

“OM4 Fiber – The Next Generation of Multimode”

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Outline

- Market Drivers
- About Optical Fiber
- OM4 Fiber – What is it?
- OM4 Fiber Standards & Specifications
- OM4's role for 40G & 100G Ethernet

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Ethernet Switch Market

Dell'Oro Group Report (Aug 2009):

“Total Ethernet Switch market to rebound in 2010.”

- Drivers:
 - 10 GbE
 - Data Centers
 - Cisco's move into server market
 - HP's expansion of Data Center portfolio
 - IBM's entrance into Ethernet Switch market

Datacom Transceiver Market

CIR Report (July 2009):

By 2014 –

*Datacom Tx market will grow 50% to **\$6.5B***

*10GbE market will reach **\$1.4B***

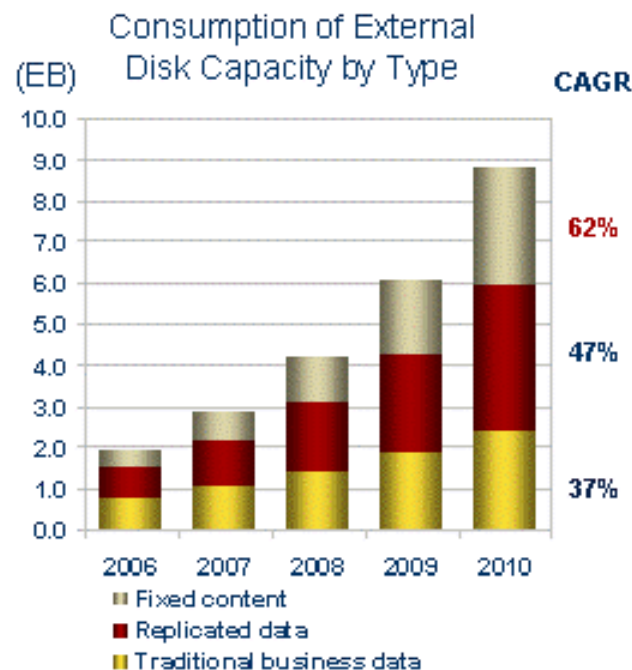
*Fibre Channel market will reach **\$1.7B***

- Drivers / Notes:

- Processor speeds catching up with networking power of 10GbE.
- 10GbE-equipped PC's expected in a few years.
- IEEE's 10GBASE-SR fiber standard well suited for data centers, will remain dominant.
- IEEE's 10GBASE-T copper standard hindered due to its huge power consumption.
- Regulatory environment driving FC in SANs,

Storage Growth

What Will We Keep: Changing Enterprise Data Profile



Structured, transaction-oriented data accounts for declining portion of storage needs

Compliance and business analysis are driving surge in replication of data

Explosion in file-based, unstructured data is changing storage needs in the data center

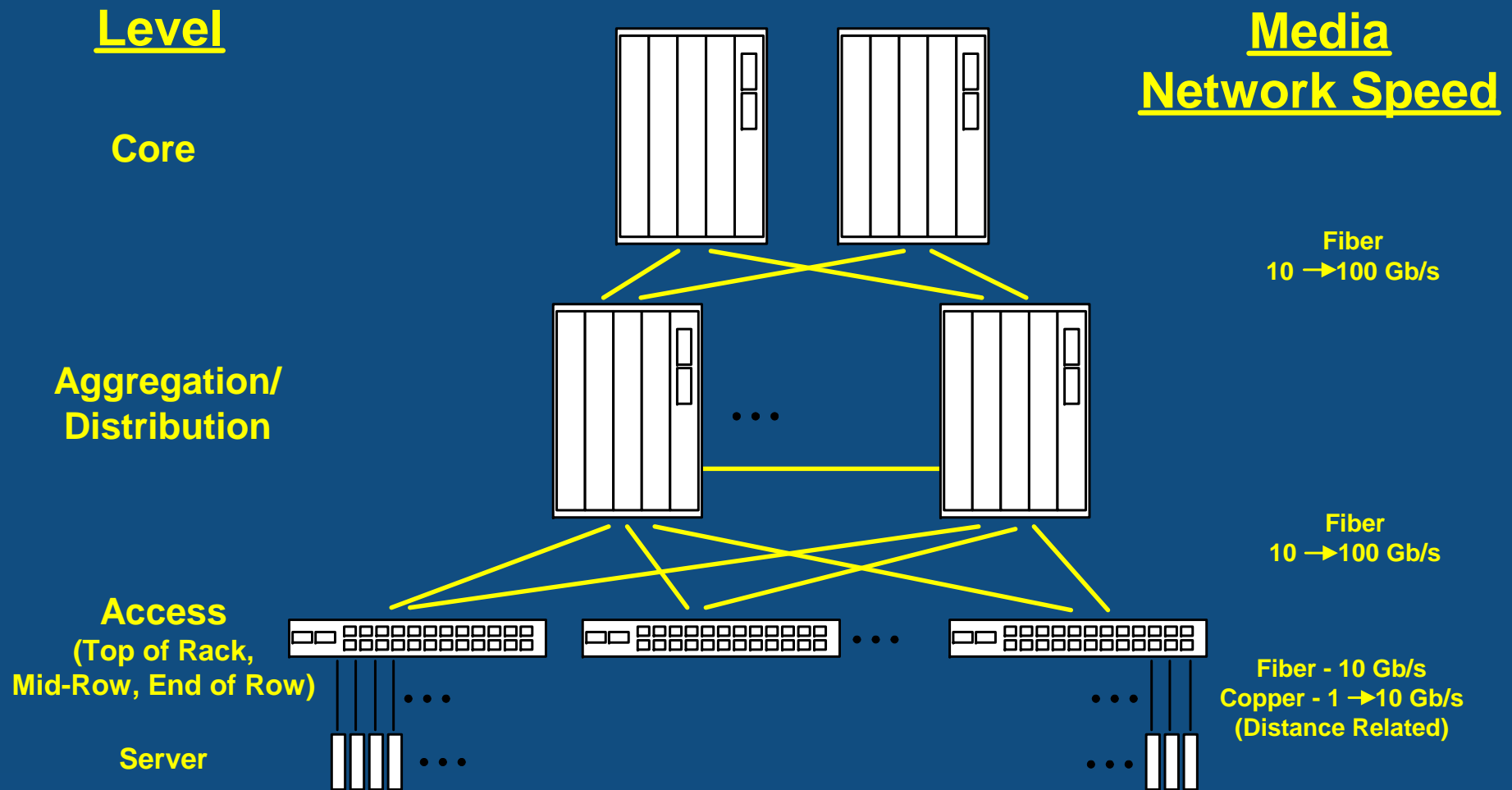
- Secondary storage is the new primary storage
- Spur to investments in file management technologies
- Cost-effective archiving becomes a hot issue

© 2007 IDC

Market Driver Summary

- IP traffic growth continues at 30+% CAGR
- Switch market expected to grow in 2010
- Transceiver growth expected to grow 50% by 2014
- Storage growth continuing at 35+% CAGR
- **Faster speeds will be required in near future to deal with increased demands**

Typical Data Center Architecture



Outline

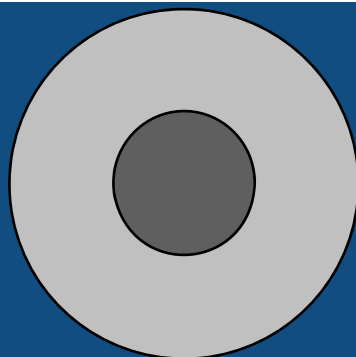
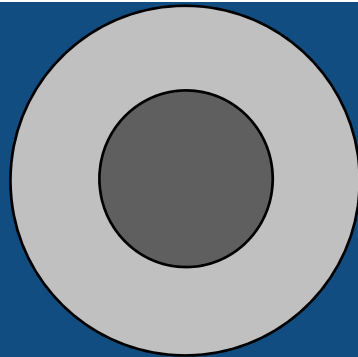
- Market Drivers
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Two Basic Optical Fiber Types

1. Multimode

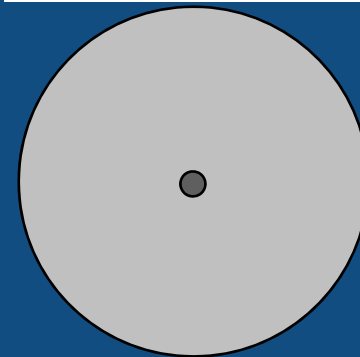
62.5 micron

50 micron



2. Single-mode

~8 micron



125 micron

850 nm
& 1300 nm

Operating
Wavelengths

1310 - 1625 nm

Larger cores and lower wavelengths drive source and system costs down



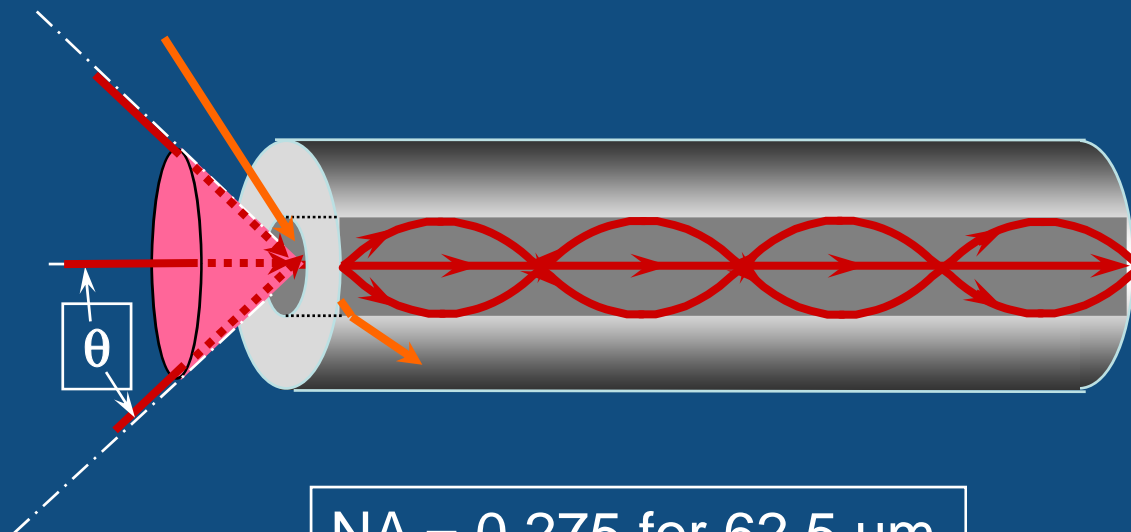
A Furukawa Company



Multimode Fiber

- Has large **Numerical Aperture (NA)**, or cone of acceptance of light.
- Light entering outside of cone escapes out of core.
- Large NA allows for easier, less precise transmitter & connector alignment.
- Lowers cost of transmitter, connectors, and installation.

NA – Cone of Acceptance of Light

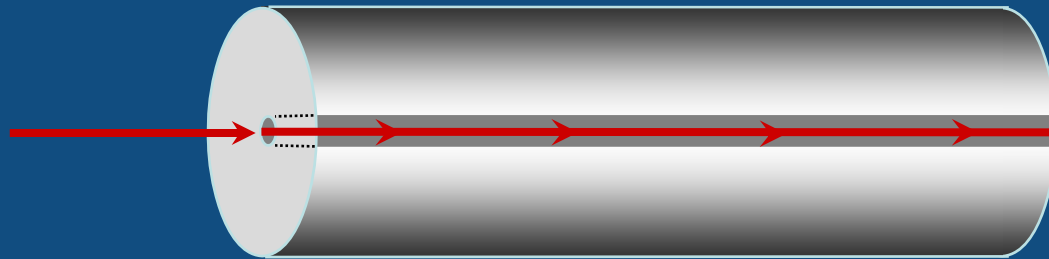


NA = 0.275 for 62.5 μm
NA = 0.200 for 50 μm

Singlemode Fiber

Small core guides only one mode

- Eliminates modal dispersion.
- Takes advantage of lower attenuation at longer wavelengths (1310 & 1550 nm).
- Enables tremendous transmission capacity over very long distances.

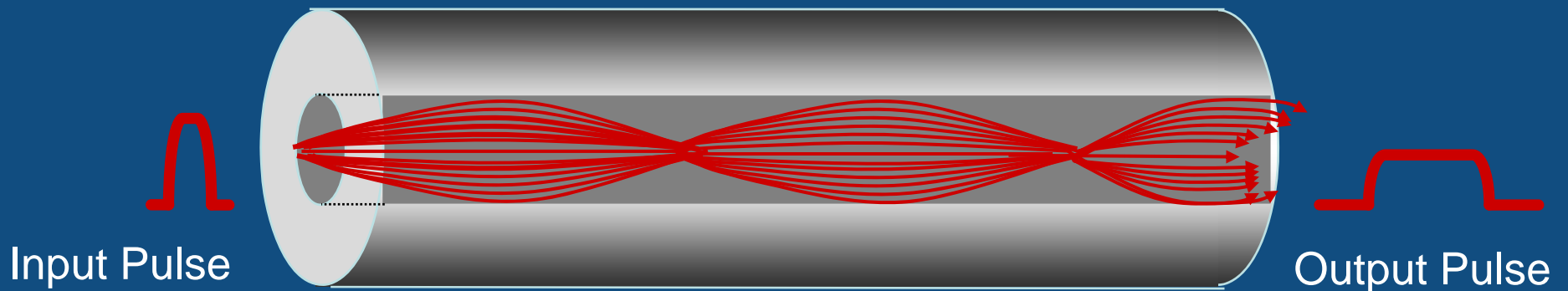


Multimode or Singlemode?

- Singlemode needed for distances greater than those supported by OM4 multimode fiber:
 - >550 meters at 10Gb/s
 - >150 meters at 40Gb/s and 100Gb/s
- Singlemode may be considered the ultimate in future-proofing, but is expensive to operate compared to Multimode.

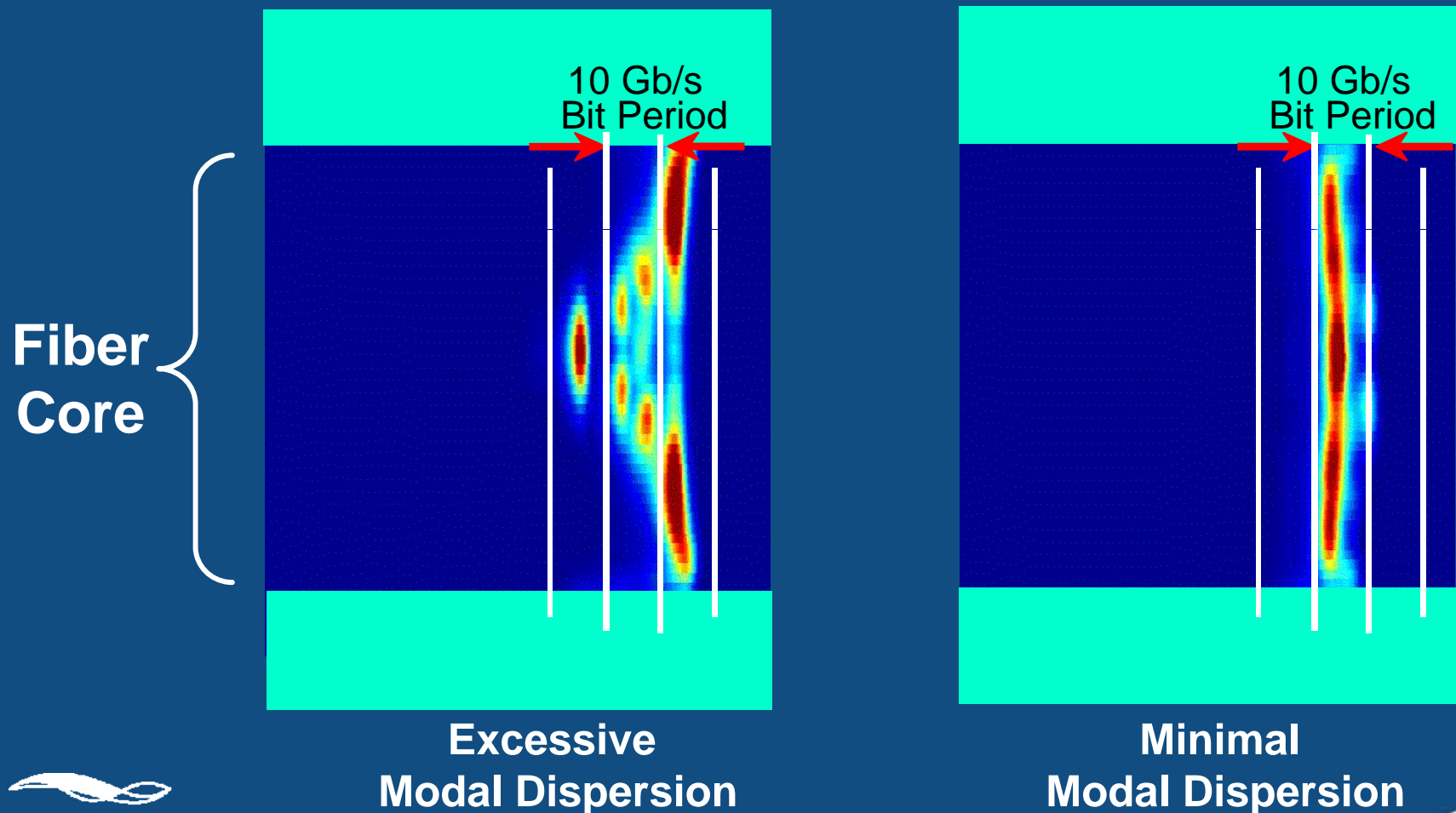
Multimode Fiber

- Light Signal (*pulse*) travels along many modes, or paths.
- Pulse spreading occurs due to **Modal Dispersion**, or **DMD** (*Differential Mode Delay*)
- Pulse spreading limits **Bandwidth** (*transmission carrying capacity*)

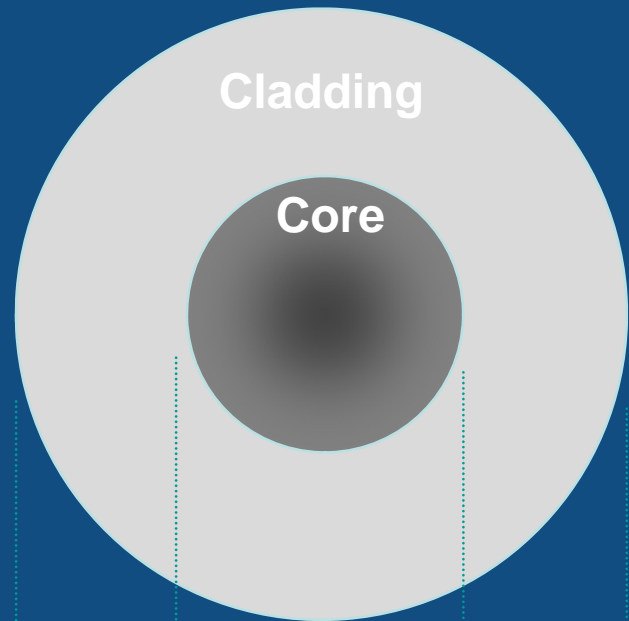


Excessive Pulse Spreading =
Intersymbol Interference (ISI) =
Bit Errors

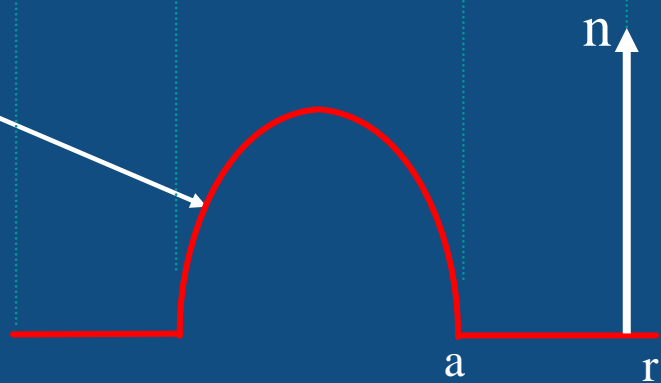
Pulses of Light Traveling Through Multimode Optical Fiber



Refractive Index Profile in MMF



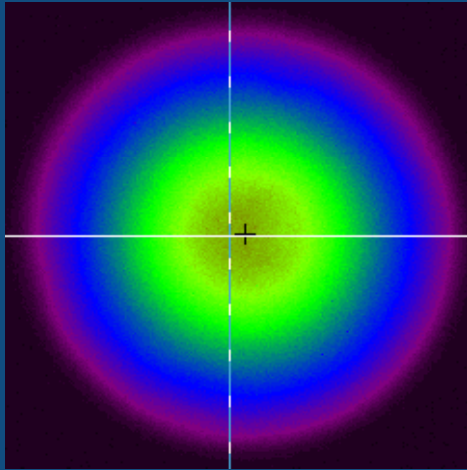
Refractive Index Profile
(Graded Index)



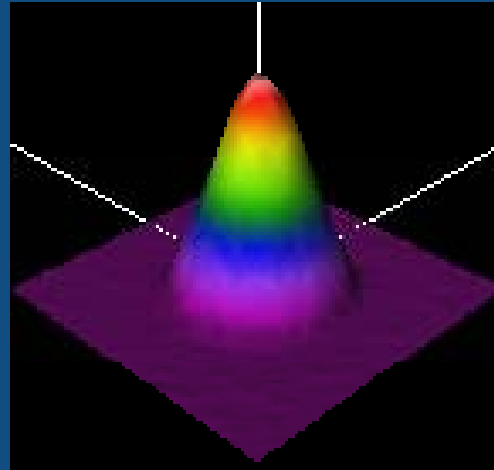
An optimized Refractive Index Profile minimizes DMD and maximizes Bandwidth
Equalizes arrival times of all the modes

$$n = c/v_g$$

LEDs vs. Vertical Cavity Surface Emitting Lasers



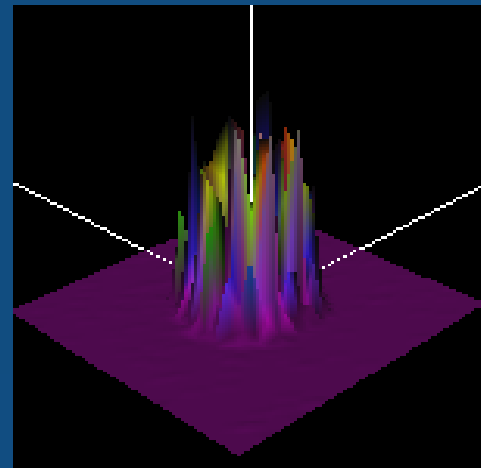
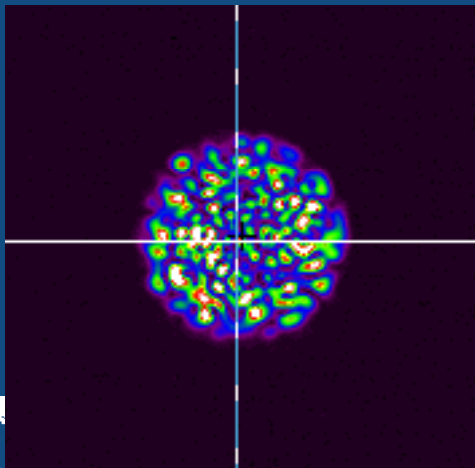
Encircled Power



3D Power map

LED (up to 622 Mbps)

- Overfills core (large spot size)
 - Excites all modes.
- Bandwidth performance dependant on all modes.
- Uniform, consistent power profile. Repeatable.



VCSEL (1 or 10 Gbps)

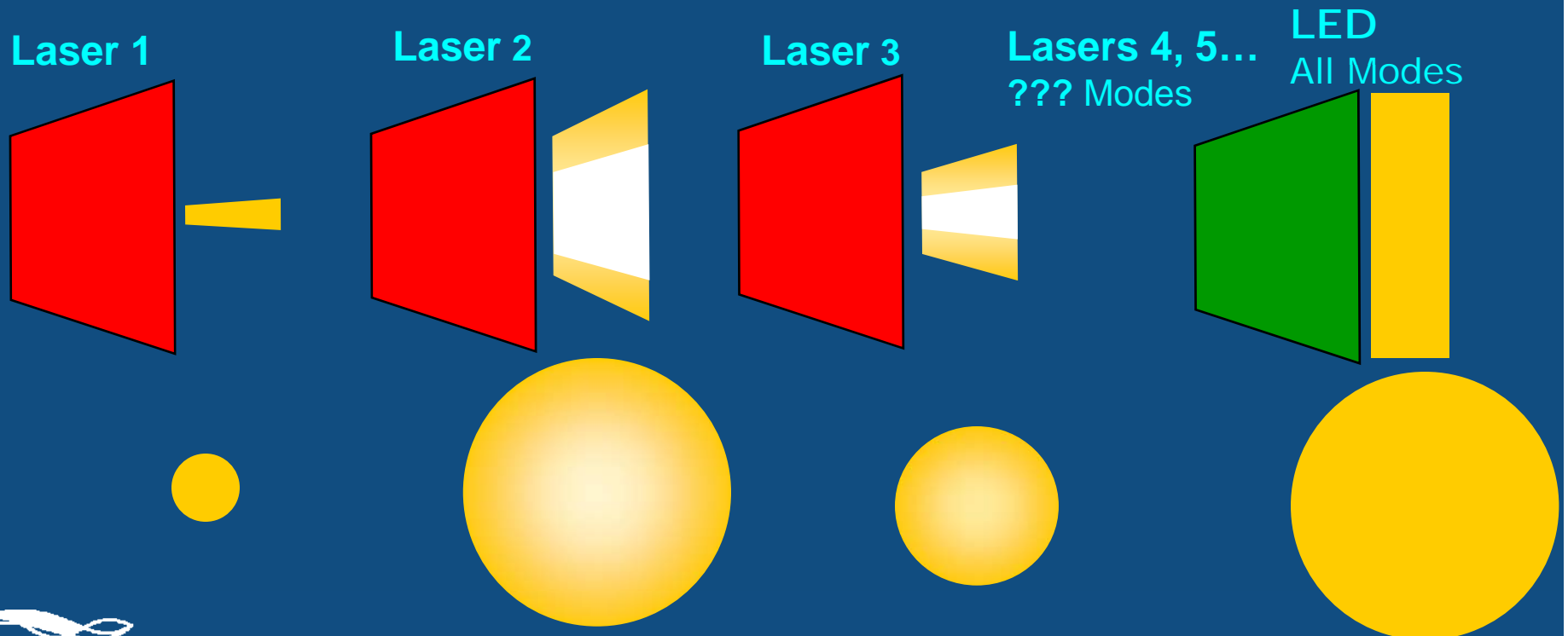
- Underfills core (small spot size)
 - Excites fewer modes
- Bandwidth dependant on which modes happen to carry power.
- Non-uniform, fluctuating, non-repeatable power profile.

Laser Bandwidth (Fiber EMB with Lasers)

Does overfilled bandwidth predict Laser bandwidth? - NO

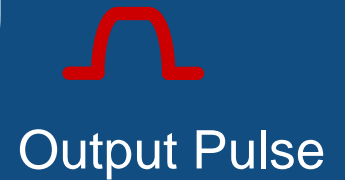
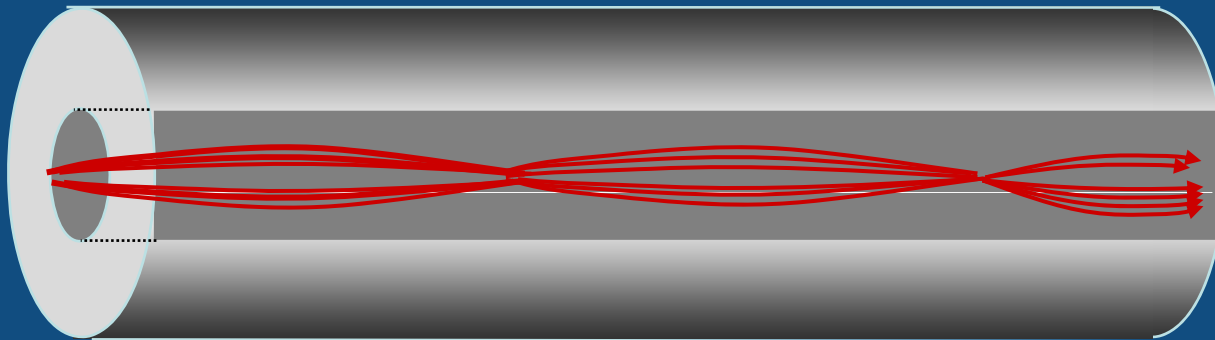
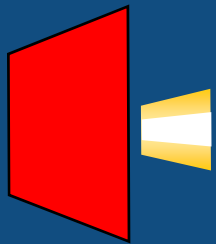
Different lasers at the same speed and wavelength:

- Have different power output profiles (Encircled flux)
- Fill a subset of the hundreds of modes in MMF
- Each fills *different subsets* of modes
- Will produce different bandwidths on the same fiber



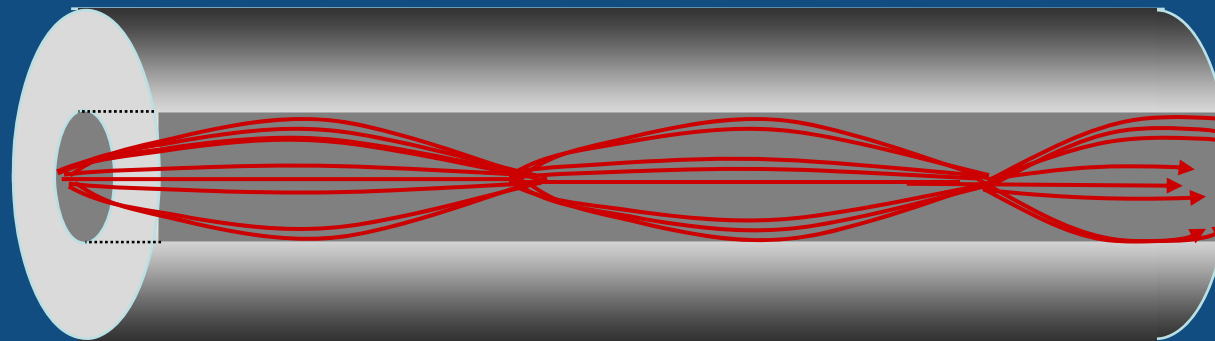
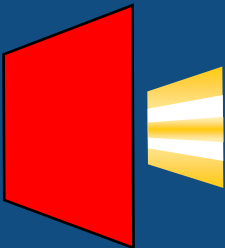
Different VCSELs give Different Bandwidth, even on the same fiber

VCSEL A



Same Fiber

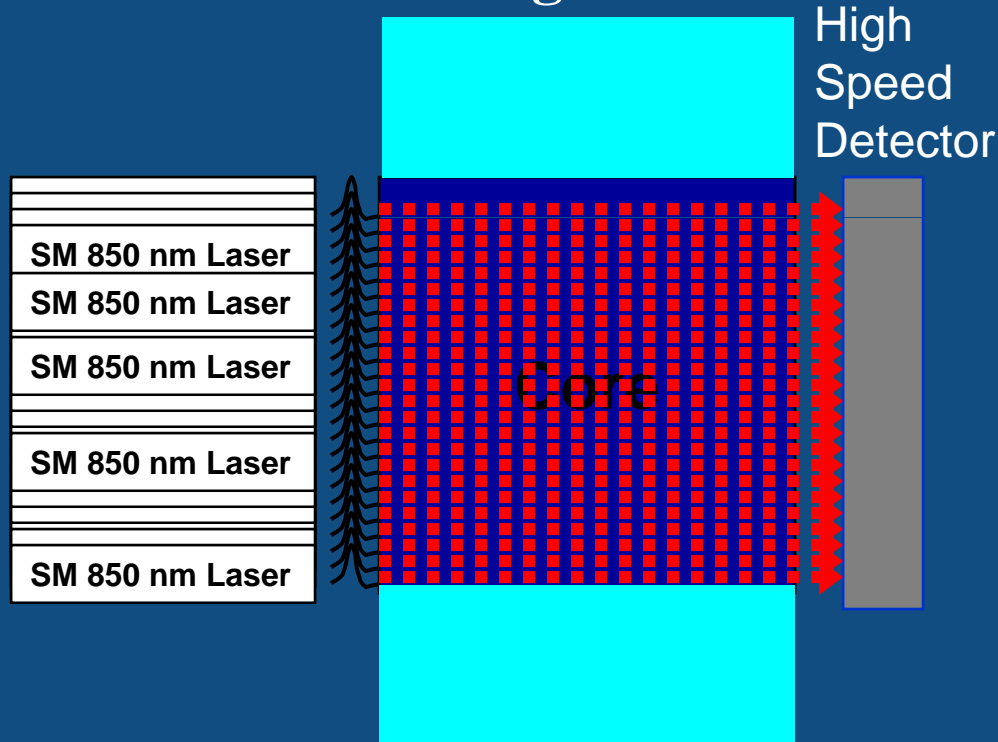
VCSEL B



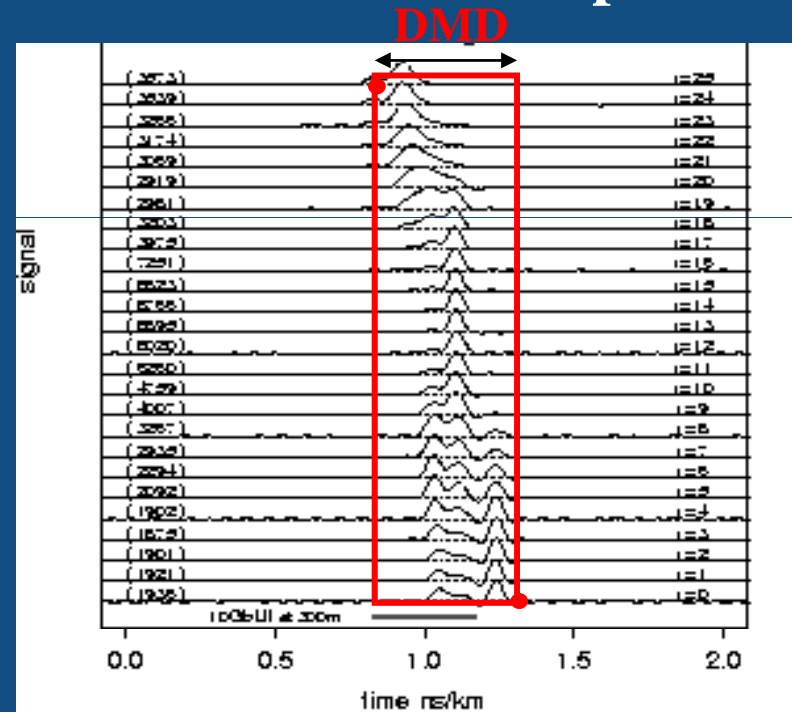
DMD Measurement Provides a Means to Assess Bandwidth for Specific Modes

(per TIA FOTP-220)

DMD Scanning Process



DMD Scan Example



a.j.rilger 22Jan00

DMD Specifications - Mask Method

(TIA-492AAAC or IEC 60793-2-10)

DMD Scan Example

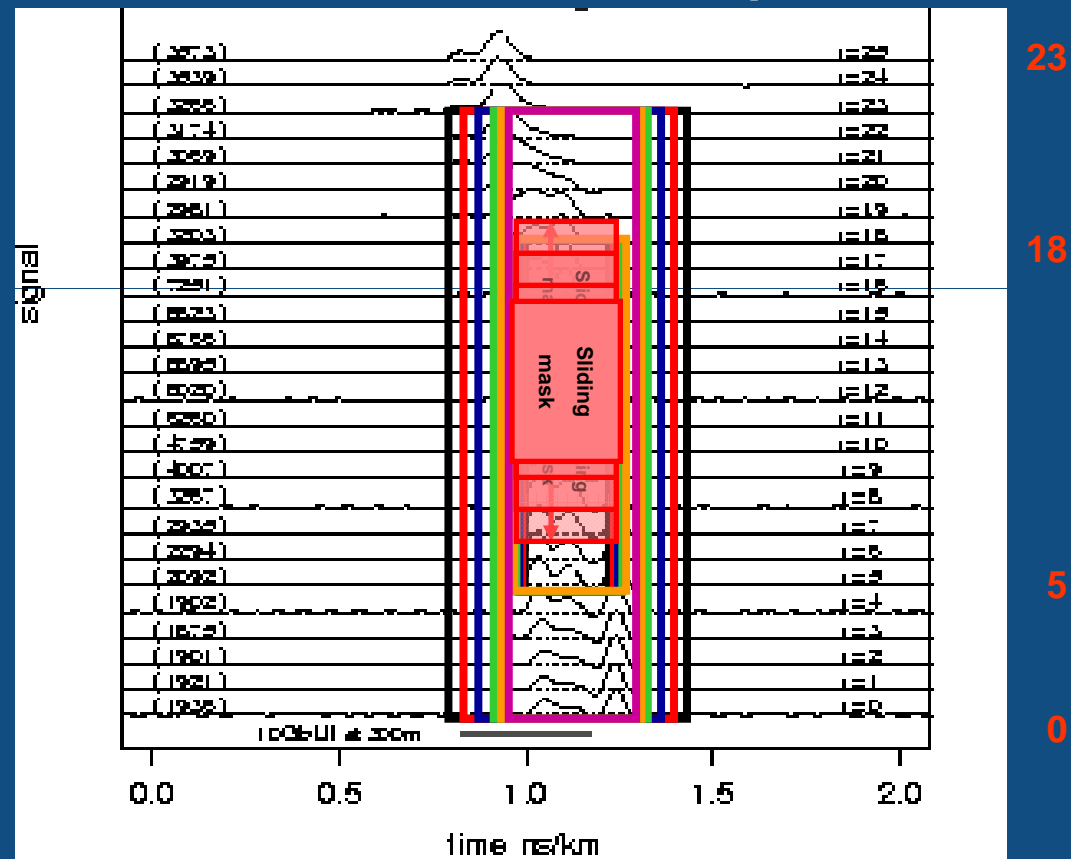
Radius
(μm)

6 DMD Templates

- Each template has **Inner** and **Outer Mask**
- Fiber must meet at least one template
- Inner mask floats temporally in outer mask

Sliding Mask

- “Smooth” DMD in critical 7-19 μm region
- DMD < 0.25 ps/m over any 6 μm window



Templates

- 1 —
- 2 —
- 3 —
- 4 —
- 5 —
- 6 —



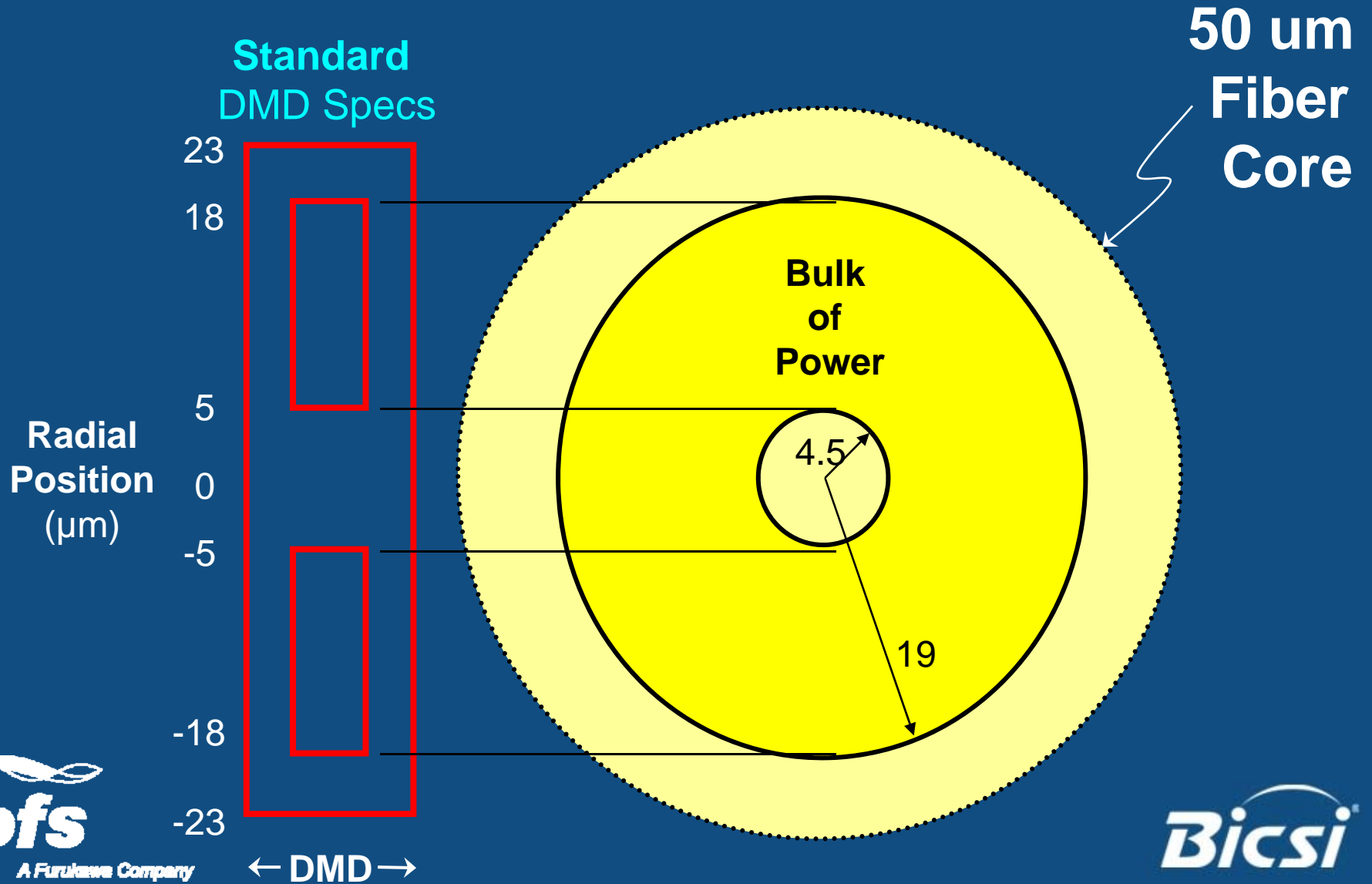
A Furukawa Company

This fiber meets templates 3, 4, and 5 and meets the sliding mask specification

BICSI

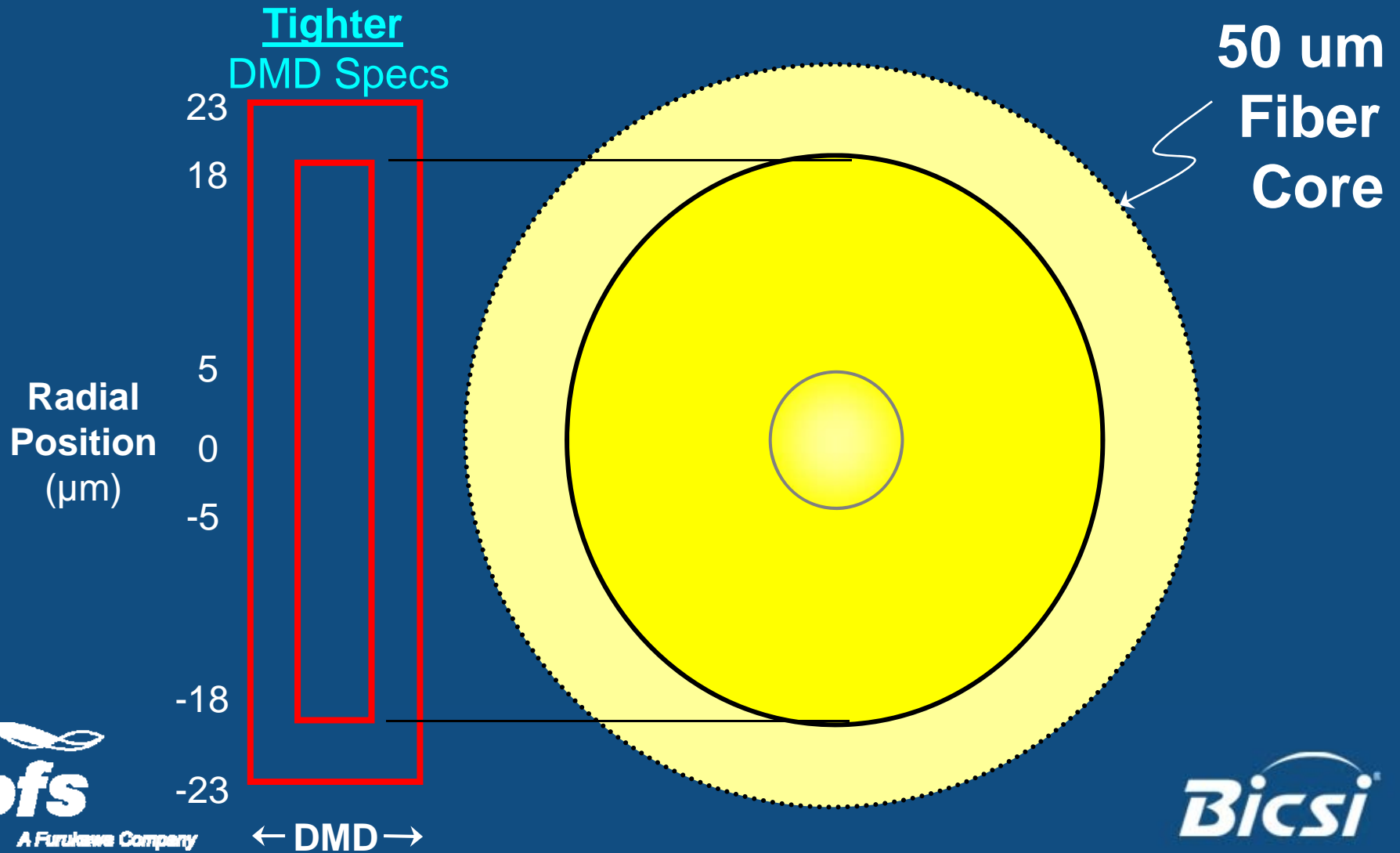
DMD Masks to Encircled Flux Correspondence

- Tight inner mask matches region carrying bulk of power



DMD Masks to Encircled Flux Correspondence

- Tighter DMD Specs (0 – 5 μm region) for added reliability



Effective Modal Bandwidth Calculated (EMBc)

(TIA-492AAAC-A, IEC 60793-2-10)

Calculated based on DMD

- DMD of fiber measured per TIA FOTP-220
- Calculated from interaction of the DMD with 10 simulated VCSELs (weighting functions)
- 10 VCSELs meant to represent a broad range of compliant VCSEL specifications
- The lowest of the 10 bandwidths is EMBc

DMD Mask Method vs. EMBc Method

DMD Mask Method

- Direct measurement of fiber performance
- Allows for closer scrutiny of specific regions of the fiber
(for example 0 – 5 μm center region)

EMBc Method

- Complex calculation (Fourier Transform of time domain data) based on 10 *theoretical* weighting functions
- Does not provide for any tighter scrutiny of fiber than the bare minimum called for in standard

Multimode Fiber Types

Multimode Fiber Types, Performance Grades

Fiber type	Wavelength (nm)	Max Loss (dB/km)	Min Bandwidth (MHz·km)	
			OFL BW	EMB
62.5 μm (OM1)	850	3.5	200	n.s.
	1300	1.5	500	n.s.
50 μm (OM2)	850	3.5	500	n.s.
	1300	1.5	500	n.s.
850-nm 10G Laser- Optimized 50 μm (OM3)	850	3.5	1500	2000
	1300	1.5	500	n.s.
850-nm 10G Laser- Optimized 50 μm (OM4)	850	3.5	3500	4700
	1300	1.5	500	n.s.

OFL BW = Overfilled Launch
Bandwidth

EMB = Effective Modal
Bandwidth
(also known as "Laser" BW)

EMB met by meeting:

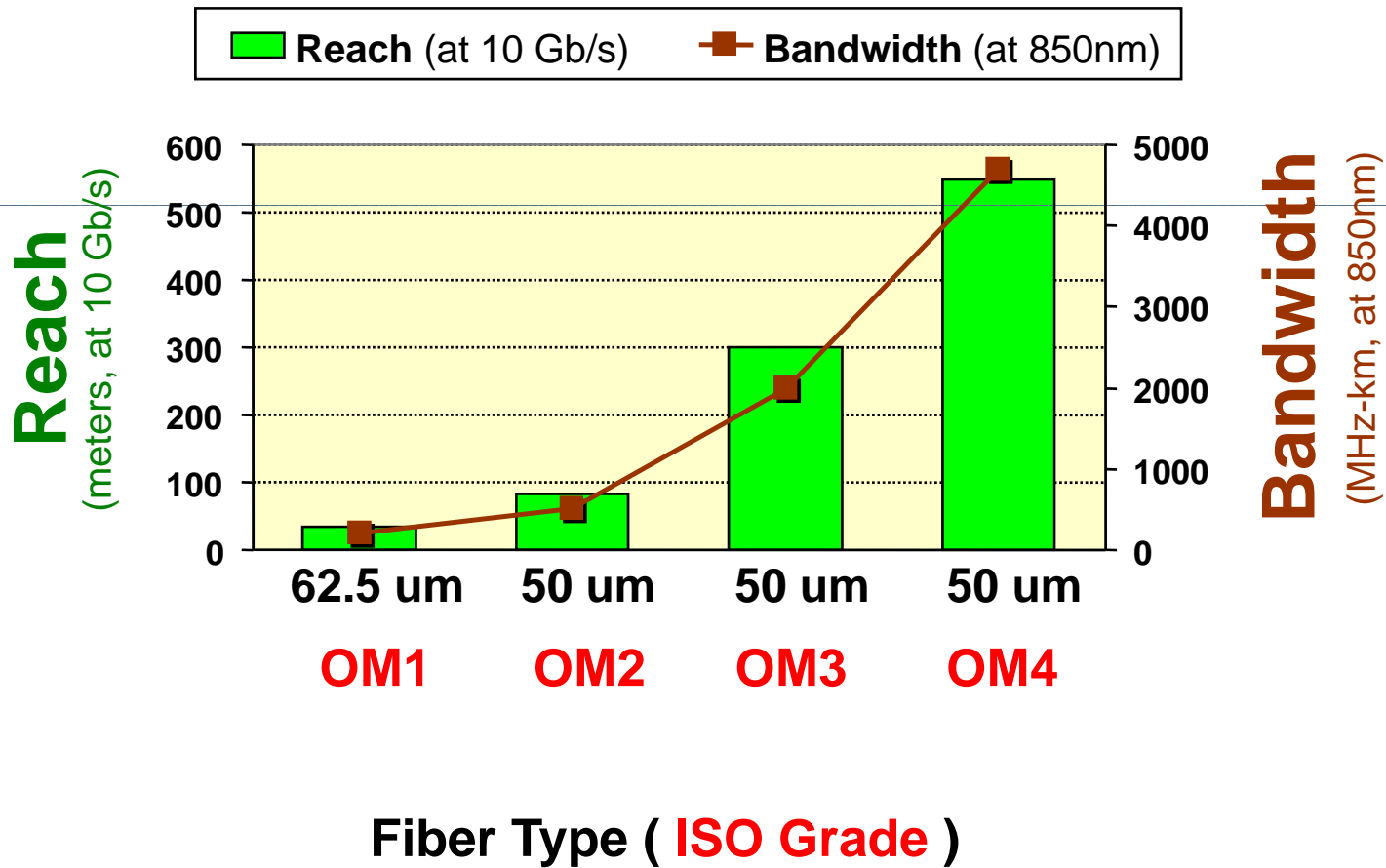
- a) DMD specifications, or
- b) EMBc

as outlined in TIA 492 AAAC

OM1, OM2, OM3 = ISO/IEC 11801 designations

Multimode Fiber Types, Performance Grades

Reach & Bandwidth by MM Fiber Type



Multimode Link Distance Support

10, 40, & 100 Gb/s Transceiver Designation	Wavelength	62.5 um (OM1)	Std 50 um (OM2)	LO 50 um (OM3)	LO 50 um (OM4)	SM (OS1)
10GBase-SR (10 Gb/s)	850 nm Serial VCSEL	33	82	300	550	NA
10GBase-LX4 (10 Gb/s)	1300 nm CWDM Laser	300 ¹	300 ¹	300	300	10,000
10GBase-LRM (10 Gb/s)	1300 nm serial Laser/EDC	220 ¹	220 ¹	220	220	NA
40GBase-SR4 (draft) (40 Gb/s)	850 nm Parallel VCSEL Array	NA	NA	100	<u>125</u>	NA
100GBase-SR10 (draft) (100Gb/s)	850 nm Parallel VCSEL Array	NA	NA	100	<u>125</u>	NA

¹Mode Conditioning Patch-cords required

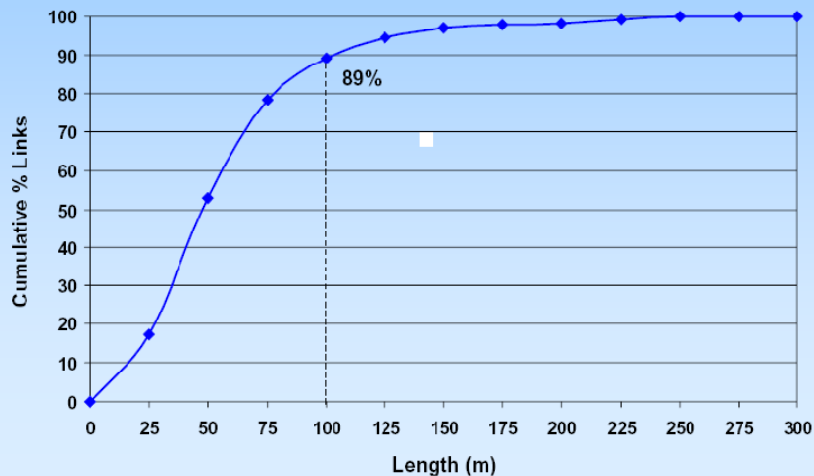
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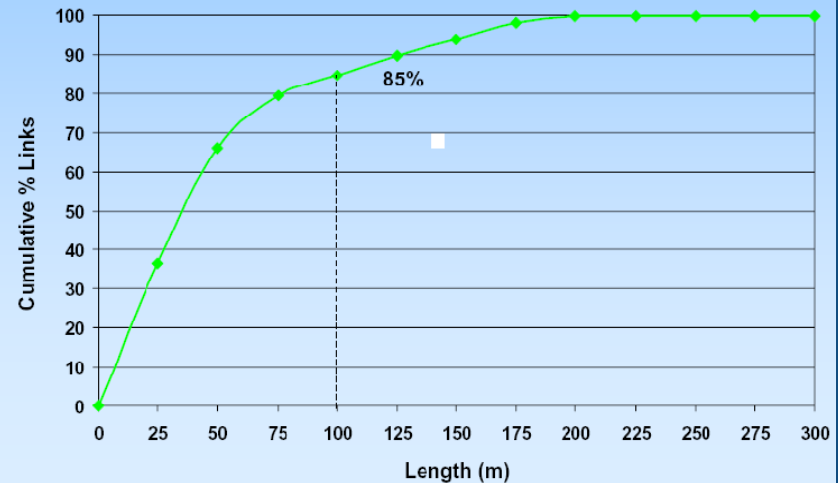
Why is OM4 important?

Fiber is not dominant in short distance Client to Access links,
but Access to Distribution and Distribution to Core links are fiber!

flatman_01_0108
Access-to-Distribution Channel Length Distribution



flatman_01_0108
Distribution-to-Core Channel Length Distribution



Alan Flatman – Principal Consultant, LAN Technologies, UK
“Long Data Center Links vs. Length”
IEEE802.3ba
Jan. 2008
Flatman_01_0108

Why is the OM4 standard important?

Gives IEEE 802.3, Fibre Channel and Infiniband input on how a standards defined multimode fiber will operate with next generation systems.

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OM4 Standardization

- Specifications agreed upon in both TIA and IEC
 - TIA-492AAAD
 - IEC 60793-2-10, Fiber Type A1a.3

General agreement to harmonize the two documents

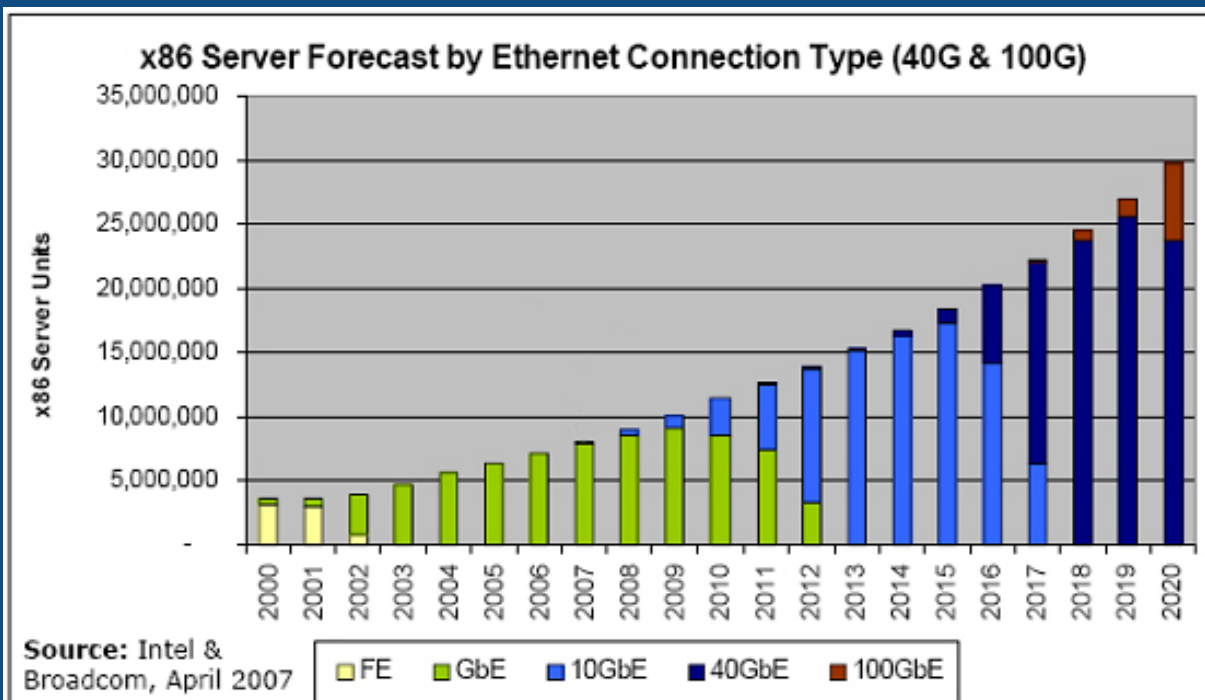
OM4 Specifications

- Effective Modal Bandwidth (EMB) ≥ 4700 MHz-km
 - Allows 2 methods for verification– **DMD Masks** or **EMBc**
- OFL Bandwidth at 850nm ≥ 3500 MHz-km
 - Ensures performance with sources that launch more power into outer modes
- OFL Bandwidth at 1300nm ≥ 500 MHz-km
 - Ensures backward compatibility with OM1, OM2, OM3 fibers for applications such as FDDI, 100BASE-FX, 1000BASE-LX, etc.

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Where is 10 Gb/s today?



Robert Hays, Intel
Howard Frasier, Broadcom
"40G Ethernet Market Potential"
IEEE 802.3 HSSG
April 2007
Hays_01_0407

- Growing adoption at server level
 - Limited by uplink speeds
 - Adoption rate increases when 40/100 Gb/s links become available
- Virtualization drives need for higher speeds

Choices for 40/100 Gb/s Networks

- Ethernet
 - Used in data centers and enterprise LAN networks
 - Migration from 1 Gb/s → 10 Gb/s → 40/100 Gb/s
 - Parallel transmission paths for short reach multimode 40/100 Gb/s
 - Single-mode CWDM for longer reach enterprise LAN networks (campus)

IEEE802.3ba

40 Gb/s Ethernet Reach Objectives

Servers, Access

- 10 km over single-mode fiber (1310 nm) 40GBASE-LR4
- ~~125~~ **150** m over OM4 multimode fiber (850 nm) 40GBASE-SR4
- 100 m over OM3 multimode fiber (850 nm) 40GBASE-SR4
- 7 m over copper 40GBASE-CR4
- 1 m over backplane 40GBASE-KR4

IEEE802.3ba

100 Gb/s Ethernet Reach Objectives

Switching, Routing, Aggregation

- 40 km over single-mode fiber (1310 nm) 100GBASE-ER4
- 10 Km over single-mode fiber (1310 nm) 100GBASE-LR4
- ~~125~~ **150** m over OM4 multimode fiber (850 nm) 100GBASE-SR10
- 100 m over OM3 multimode fiber (850 nm) 100GBASE-SR10
- 7 m over copper 100GBASE-CR10

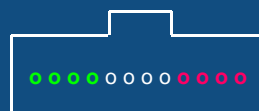
IEEE802.3ba 40 & 100 Gb/s Ethernet

- Reduced Reach (*from 10Gb/s*) on OM3 due to relaxation in transmitter spectral width
 - From 0.65 to 0.45 nm
- Proposal for extended reach on OM4 accepted in January 2010 IEEE meeting
 - **150** meter link distance
 - Addresses links greater than 100 m that would otherwise require singlemode fiber
 - Increased link margin for higher reliability

40G & 100G Ethernet – MDI Recommendations

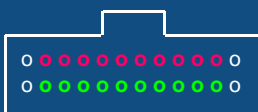
References MPO interface req's/specs of IEC 61754-7.

40GBASE-SR4

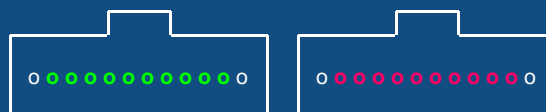


Left 4 pins are Tx
Right 4 pins are Rx
(inner 4 pins unused)

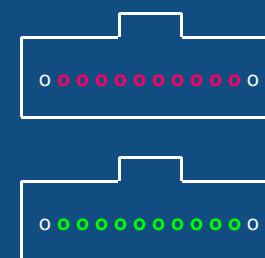
100GBASE-SR10



Inner 10 pins, Top Row are Rx
Inner 10 pins, Bot Row are Tx
(outermost pins both rows unused)



Inner 10 pins, Left Side are Tx
Inner 10 pins, Right Side are Rx
(outermost pins each side unused)



Inner 10 pins, Top are Rx
Inner 10 pins, Bot are Tx
(outermost pins Top & Bot unused)



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Option A
(recommended)

Option B

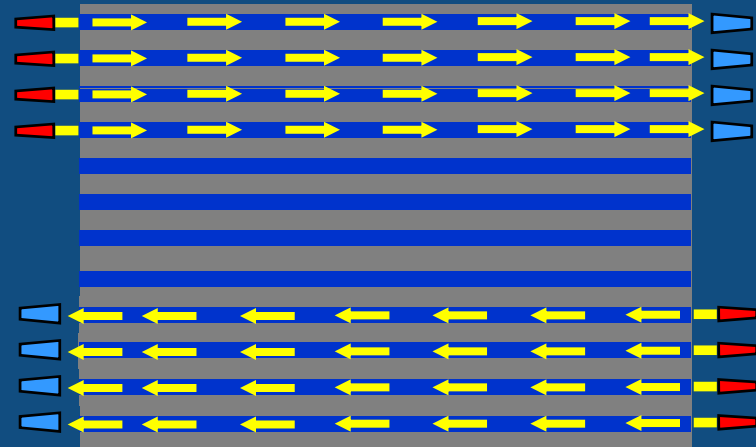
Option C

June 11, 2009 

High Speed Short Reach Technologies: Multiple Fiber Parallel Systems

for 40G:

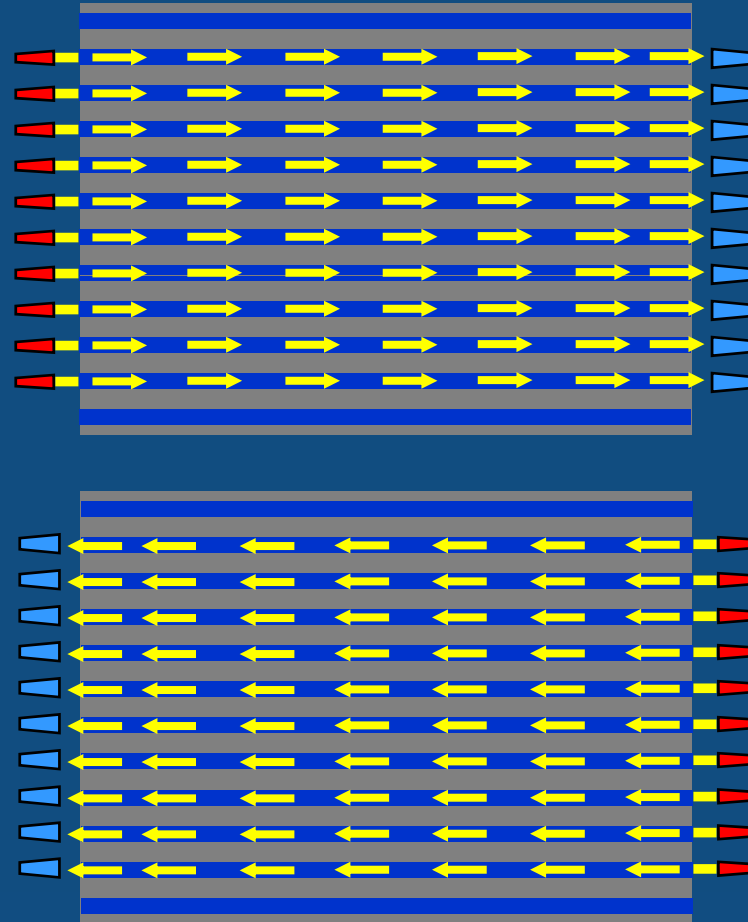
- One 12-fiber cable
 - duplex link
 - 8 active fibers
- 4 x 10 Gb/s
- 12 Fiber MPO connector
- One wavelength per fiber



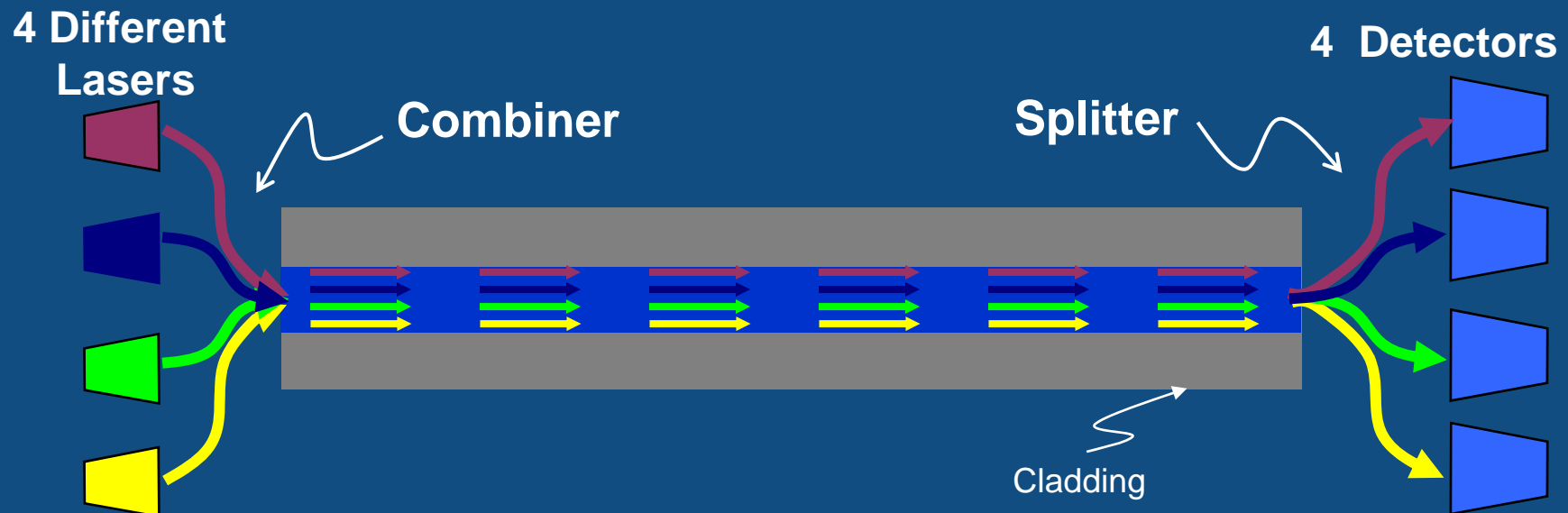
High Speed Short Reach Technologies: Multiple Fiber Parallel Systems

for 100G:

- Two 12 Fiber Cables, or 24 fiber Cable
 - 20 Active
 - Duplex link
- 10 x 10 Gb/s
- MPO connector
 - 2 x 12 fiber
 - 1 x 24 fiber
- One wavelength per fiber



High Speed Long Reach Technologies: Wavelength Division Multiplexing



For 100G

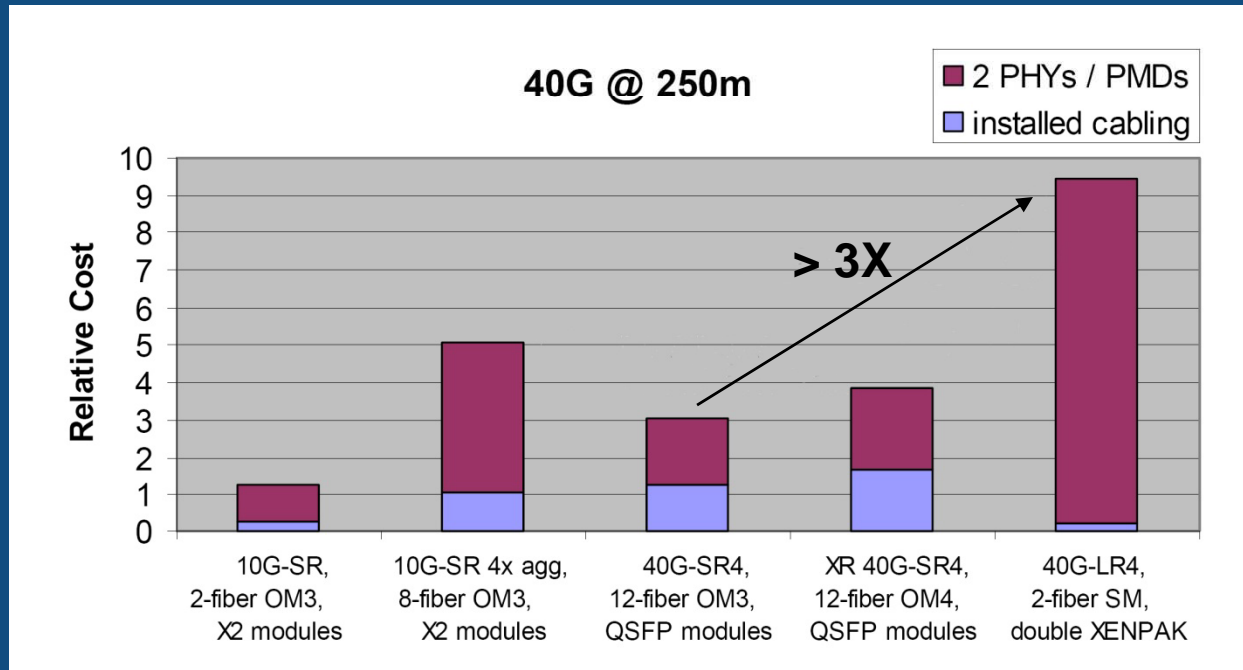
- 2 Fiber Cable
- Multiple Lasers and Detectors
- 4 x 25 Gb/s

Cost Comparison between Single-mode and Multimode Fiber Systems

Traditionally, optoelectronics have driven the cost difference between single-mode and multimode

- Single-mode CWDM system
 - Pro – Lower cable cost
 - Con – Significantly higher transceiver cost
- OM3 and OM4 multimode parallel systems
 - Pro – Much lower transceiver cost using existing 10Gb/s VCSELS
 - Con – Higher cabling cost

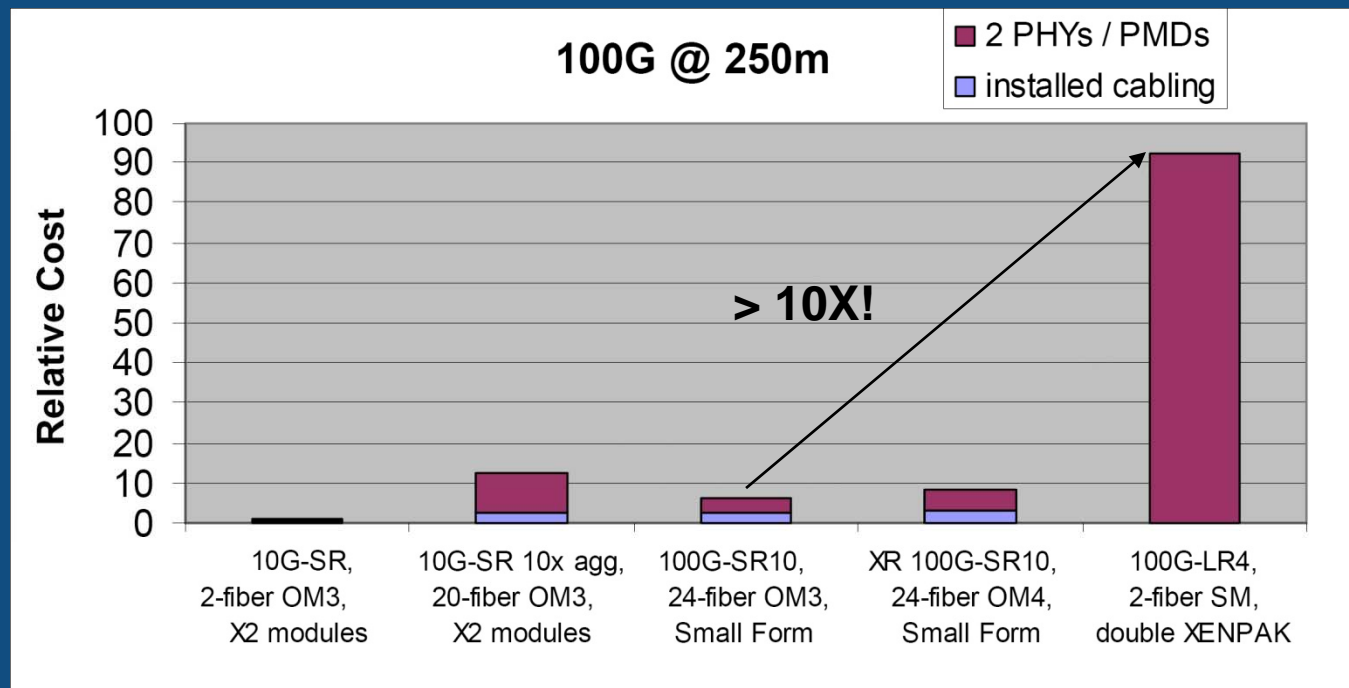
Cost Comparison between Single-mode and Multimode Fiber - 40G Systems



Paul Kolesar
CommScope
"The Case for Extended Reach Multimode Objectives"
IEEE 802.3ba
September 2008
Kolesar_01_0908

- Single-mode cabling costs less than multimode, but total link cost over 3x higher!

Cost Comparison between Single-mode and Multimode Fiber - 100G Systems



Paul Kolesar
CommScope
"The Case for Extended Reach Multimode Objectives"
IEEE 802.3ba
September 2008
Kolesar_01_0908

- Cabling costs insignificant compared to optoelectronics
 - Single-mode total cost over 10x multimode system!

Power Consumption

- Lower power consumption critical as link density and speed increase
 - 10G SFP Fiber transceivers consume <1watt
 - 10GBASE-T copper transceivers can consume >10watts
- **Savings ~ 9 watts/transceiver**
- **Cooling – another 9 watts/transceiver**

Thank you.....

