



Leading Optical Innovations

Selecting the Optimum Fiber for Fiber to the Desk

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BICSI Nashville August 2003

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A photograph of a modern office building at night, illuminated from within, representing fiber applications in premises.

premises

A photograph of a city skyline at night, representing fiber applications in metro areas.

metro

A photograph of rugged, snow-capped mountains under a blue sky, representing fiber applications in long-haul scenarios.

long haul

A photograph of two dolphins swimming in clear blue water, representing fiber applications in transoceanic scenarios.

transoceanic

Selecting the Optimum Fiber for Fiber to the Desk

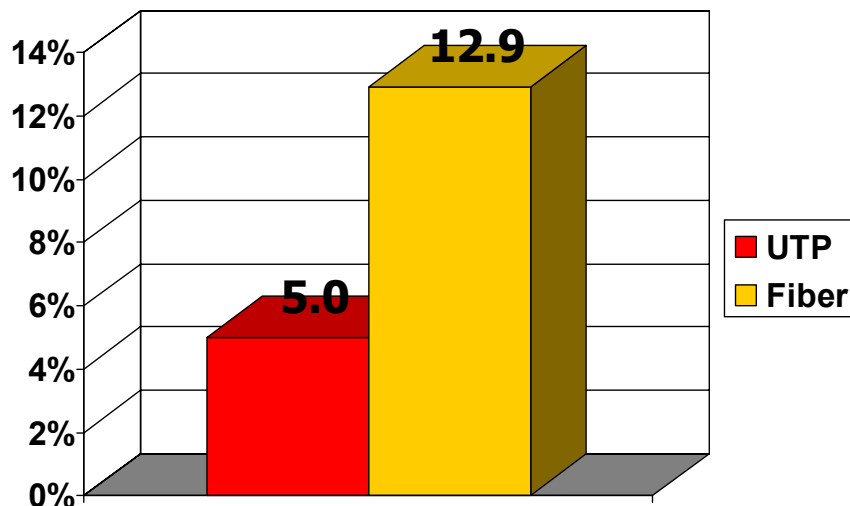
Outline

- **Fiber to the Desk Growth**
- Architectures and Standards for FTTD
- Should singlemode, 62.5, or 50 micron be used?
- How should channel insertion loss be managed?
- FTTD Fiber Application Matrix

Market Trends

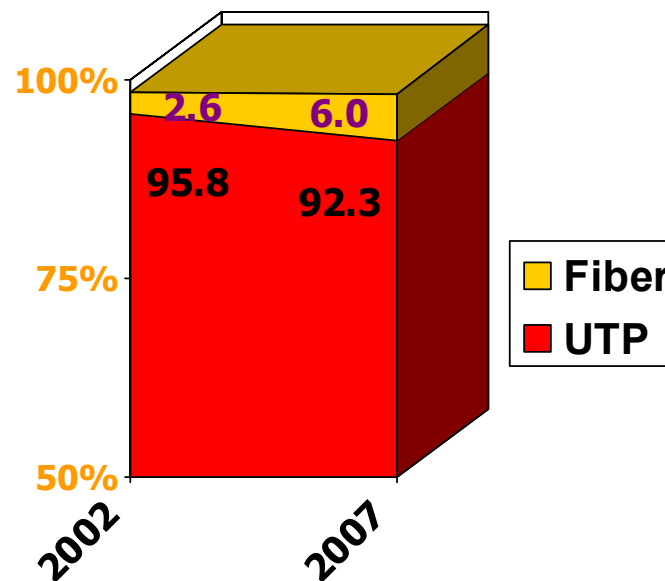
Fiber and UTP Mix

Cabling Market Growth (%) 2002 – 2007



- Overall UTP growth limited to single digits
- GbE adds 70%+ to fiber market during period
- SANs, Switch-Switch, FTTZ, FTTD

LAN Node Mix

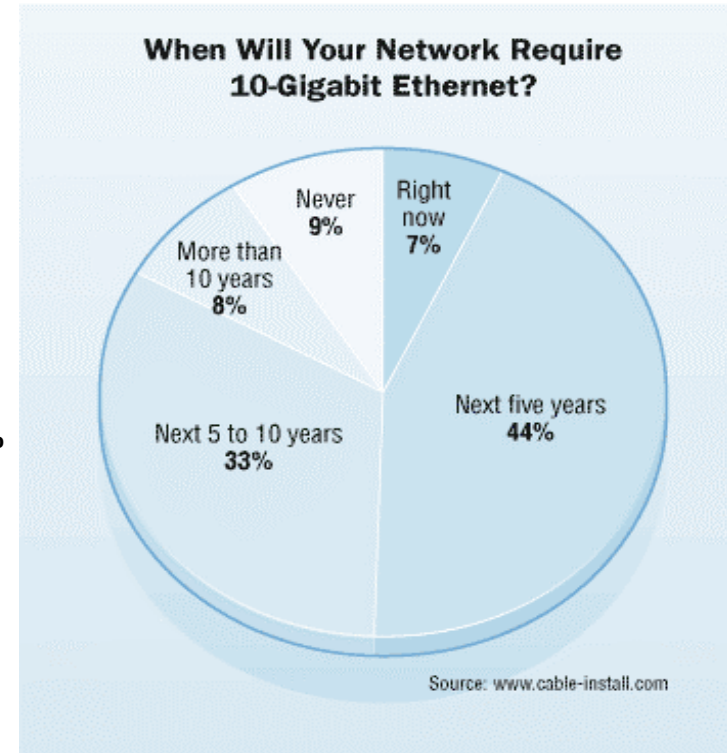
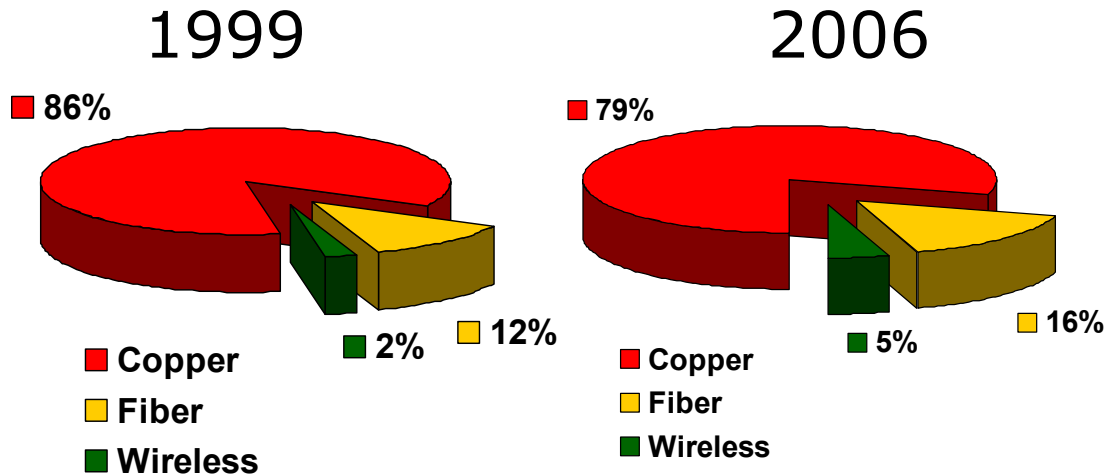


- First stage of cautious FTTD deployment
- FTM projects fiber will surpass copper in 2007-2012 timeframe

Source: FTM Consulting, May, September 2002

Market Trends

Ports in LANs, 10 Gigabit Ethernet



- “While copper cabling is still expected to dominate throughout the forecast period, its growth has obviously matured.”
- “In-Stat/MDR Group believes the real growth opportunities lie with fiber, which has a CAGR of 23.7% through 2006.”

Source: In-Stat/MDR, August 2002

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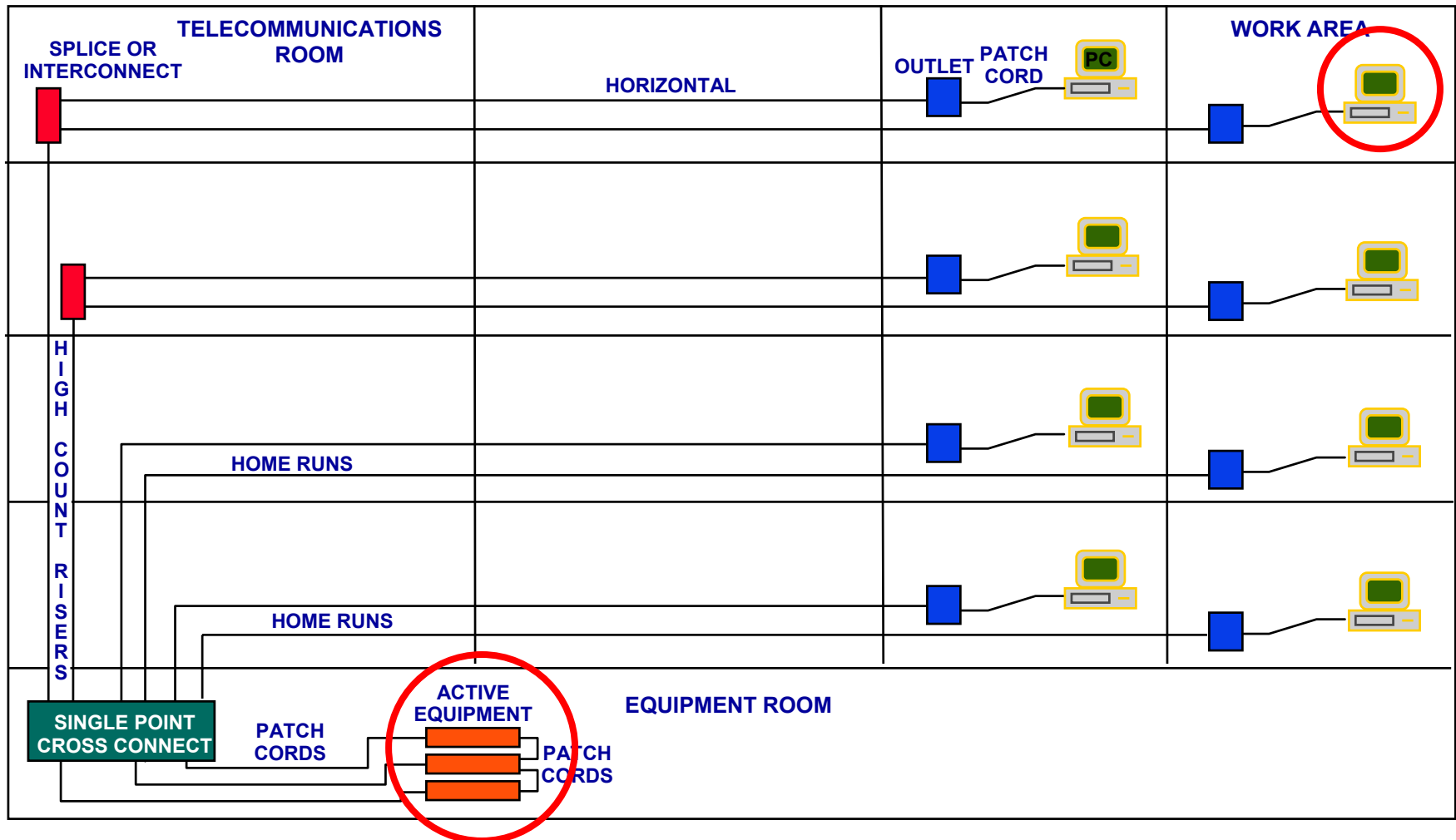
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Centralized Fiber Optic Cabling

TIA and ISO include 50, 62.5, or SM

300 meter max distance from Actives to Desks



Ethernet Standards Support FTDD

Provide Low cost 850 nm solutions up to 10 Gb/s

Data Rate	Designations	Source Type	300 meter support for FTDD?		
			62.5 Micron	50 micron	Singlemode
100 Mb/s	100BASE-SX TIA-785	850 nm LED (Lower cost)	Yes	Yes	No
	100BASE-FX	1310 nm LED	Yes	Yes	No
1 Gb/s	1000BASE-SX	850 nm Laser (Lower Cost)	Yes	Yes	No
	1000BASE-LX	1310 nm Laser	Yes	Yes	Yes
10 Gb/s	10GBASE-SR	850 nm Laser (Lower Cost)	No, only 26 meters	Yes, OM-3	No
	10GBASE-LR	1310 nm Laser	No	No	Yes
	10GBASE-LX4	1310 nm Laser (Highest cost)	Only w/ mode conditioning patch cords	Only w/ mode conditioning patch cords	Yes

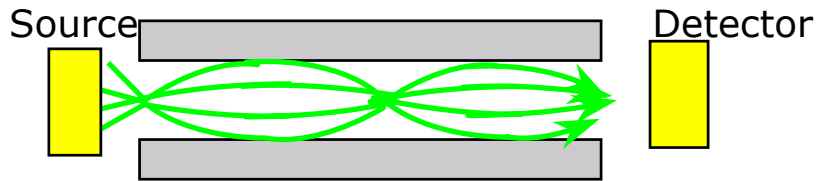
Selecting the Optimum Fiber for Fiber to the Desk

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SM vs. MM Systems Comparison

Multimode



- + Low cost sources
 - + 850 nm and 1310 nm LEDs
 - + 850 nm lasers at 1 & 10G
 - + Low precision packaging
- + Low cost connectors
- + Lower installation cost
- Higher fiber cost
- + **Lower system cost**
- Higher loss, lower bandwidth
- Distance up to 2 km

Best for:

- **Premises, Data Center, CO**

Single-mode



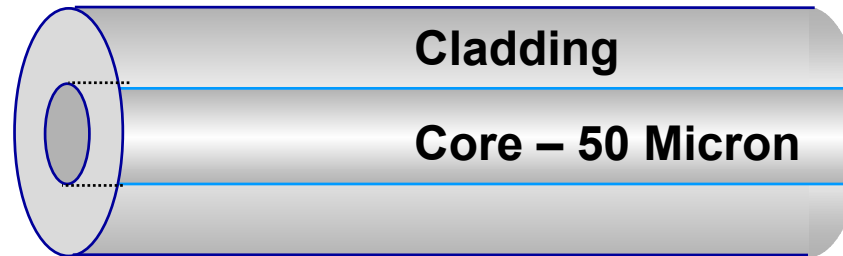
- High cost sources
 - 1310+ nm lasers 1 and 10G
 - 1000 Gb/s+ w/ DWDM
 - High precision packaging
- Higher cost connectors
- Higher installation cost
- + Lower fiber cost
- **Higher system cost**
- + Lower loss, higher bandwidth
- + Distance to 60 km+

Best for:

- **WAN, MAN, Access, Campus**

50 Micron vs. 62.5 for FTTD

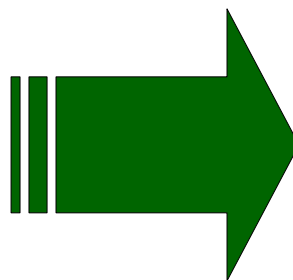
- Same reach as 62.5 for 100 Mb/s
- 60% - 200% longer reach at 1 Gb/s 850 nm
- 3 - 12X longer at 10 Gb/s 850nm
- Uses existing low cost multimode connectors and installation.



Does 50 micron require new installation techniques? *No, it's the same as 62.5.*

50 Micron installation vs.. 62.5

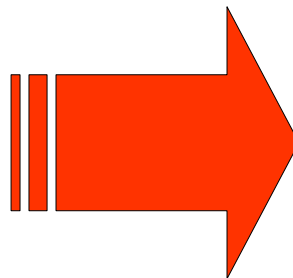
- Same connectors
- Same termination procedures
- Same cable installation process
- Same installer skill set



50 –
same installation
cost as 62.5

Single mode vs.. 50 micron

- More expensive connectors
- More difficult termination
- Different installer skill set.
- More time/connector.



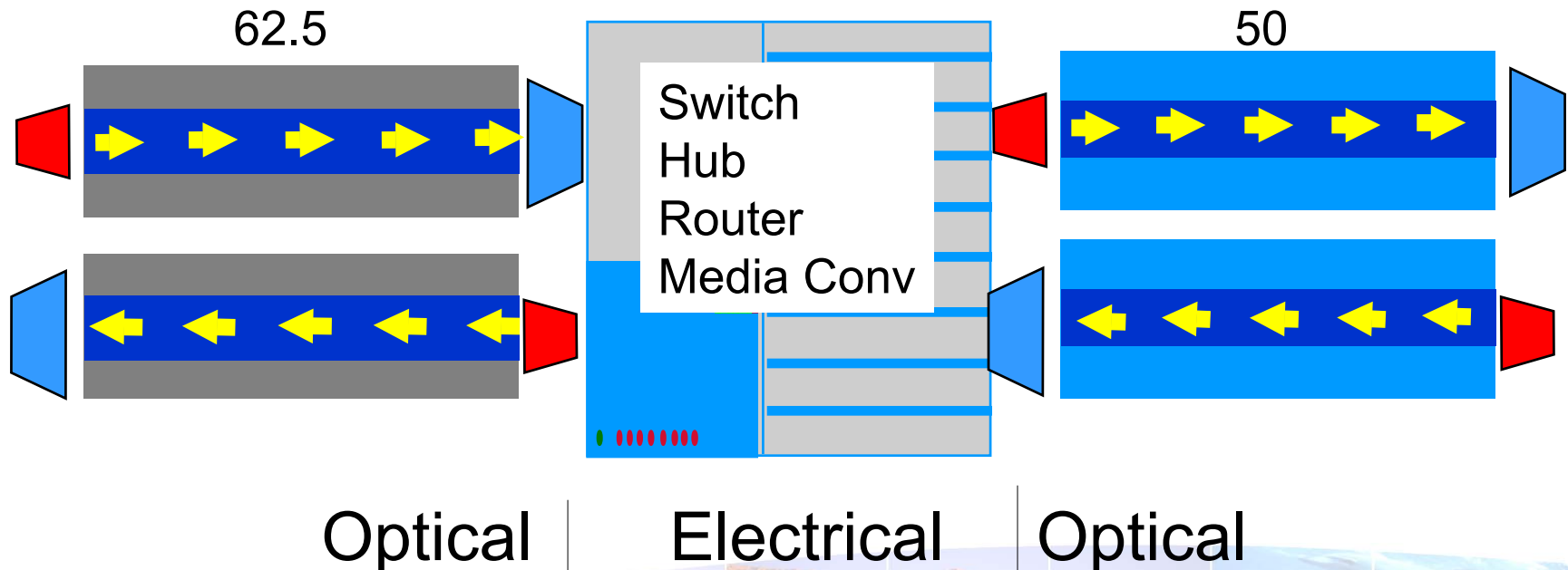
SM -
higher installation cost than
50 or 62.5

Can I mix 62.5 and 50 in the same network?

It depends

Scenario 1: 62.5 and 50 connected through electronics

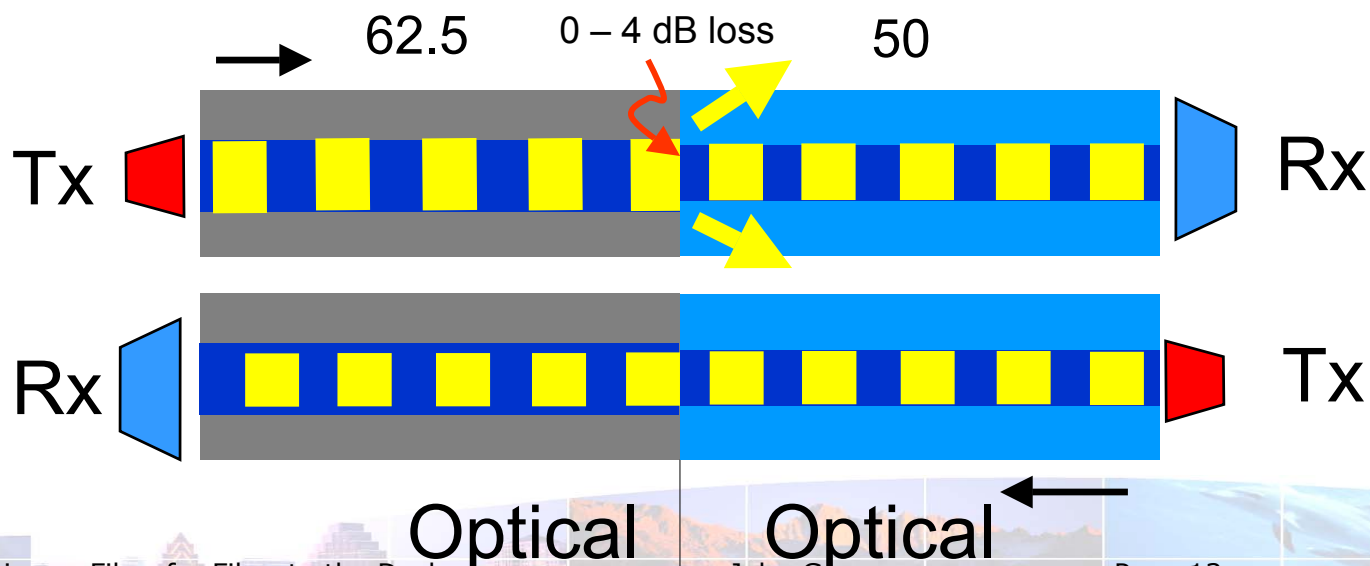
- Can be mixed if through O-E-O conversion.
- 50 micron link will support 50 micron reach and bandwidth
- 62.5 micron link will support 62.5 micron reach and bandwidth
- No reliability risk



Can I mix 62.5 and 50 in the same network?

Scenario 2: 62.5 and 50 connected through optical connection

- Generally not recommended.
- LED applications: 4 dB addition loss in link at 62.5 to 50 interface.
- Laser applications: 0 – 4 dB additional loss at 62.5 to 50 interface.
 - Loss varies depending on spot size (encircled flux) of laser.
 - Can introduce added modal noise than can result in link failure
- Reach vs... the standards rated maximum may be limited based on relative lengths and bandwidths of 62.5 and 50.



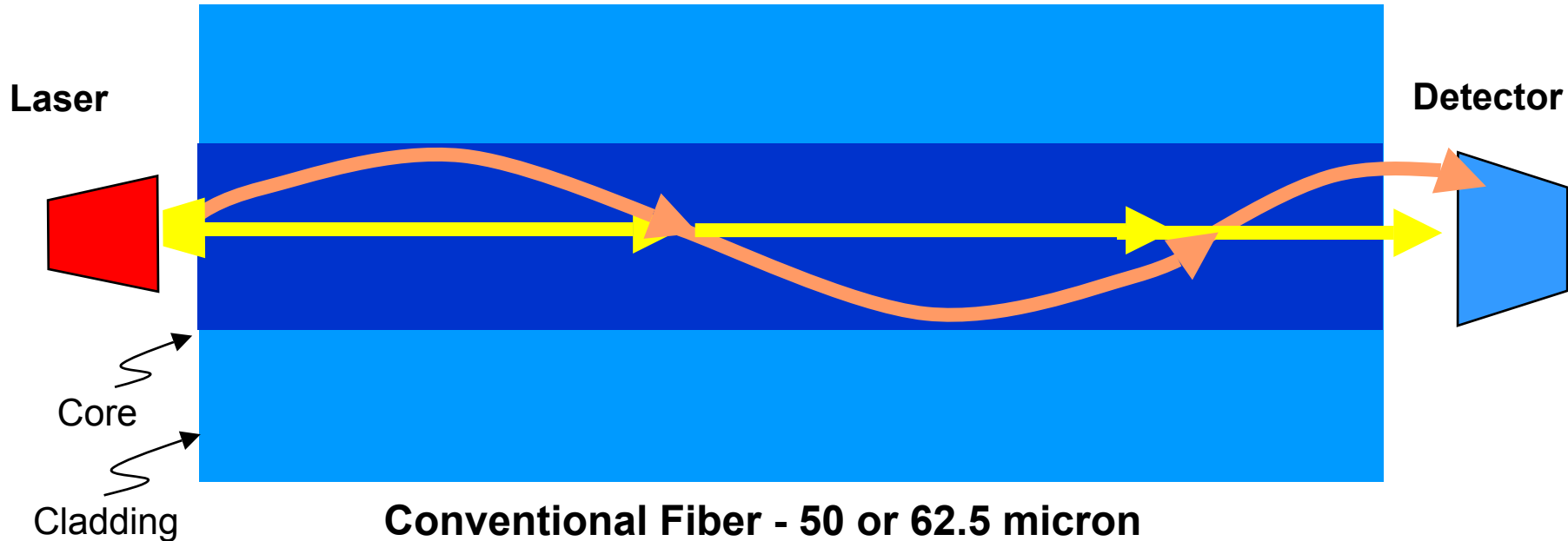
Conventional Multimode Fiber

What limits Laser Bandwidth?

Differential Mode Delay (DMD)

- Different modes reach the detector at different times

Mode 1  Mode 2 

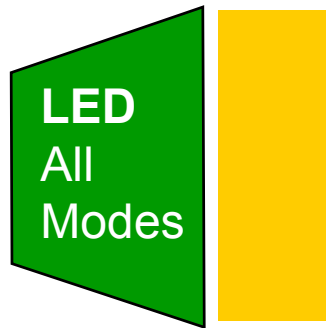


Conventional Fiber - 50 or 62.5 micron

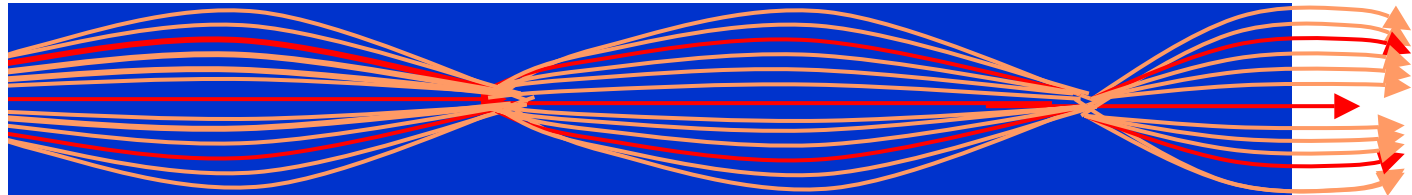
Multimode fibers have hundreds of modes

Laser Applications Impacted

How DMD Affects Performance

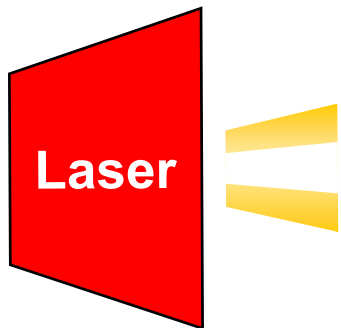


100 Mb/s

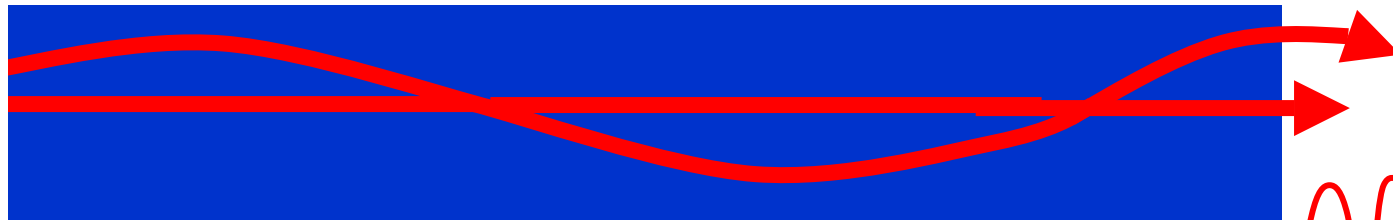


DMD only slightly degrades system performance

Power in high DMD modes relatively low, causes secondary pulse very low amplitude, overall **pulse detectable as one**

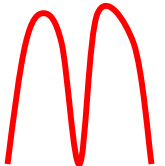


1 Gb/s
10 Gb/s



DMD causes bit errors

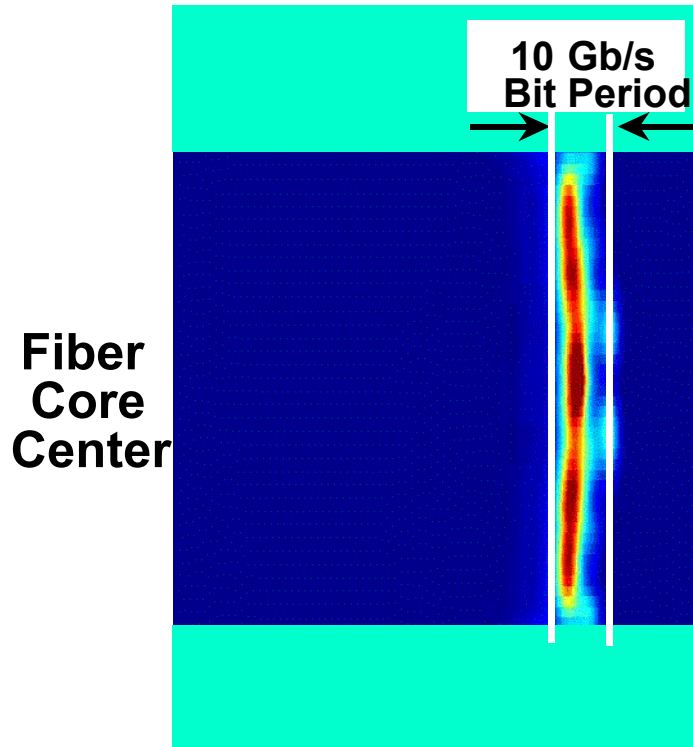
Power concentrated in 2 modes w/ high delay, causes **split pulse**



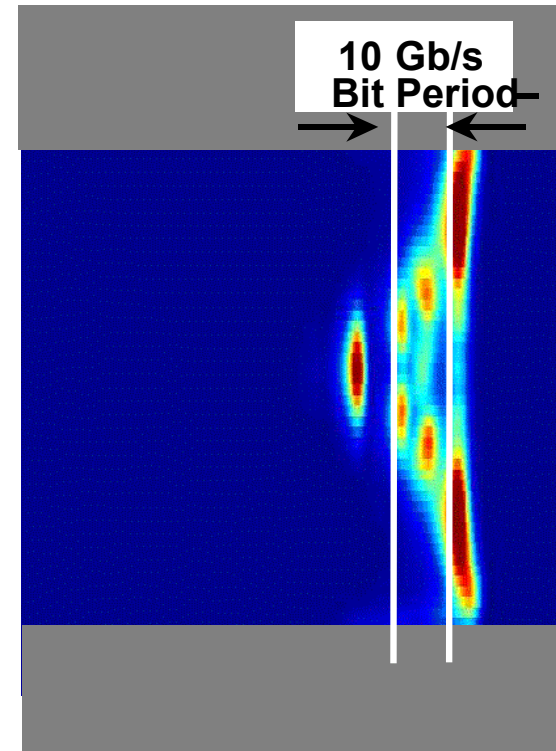
DMD Controlled and Measured Fiber

Essential to support Laser-based systems

Laser Optimized 50 micron



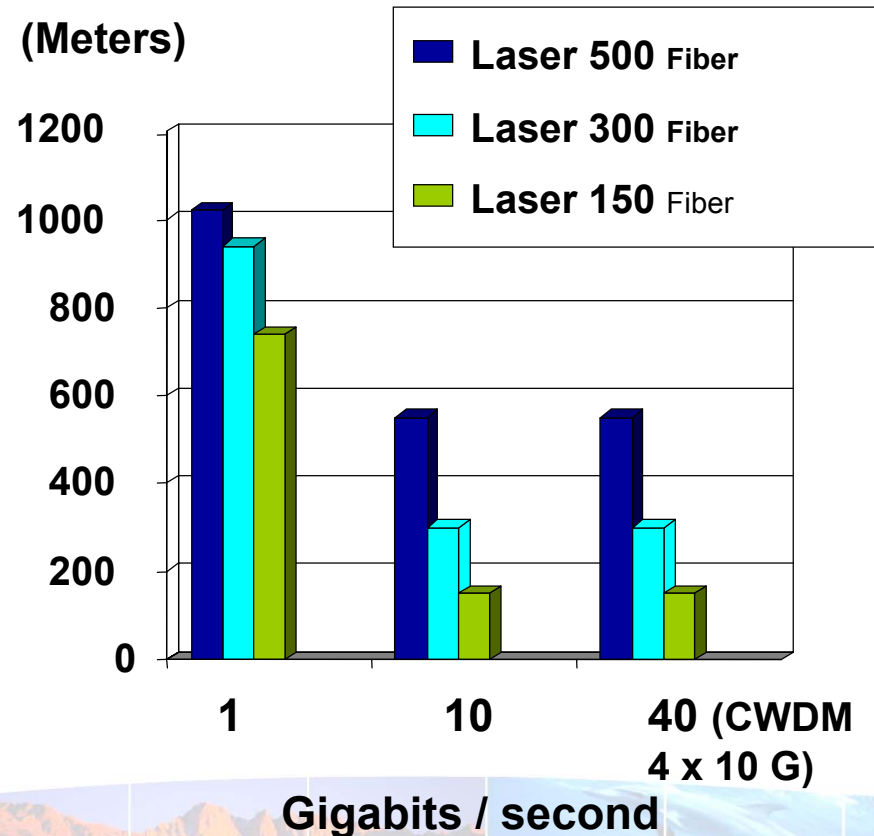
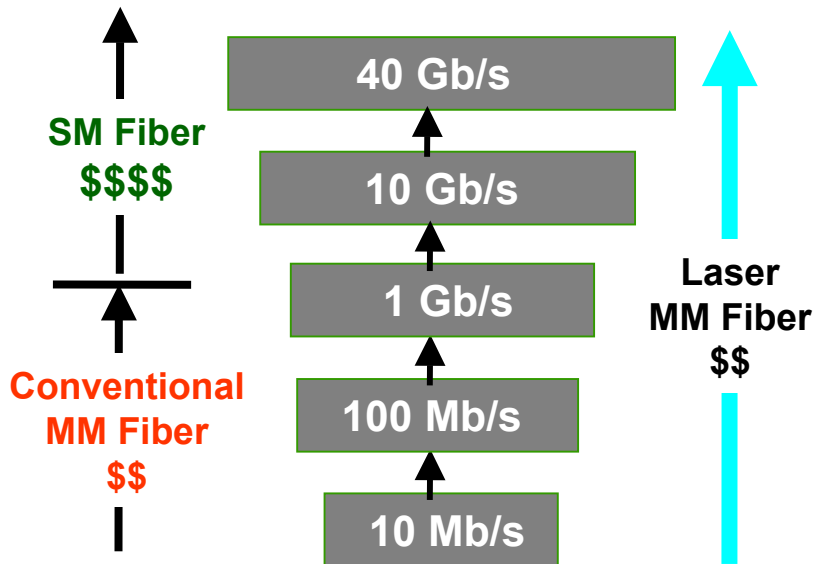
Conventional
50 or 62.5 micron



Received pulse at 10 Gb/s over 300 meters

Laser Optimized 50 Micron Fibers

- Lowest system cost from 10 Mb/s to 10 Gb/s plus, with ***no changes to cabling***
- **Specified in the key application, fiber and cabling standards.**
- Building backbone/data center, **fiber to the desk.**



10 Gigabit Ethernet – 850 nm Serial PMD

From Table 52-25 in IEEE 802.3ae

10GBASE-S

(Ports from Foundry, Avaya, Intel, Riverstone)

Description	62.5 μm MMF		50 μm MMF			Unit
	850	850	850	850	850	
Wavelength	850	850	850	850	850	nm
Modal bandwidth (min)	160	200	400	500	2000	MHz*km
Operating Distance (max)	25	33	66	82	300	meters

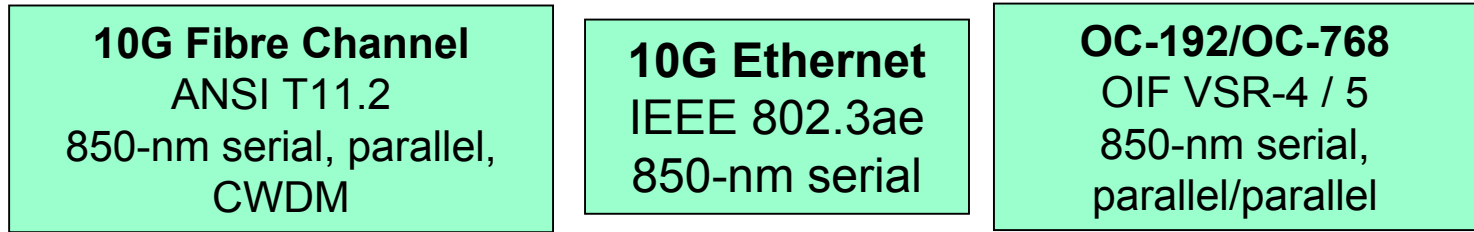
Laser 300 Fiber: 2000 MHz-km* 300 meters

•850 nm Bandwidth Assured by DMD Specifications

(distance w/1.5 dB connection loss)

10 Gigabit Multimode Standards

Applications



Cabling

2000 MHz-km
@ 850-nm Laser
Launch Bandwidth

Fiber

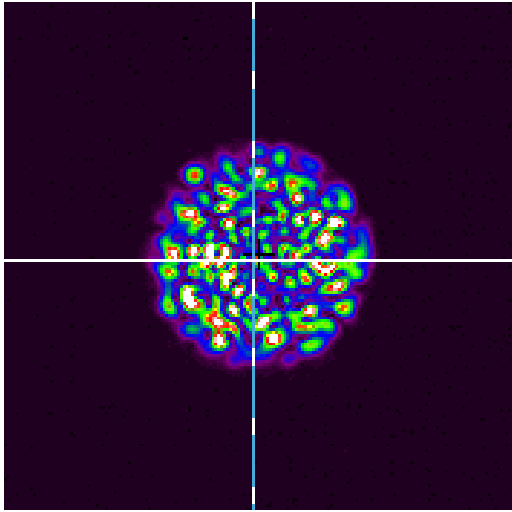
Laser Bandwidth
DMD specification

Measurements

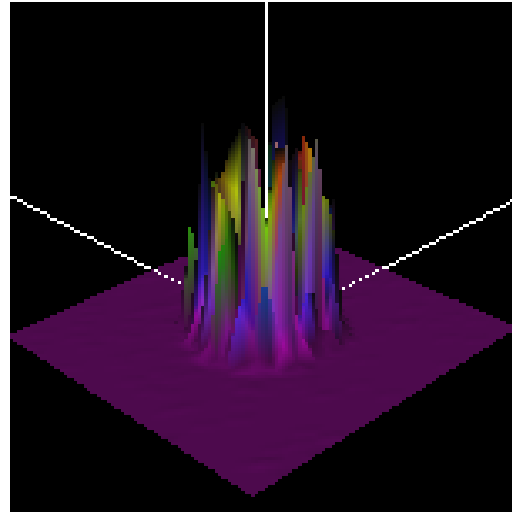
DMD measurement test
procedure

Lasers vs... LEDs

10 Gb/s - 850 nm VCSEL



Encircled Power

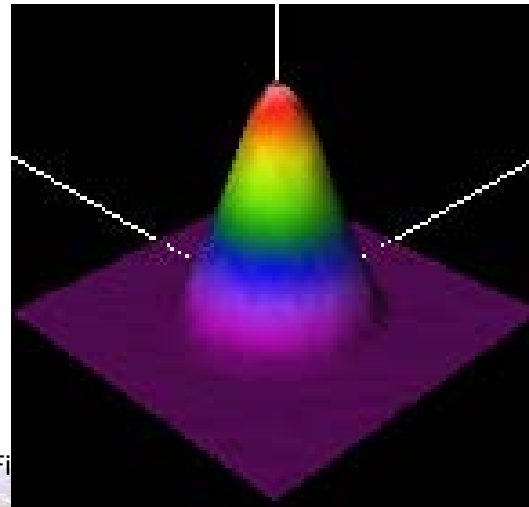
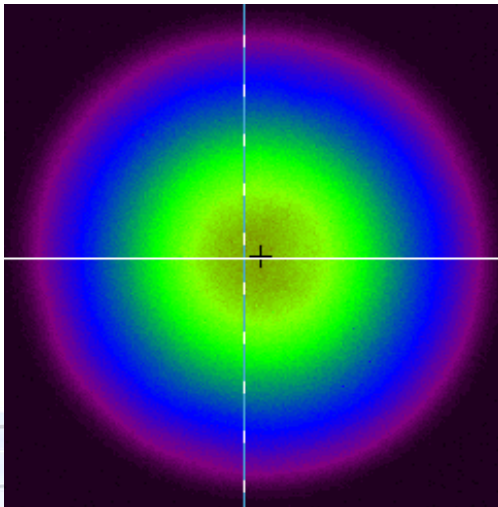


3D Power map

Different properties require different fiber measurements

- Each VCSEL is *different*, fills unique subset of fiber modes
- Overfilled bandwidth very poor predictor of Laser bandwidth, per TIA F02.2.
- **DMD best** predictor of Laser bandwidth, per TIA, IEC, ISO

Low speeds - LED



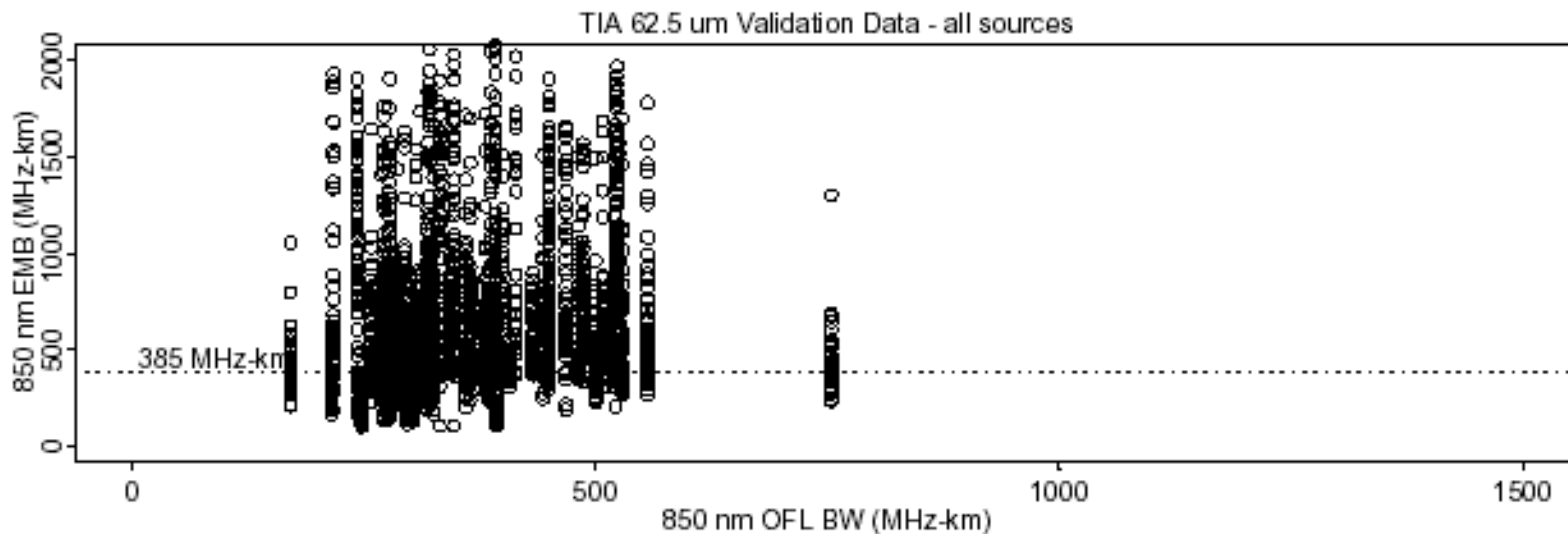
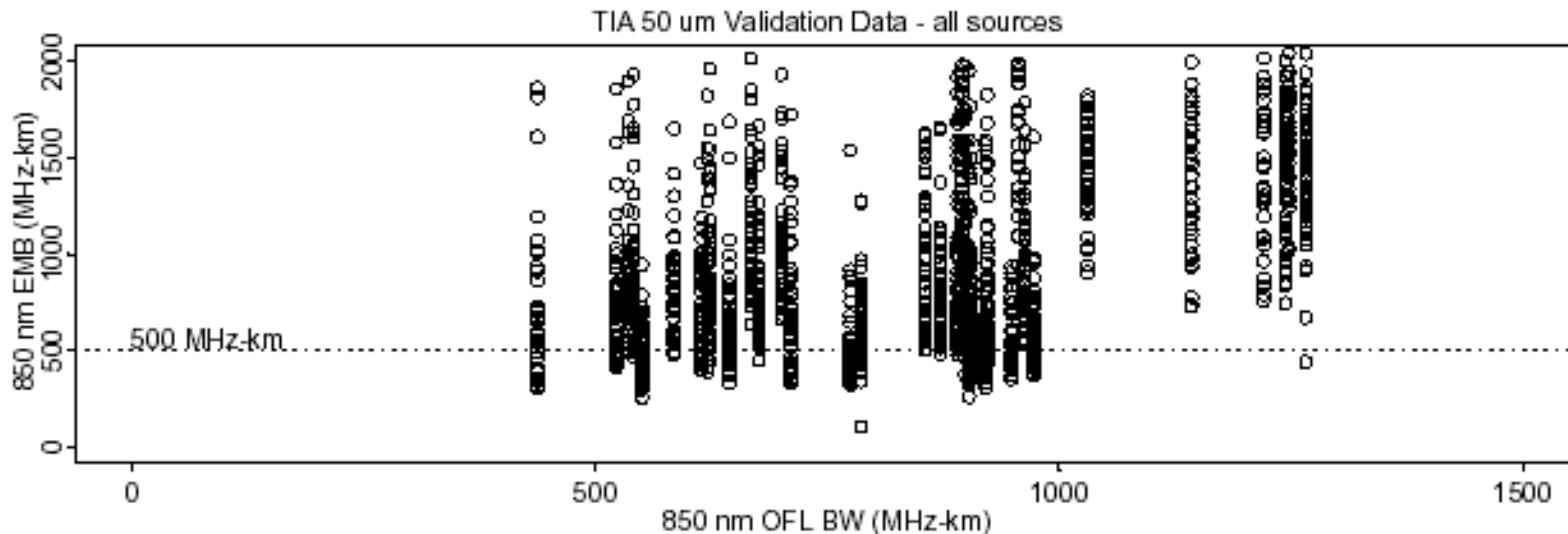
- Every LED fills all fiber modes
- **Overfilled bandwidth** best predictor of LED bandwidth

Overfilled Bandwidth

Very Poor Predictor of Bandwidth in Laser based Systems



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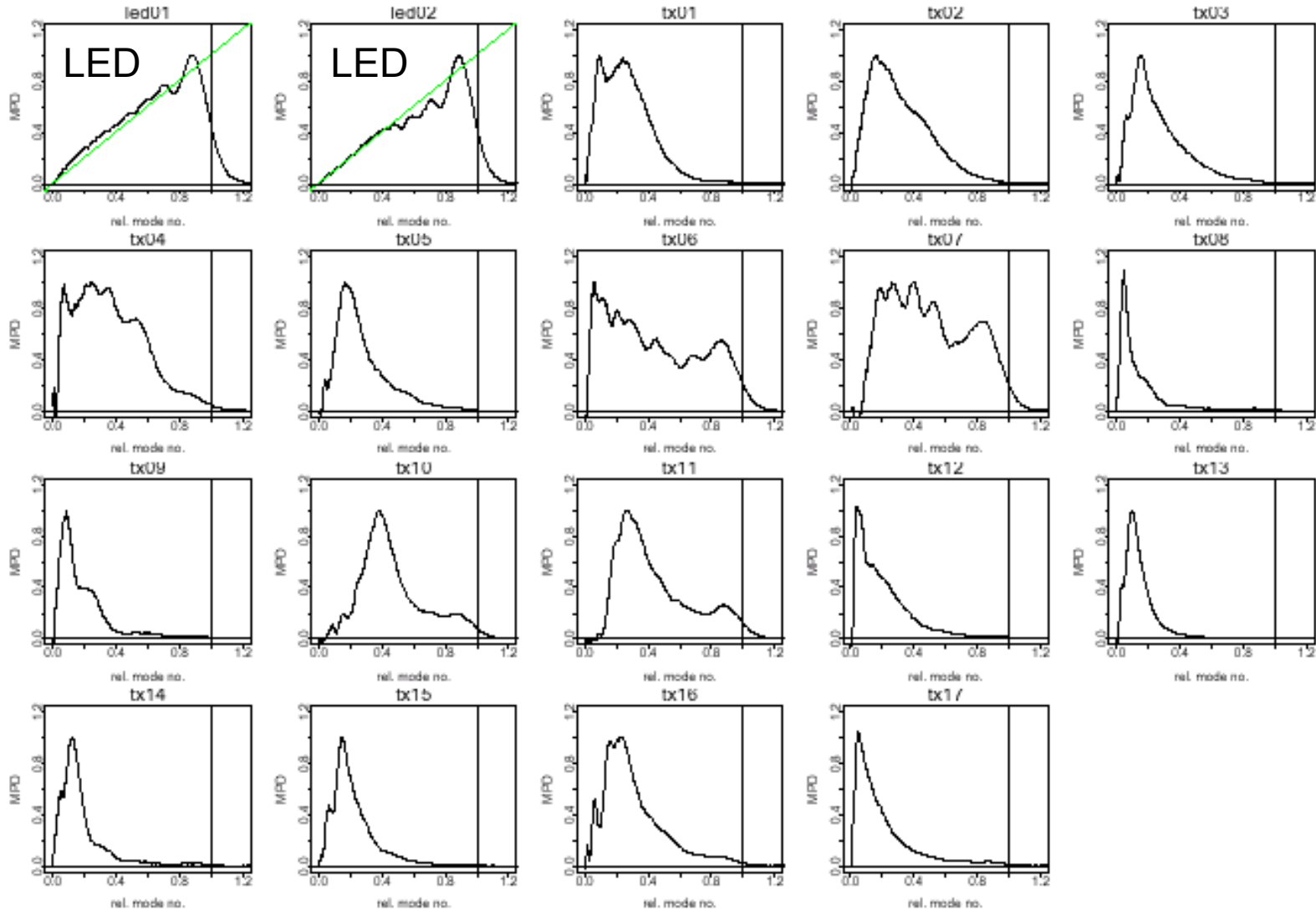
Mode Power Variations

TIA FO2.2 850 nm 1G Sources in 62.5 μm



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TIA Round Robin Sources



Lucent Technologies

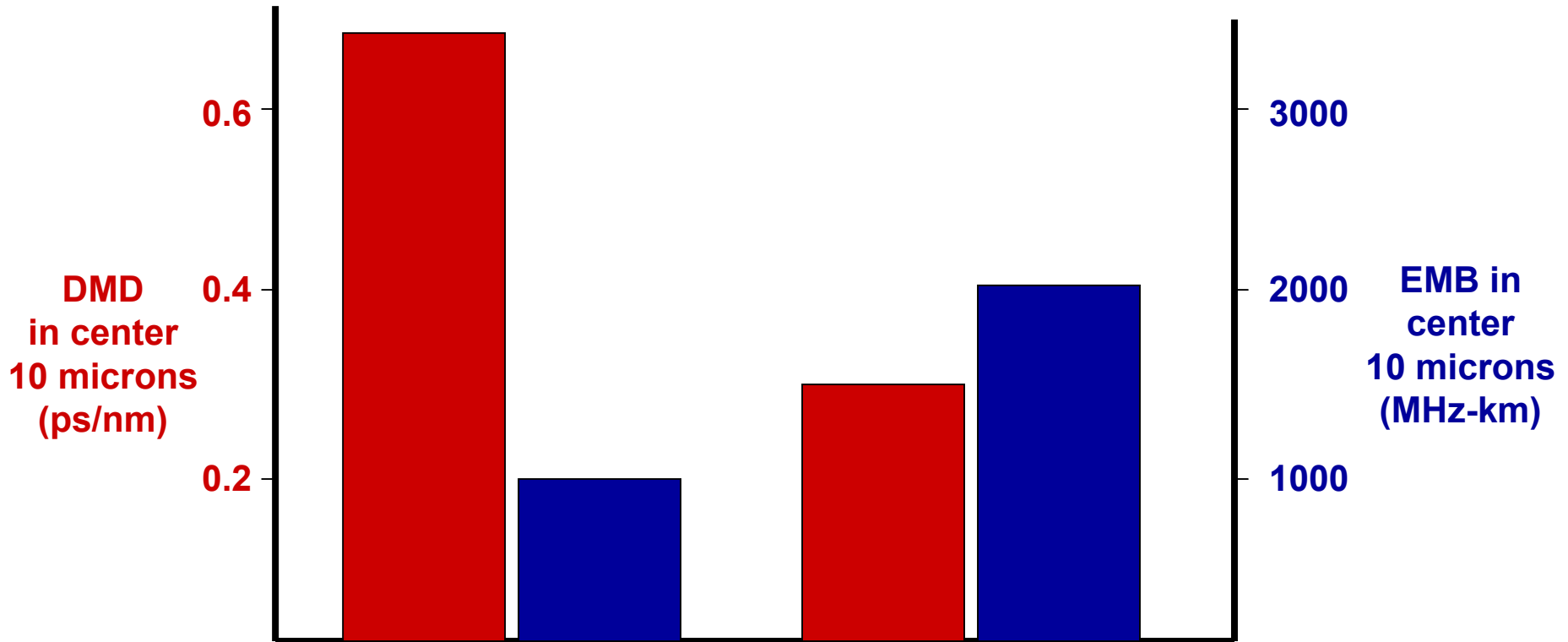
Select

A.J. Ritger April 1999

BICSI Nashville August 2005

Tighter DMD Specifications

Enables Higher EMB with larger variety of 850 nm VCSELs



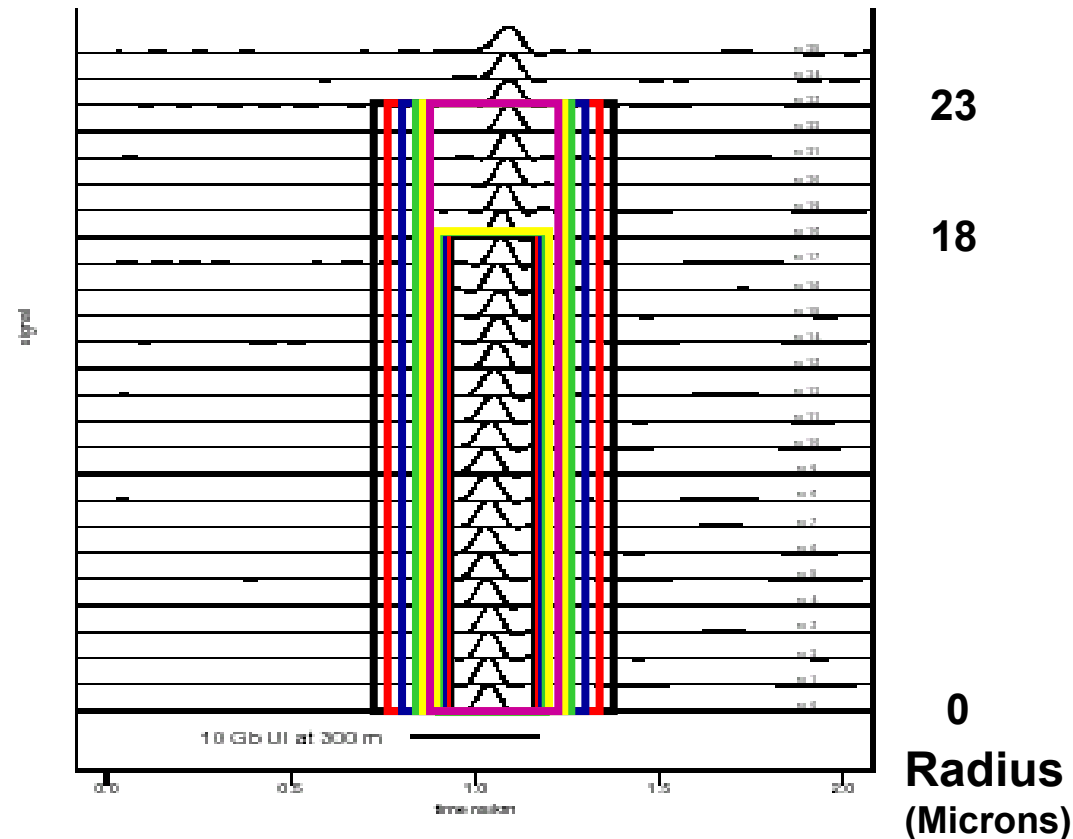
TIA/ISO Standards

**Tighter center DMD,
superior to and compliant
with TIA/ISO**

Laser Optimized 50 Micron Fiber

Ideal DMD Profile

- All pulses aligned in time
- Tight DMD in center
0 – 18 micron region
- Enabled by superior MCVD manufacturing process
- >4000 MHz-km of Laser bandwidth



Laser 500 Fiber
DMD scan of Production Fiber

OFC 2002 - 10 Gb/s 850 nm serial over 1 KM Laser 300 Multimode Fiber



- Over double length of previous record
- Production transceivers and fiber
- >3 times 300m reach in the 10G Ethernet std
- 100 times better error rate than the 10G std

Demonstrates the superior reliability and performance of the Laser 300 solution

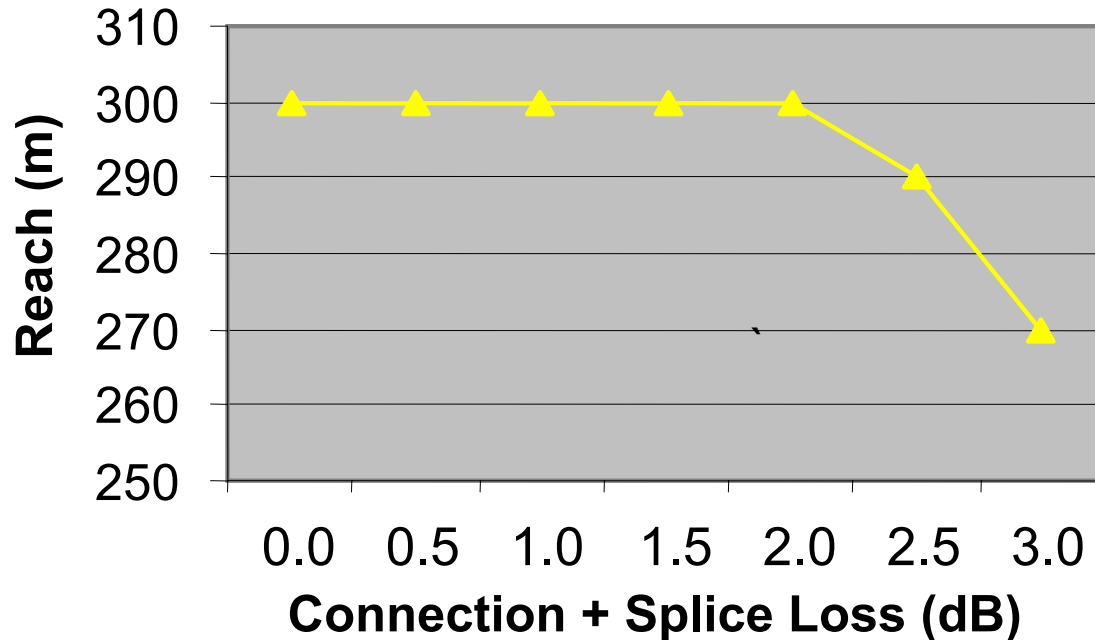
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10 Gb/s Cabling System Reach vs. Loss

10 Gb/s Ethernet (10GBASE-S) Laser Optimized "300" 50 Micron



Low cost 850 nm transceivers

Margin exists below 2 dB loss

LC connector – lowest loss SFF connector available

- Easily supports 4 connections at less than 2 dB total loss
- Enables 300 meter 4 connection support required with Centralized FTTD

Multimode Fiber Tolerances and Attenuation

Tighter Specifications extend reach, allow more connections



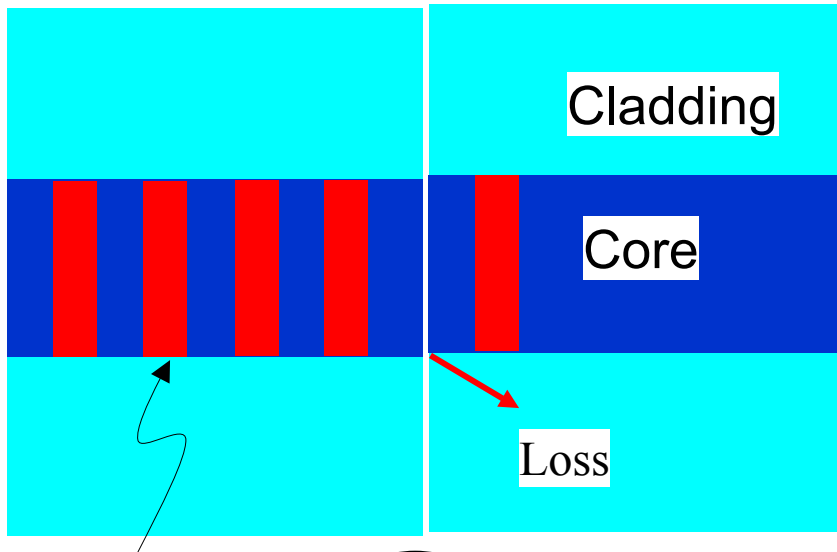
Specification	Superior	Typical
Cladding diameter	$125 \pm 1 \mu\text{m}$	$125 \pm 2 \mu\text{m}$
Core/cladding concentricity error (offset)	$\leq 1.5 \mu\text{m}$	$\leq 3.0 \mu\text{m}$
Bare fiber attenuation (850/1300 nm)	$\leq 2.4/0.7 \text{ dB/km}$	$\leq 2.5/0.8 \text{ dB/km}$

- Superior core centering benefits
 - Better connector performance
 - Improved coupling/centering of VCSELs to LOMF
- Superior attenuation benefits
 - Lower overall cable attenuation
 - Cabled fiber better meets strict 1 & 10 Gbps power budgets

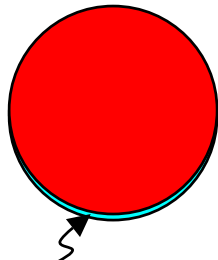
Multimode Fiber Tolerances

Superior Dimensional Tolerances for Superior Performance

Superior Tolerances



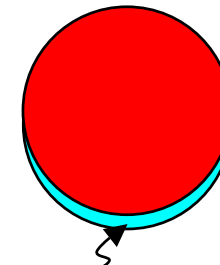
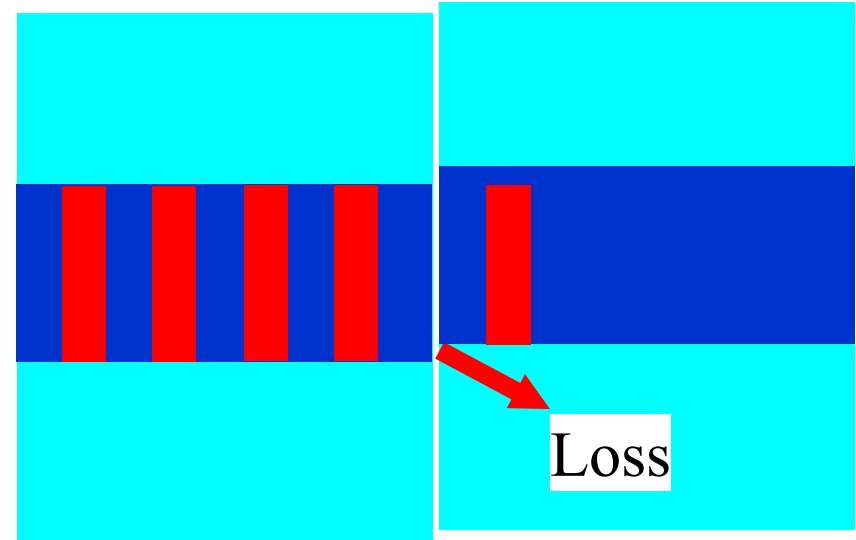
Digital pulses



4 Micron core offset, ~ 0.1 dB loss *

*Loss from core offset effect only, **worst case**

Typical Tolerances



8 Micron core offset, ~ 0.4 dB loss *

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The Optimum Fibers for FTTH

Laser Optimized 50 micron

10 Gb/s possible in life of the system?

- **Laser 300 fiber**

- at least 300 m at low cost 850 nm for 100 Mb/s – 10 Gb/s
- DMD controlled and optimized to support 1 and 10 G lasers

1 Gb/s will be the limit for the life of the system?

- **Laser 150 fiber**

- at least 300 m at low cost 850 nm for 100 Mb/s – 1 Gb/s
- DMD controlled and optimized to support 1 G and 10 G lasers

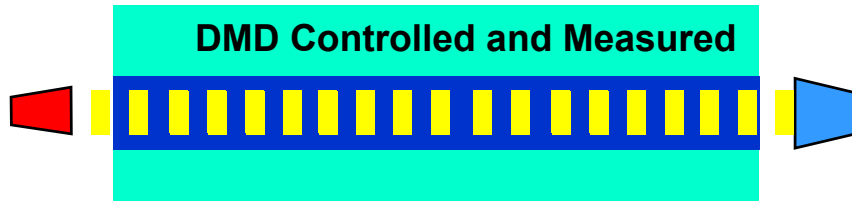
Laser Optimized 50 Micron Fiber Specification Example



	Laser Optimized 50 micron Fibers				Typical 50 µm	Typical 62.5 µm
	500 50 µm	300 50 µm	150 50 µm			
Bandwidth (MHz-km) Minimum						
Laser @ 850-nm (EMB)	4000	2000	950	Not Specified	Not specified	
Laser @ 1300-nm (EMB)	500	500	500	Not specified	Not specified	
Overfilled @ 850-nm	3000	1500	700	500	160	
Overfilled @ 1300-nm	500	500	500	500	500	
DMD (ps/m) Maximum						
850-nm	Superior to, and compliant with TIA-492			0.70	Not specified	Not specified
1310-nm	0.88	0.88	0.88	0.88	Not specified	Not specified

Laser Optimized 50 Micron Fiber

The Optimal Solution for FTTD



- 10Mb/s- 40 Gb/s lowest cost system
- 10 Gb/s w/850 nm VCSELs to 500m
- Adopted by the leading standards.
- Embraced by end users and vendors.

LO 50 micron Fiber Applications

