Selecting the Optimum Fiber for Fiber to the Desk

John George

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Johngeorge@ofsoptics.com
770-798-2432

Selecting the Optimum Fiber for Fiber to the Desk

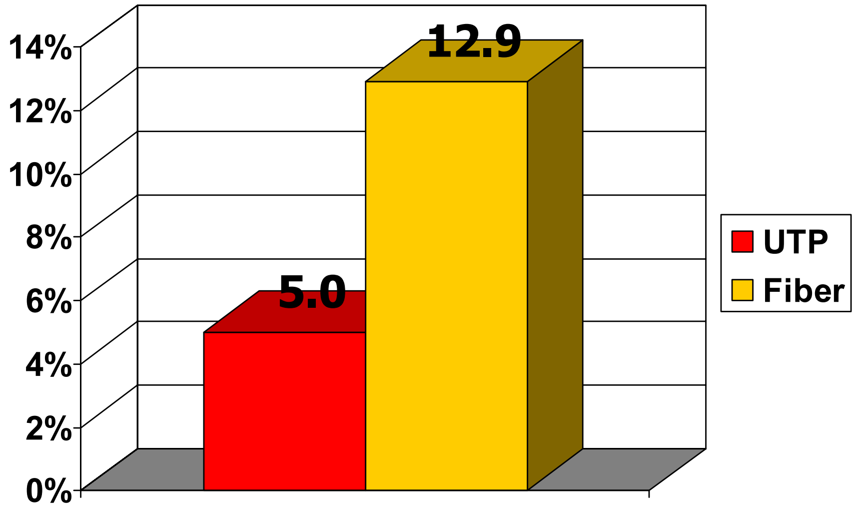
Outline

- **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

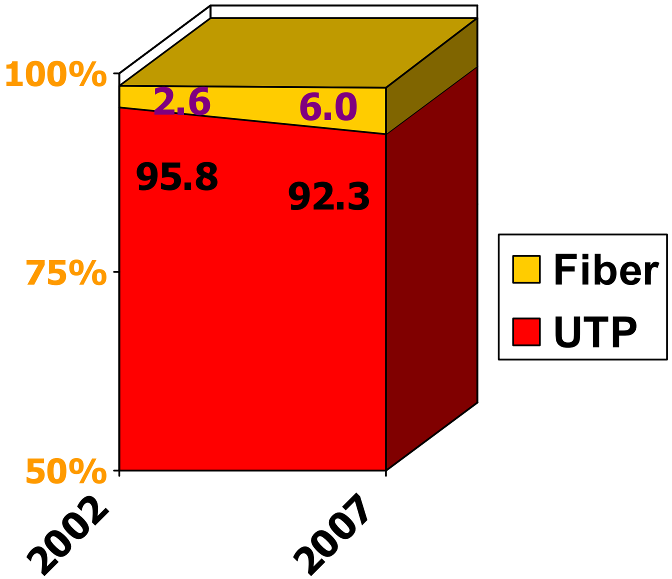
Market Trends

Fiber and UTP Mix

Cabling Market Growth (%) 2002 – 2007



LAN Node Mix



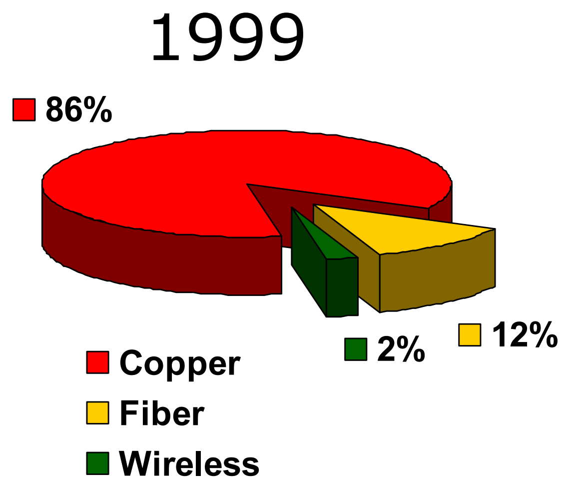
- Overall UTP growth limited to single digits
- GbE adds 70%+ to fiber market during period
- SANs, Switch-Switch, FTTZ, FTTD

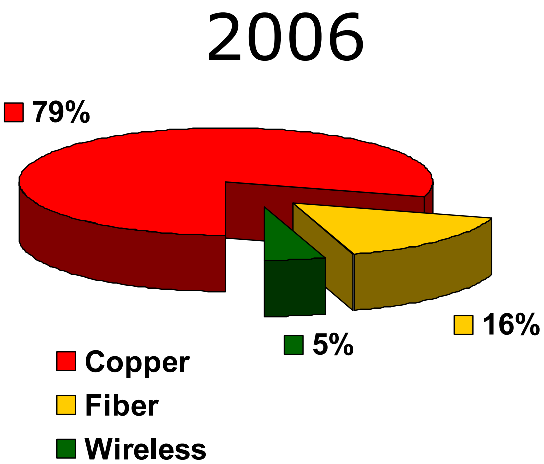
- First stage of cautious FTTD deployment
- FTM projects fiber will surpass copper in 2007-2012 timeframe

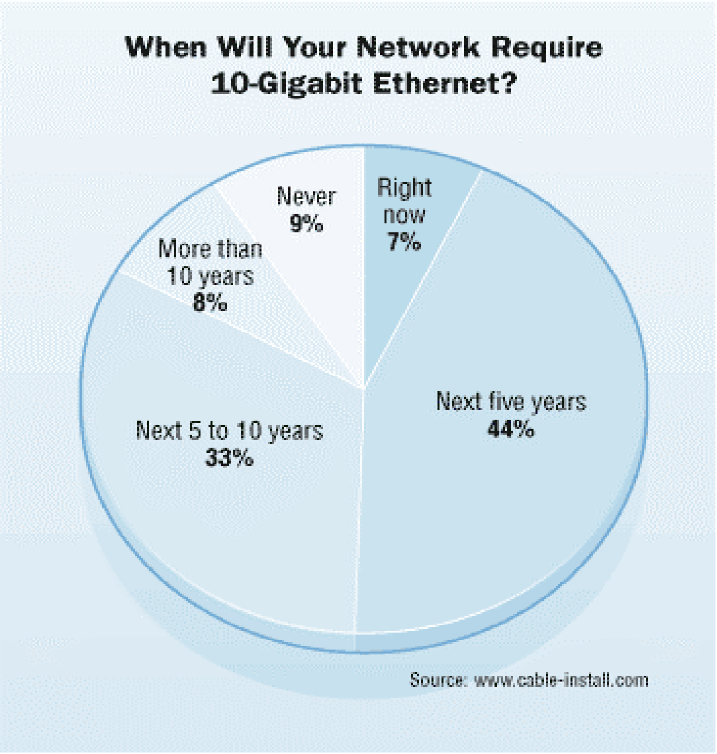
Source: FTM Consulting, May, September 2002

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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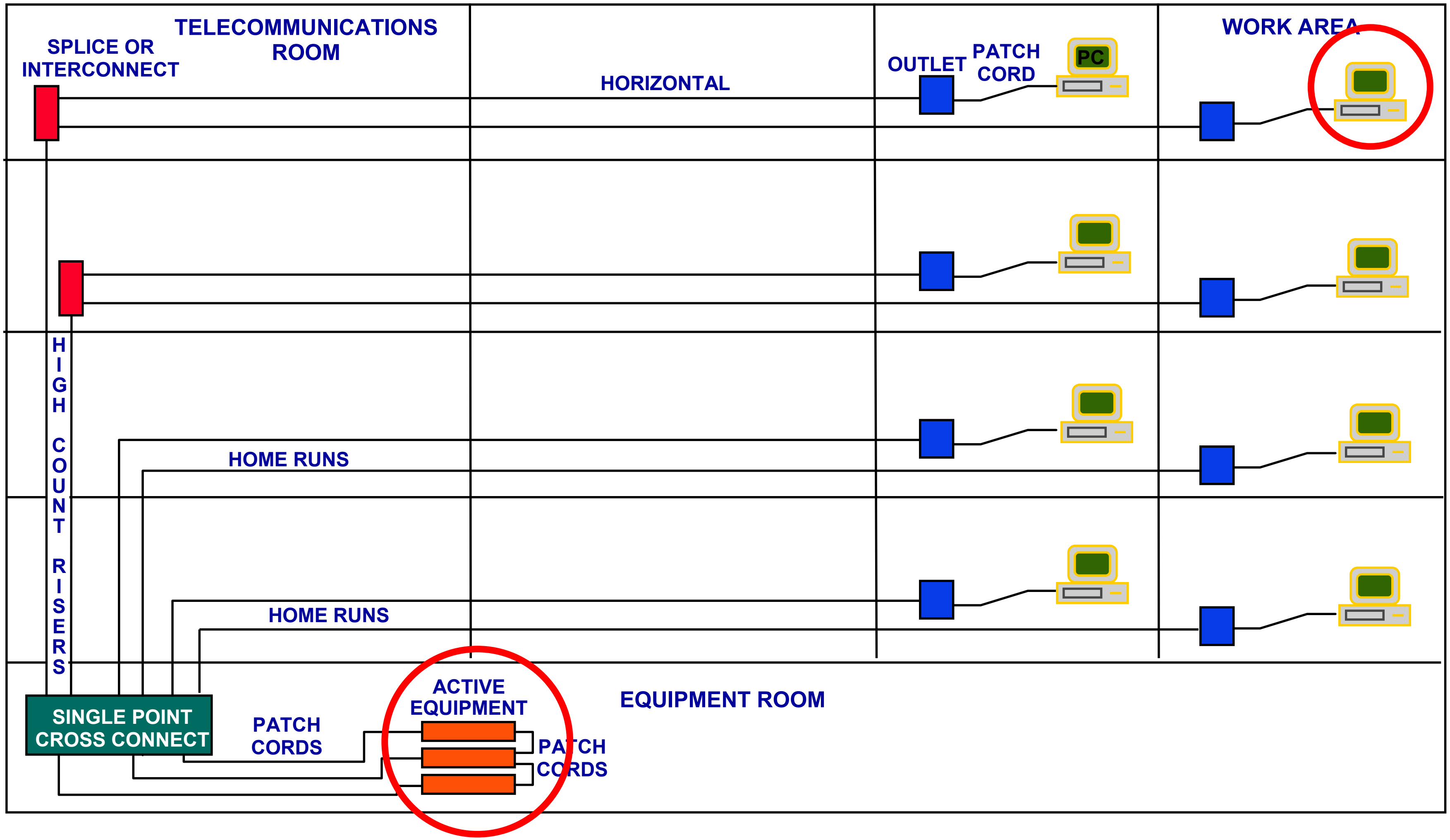
Centralized Fiber Optic Cabling

TIA and ISO include 50, 62.5, or SM

300 meter max distance from Actives to Desks



Ethernet Standards Support FTTD

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

Data Rate	Designations	Source Type	300 meter support for FTTD?		
			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

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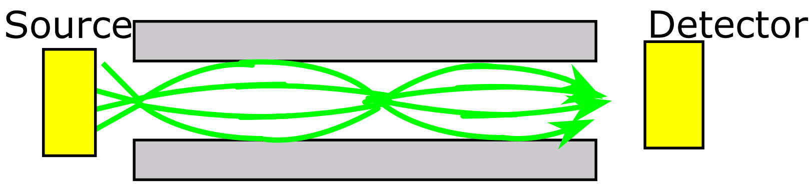
SM vs. MM Systems Comparison

Multimode

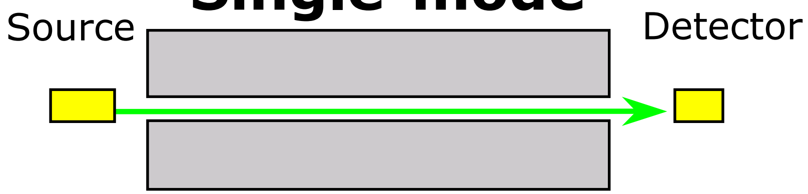


+ Low cost sources
    + 850 nm and 1310 nm LEDs
    + 850 nm lasers at 1 & 10G
    + Low precision packaging
+ Low cost connectors
+ Lower installation cost
- Higher fiber cost
+ Lower system cost
- Higher loss, lower bandwidth
- Distance up to 2 km

Best for:

- ***Premises, Data Center, CO***

Single-mode



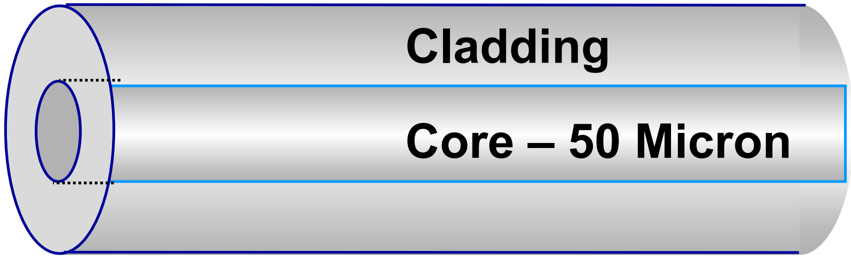
- High cost sources
    - 1310+ nm lasers 1 and 10G
    - 1000 Gb/s+ w/ DWDM
    - High precision packaging
- Higher cost connectors
- Higher installation cost
+ Lower fiber cost
- Higher system cost
+ Lower loss, higher bandwidth
+ Distance to 60 km+

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.

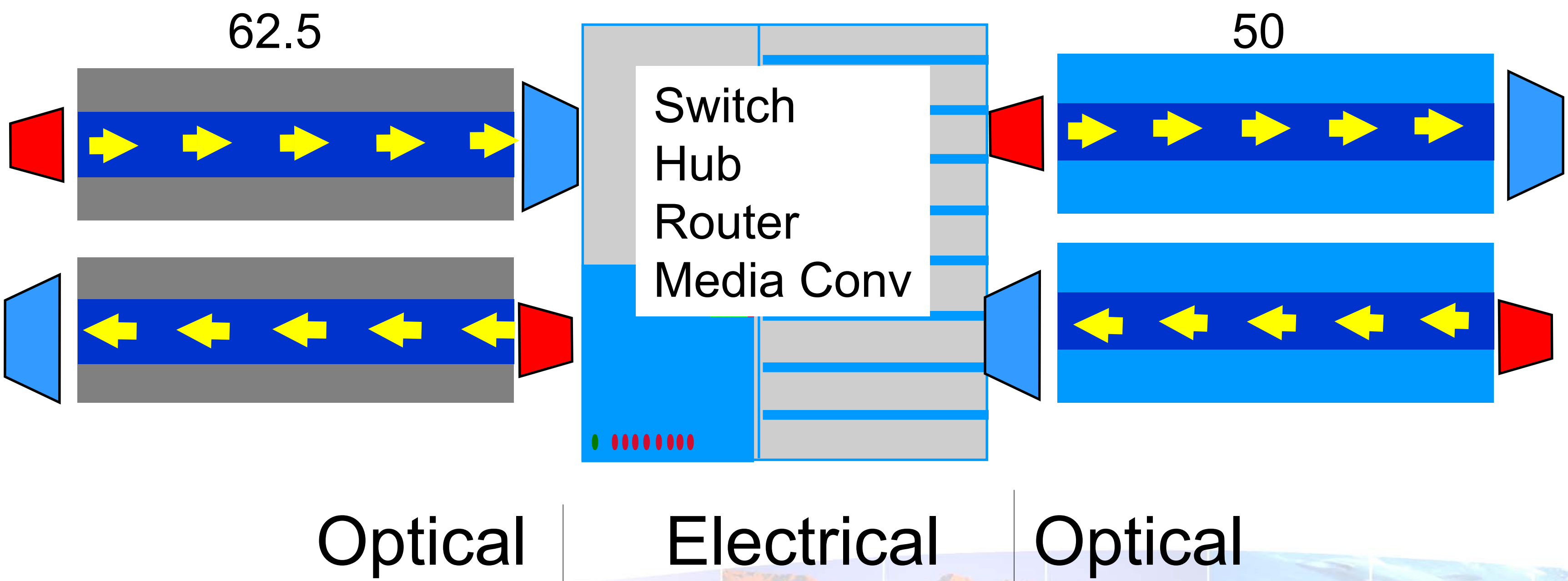
SM -
higher installation cost than
50 or 62.5

Can I mix 62.5 and 50 in the same network?

It depends

Scenario 1: 62.5 and 50 connected through electronics

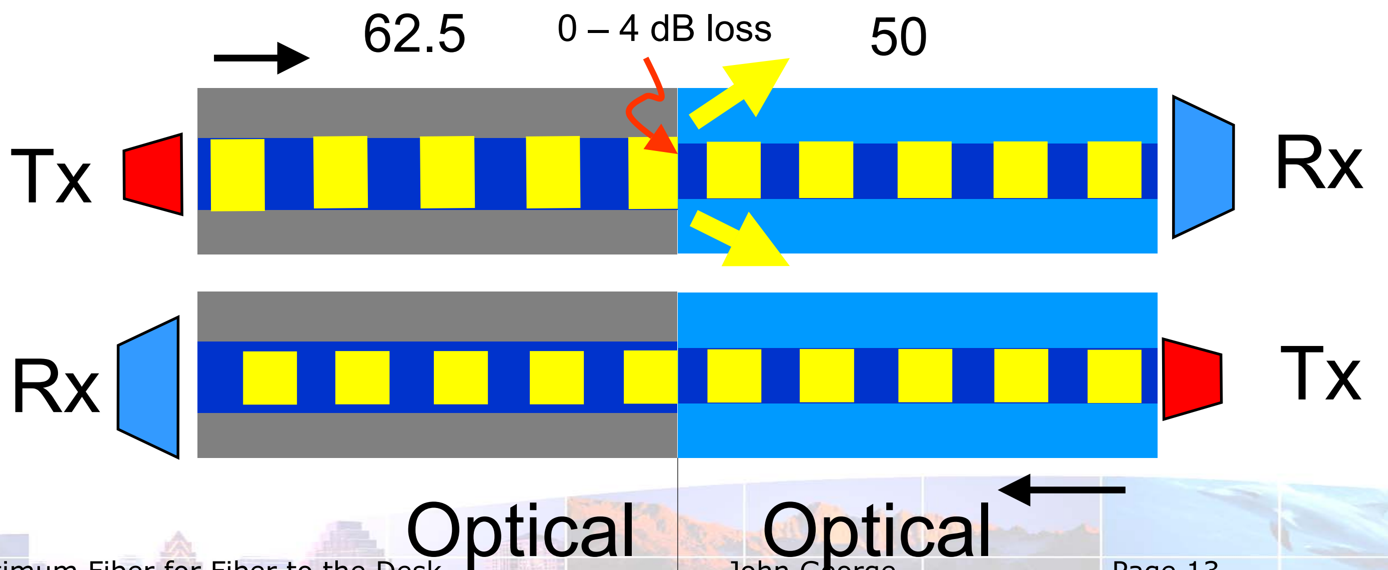
- **Can be mixed if through O-E-O conversion.**
- 50 micron link will support 50 micron reach and bandwidth
- 62.5 micron link will support 62.5 micron reach and bandwidth
- No reliability risk



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.

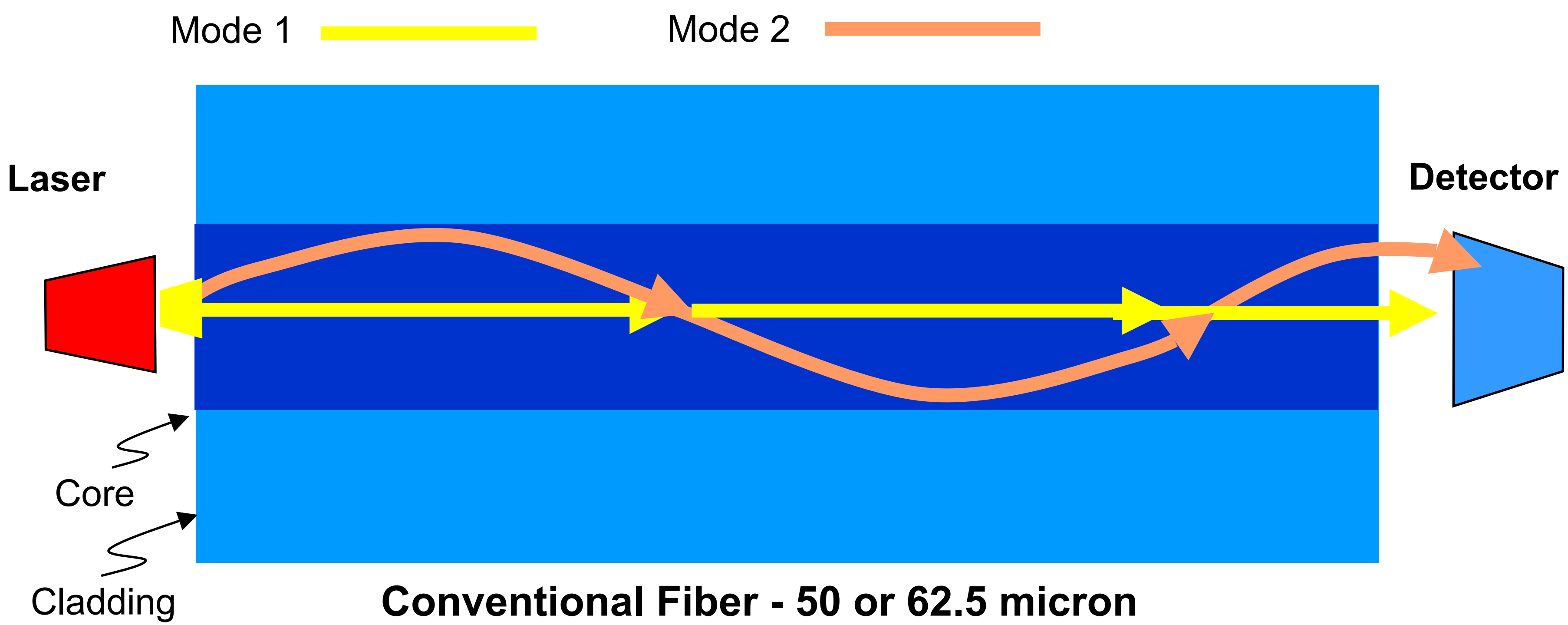


Conventional Multimode Fiber

What limits Laser Bandwidth?

Differential Mode Delay (DMD)

- **Different modes reach the detector at different times**

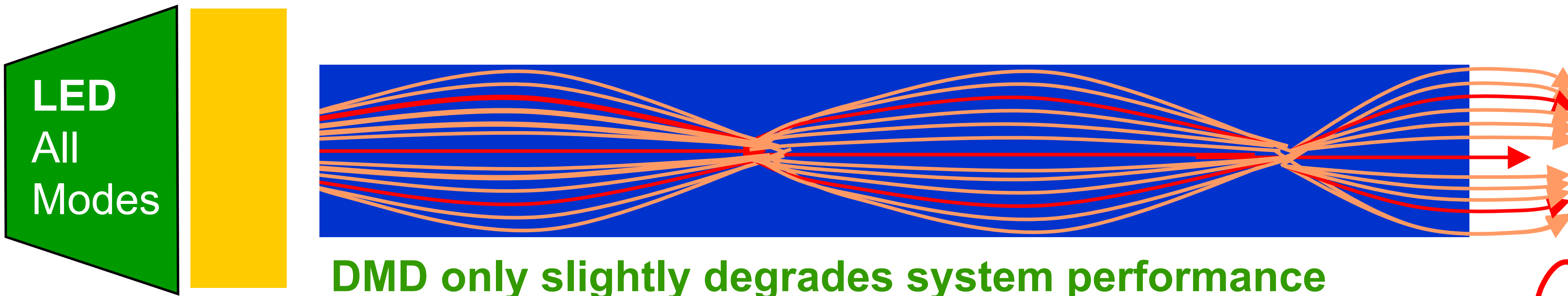


Conventional Fiber - 50 or 62.5 micron

Multimode fibers have hundreds of modes

Laser Applications Impacted

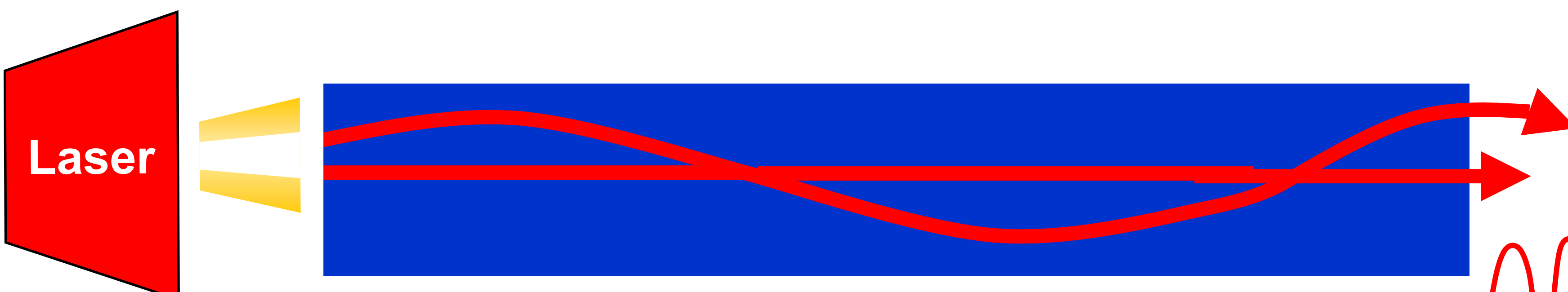
How DMD Affects Performance

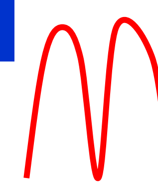


100 Mb/s

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**

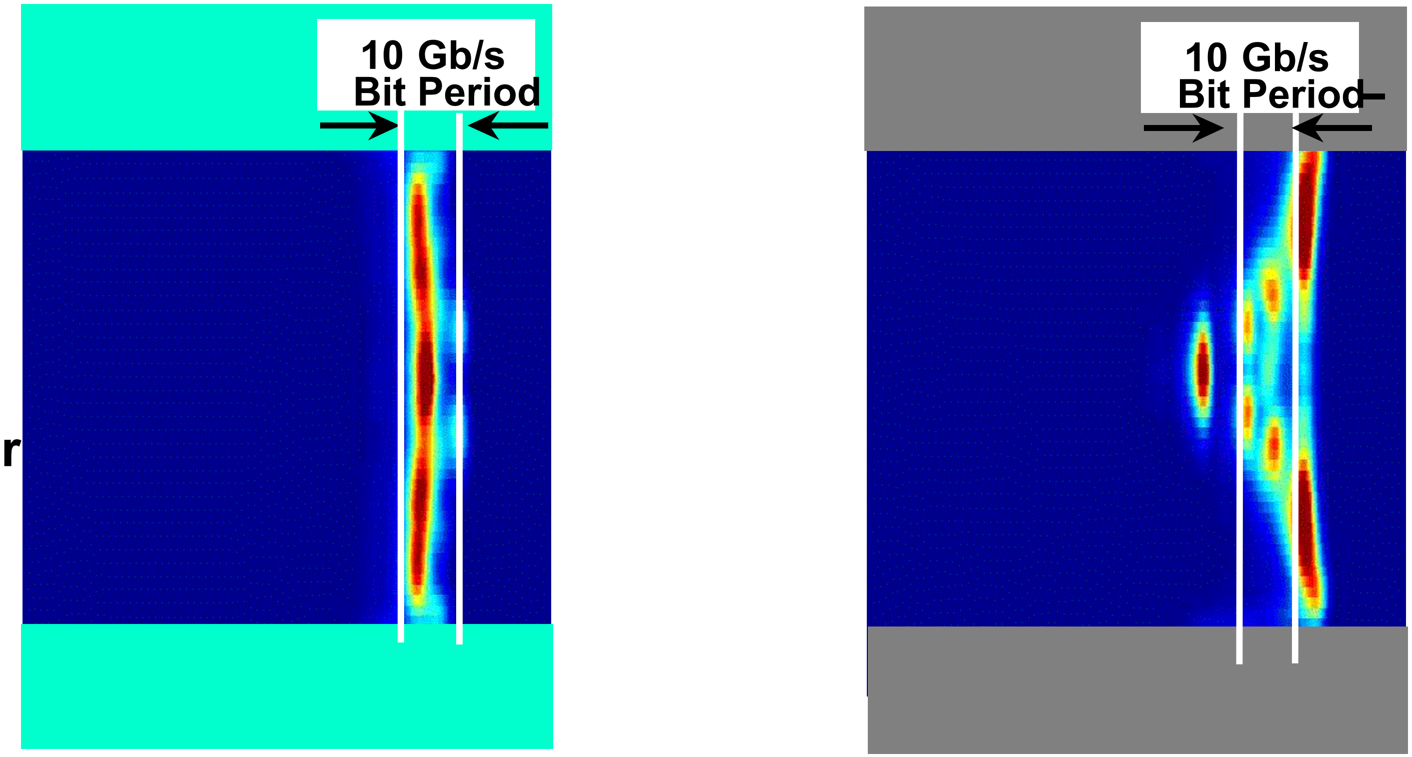
DMD Controlled and Measured Fiber

Essential to support Laser-based systems

Laser Optimized 50 micron

Conventional 50 or 62.5 micron

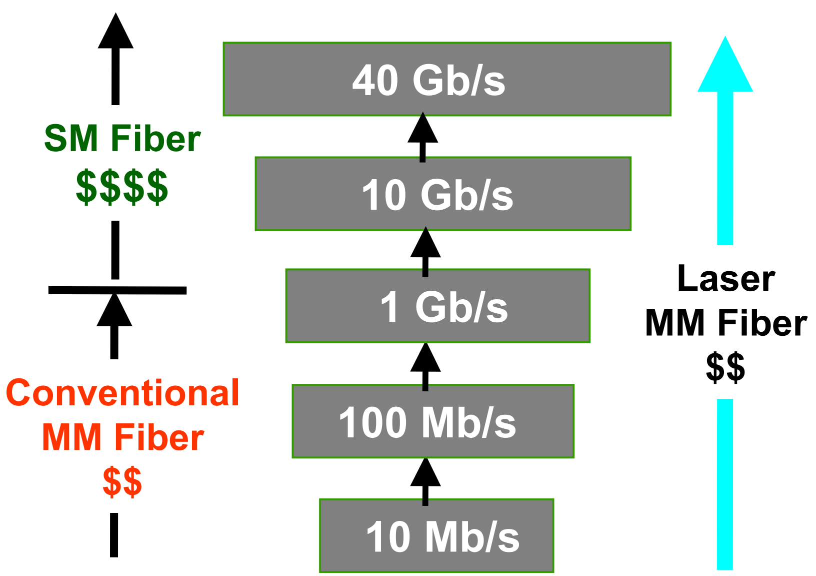
Fiber Core Center

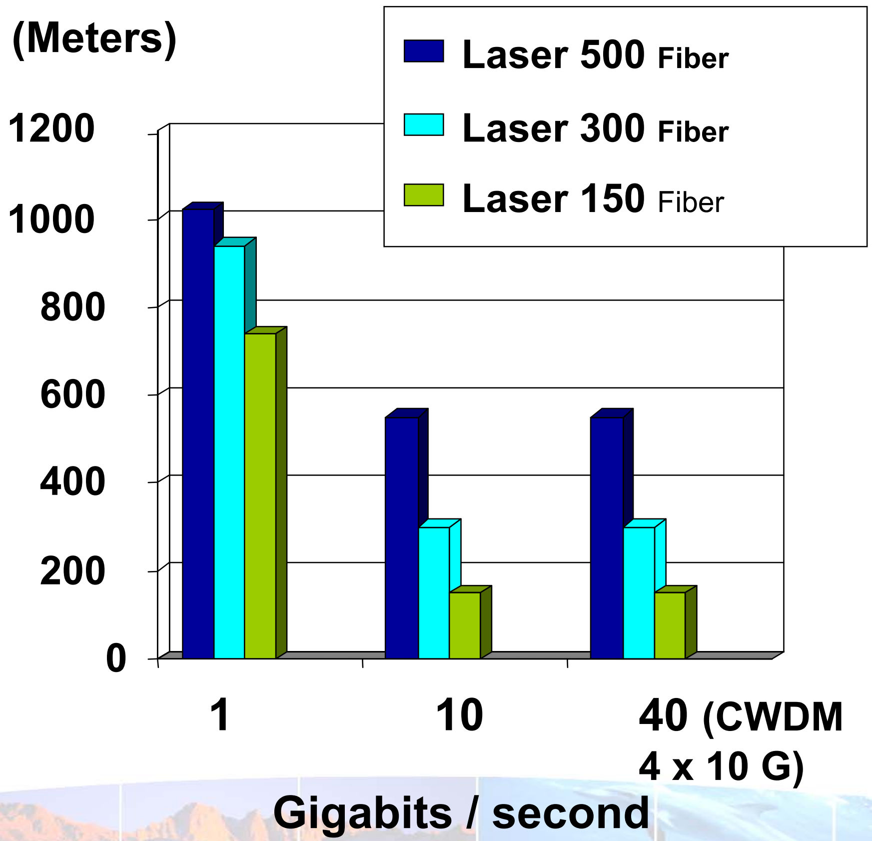


Received pulse at 10 Gb/s over 300 meters

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
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

Leading Optical Innovations

Applications

10G Fibre Channel
ANSI T11.2
850-nm serial, parallel, CWDM

10G Ethernet
IEEE 802.3ae
850-nm serial

OC-192/OC-768
OIF VSR-4 / 5
850-nm serial, parallel/parallel

Cabling
2000 MHz-km
@ 850-nm Laser
Launch Bandwidth

IS0-11801 2nd Edition
OM3 Fiber

TIA 568 B.3-1 **850-nm Laser Optimized 50 micron**

Fiber
Laser Bandwidth
DMD specification

IEC-60793-2-10 ed2

TIA-492AAAC

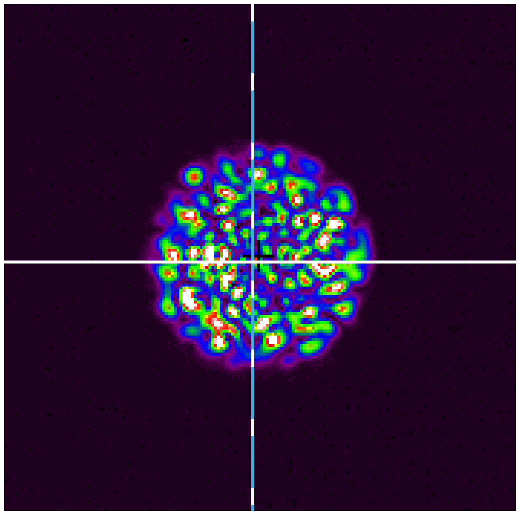
Measurements
DMD measurement test procedure

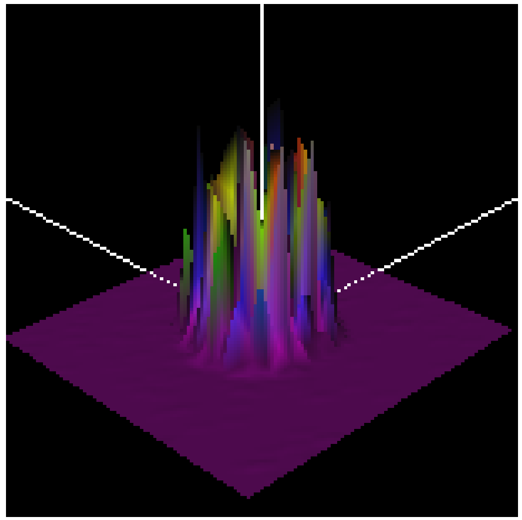
IEC 60793-1-49

TIA/EIA 455-220

Lasers vs... LEDs

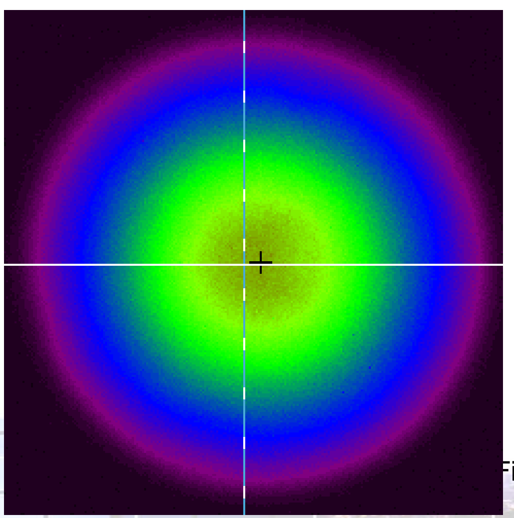
10 Gb/s - 850 nm VCSEL

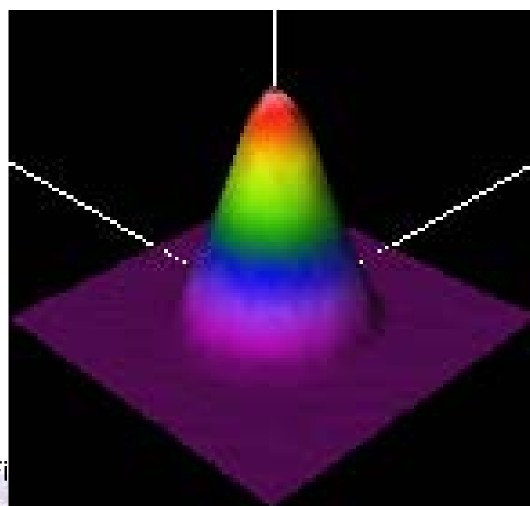




Encircled Power   3D Power map

Low speeds - LED



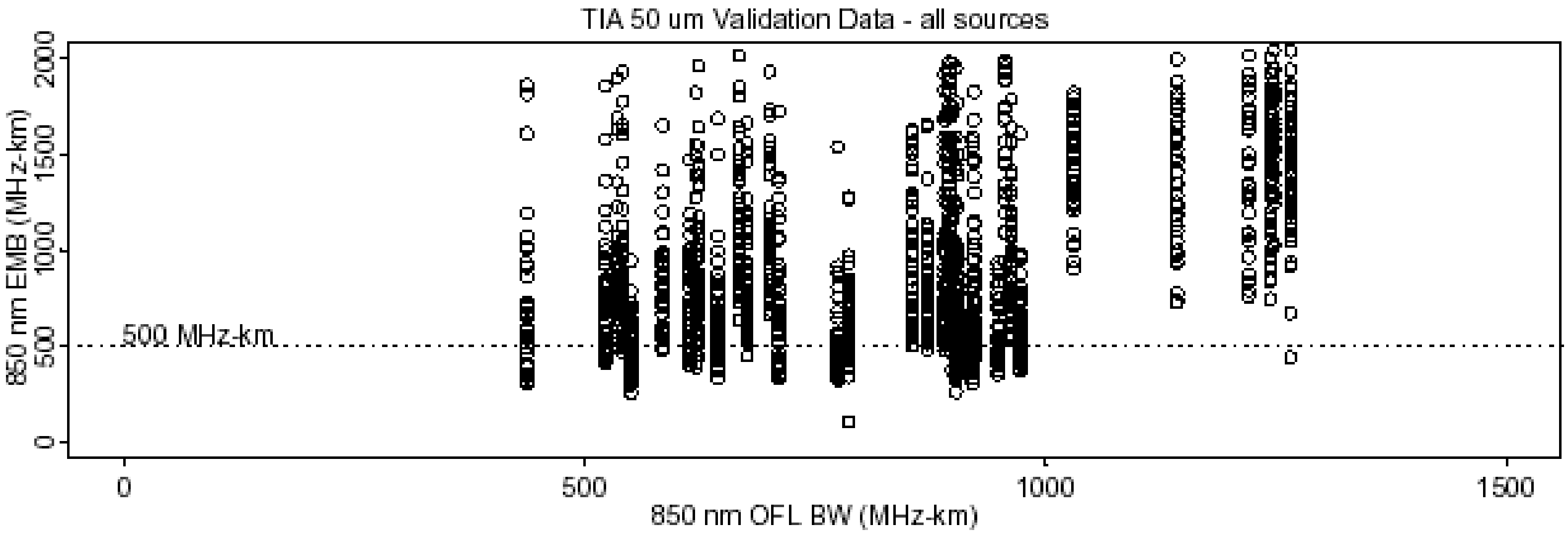


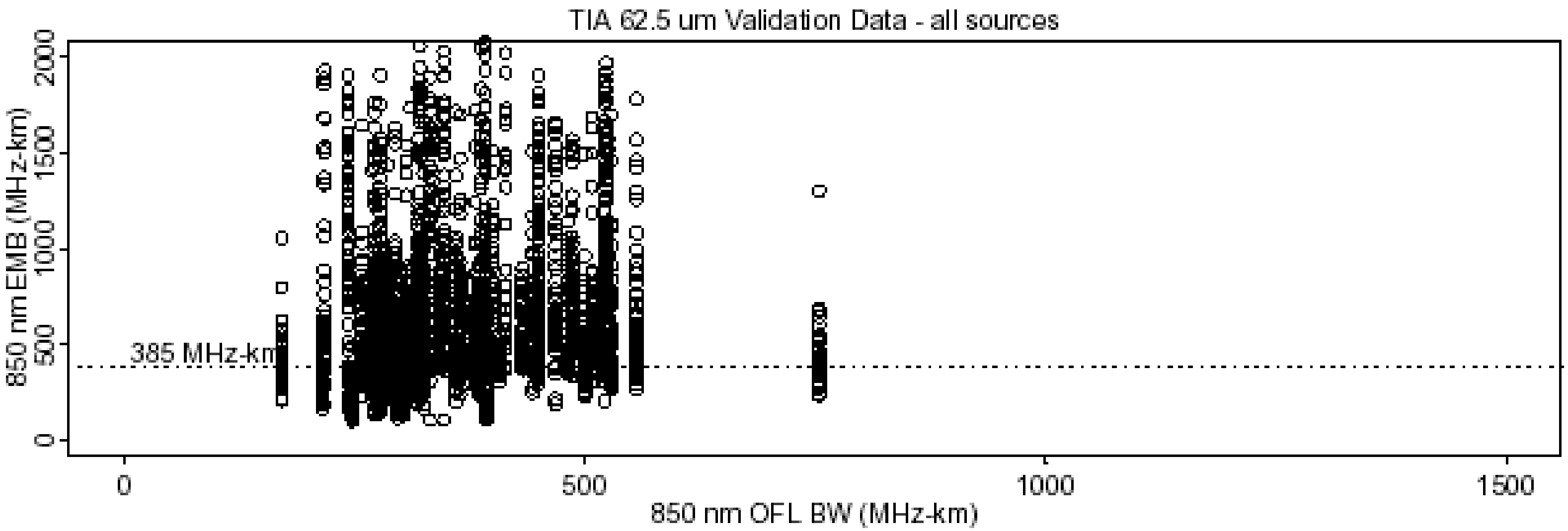
Different properties require different fiber measurements

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

Overfilled Bandwidth

Very Poor Predictor of Bandwidth in Laser based Systems

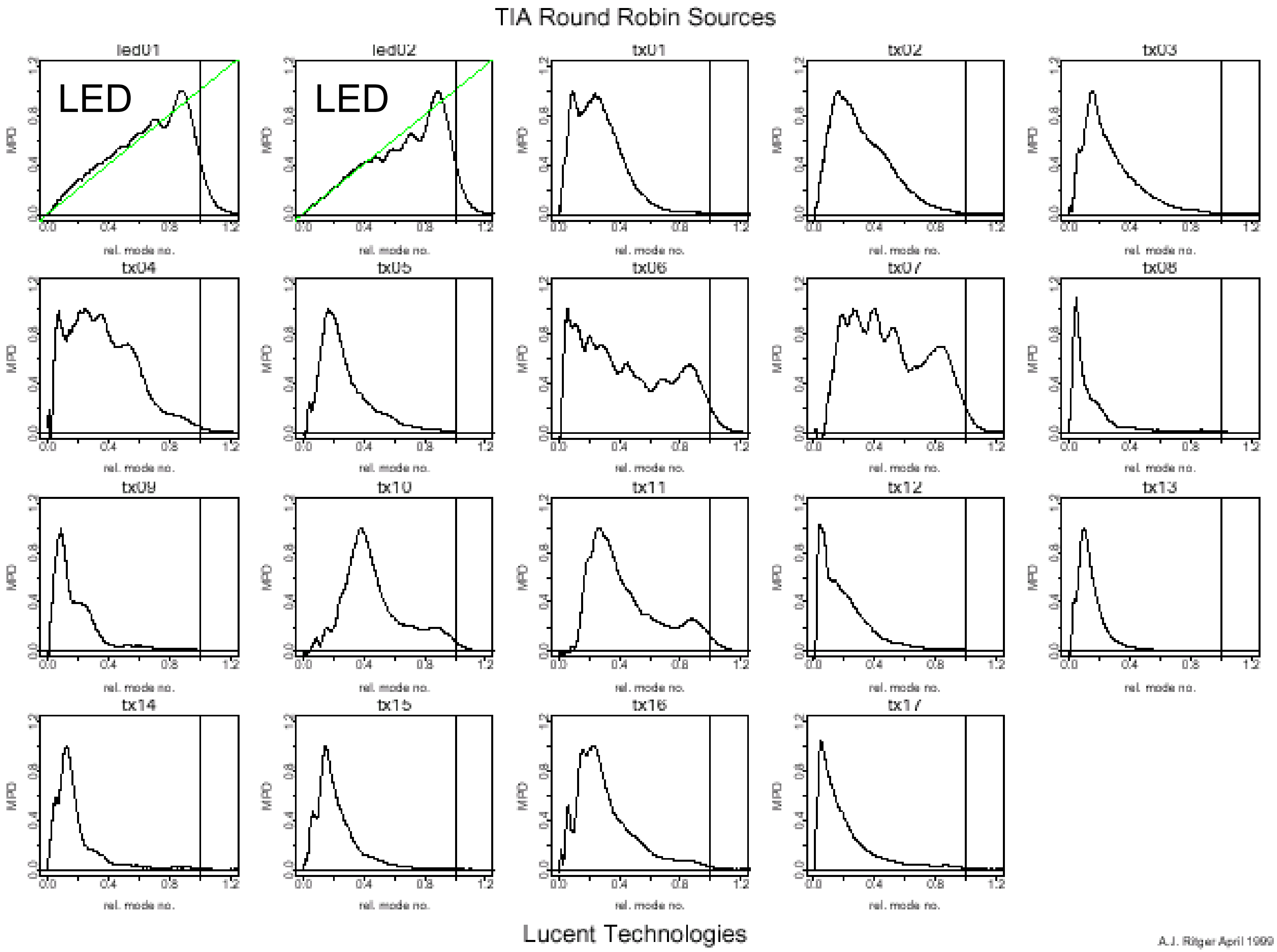




Sel

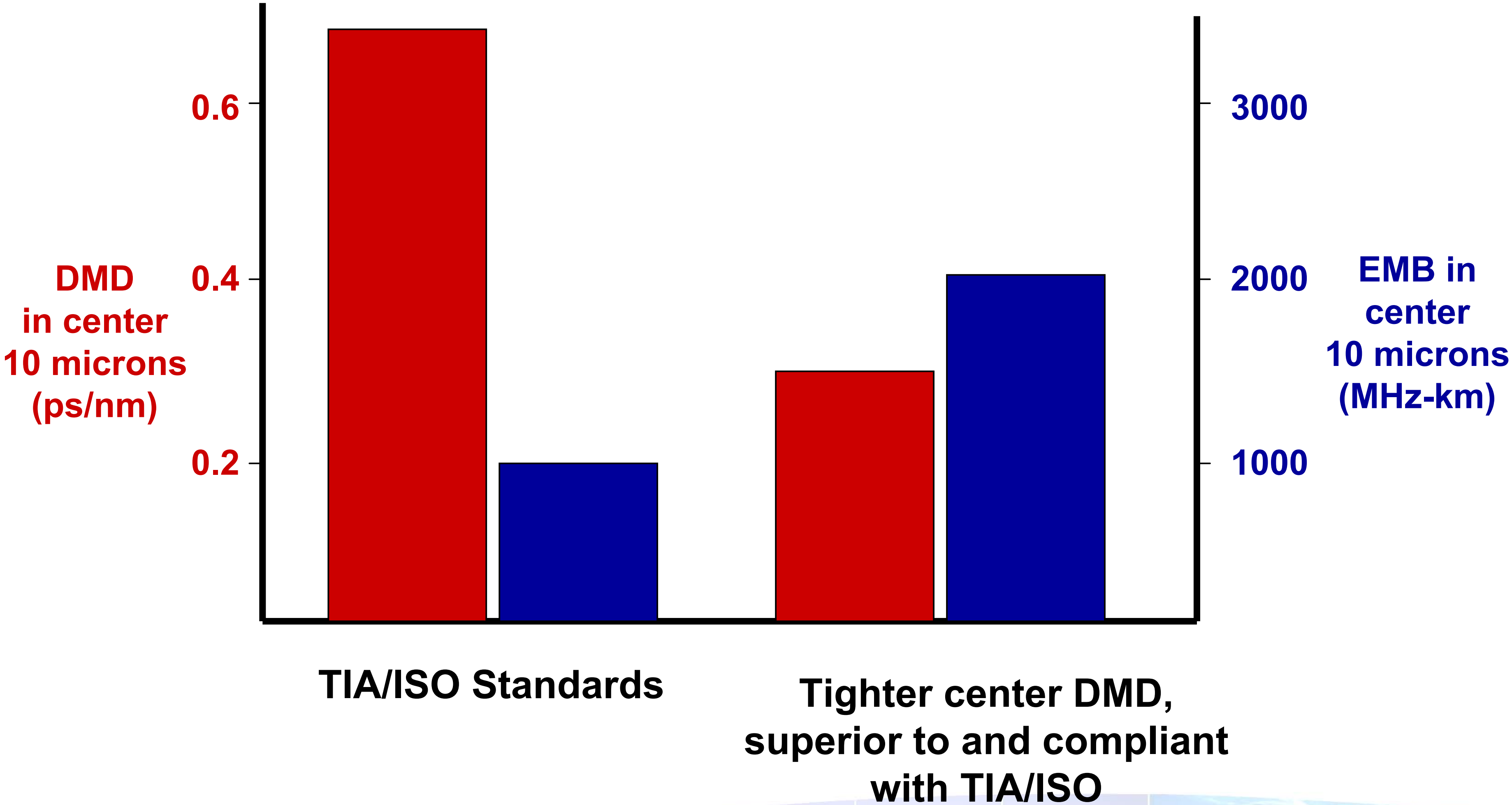
Mode Power Variations

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



Tighter DMD Specifications

Enables Higher EMB with larger variety of 850 nm VCSELs



Laser Optimized 50 Micron Fiber

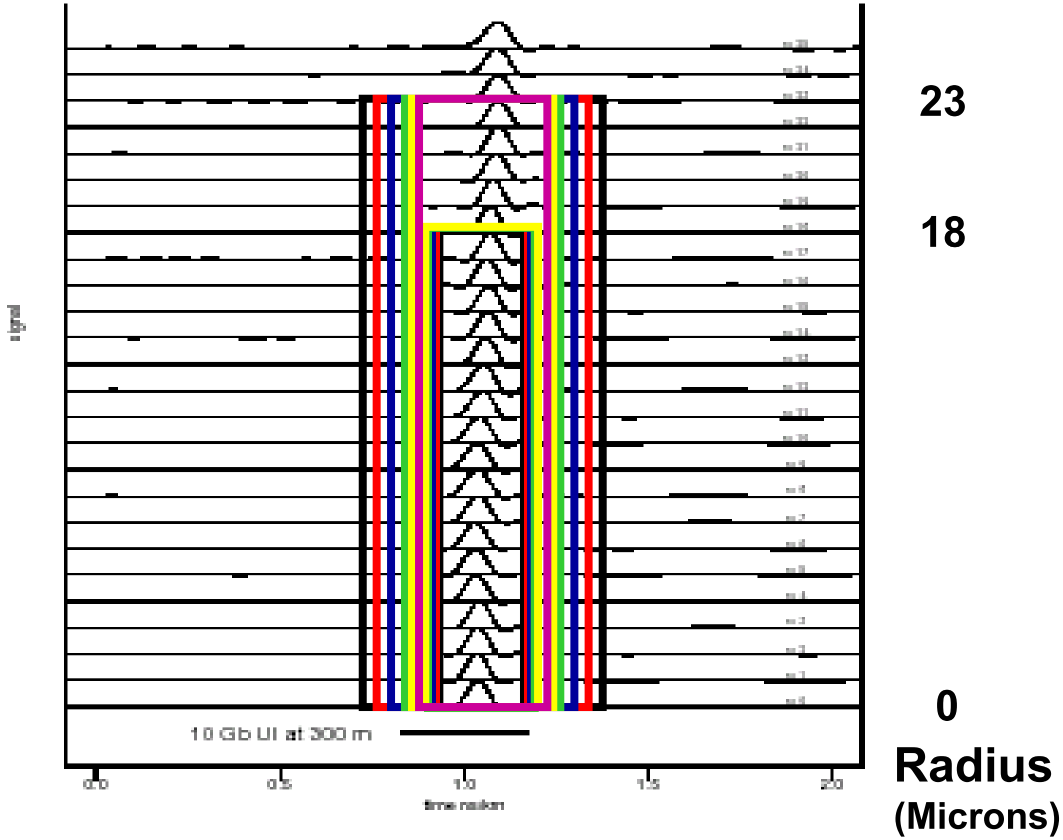
Ideal DMD Profile

- 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

ofs
Leading Optical Innovations

- 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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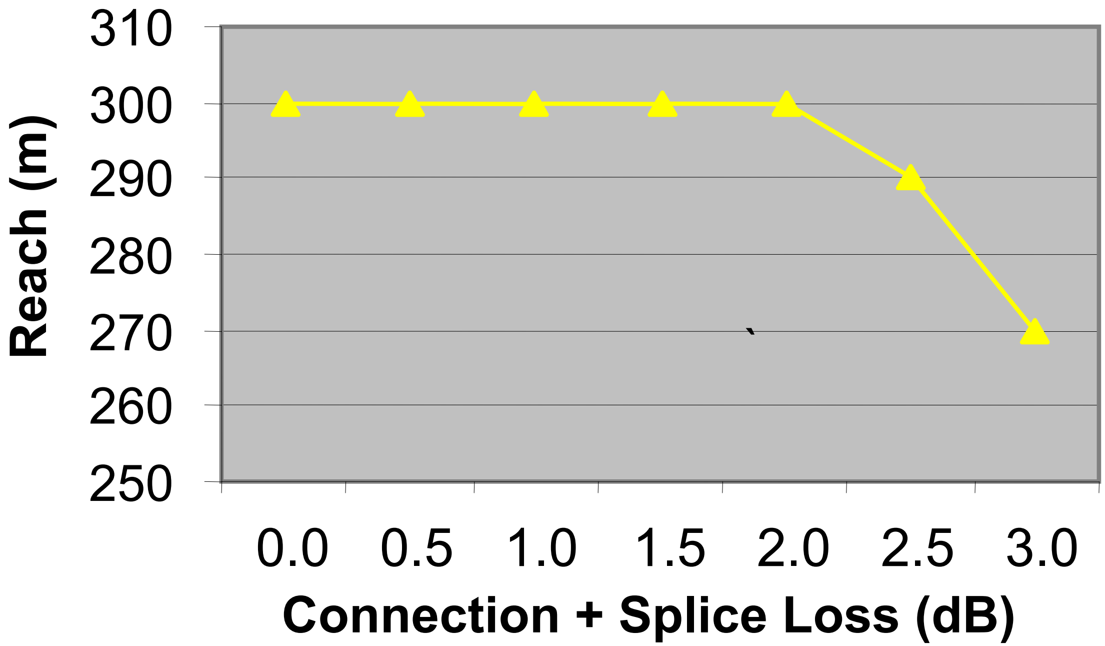
10 Gb/s Cabling System Reach vs. Loss

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

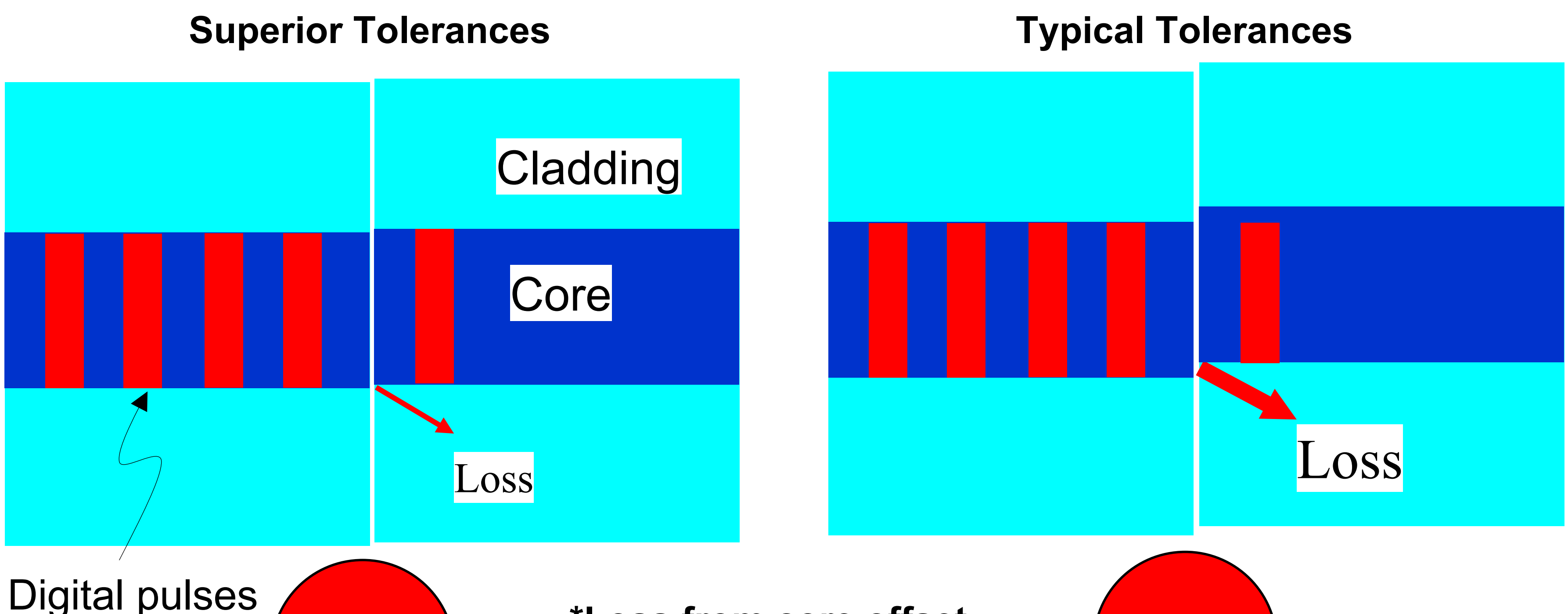
Tighter Specifications extend reach, allow more connections

Specification	Superior	Typical
Cladding diameter	125 ± 1 µm	125 ± 2 µm
Core/cladding concentricity error (offset)	≤ 1.5 µm	≤ 3.0 µm
Bare fiber attenuation (850/1300 nm)	≤ 2.4/0.7 dB/km	≤ 2.5/0.8 dB/km

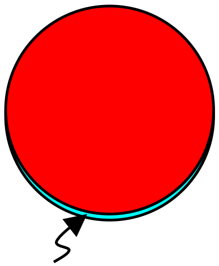
- Superior core centering benefits
  - Better connector performance
  - Improved coupling/centering of VCELS to LOMF
- Superior attenuation benefits
  - Lower overall cable attenuation
  - Cabled fiber better meets strict 1 & 10 Gbps power budgets

Multimode Fiber Tolerances

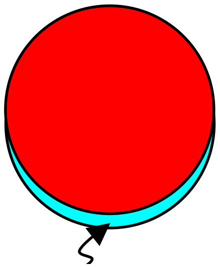
Superior Dimensional Tolerances for Superior Performance



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



4 Micron core offset, ~ 0.1 dB loss *



8 Micron core offset, ~ 0.4 dB loss *

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The Optimum Fibers for FTTD

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

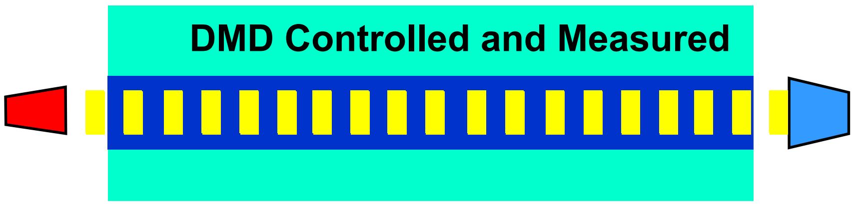
Laser Optimized 50 Micron Fiber Specification Example

Leading Optical Innovations

	Laser Optimized 50 micron Fibers				
Bandwidth (MHz-km) Minimum	**500** 50 µm	**300** 50 µm	**150** 50 µm	**Typical** 50 µm	**Typical** 62.5 µm
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.