Optical Random Access Memory (ORAM)

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Bowers Group

DARPA DOD-N

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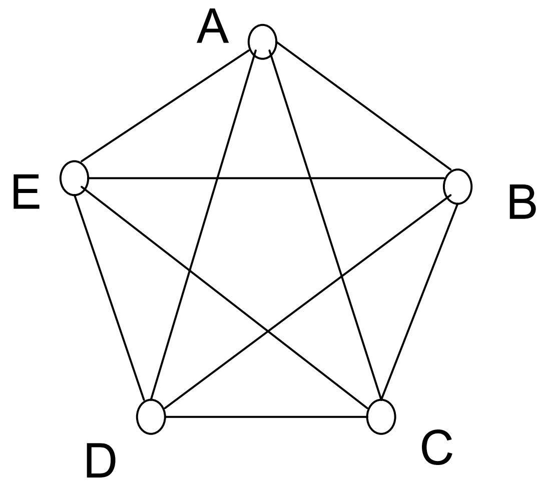
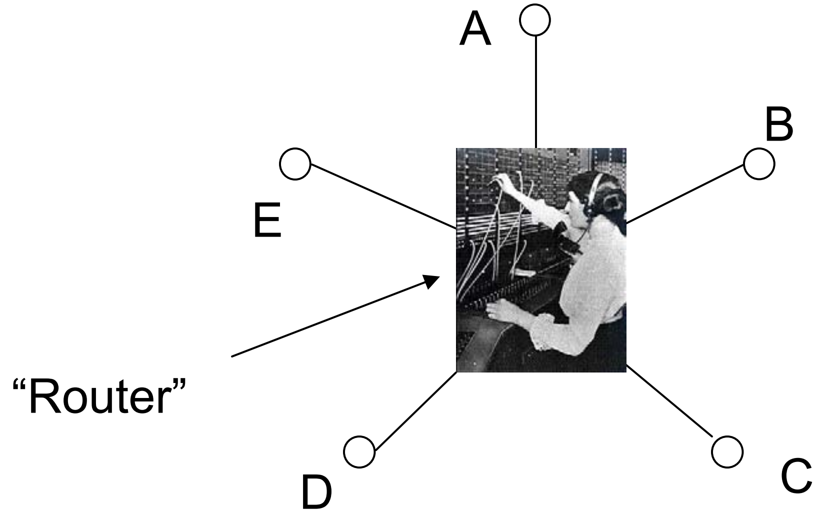
General Idea:

- Routers in data communication networks
  - Why router? =>simplified idea

5 nodes



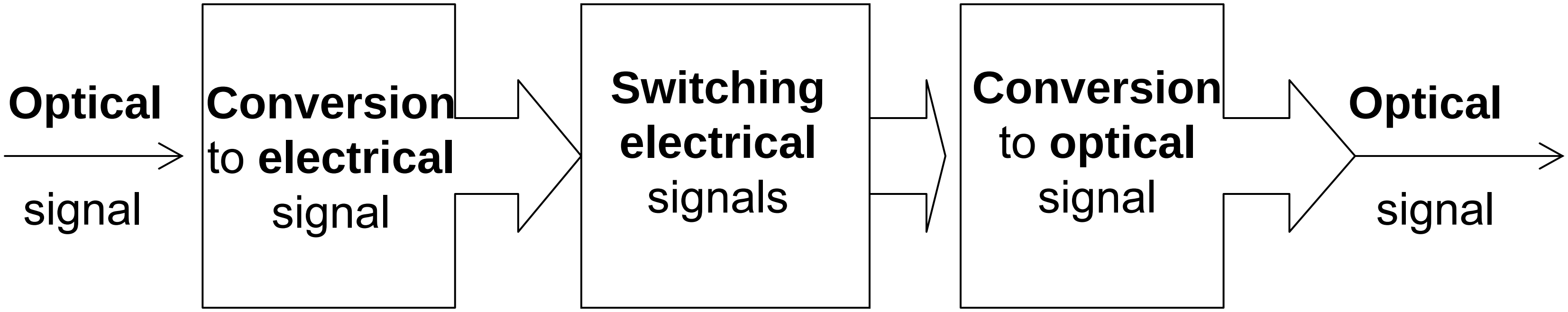


10 ← **Transmission Lines** → **5**

50 nodes	**1225**	**50**
500 nodes	**124,750**	**500**
5000 nodes	**12,497,500**	**5000**

General Idea (cont'd):

- Current technology in data communications: Electrical and Optical Hybrid Network (electrical router + optical transmission lines)
  - Electrical router:

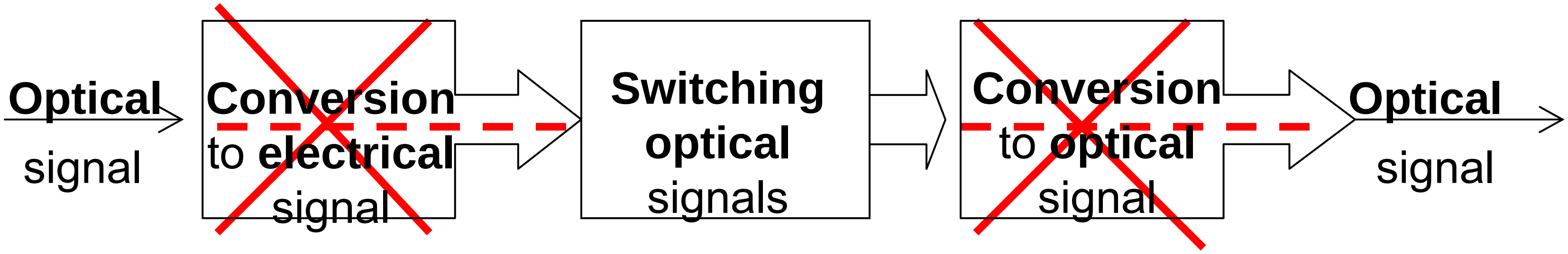


Optical signal → **Conversion** to **electrical** signal → **Switching electrical** signals → **Conversion** to **optical** signal → **Optical** signal

  - Problem? Electrical routers are not capable of handling the data rate speed offered by optical fibers

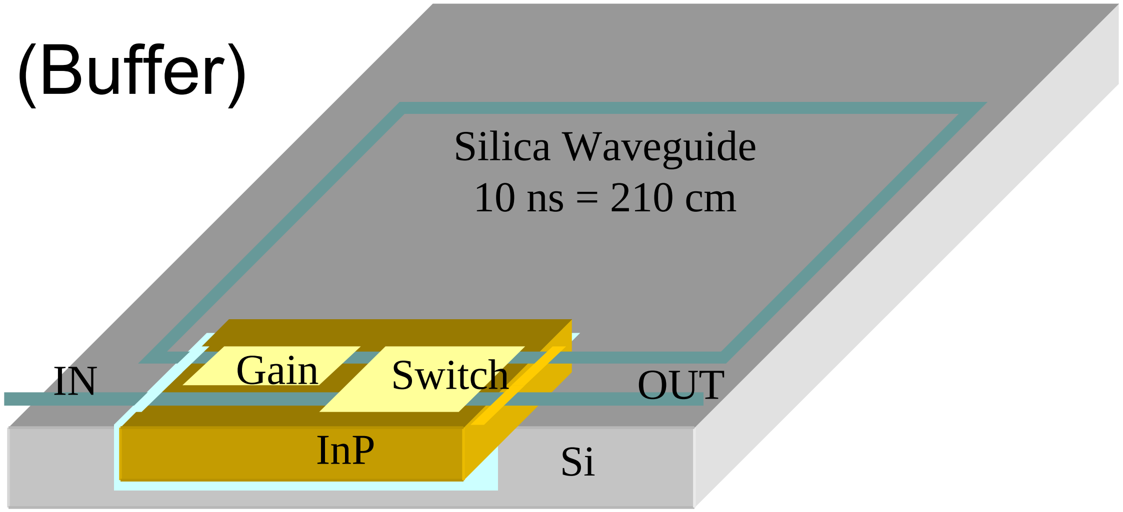
General Idea (cont'd):

- Ideal Technology: All Optical Network
- Optical Router



Optical signal → ~~**Conversion** to **electrical** signal~~ → **Switching optical** signals → ~~**Conversion** to **optical** signal~~ → **Optical** signal

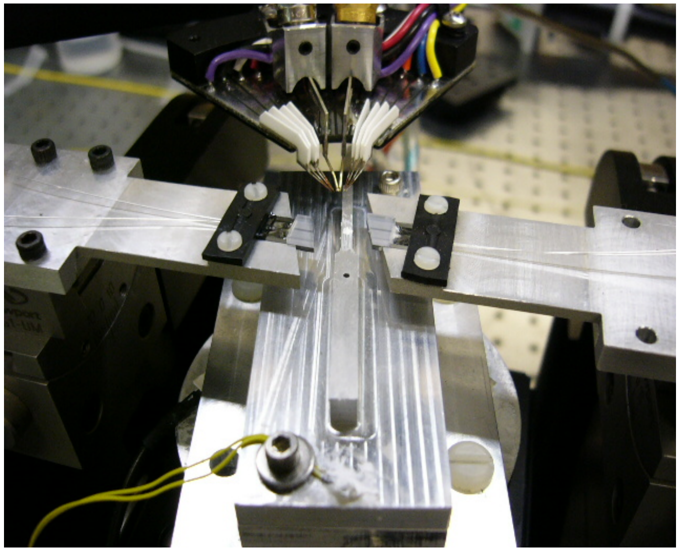
- Optical Random Access Memory
  - Switch-to direct data to a buffer
  - Recirculating Loop (Buffer)
  - Amplifiers



Courtesy of Emily F. Burmeister

Activities:

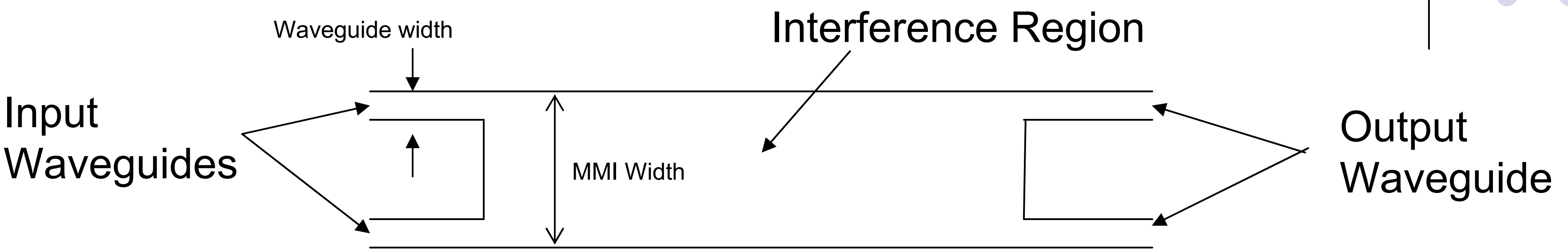
1. Simulation (BeamPROP)
   - Optical propagation tool
2. Testing (All parameter analyzer)
   - Silica waveguide
3. Programming
   - Stages’ motion controller (MATLAB, GPIB*)
   - Secondary instruments (MATLAB, GPIB)



*General Purpose Interface Bus

1. Simulation:

- Multi Mode Interference Devices (MMIs)



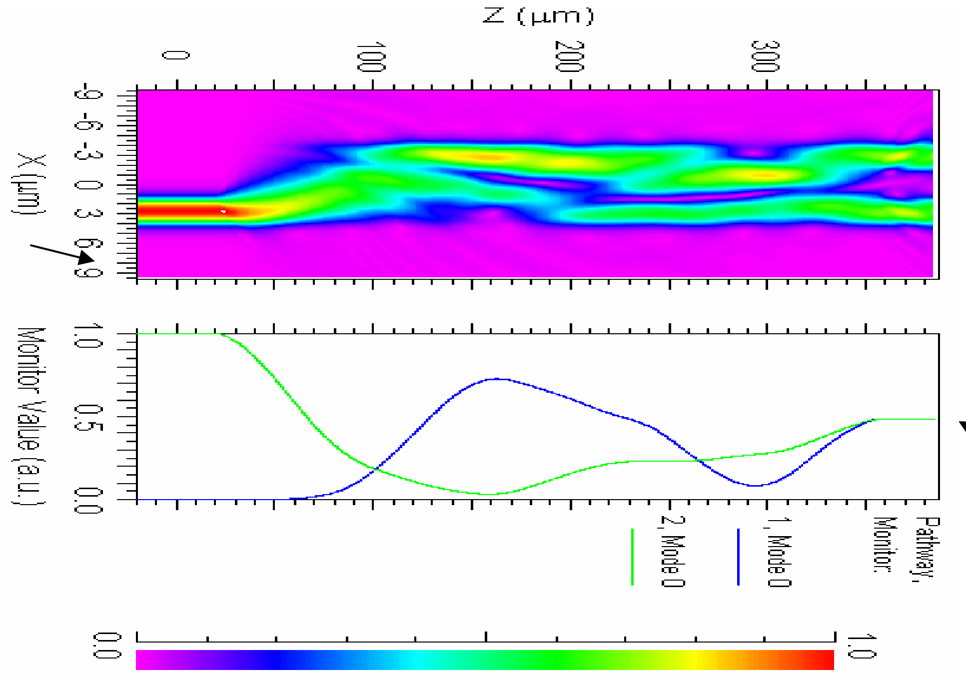
Waveguide width

Interference Region

Input Waveguides

MMI Width

Output Waveguide



Light Interference pattern inside the MMI

Power vs. Position Diagram

- The power of two “beams” coming out are both equal and about 0.49 * input power

- Calculate possible error due to fabrication tolerance.
  - Extract data from BeamPROP and analyze in MATLAB

Splitting ration vs. dimensions		MMI Width (micro meters)		
		7.9	8	8.1
waveguide width (micro meters)	2.4	1.0018	1.0102	1.0137
	2.5	1.0009	1.0097	1.0085
	2.6	0.9965	1.0056	1.0017

% Error wrt. Split ratio of 1		MMI Width (micro meters)		
		7.9	8	8.1
waveguide width (micro meters)	2.4	0.180	1.020	1.370
	2.5	0.090	0.970	0.850
	2.6	0.350	0.560	0.170

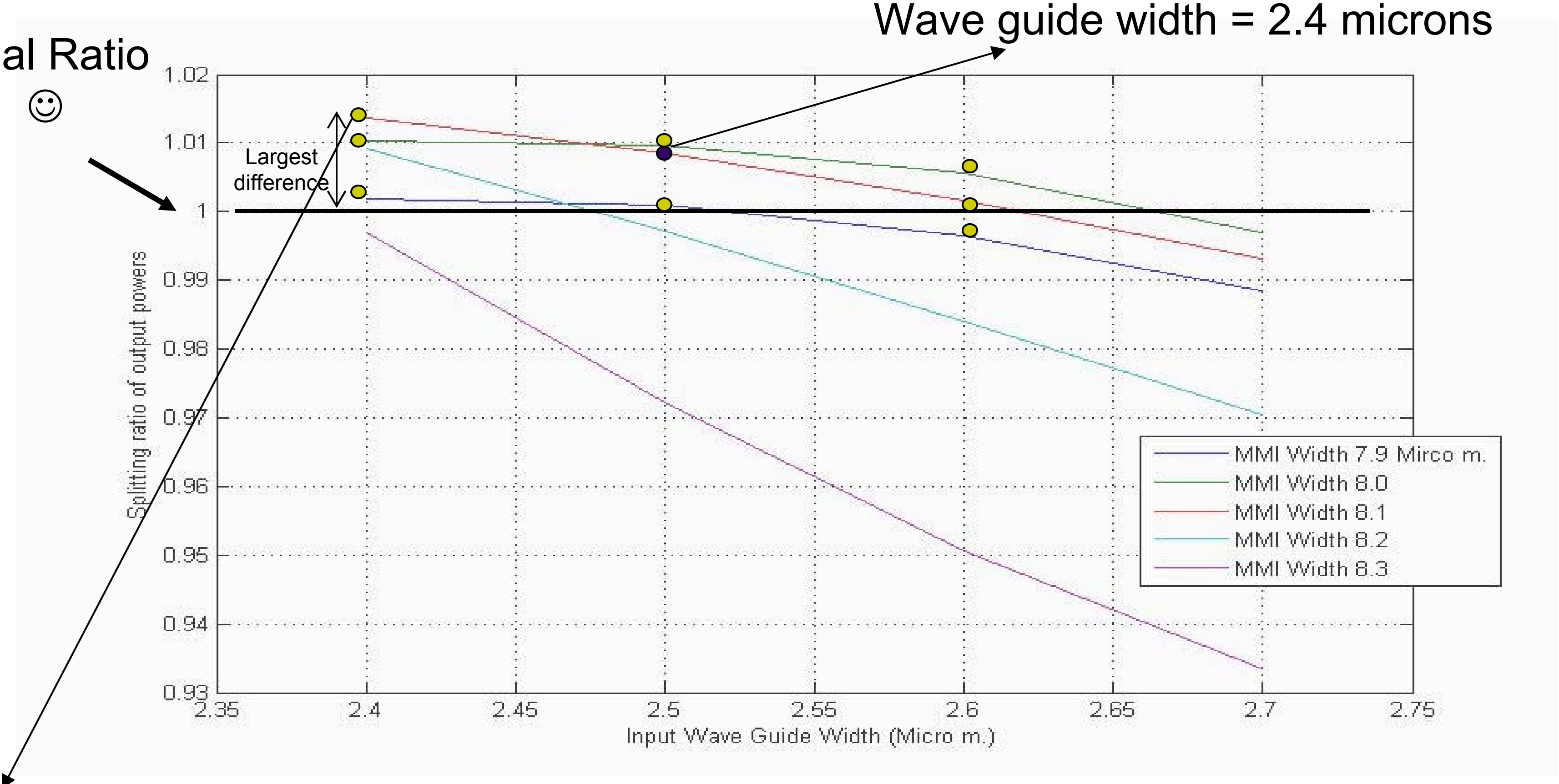
→ Worst splitting ratio: 1.0137 with 1.370 percent difference
for waveguide width=2.4 & MMI width =8.1

- Calculate possible error due to fabrication tolerance.

Splitting ratio vs. Dimension

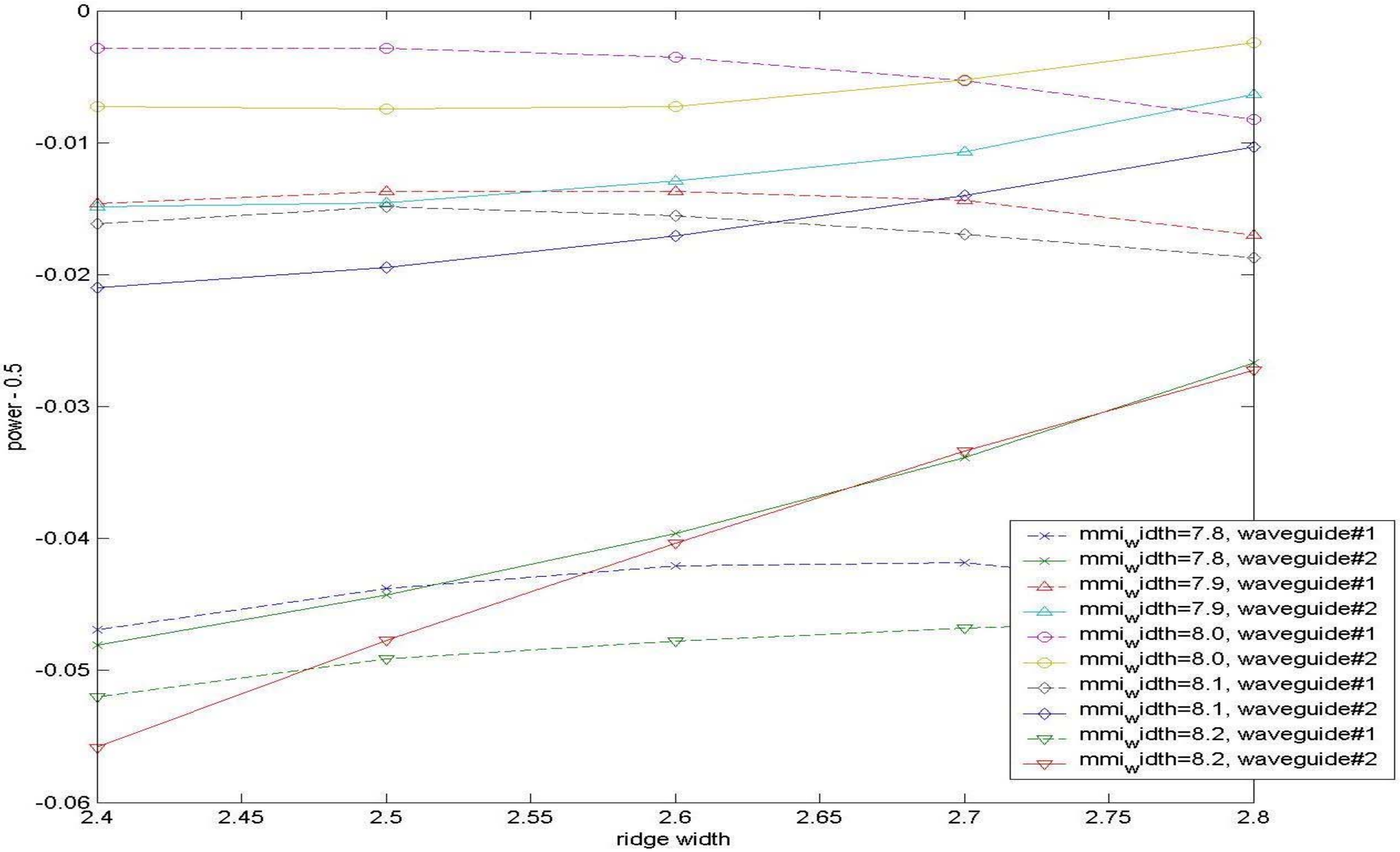
Designed dimensions: MMI width= 8.0microns
Wave guide width = 2.4 microns

Ideal Ratio
☺



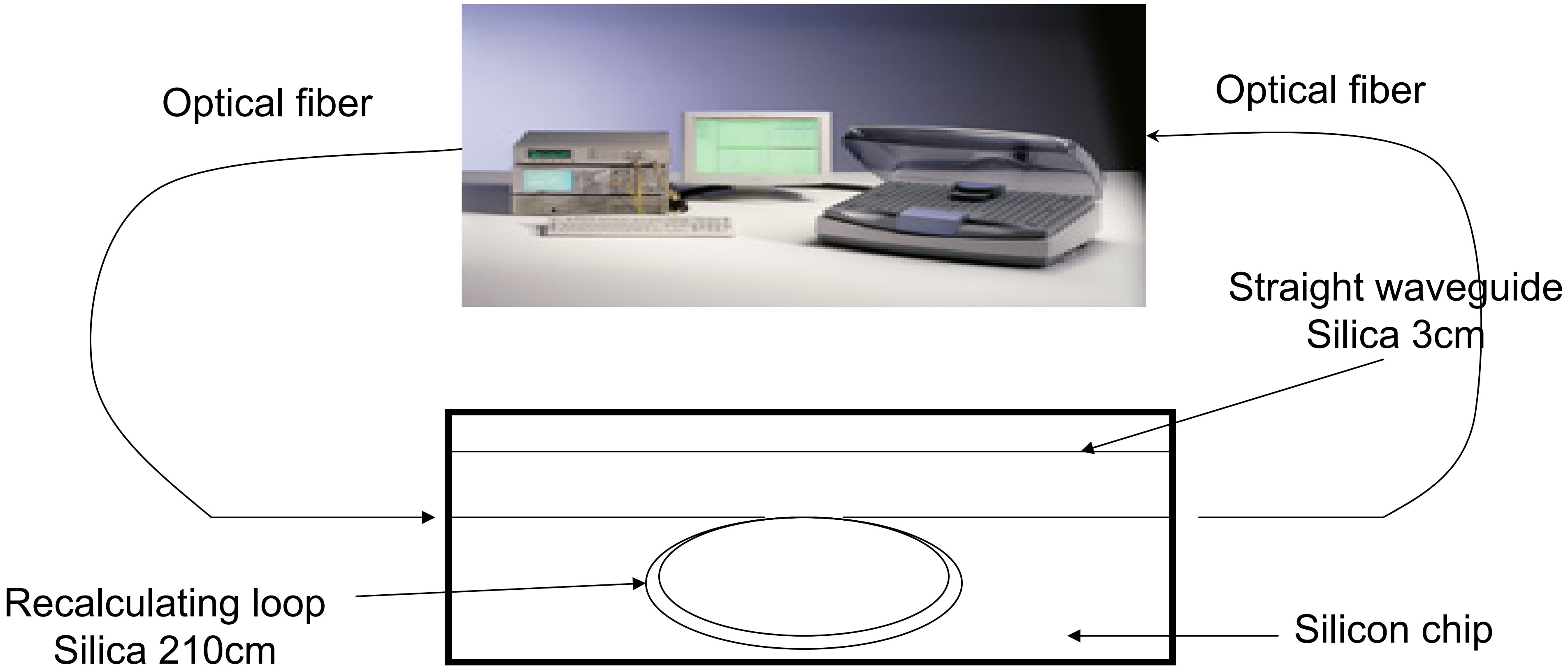
=> Worst case scenario for splitting ratio is about 1.0137 with 1.37 percent error for MMI width=8.1 microns, waveguide width = 2.4 microns

Relative Power vs. Dimension (Width):



2. Testing: (all parameter analyzer)

- Recirculating Loop and straight waveguide for 5 parameters for different wavelenghts
  - Waveguides are made of Silica on a silicon chip



Optical fiber

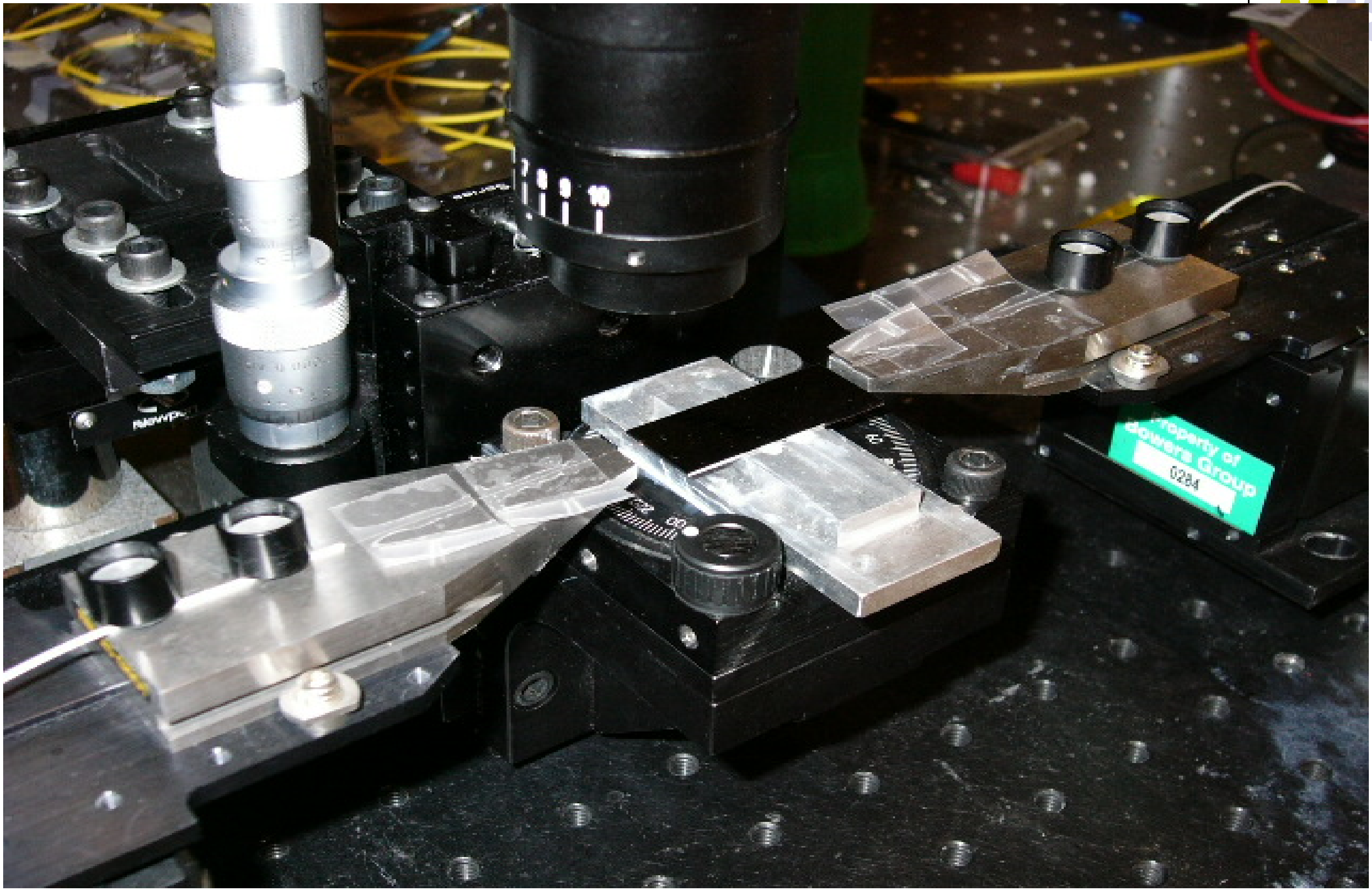
Optical fiber

Straight waveguide
Silica 3cm

Recalculating loop
Silica 210cm

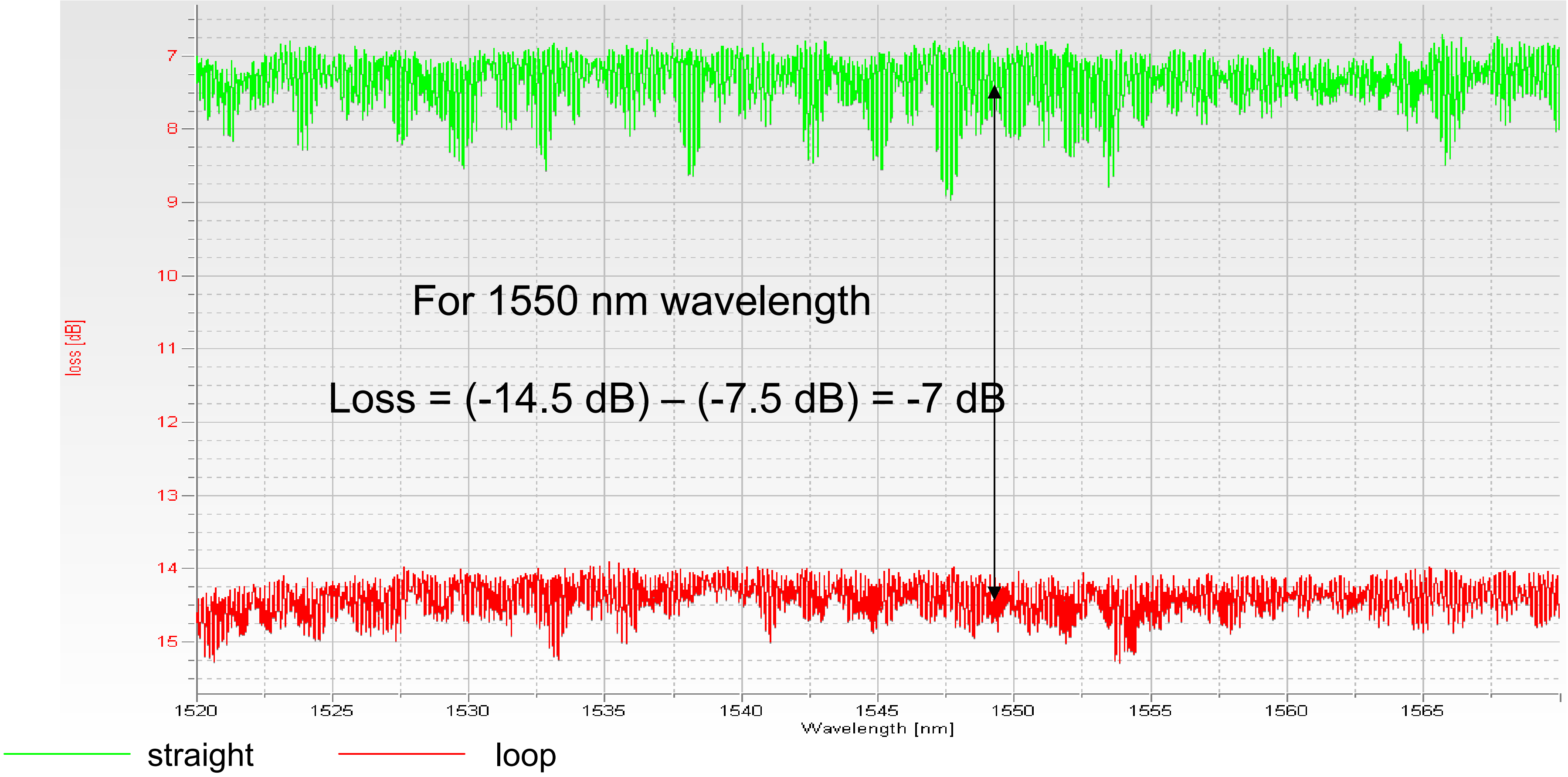
Silicon chip

- **A picture of the setup**



1. **Loss:** losing optical power due to scattering of light

actual loss for loop = measured loss for loop – measured loss for straight waveguide

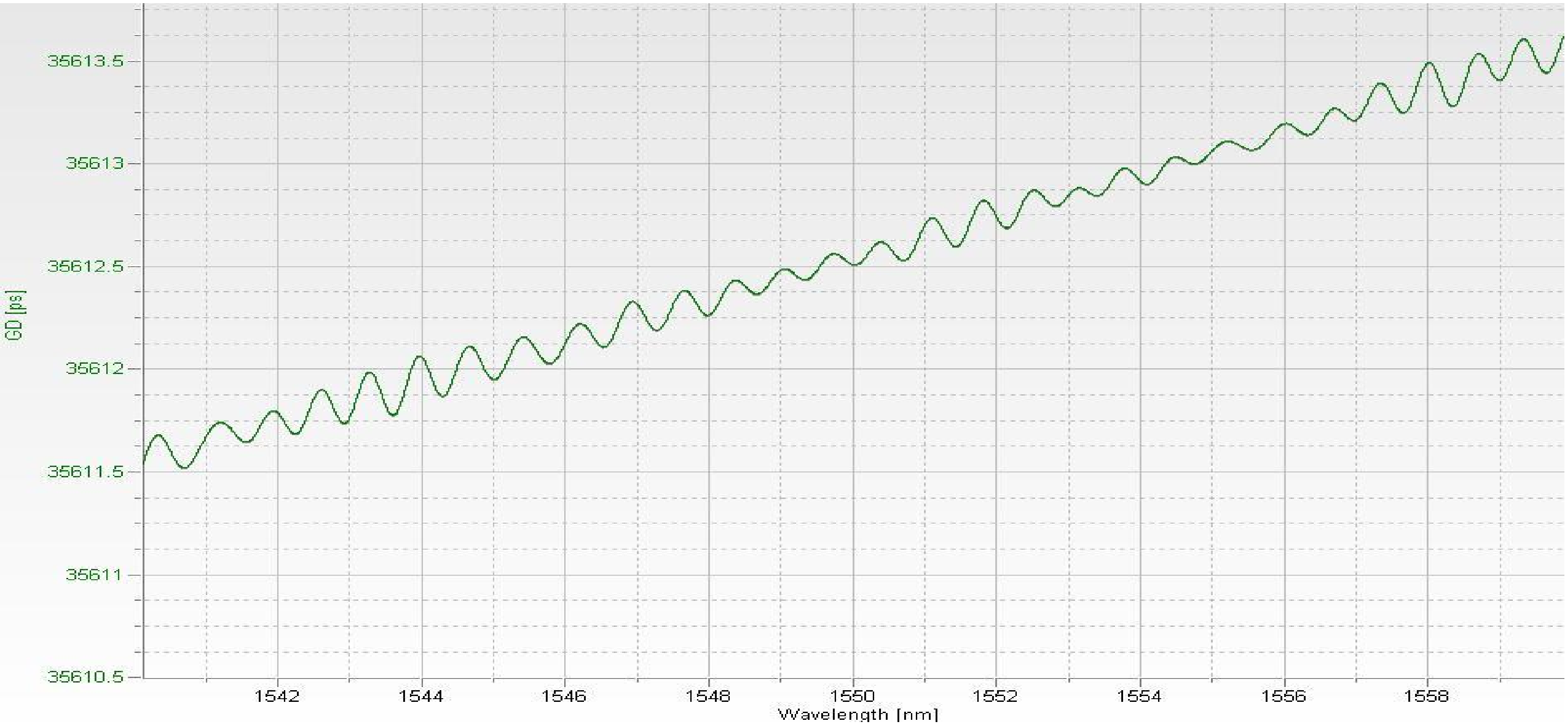


For 1550 nm wavelength

Loss = (-14.5 dB) – (-7.5 dB) = -7 dB

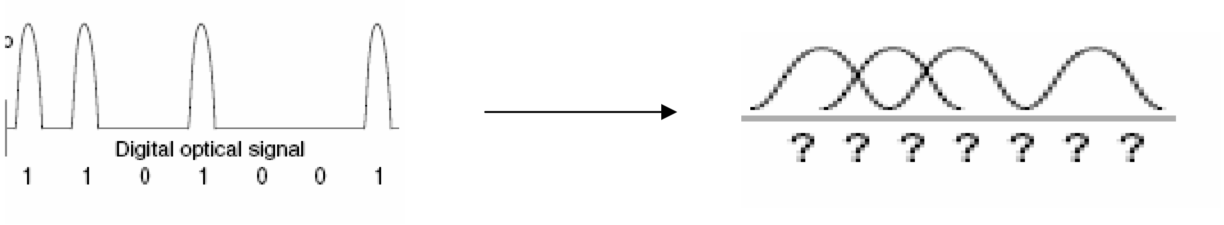
- **Group Delay (GD):** The time it takes for the signal to travel through the loop

actual GD for loop = measured GD for loop – measured GD for straight waveguide



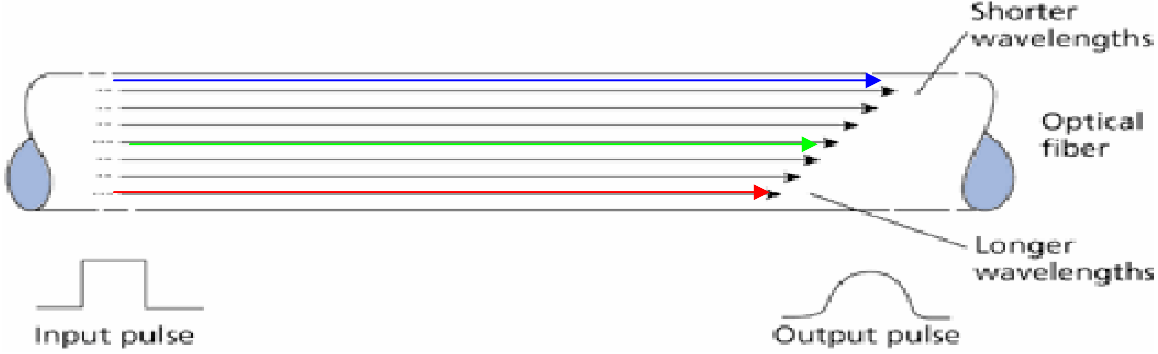
Dispersion

- Definition: widening or compressing of an optical pulse.
  - Why does it matter?



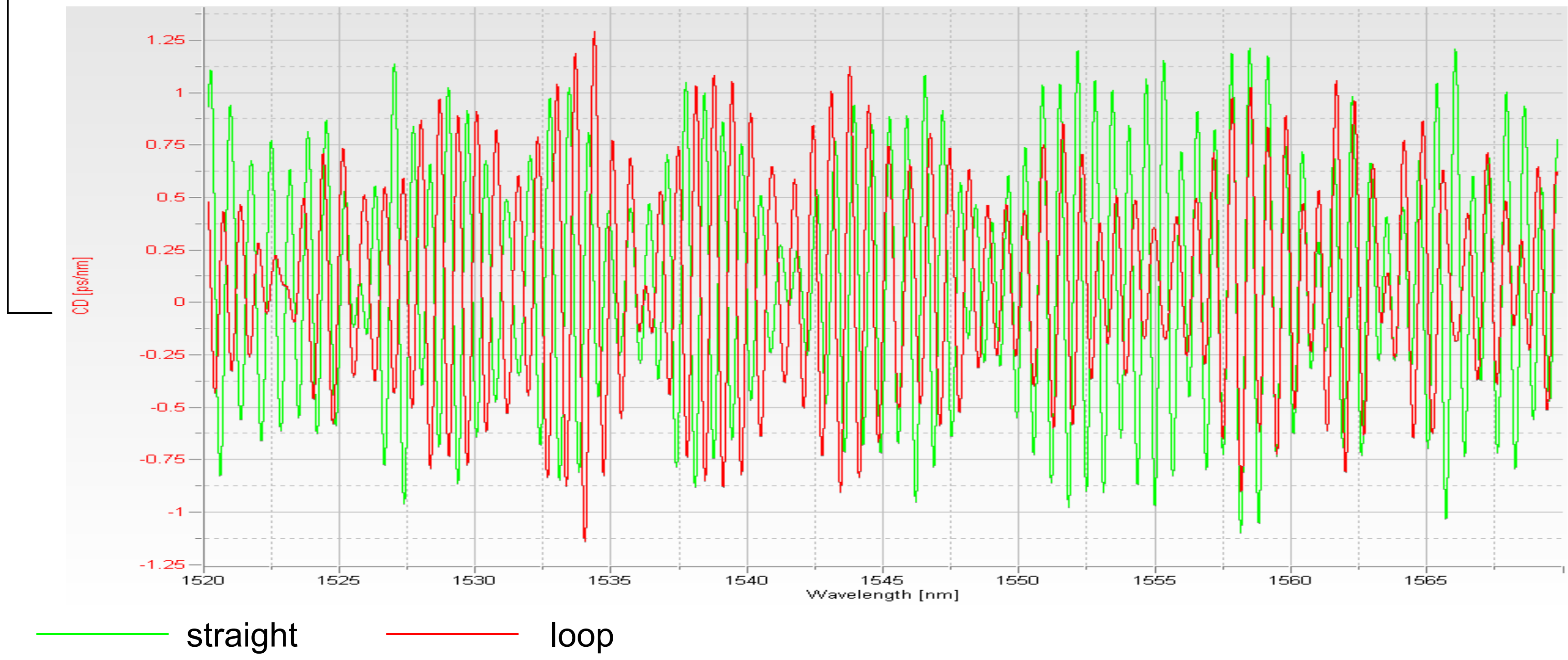
  - Bits won’t be distinguishable
- Dispersion happens if parts of the pulse travel at different speeds.
- Two types:
  - Chromatic Dispersion
  - Differential Group Delay

2. **Chromatic Dispersion (CD):** widening of the pulse due to difference of speed in wavelength that make up that pulse



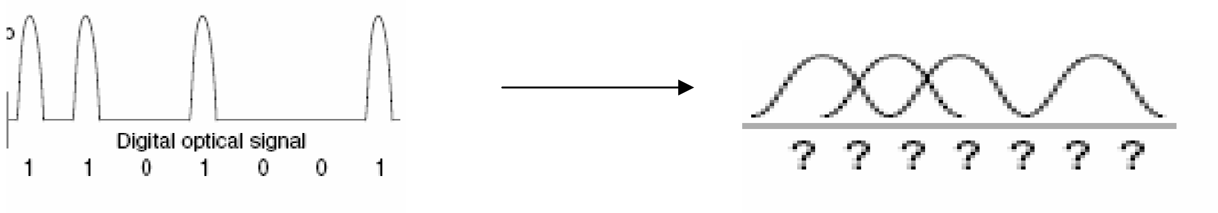
http://www.reed-electronics.com/tmworld/article/CA197792.html

CD (average)
is about 0
for both the
loop
and the
straight line



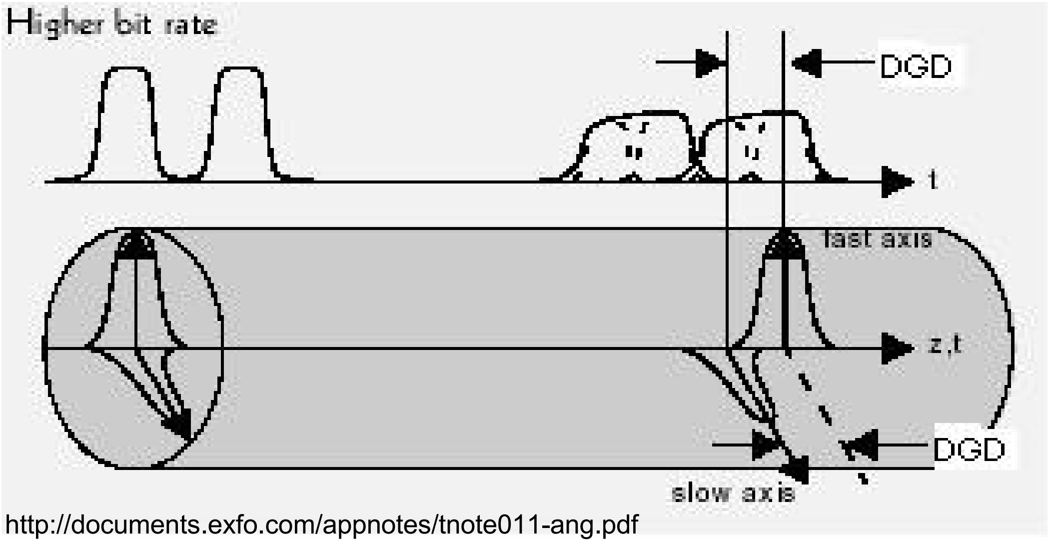
Dispersion

- Optical pulses are made up of a range of wavelengths
- The narrower the pulse the wider the range of wavelengths
- Different wavelengths travel with different speeds depending on the media
- Therefore, pulses can be widened or compressed.



- Widened pulses will result in errors in high speed transmission
- Two types of dispersion were measured.

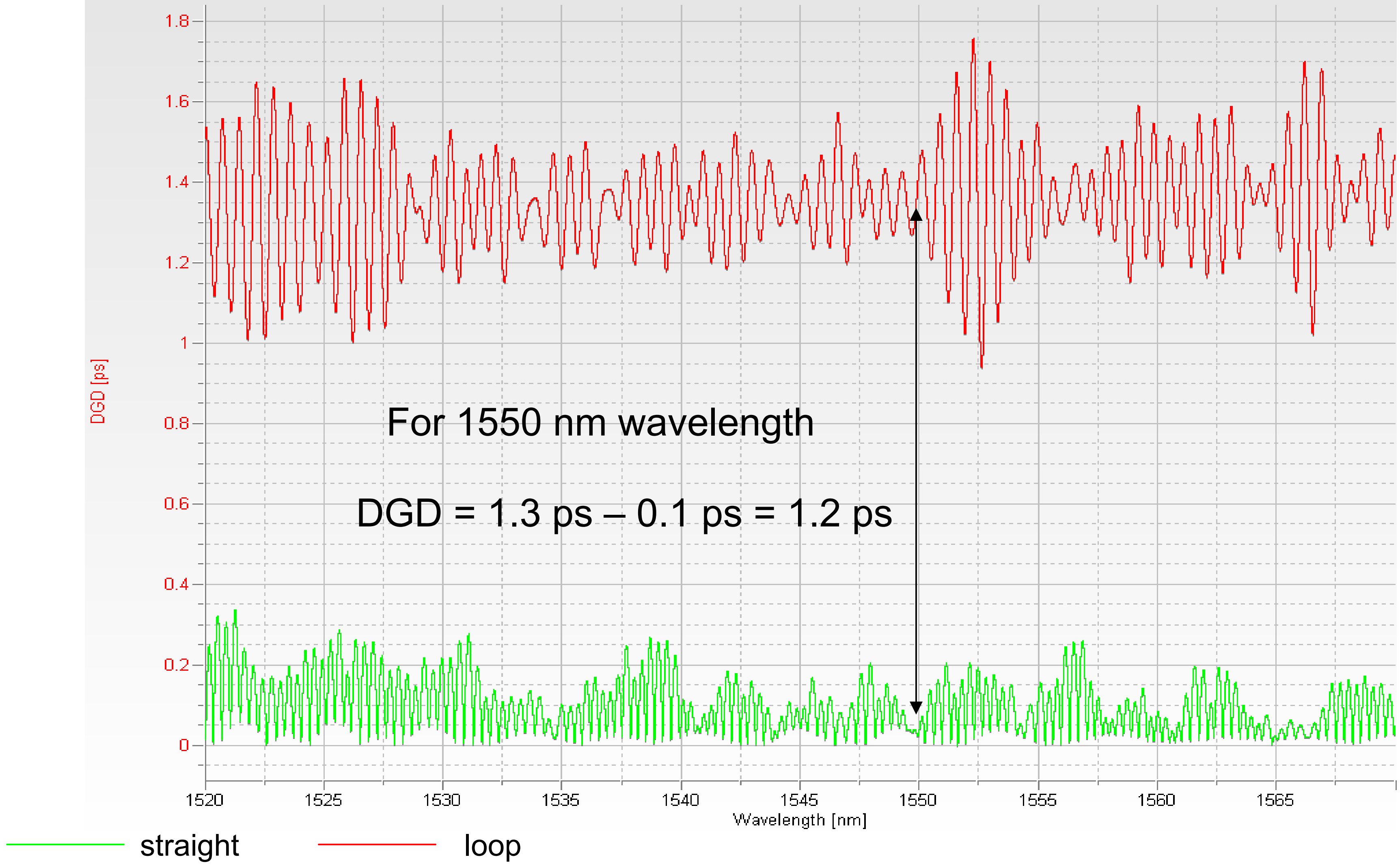
3. **Differential Group Delay DGD**: dispersion of pulse due to difference of speeds of light polarized in different directions.



http://documents.exfo.com/appnotes/tnote011-ang.pdf

- **Why?**
  - The core of optical fiber is not symmetric
  - Temperature, tension, etc.

actual DGD for loop = measured DGD for loop – measured DGD for straight waveguide



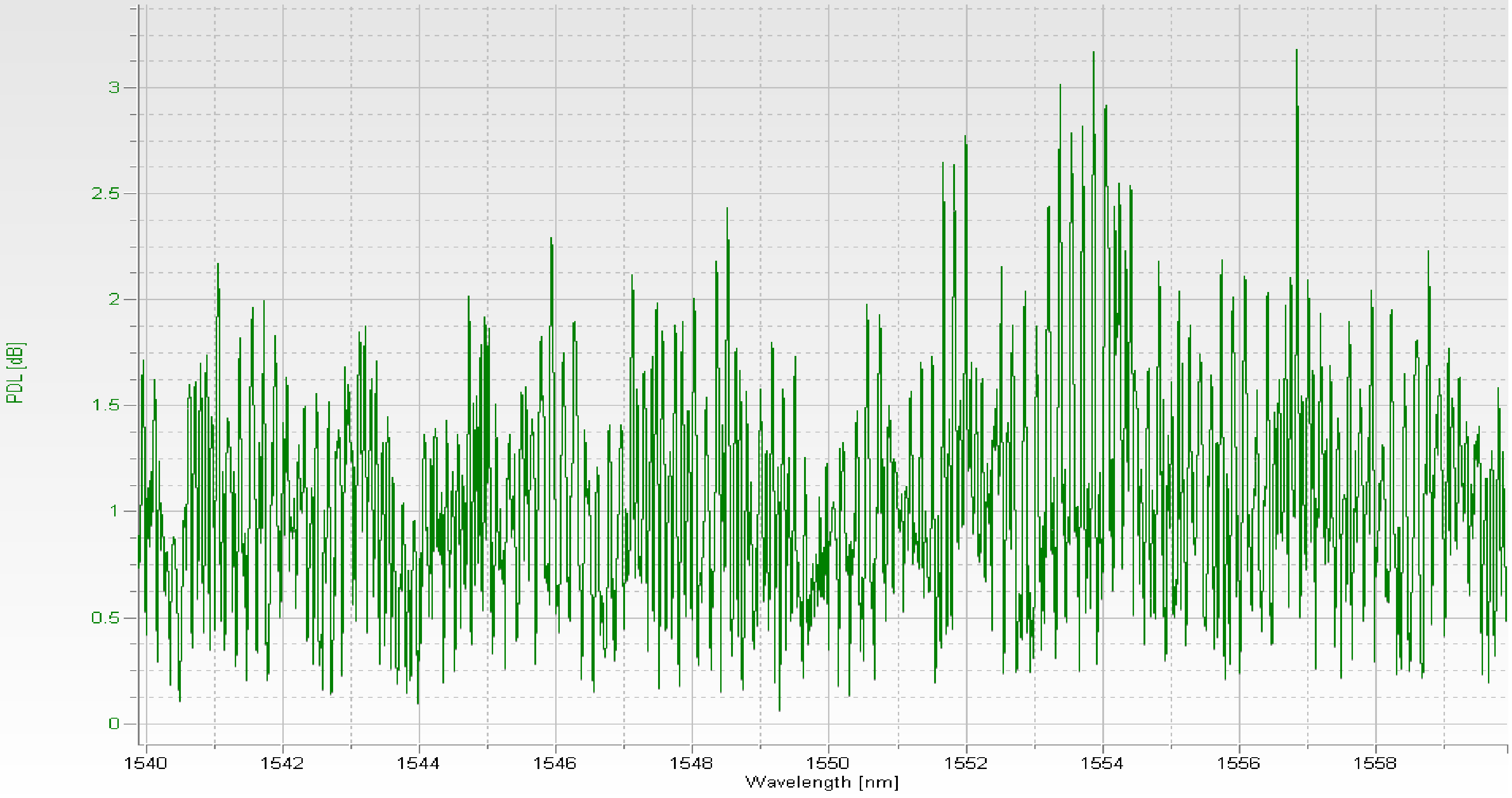
For 1550 nm wavelength

DGD = 1.3 ps – 0.1 ps = 1.2 ps

- **Polarization Dependent Loss (PDL):** loss is different for different polarization axis

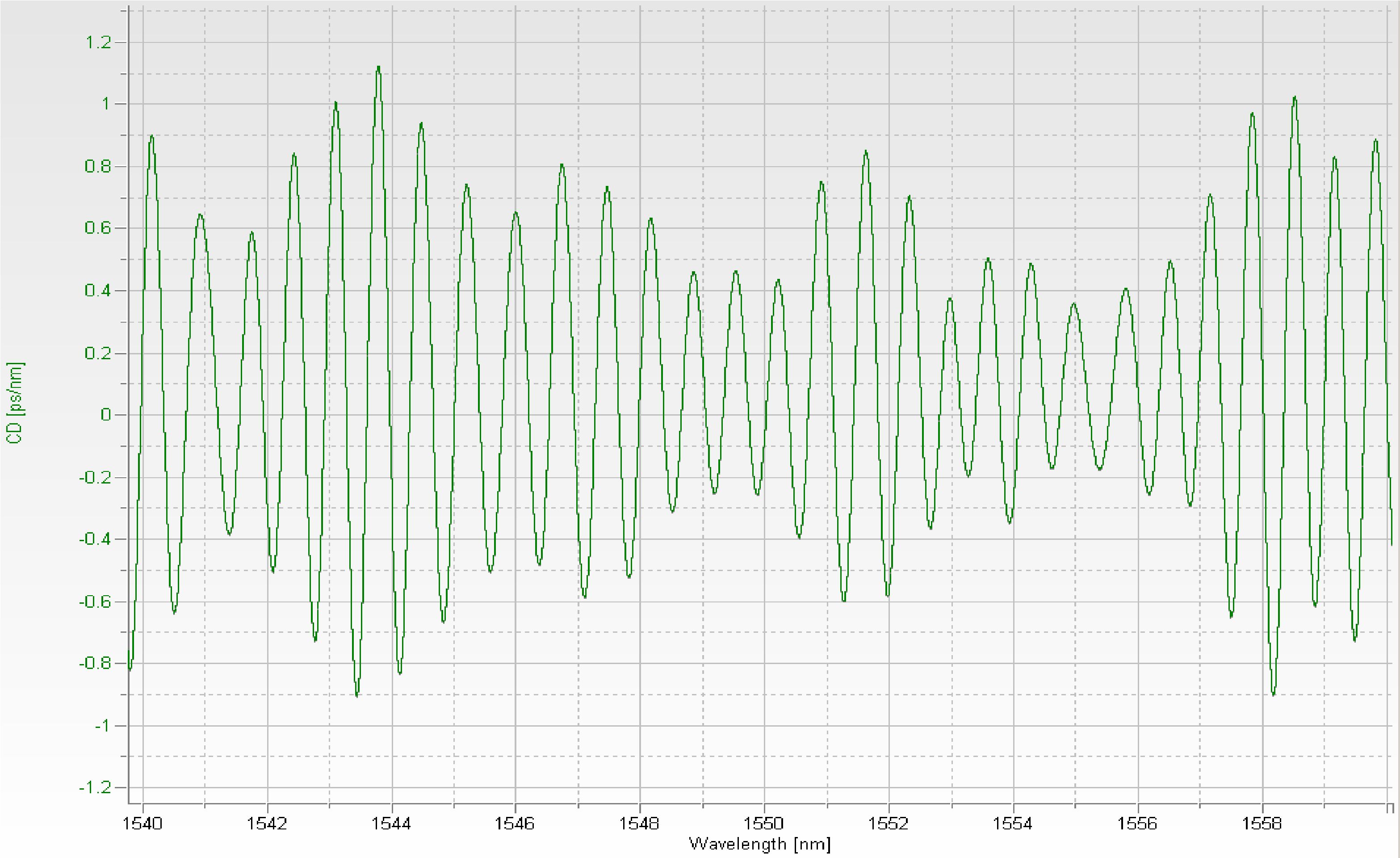
$$PDL = 10 \log \frac{P_{MAX}}{P_{MIN}}$$

www.exfo.com



actual CD for loop = measured CD for loop – measured CD for straight waveguide

- CD vs. Wavelength



Conclusion

- Fabrication tolerance in MMI will create a maximum 1.37% error which is reasonable.
- Loss per cm for silica is 0.04 dB/cm which is higher than we expected but better than silicon and InP.
- Chromatic dispersion is not significant
- DGD is about 1.2 ps which is acceptable for 40 Gbits/s data speed

Future Plan

- Analyze the loss data further to find out why our loss is more than we expected
- Further study the fluctuations in measurements
- Implement a program that controls the stages’ controller

Acknowledgements

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- My science professors at Saddleback College

Mach-Zehnder Switch:

- Adjustable index of refraction
- Interference destructively or constructively