB
NF= 0 dB

Optiwave



Simulation results



S. Bigo et. al.,IEEE Poton. Tech. Lett. 11, pp. 605, 1999.

M. I. Hayee and A. E. Willner, IEEE Poton. Tech. Lett. 9, pp. 1271, 1997.

Dispersion compensation schemes

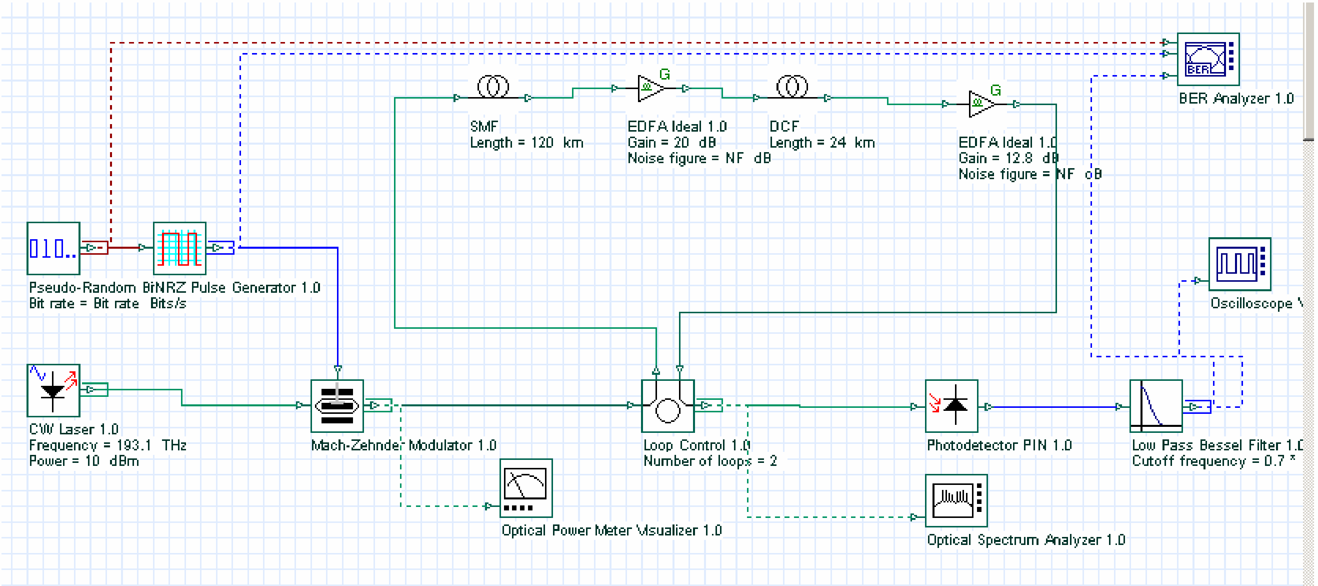
- In this example, we investigate three different dispersion compensation schemes
  - Pre-compensation
  - Post-compensation
  - Symmetrical-compensation
- System performances in terms of Q factor for these three cases are compared
- The best performance is obtained by using symmetrical dispersion compensation

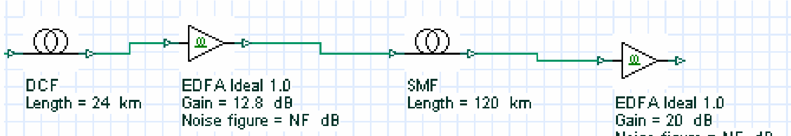
M. I. Hayee and A. E. Willner, PTL 9, pp. 1271, 1997.

Sebastian Biga et. al., PTL 11, pp. 605, 1999.

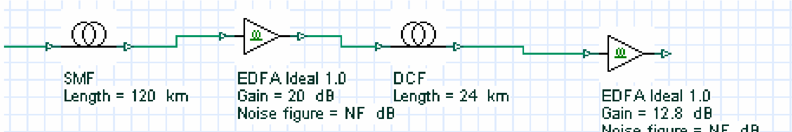
Giovanni Bellotti et. al., PTL 11, pp.824, 1999.

Project layout

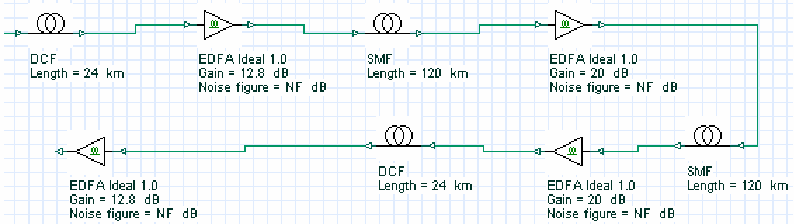




pre

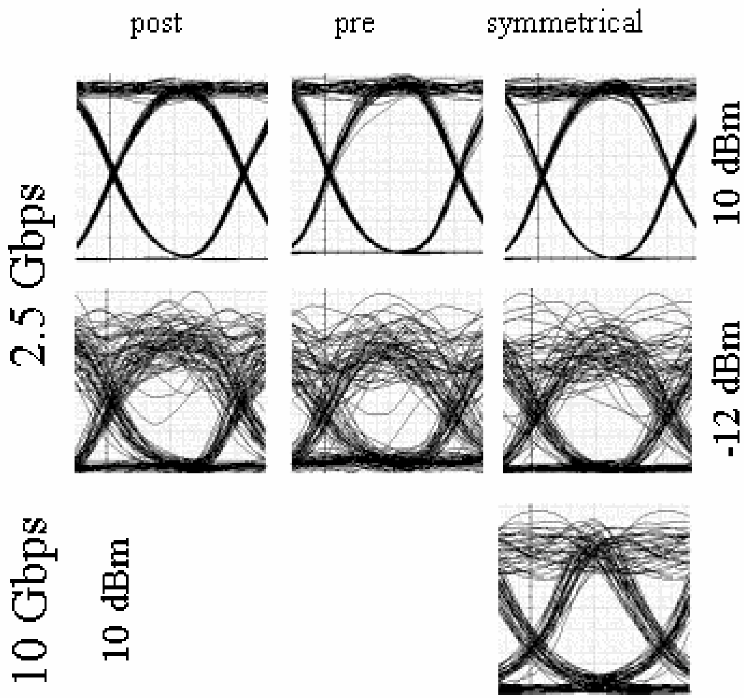


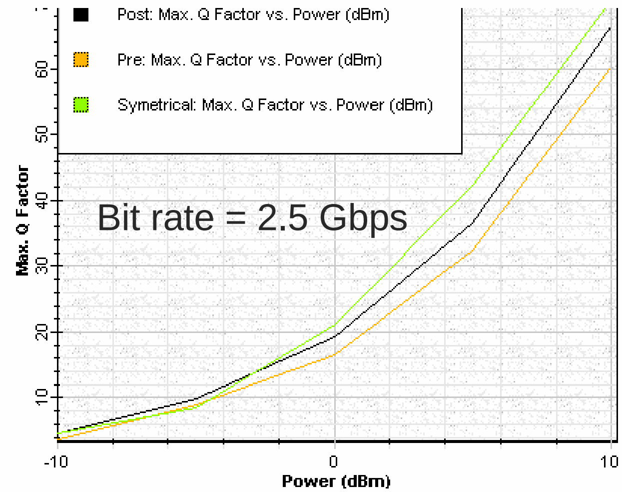
post

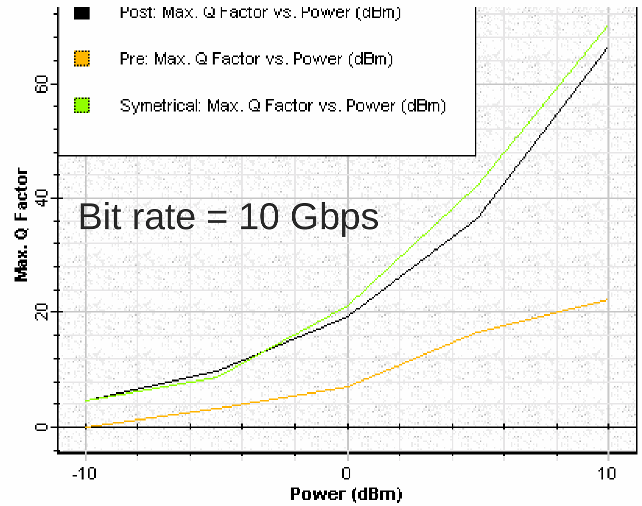


symmetrical

Simulation results

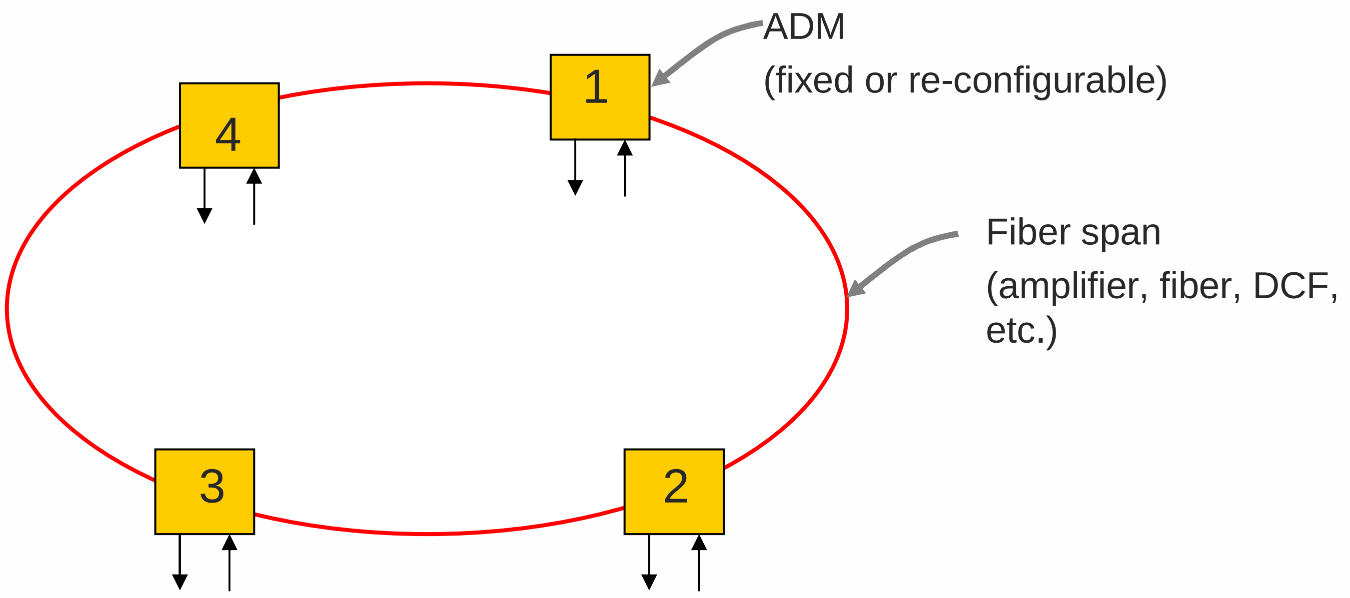




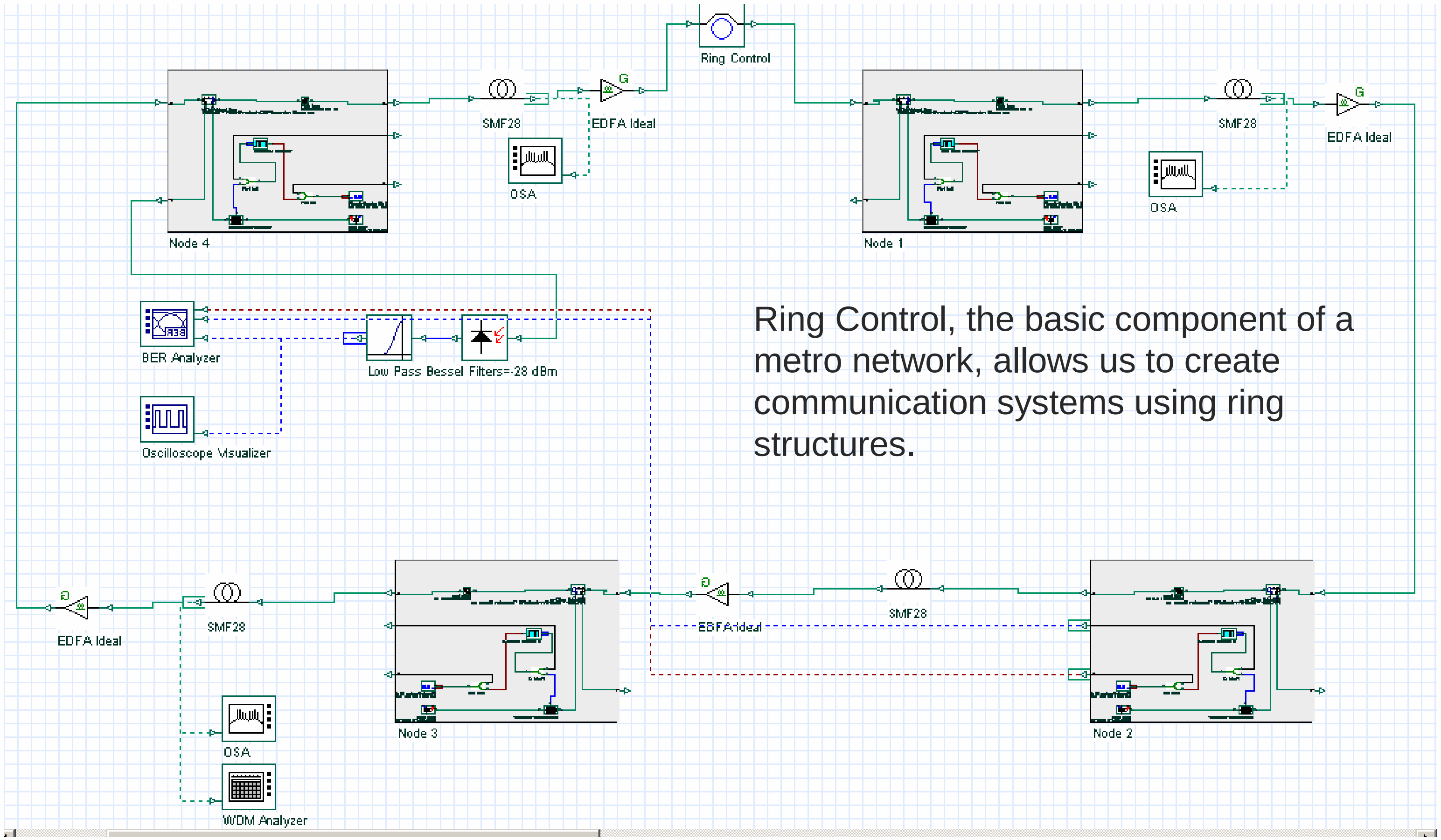


Designing a basic ring network

- In this example, we show a basic two channel WDM metro ring network with four nodes
- Node 1 communicates with Node 3 on Channel 1 at 1551.0 nm
- Node 2 communicates with Node 4 on Channel 2 at 1551.8 nm

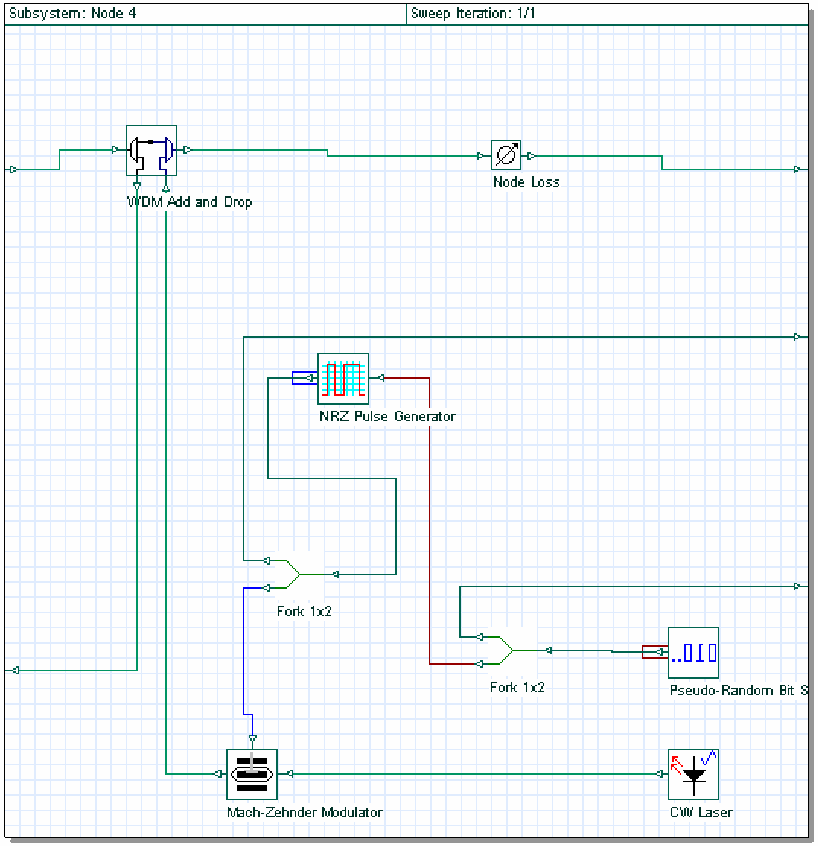


Project layout



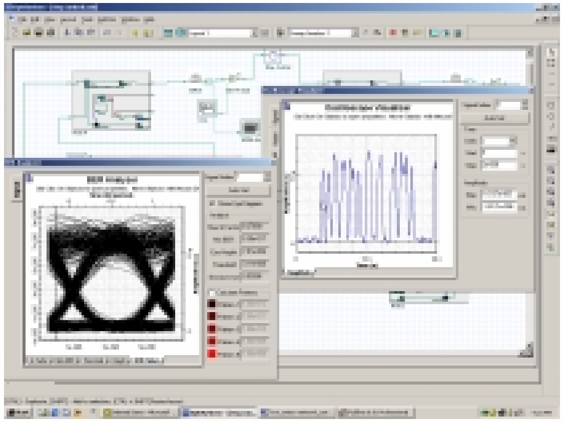
Ring Control, the basic component of a metro network, allows us to create communication systems using ring structures.

Node detail

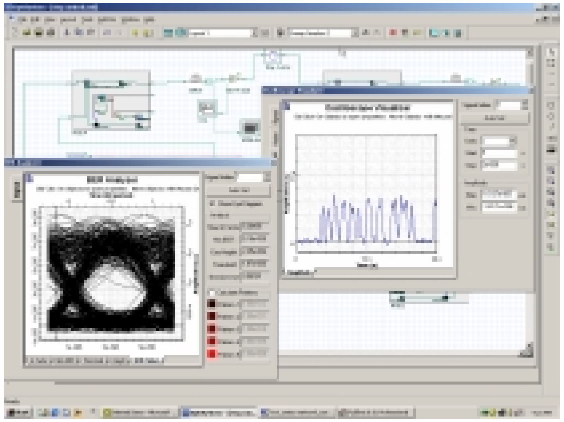


Subsystem: Node 4
Sweep Iteration: 1/1
WDM Add and Drop
Node Loss
NRZ Pulse Generator
Fork 1x2
Fork 1x2
Pseudo-Random Bit S
Mach-Zehnder Modulator
CW Laser

Simulation resuls



No temperature chance at Node 3
Q factor is about 8.3



Temperature chances at Node 3
Q factor is about 5.3

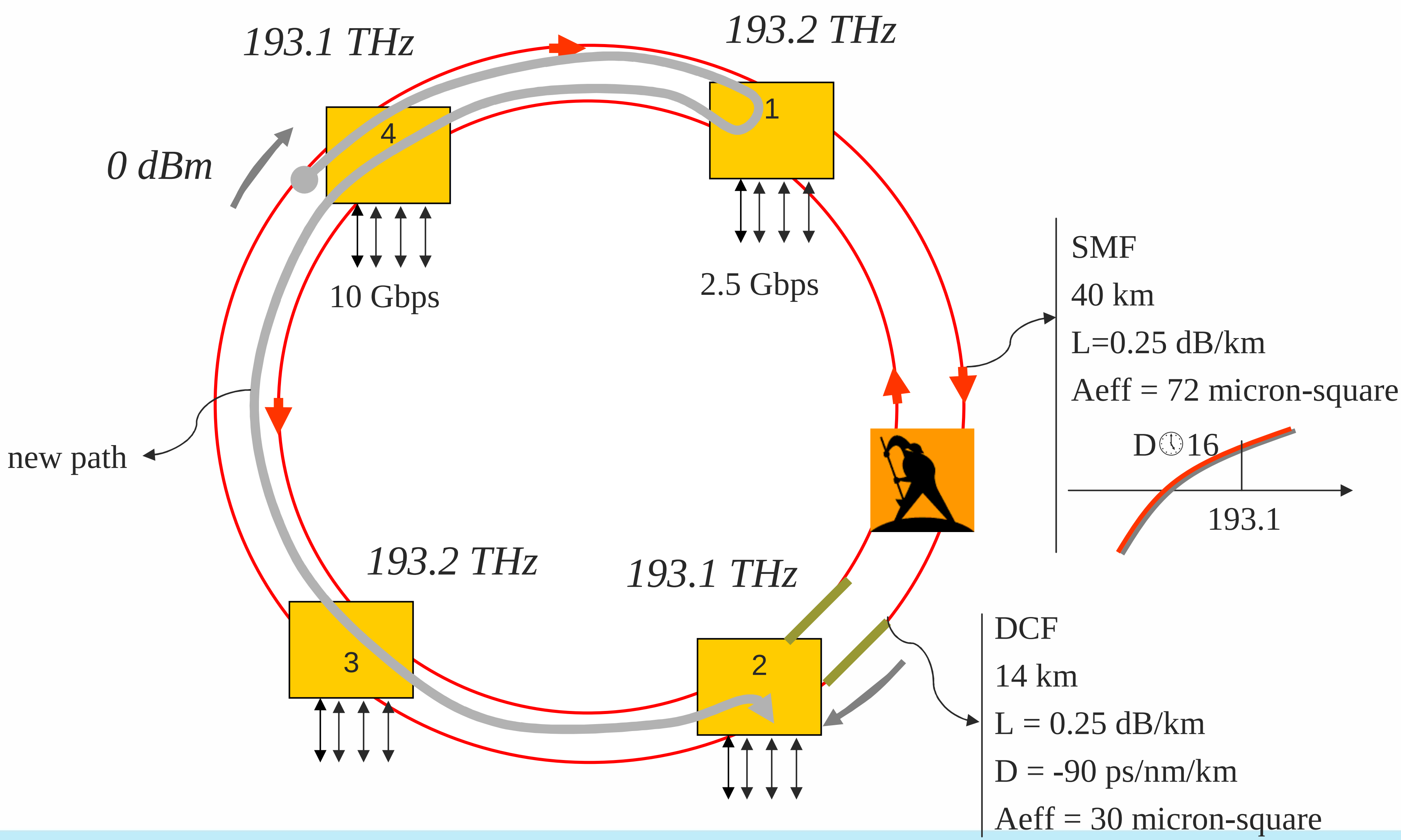
- Imperfection on the performance of add-drop MUX filters may greatly affect the overall network performance.
- We want to see if any center frequency deviation of the optical filter at Node 3 due to temperature change can affect the received signal at Node 4. Note that these two nodes are communicating on two different channels.

Dual fiber protected ring architecture

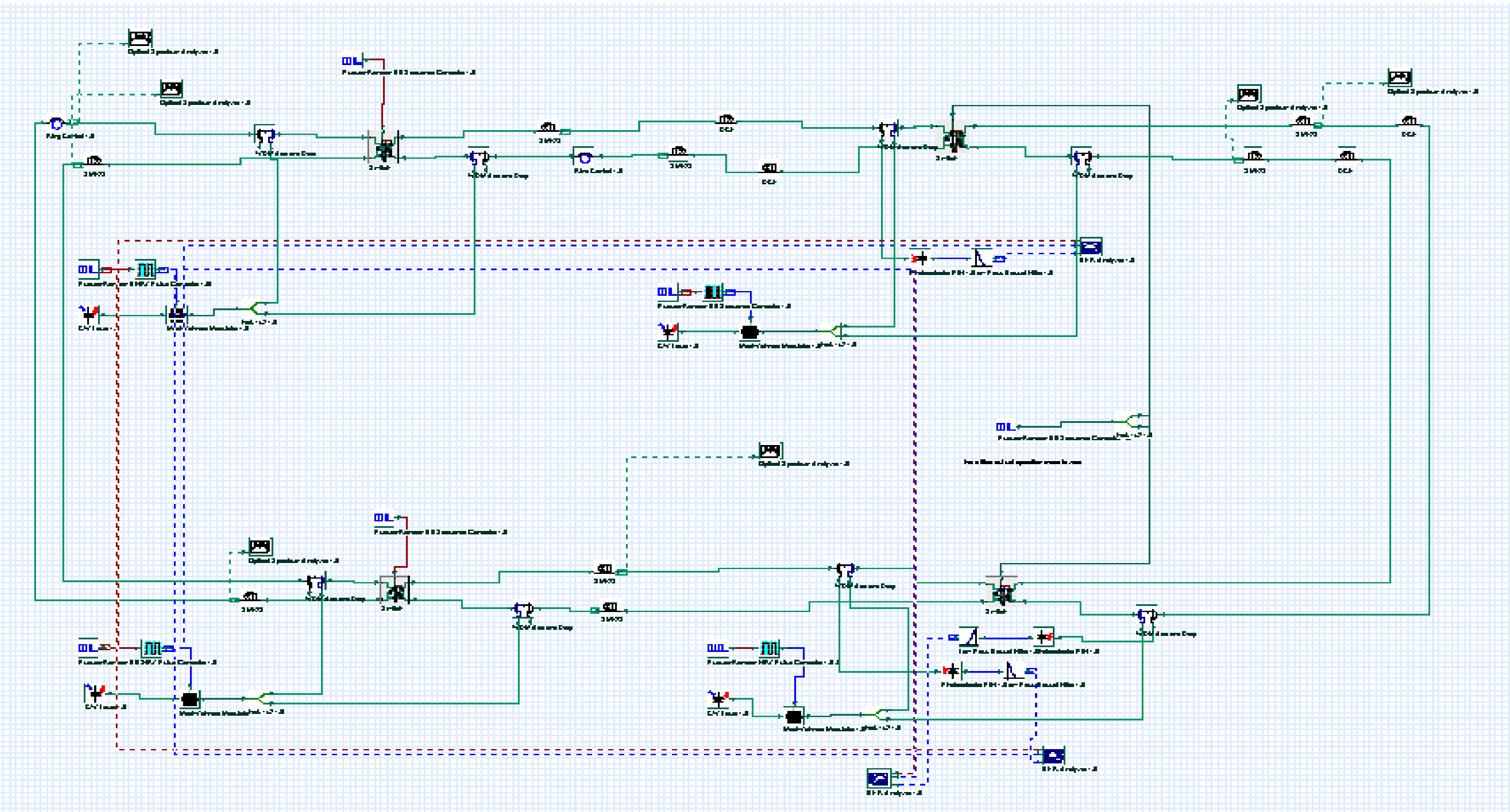
- In this example, we show design of a dual fiber protected ring architecture and investigate
  - How a “lumped” dispersion compensation behaves for a dynamic network
  - How the bit rate affects the network performance

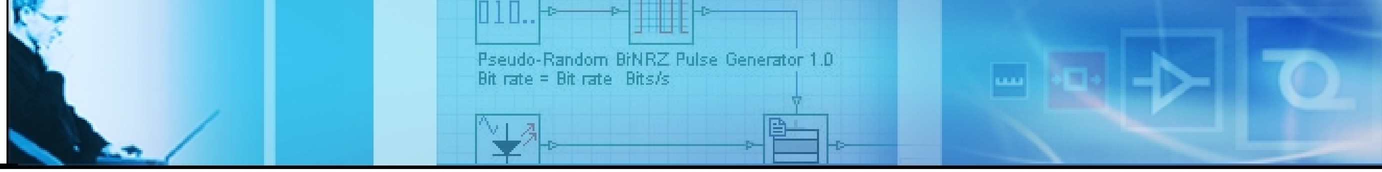
Peeya Iwagoshi, “High-speed ethernet optical architecture for metropolitan area networks”, NFOEC’2001, 2001.

Topology layout



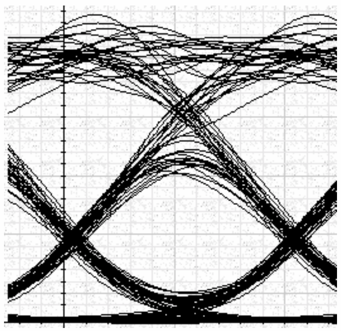
Project layout



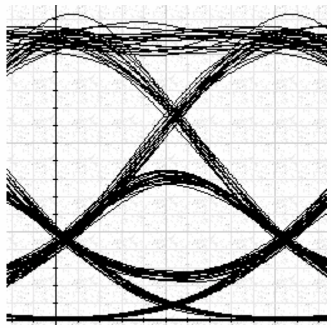


Simulation results

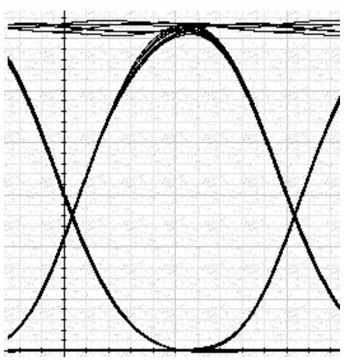
normal operation



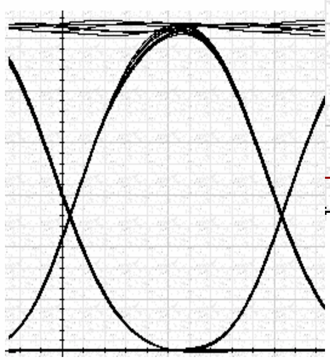
Ch 1 on primary path



Ch 1 on secondary path

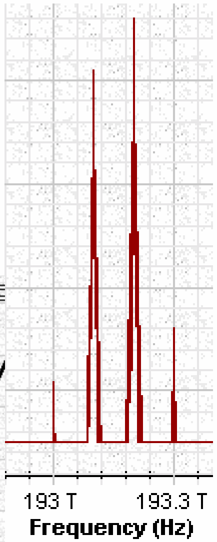


Ch 2 on primary path

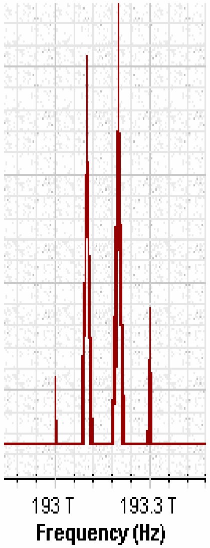


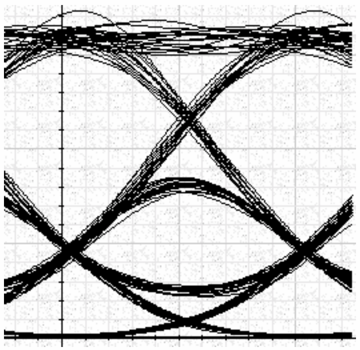
Ch 2 on secondary path

Spectrums over the paths

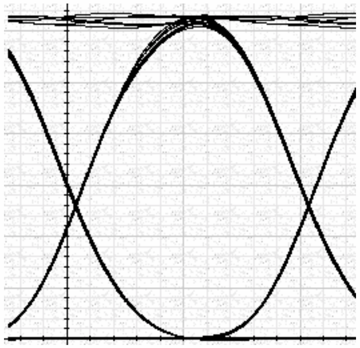


fiber cut





Ch 1 on new path



Ch 2 on new path