Fiber Optic Testing Challenges in Metro Networks

Agilent Technologies

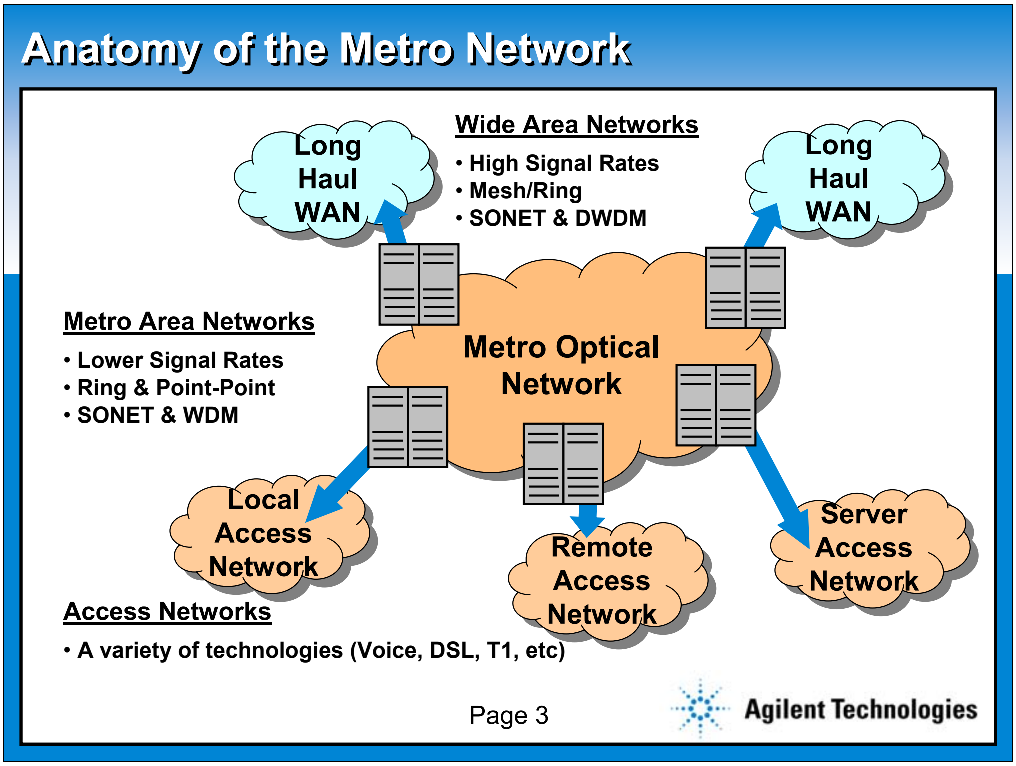
January 31, 2003

presented by:

Frank Buchanan
Applications Engineer

Agenda

1. Anatomy and Issues of the Metro Network
2. Utilizing and Testing WDM
3. Utilizing Higher Data Rates and Testing Dispersion
4. Summary

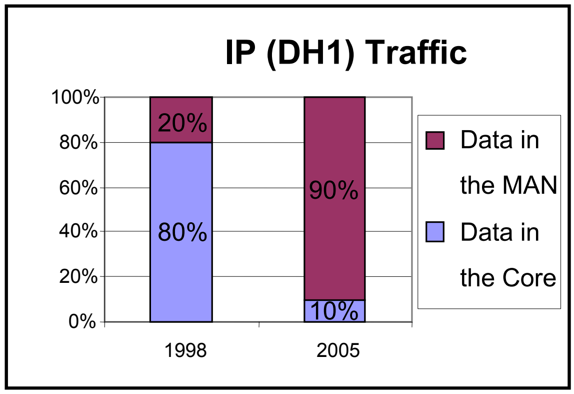


Here's an overview of today's network, graphics courtesy of Sorrento Networks. Starting at the bottom, we have identified key services that are delivered to enterprises and homes. Often, services will be correlated with an access method, such as wireless, residential broadband, SANs, and so forth. These are brought from the "Metro Edge" to a transport network sometimes refered to as the "Metro Core". A significant amount of traffice stays within the Metro environment. Traffic destined to outside the network goes to Regional, Long-haul, Ultra-long-haul, or even submarine networks. This sometimes is known as "Core" transport, but this term can sometimes be confused with the "Metro Core", so be careful of it's use.

The Metro Network is the data "Bottleneck"

Issues

- SONET is not data friendly
- Metro access is too expensive
- The Metro is full of lighted, legacy fiber



Possible Solutions

- Make SONET data friendly
- Migrate towards lower cost GbE
- Increase optical channel data rates
- Increase the bandwidth through Wavelength Division Multiplexing techniques

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The Physical Layer

Issues

- Too expensive to lay more fiber
- No room left to lay more fiber
- Most of the fiber is lighted

How do we maximize the use of this legacy fiber?

- Increase the bandwidth through WDM.
- Increase data rates per channel to the dispersion limits

These solutions have fiber optic testing implications!!!

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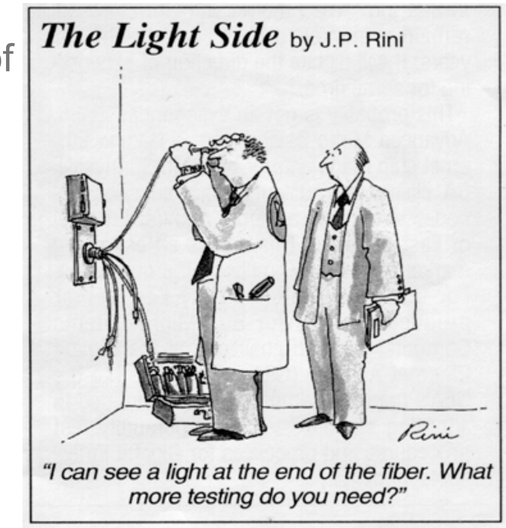

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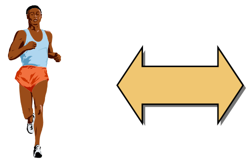
Increase Bandwidth Through WDM

Coarse WDM or CWDM

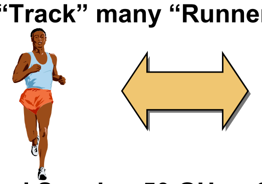
Same "Track" more "Runners"



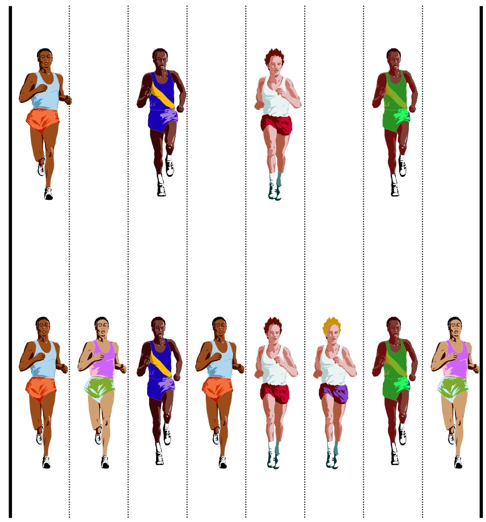
Channel Spacing 200 GHz ≈ 1.6 nm

Dense WDM or DWDM

Same "Track" many "Runners"

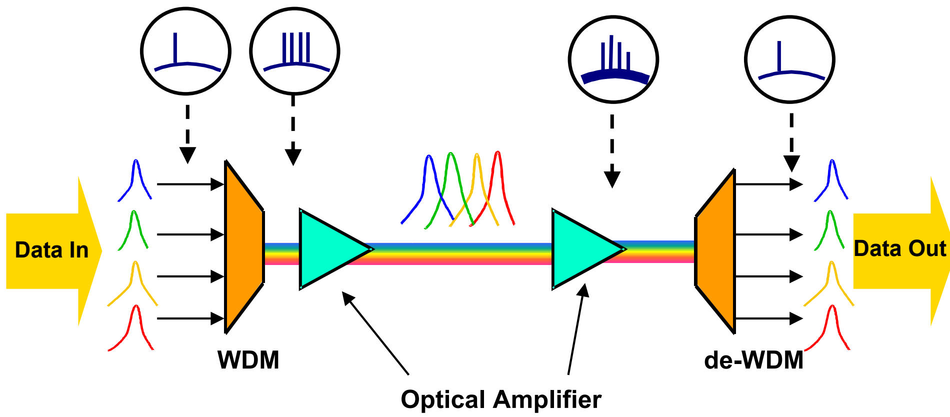


Channel Spacing 50 GHz ≈ 0.4 nm



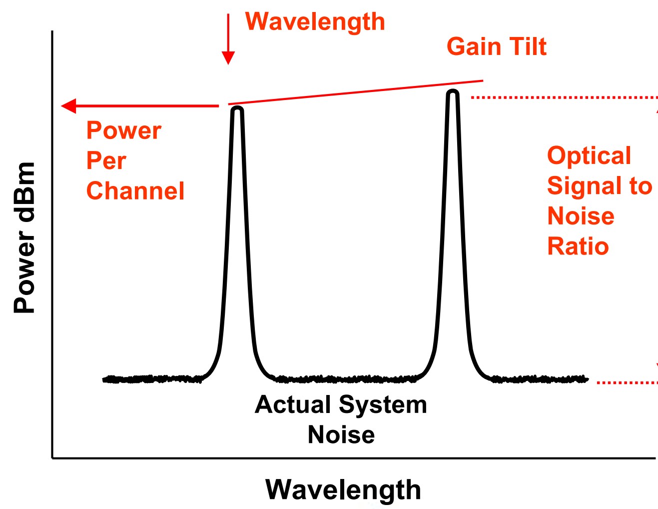
How do we Test the Channels in a DWD link?

An Optical Spectrum Analyzer is an excellent tool in which to characterize an optical network using WDM



Tests Using an OSA

- Total Power of all channels
- Power per Channel
- Wavelength
- Gain Tilt
- Optical Signal to Noise Ratio (OSNR)



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What can go wrong in a WDM link?

- Dirty connections are 90% of all problems
- Laser Transmitter failed
- Optical Amplifier failure or degradation

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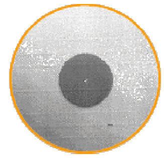
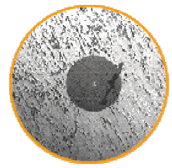
- Dirty connections are 90% of all problems
  - Loss of signal or signal interference





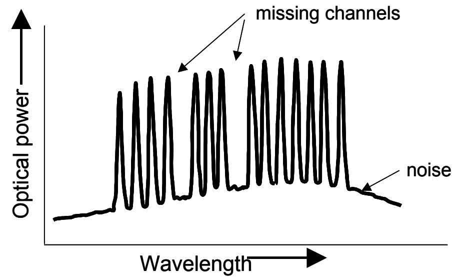
- Laser Transmitter failed
- Optical Amplifier failure or degradation

Don’t look at the end of the fiber with your eye! Up to 1 Watt of optical power from an EDFA!

What can go wrong in a WDM link?

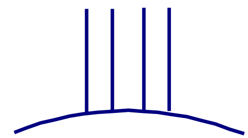
λ_1, λ_2 . . . λ_n

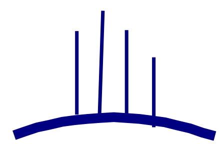
- Dirty connections are 90% of all problems
  - Loss of signal or signal interference
- **Laser Transmitter failed**
  - **Detecting one or many**
- Optical Amplifier failure or degradation



What can go wrong in a WDM link?

- Dirty connections are 90% of all problems
  - Loss of signal or signal interference
- Laser Transmitter failed
  - Detecting one of many
- **Optical Amplifier failure or degradation**
  - **Loss of signal or increased noise.**





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“Half Time” Q&A

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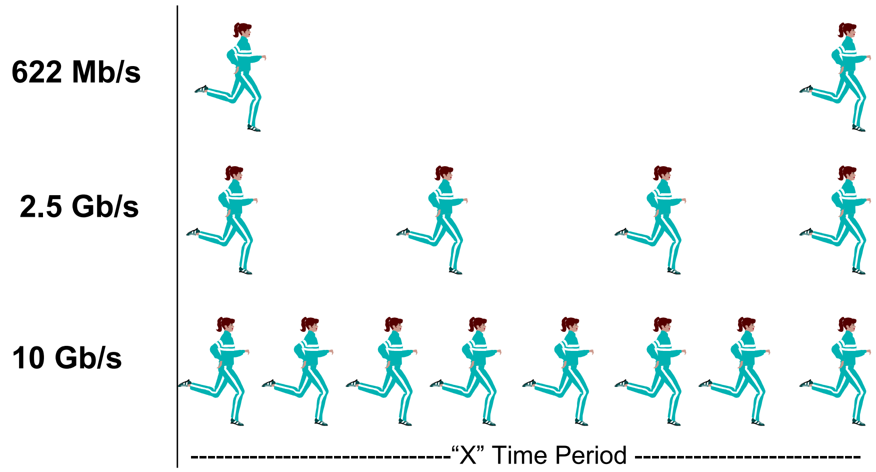
Increase Bandwidth Through Higher Data Rates

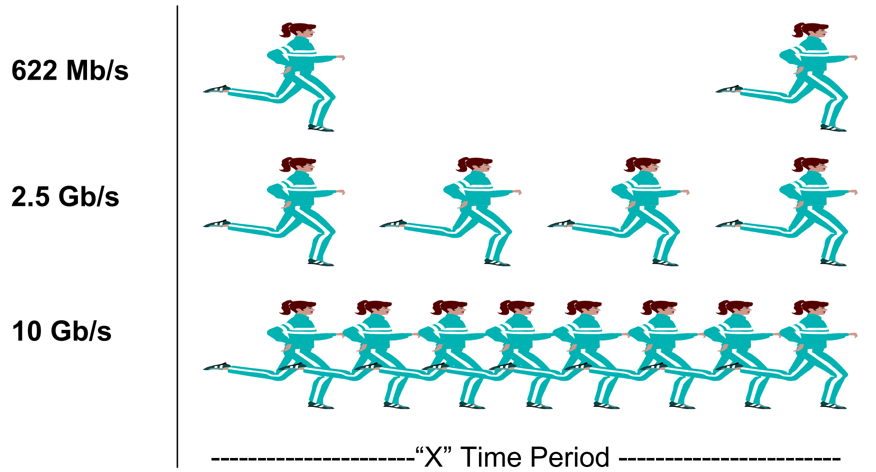
More and more "Runners" on the "track" in a given time period



Picture after a short distance down the "track"

Bandwidth is Limited by Dispersion

The more “runners” the harder it is to distinguish them after some time



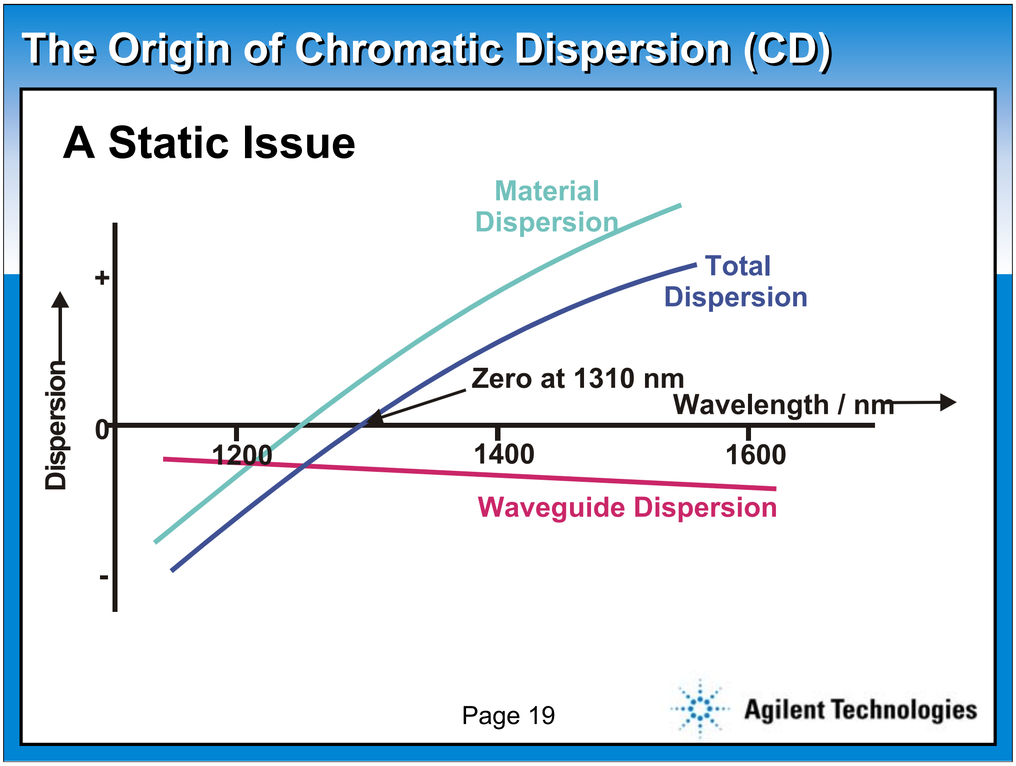
Picture after a longer distance down the “track”

Dispersion – Two Basic Types

- **Chromatic Dispersion**
- **Polarization Mode Dispersion**

Both translate to signal pulse broadening but…

… that is were the similarities end!

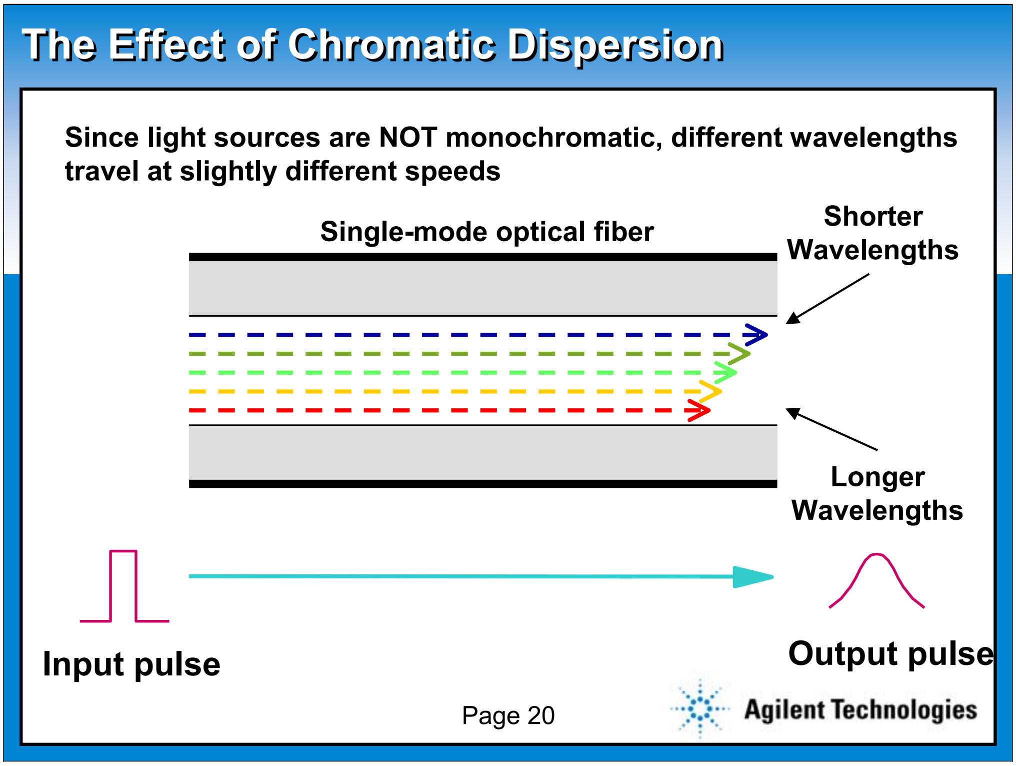


Single-mode fibers solved the modal dispersion problem, but now another lesser form of dispersion appears, known as chromatic dispersion or "CD."

Chromatic dispersion occurs because light of different wavelengths travel at different speeds. This way, the different "colors" contained in a light pulse propagate at different speeds. Depending on the spectral width, this effect results in pulse broadening called chromatic dispersion. This form of dispersion is a limiting factor in modulation bandwidth or system capacity.

Chromatic dispersion is always present, however it is not observed in multimode fibers because its effect is about 1000 times smaller than that of modal dispersion. A typical value of chromatic dispersion for single mode fiber may be about 10 ps/(nm*km), as compared to the 10 ns/(nm*km) for modal dispersion. The "ps/(nm*km)" units used for chromatic dispersion reflect their dependency on wavelength range (i.e., double the distance or double the wavelength range yields double the effect of "CD").

Even when chromatic dispersion is a small quantity, its effect adds up significantly for long runs of fiber, such as in the case of a Trans-Atlantic optical cable link. It also can become an issue when transmitting very high data rates, such as 10 Gb/s or higher, over several hundred kilometers.



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Why Measure CD?

Measure CD to…

- assess the transmission capacity of the fiber
- properly dispersion-manage using "dispersion compensators" to optimize the transmission capacity of the fiber

Bit rate	Measure	Static compensation	Dynamic compensation
2.5 Gb/s			
10 Gb/s	x	x	
40 Gb/s	x	x	x

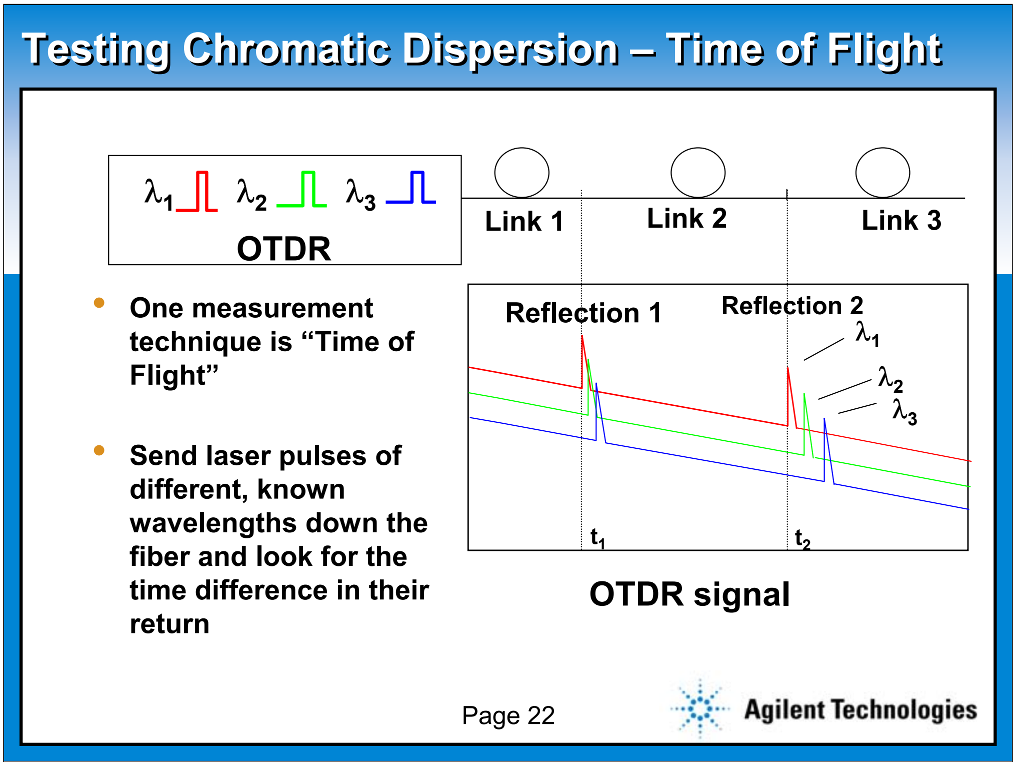
Once we have found solutions for the modal and chromatic dispersions, now we observe a third kind, known as "Polarization-Mode Dispersion."

The modes travel through the same path in the fiber, but they have different orientation in polarization. Each polarization state, horizontal and vertical, has slightly different transmission characteristics, thus creating dispersion on the modulated signal been carried.

These different polarization paths also produce different losses, therefore creating a loss dependency on polarization know as "Polarization Dependent Loss" or PDL.

Typical values for PMD are in the ps/(nm*km) range. Specifically, they cannot be compensated for, like in the case of CD, thus they add up significantly for long runs of fiber.

PMD can become a problem in the long distance network at 10 Gb/s or higher bit rates. Newly deployed fiber usually has been designed to minimize PMD but fiber installed some years ago may have significant PMD.



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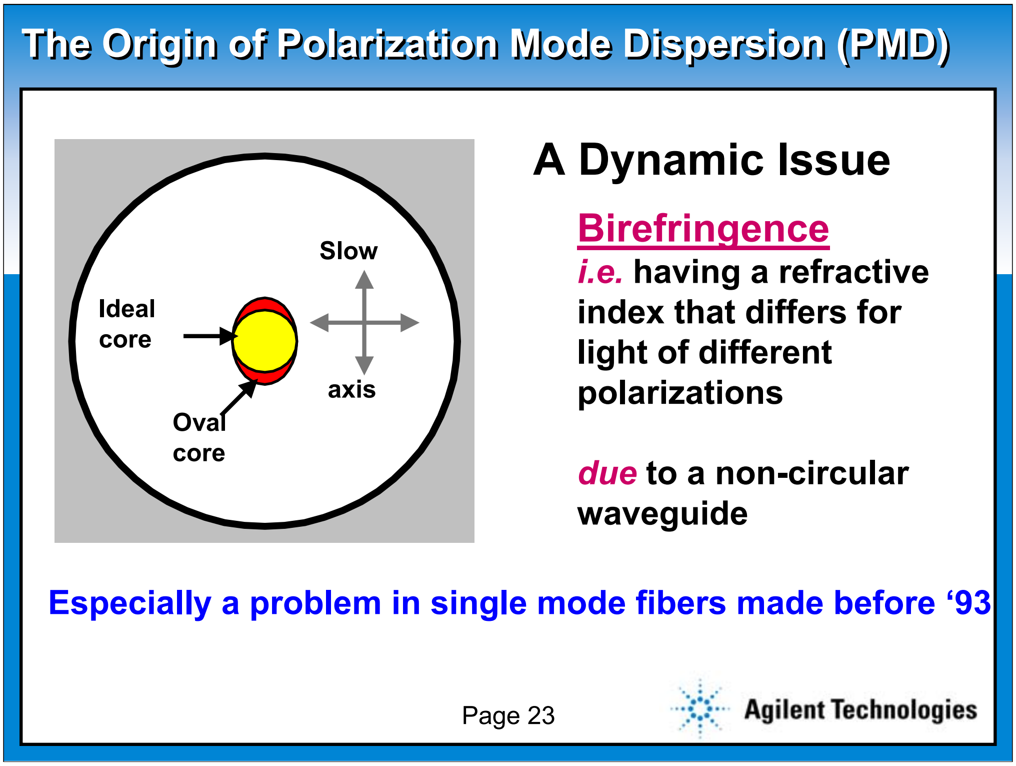

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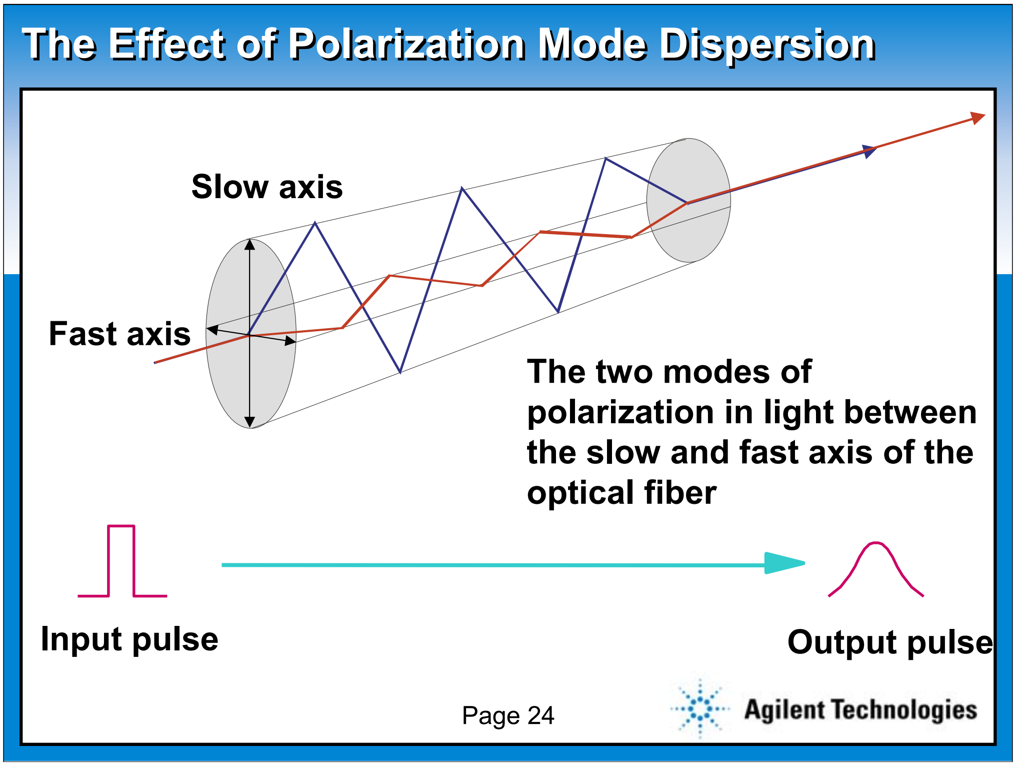

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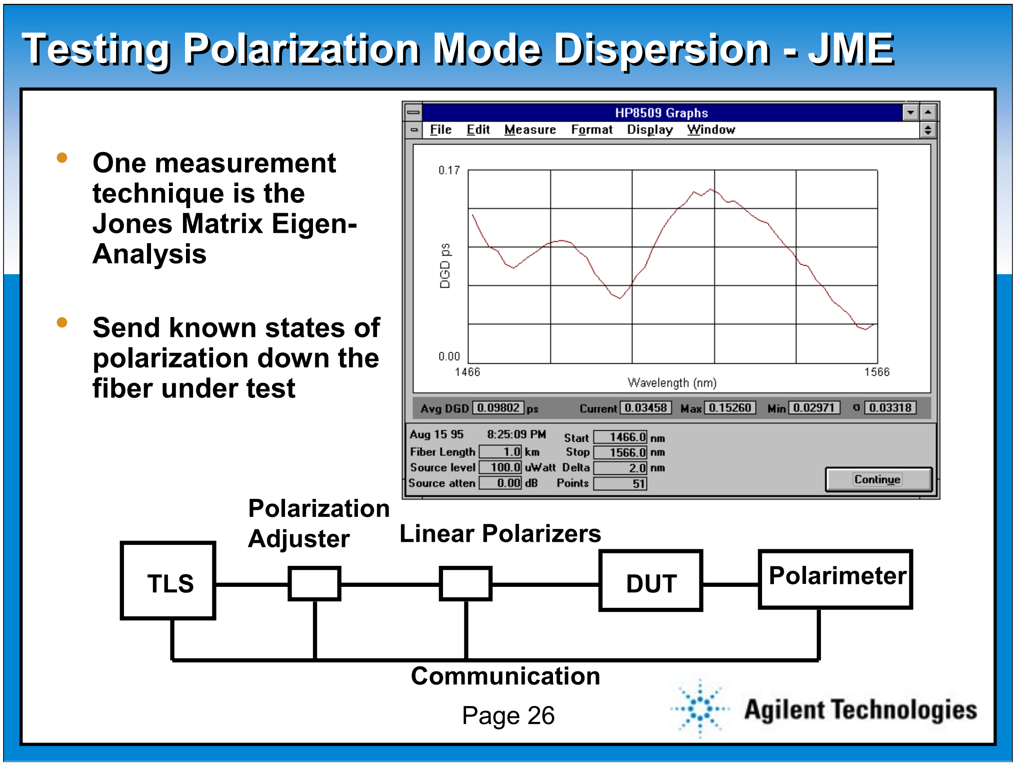

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Summary

- The Metro is the data "bottleneck"
- Solutions to this bottleneck include the use of WDM and higher data rate optical signals
- Increasing the number of wavelengths on a single fiber through CWDM or DWDM increases the bandwidth but must be measured for signal quality
- Increasing the data rate increases the bandwidth. However, CD and PMD effects must be measured and mitigated

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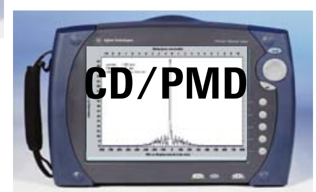
One
Platform…

…all the
solutions !!!



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- **SUPERCOMM 2003 - Georgia World Congress Center, Atlanta, Georgia June 1-5**

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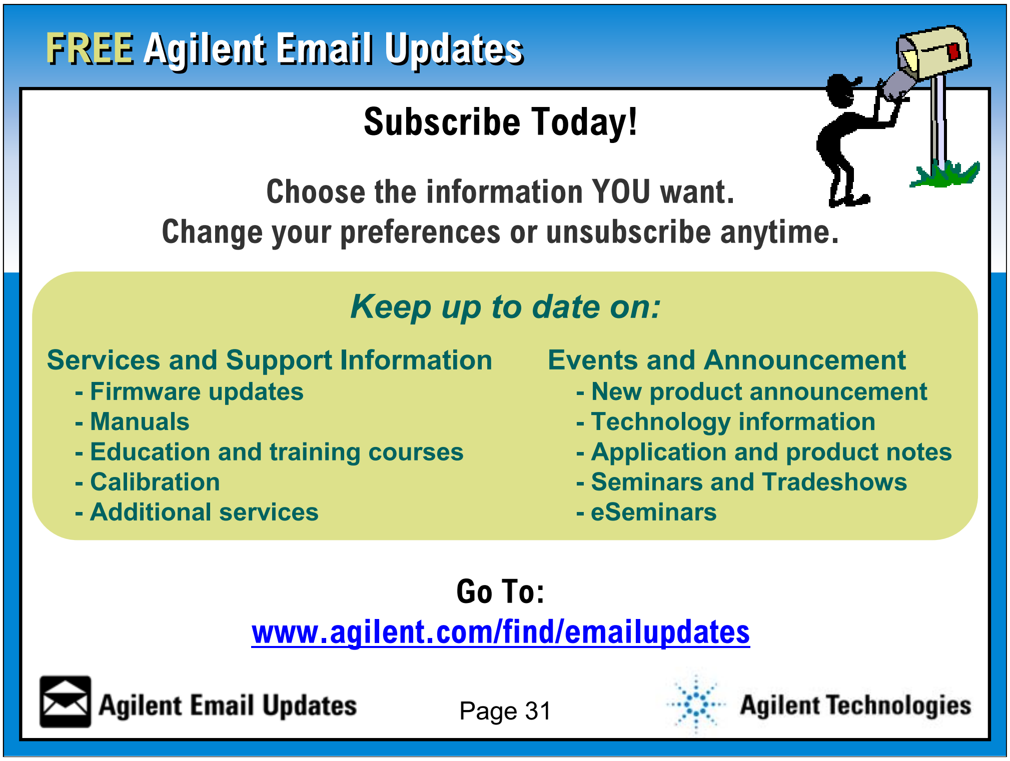
Thank you!

from Agilent Technologies' Optical Network Test Division

For more information go to www.otdr.com

Now Q&A!



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