10:40 Gb/s Multiplexer for High-Speed Optical Networks

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Outline

- Introduction to fiber optics and information networks
- Learn what a multiplexer is and how it works
- Building my multiplexer
- Results and Data from the multiplexer
The Big Picture

- The OCPN is designing the world’s first all optical information network.
- My mentor is working on an experiment to test the capabilities of an all optical network.
- I am building a device called a ‘multiplexer’ for this experiment.
Information Networks

Local Area Network (Copper wire)  Metropolitan Area Network  Long Haul Interexchange Network (Optical Fiber)

Routers are electrical

Trunk lines are optical
What is Optical Fiber, Anyway?

- Replacement for electrical wire
- Uses light to transmit data
- Made from very pure glass (Silica)

Advantages:

- Less prone to interference than copper wire
- Potential for MUCH higher speeds
- Lower power
- Longer distances

Information Networks

Local Area Network (10 Mb/s)

Metropolitan Area Network (2.5 Gb/s)

Long Haul Interexchange Network (40 Gb/s)

Trunk

Twigs and Leaves

Branches

Boston

NYC

Chicago
Our Mission:

- To build an optical multiplexer for an optical network experiment!
  - Learn to splice fibers together
  - Order all the parts for the multiplexer
  - Build and test the multiplexer
Time Division Multiplexing

- Several data streams offset by short amounts of time so that they can be combined into one stream.
- Each stream given its own time ‘slot’ for its information.

![Diagram of Time Division Multiplexing]

- 10 Gb/s
- 40 Gb/s
My 10:40 Gb/s Multiplexer

Undelayed 10 Gb/s signal

Undelayed 20 Gb/s signal

Delayed 10 Gb/s signal

Delayed 20 Gb/s signal

Input: 10 Gb/s

20 Gb/s

Output: 40 Gb/s
My 10:40 Gb/s Multiplexer

Polarization Controller

PM variable delay lines

PM Variable attenuators

1:2 PM coupler

ΔT=12.5 ps

2:2 PM coupler

ΔT=6.25 ps

2:1 PM coupler

10:20 Gb/s

20:40 Gb/s
Polarization Maintaining Splicer

- **Stripping** - Fibers must be stripped of protective shells and coatings.

- **Cleaving** - Fibers must be cut perfectly straight.

- **Aligning** - Fibers aligned perpendicularly and along their slow and fast axis.

- **Fusing** - Electrical arc across two electrodes fuses fibers together.
Building Challenges

- Parts difficult to order
- Parts slow to arrive
- Some parts broken
- Laying out Multiplexer
- Designing Plexiglass enclosure

- None of the parts ordered have arrived yet!
Problems to Correct

- Polarization
- Power loss
- Bit rate errors (variable delay not lined up correctly)
Coping With Loss

- We want 50% power in each ‘arm’
- Power difference in each arm causes amplitude variation in 20 Gb/s signal
Coping with Loss

- Attenuator and patchcords removed to reduce power difference.
- Adjusted delay line until power difference was zero!

1.6 dB<loss<3.0 dB

After adjustment, 0 dB difference!
Input Signal

Input: 10 Gb/s signal, with period of 100 ps
Output signal

Output: 20 Gb/s signal with period of 50 ps!
Input and Output Together

Power

Time
Conclusions

- Finished half of multiplexer and had it work
- Power loss was higher than desired
- I learned how to successfully use the PM fiber splicer
- I ordered the remaining parts successfully, but they have not arrived yet
The Future…?

- Multiplexer used in optical networking experiment
- Optical networking will (hopefully) revolutionize the internet
- …I keep working on it?
What I Learned This Summer

- Learned a lot about electronics, optics, and computers
- Science is cooperative
- Things can take longer than expected
- Possible career choice
- I am a geek, but that’s okay.
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FIN
Q: How Optical Fibers Work

- Light able to propagate because of a *Total Internal Reflection*.
- Walls of fiber act like mirrors, even though they are clear.
- Information sent through pulses of light from a laser, like Morse code.
- Pulses translated into binary (1’s and 0’s)
Q: Polarization

- Light is an electromagnetic wave with two polarizations
- Polarizations can propagate differently in fiber
- Drifting of polarizations can lead to errors
- Polarization maintaining (PM) fiber can prevent errors
Q: (Future) Fiber Optic Networks

The Present:

- Processing and routing done electronically
- Information translated between electrical and optical domains several times
- Slower, inefficient, costly

The Future:

- Reducing processing demands on routers
- Information stays in optical domain for its entire journey
- Faster, very efficient, cheaper
Q: What is a ‘Multiplexer’?

- A device that increases the speed of optical fibers.
- Takes several channels, and combines them so they can be transmitted simultaneously.
- A demultiplexer does the opposite.

Picture: http://www.lightreading.com
Q: Optical Label Swapping

- Optical ‘label’ attached to IP (internet) packets that acts like a zip code
- Label contains info such as destination address, priority, and TTL (Time To Live)