Optical Fiber for High-Performance Enterprise Networks

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OFS

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3:30 – 4:30 pm

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Outline

- The need for more bandwidth
- Optical fiber types
- Today's enterprise applications
- Tomorrow's technology
- Maximizing performance

The Need for More Bandwidth

Rapid growth of network and internet traffic

HDTV / IPTV / Video-on-Demand

Digital Photos

Gaming

MySpace, YouTube

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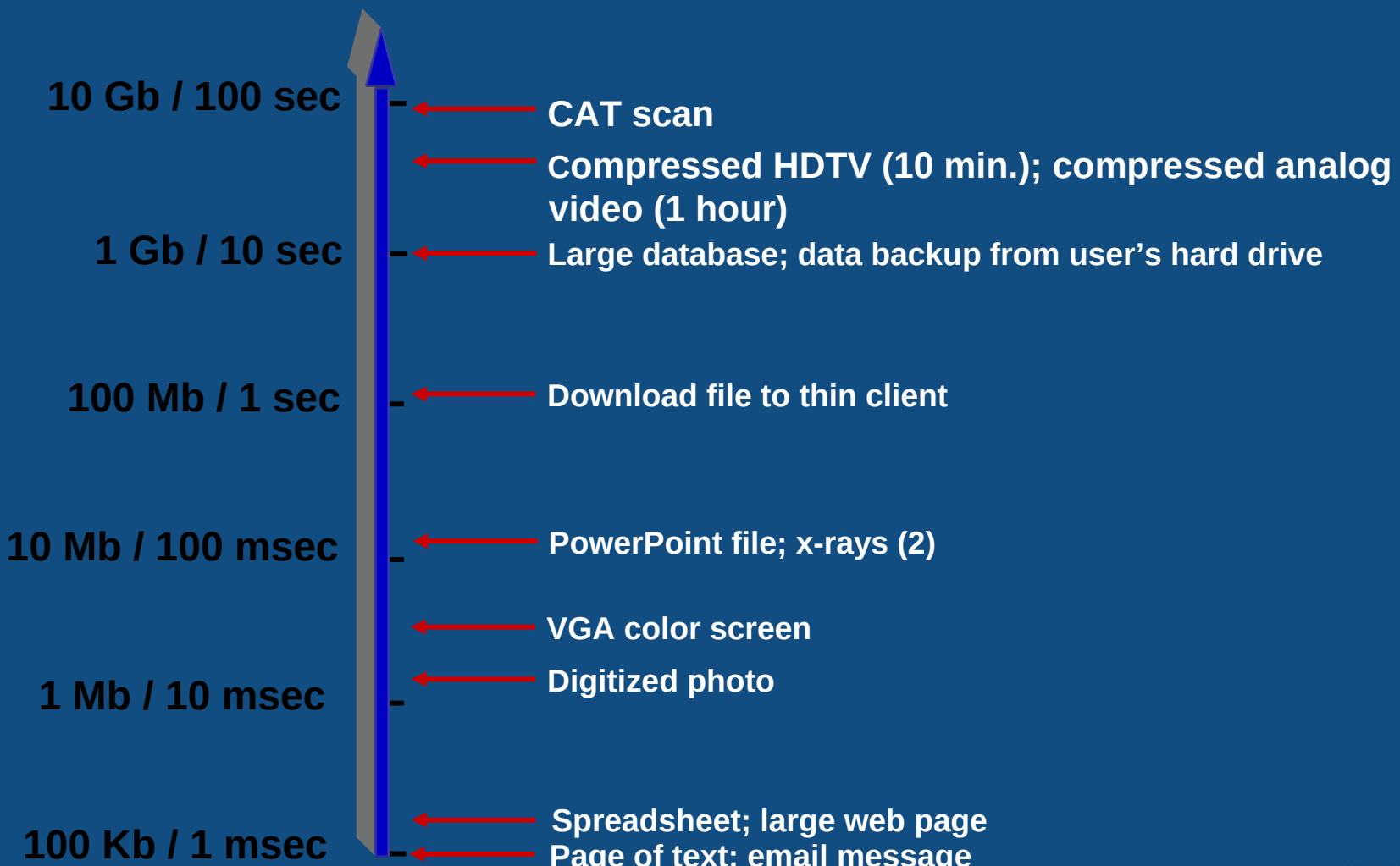
File Transfer Times at 1Gb/s

WANTED: Faster File Transfers



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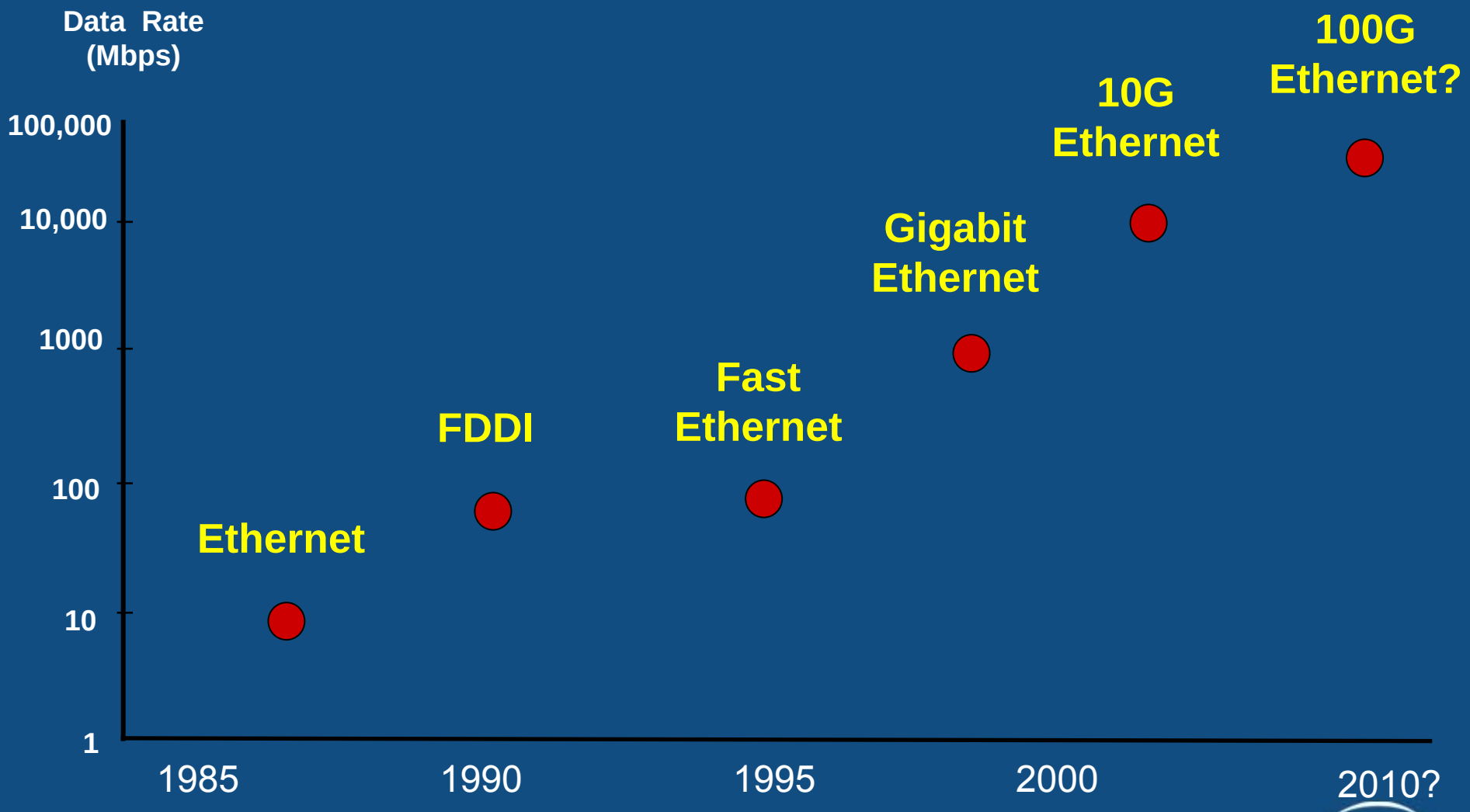
Evolution of LAN Ethernet Speeds



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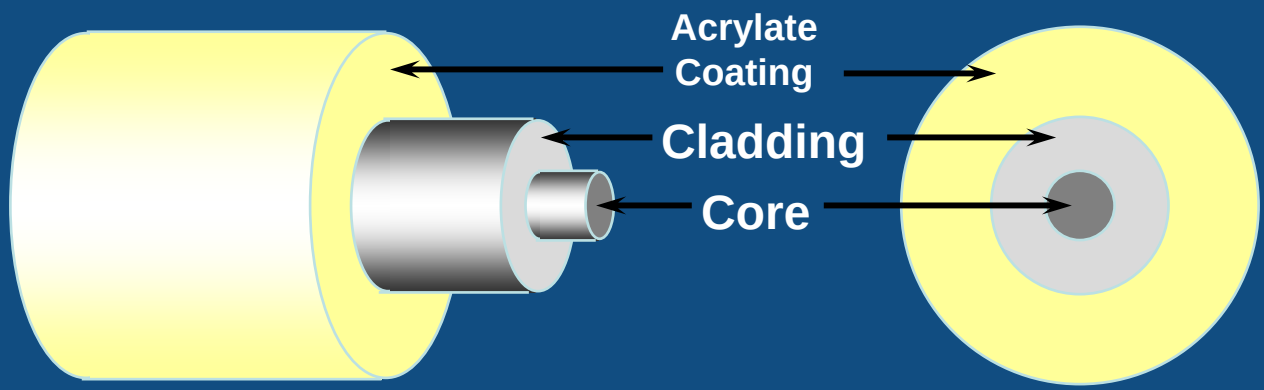
Optical Fiber Types

Optical Fiber

Composed of Two Optically Different Materials



- Optical Signals Propagate in Core
  - Core has higher *refractive index* than Cladding
- Coating cushions & protects Cladding & Core

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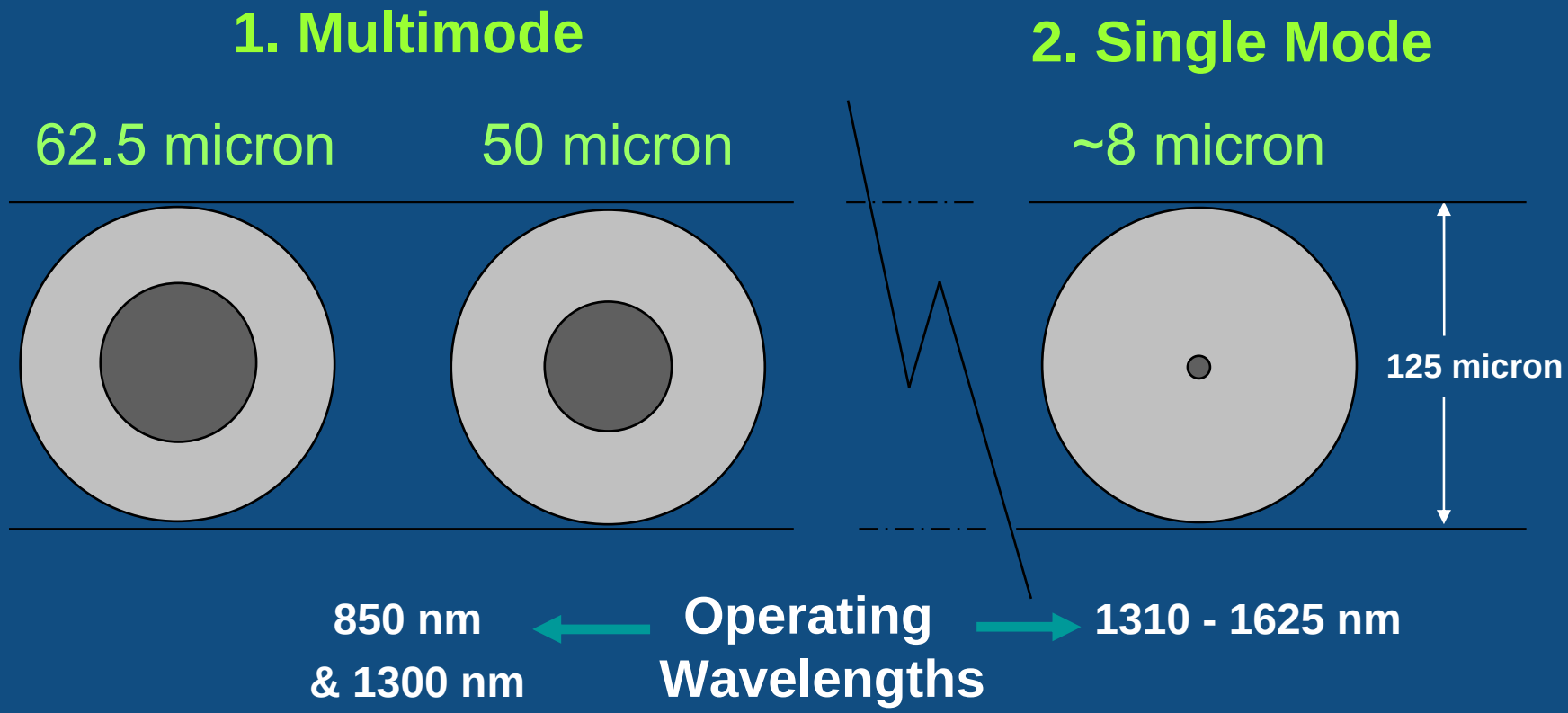
Two Basic Optical Fiber Types



Larger cores and lower wavelengths drive source and system costs down

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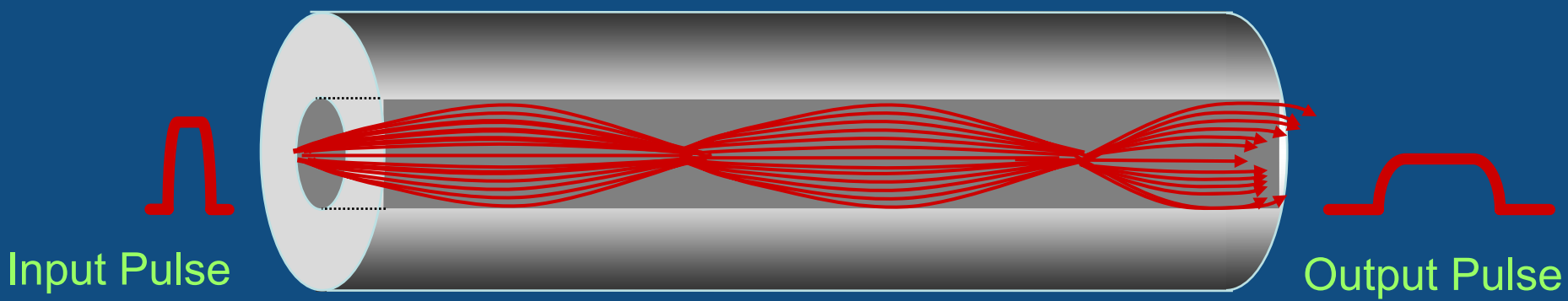
Multimode Fiber

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



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

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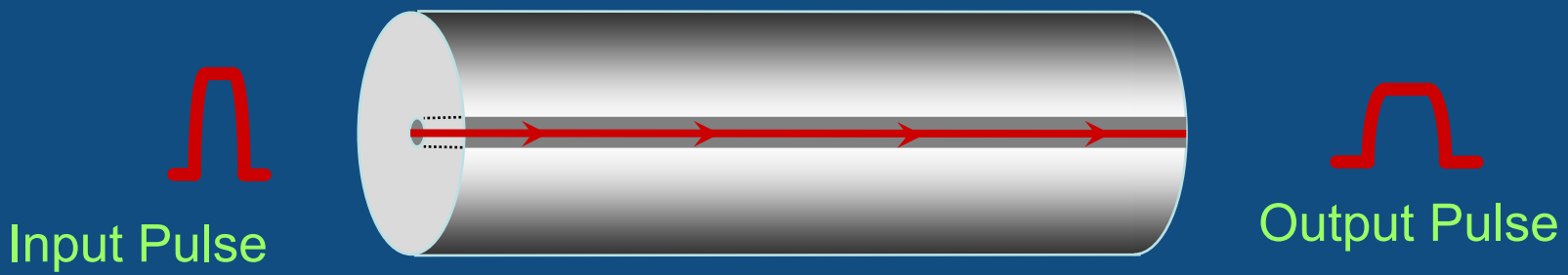
Single Mode Fiber

Small core guides only one mode

- Eliminates modal dispersion.
- Enables very long distance transmission.



Transmission Speed and distance limited by:

- **Chromatic Dispersion**
- **PMD** (Polarization Mode Dispersion)

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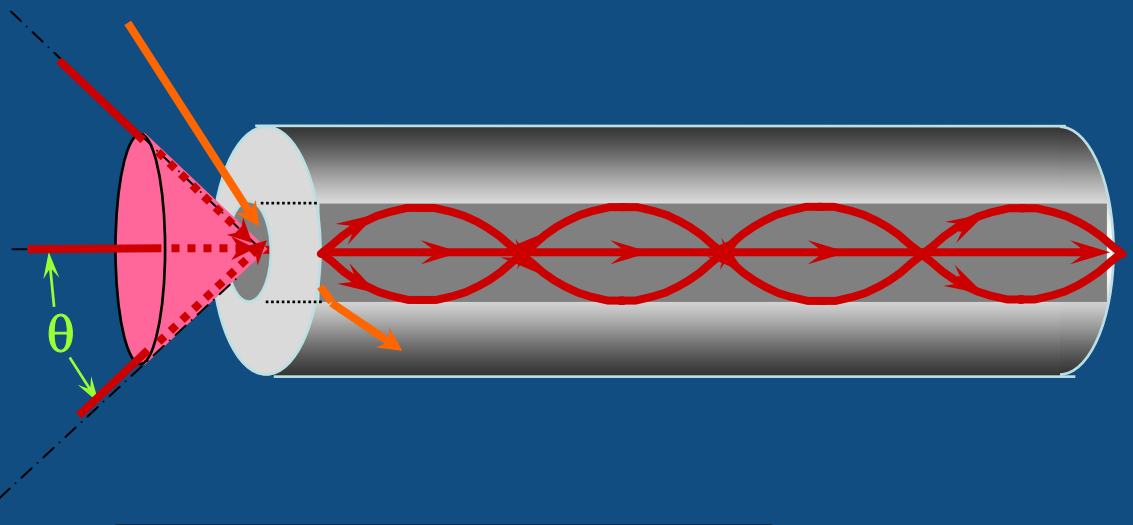
Multimode Fiber

Large **Numerical Aperture** *(NA)*

- Large NA allows for easier transmitter & connector alignment.
- Lowers cost of transmitter, connectors, and installation.



NA = sin θ

NA = 0.275 for 62.5 um
NA = 0.200 for 50 um

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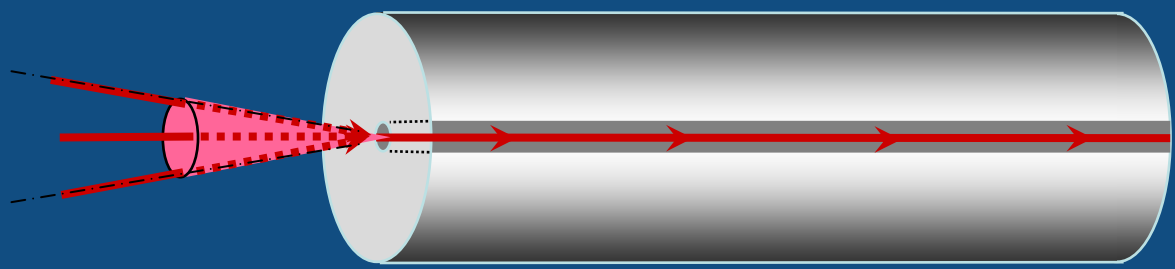
Single Mode Fiber

Small NA

- Requires precise alignment of transmitter & connectors; *drives up cost of components, installation.*



NA ~ 0.12 for SM

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Singlemode – Preferred Choice for Distances > 550 meters (10G)

- Higher cost 1310nm lasers
- Complex transmitter packaging
- Higher cost connectors
- Higher installation cost
- **Higher system cost**

+ Lower fiber cost
+ Lower loss, higher bandwidth
+ Distances to 40 km

Best for Campus, WAN, MAN, Access Networks

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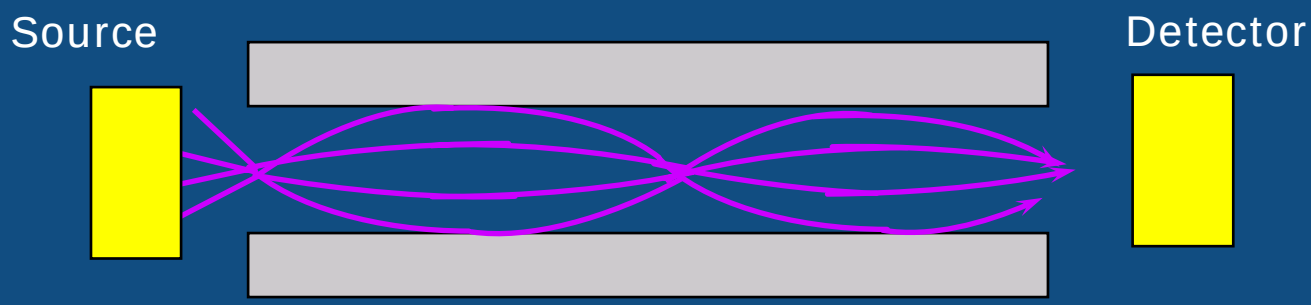
Multimode –
for Distances < 550 meters (10G)



- Higher fiber cost
- Higher loss, lower bandwidth
- Distance up to 550m (10G)

+ Low cost 850nm lasers
+ Easy transmitter packaging
+ Low cost connectors
+ Lower installation cost
+ **Lower system cost!**

Best for Premises, Data Center, CO Networks

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Multimode Performance Grades

Type / ISO Grade	Bandwidth (850nm / 1300nm, MHz-km)	Reach @10Gb/s (meters)
62.5 μm / OM1	200 / 500	33
50 μm / OM2	500 / 500	82
50 μm / OM3	2000 / 500	300
50 μm / OM3+	4700 / 500	550

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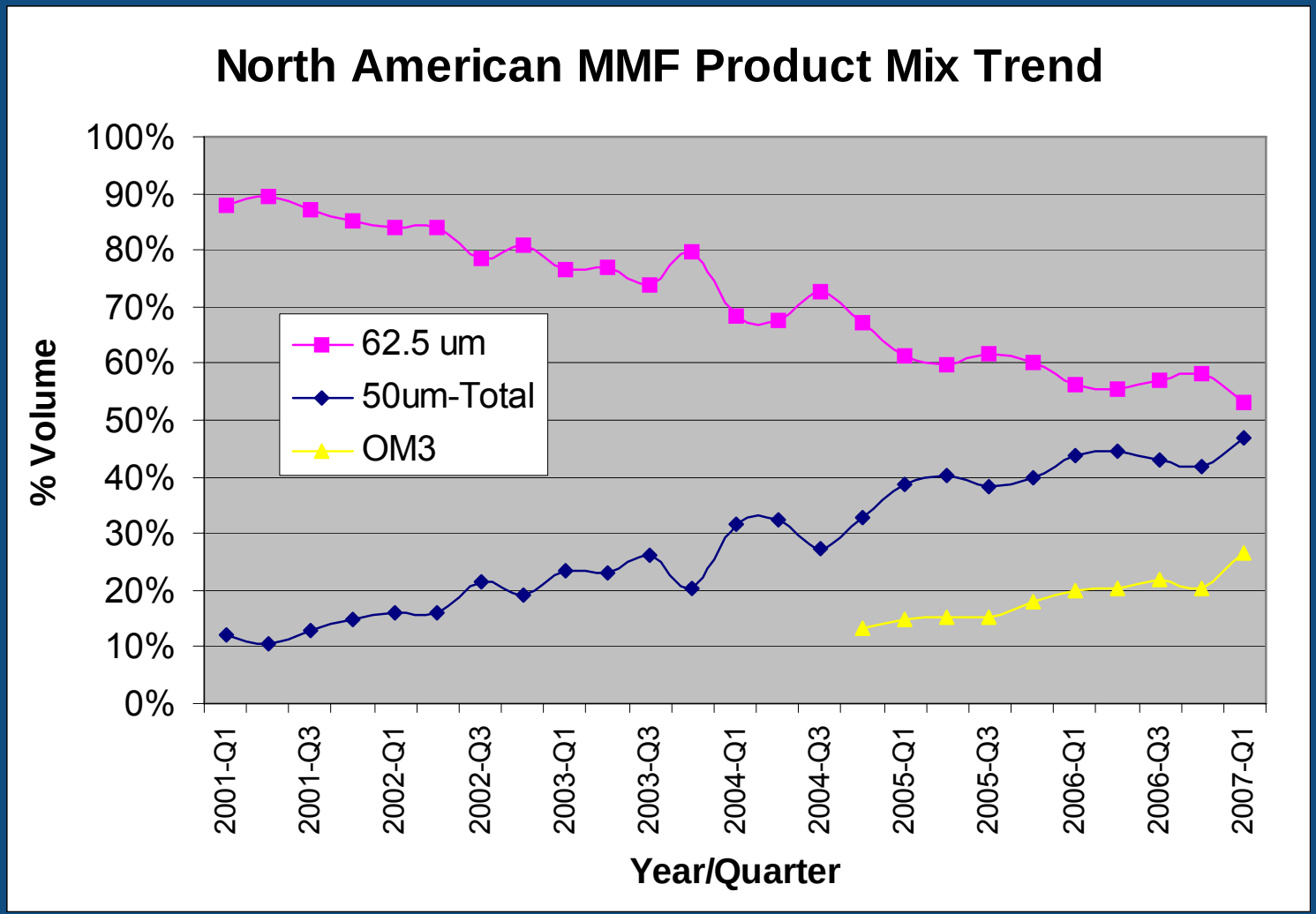
Product Mix Behavior



Source: Burroughs MM Report, Q1 2007

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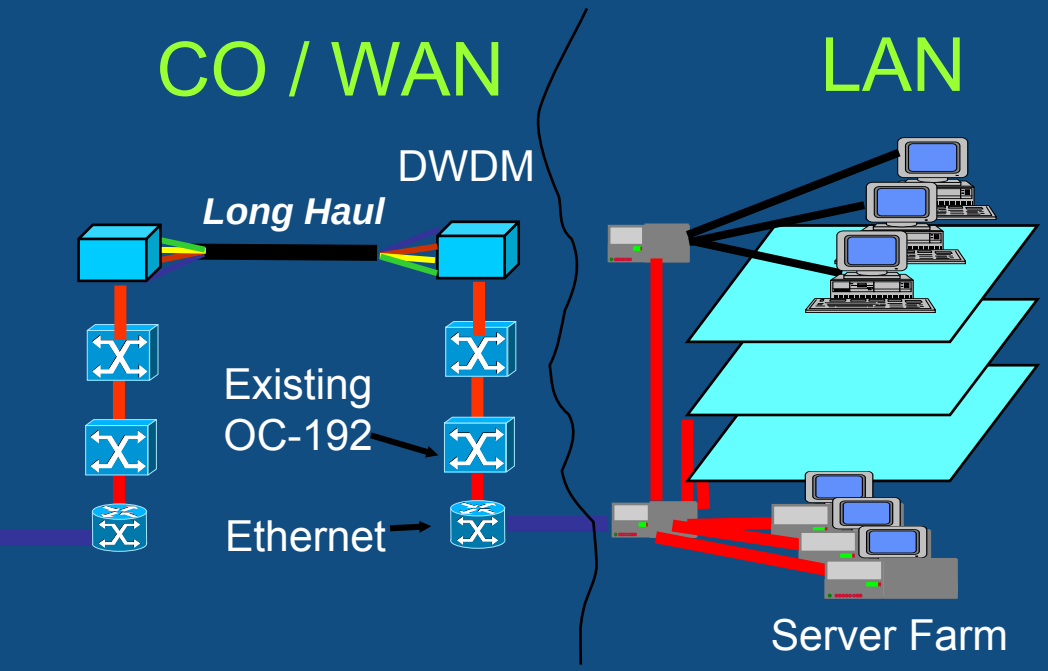
Today's Enterprise Applications

10 Gigabit Ethernet Standard (IEEE 802.3ae)

- Extends low cost Ethernet Technology to 10Gb/s
- LAN Phy (Physical Layer) supports LAN connections – R suffix
- WAN Phy supports 10 GbE interface to OC-192/STM-64 – W suffix



Short Reach - MMF

10GBASE-SR/SW	300m	$
10GBASE-LX4	300m	$$

Long Reach – SMF or ZWPF

10GBASE-LR/LW	10km	$$
10GBASE-LX4	10km	$$
10GBASE-ER/EW	40km	$$$$$

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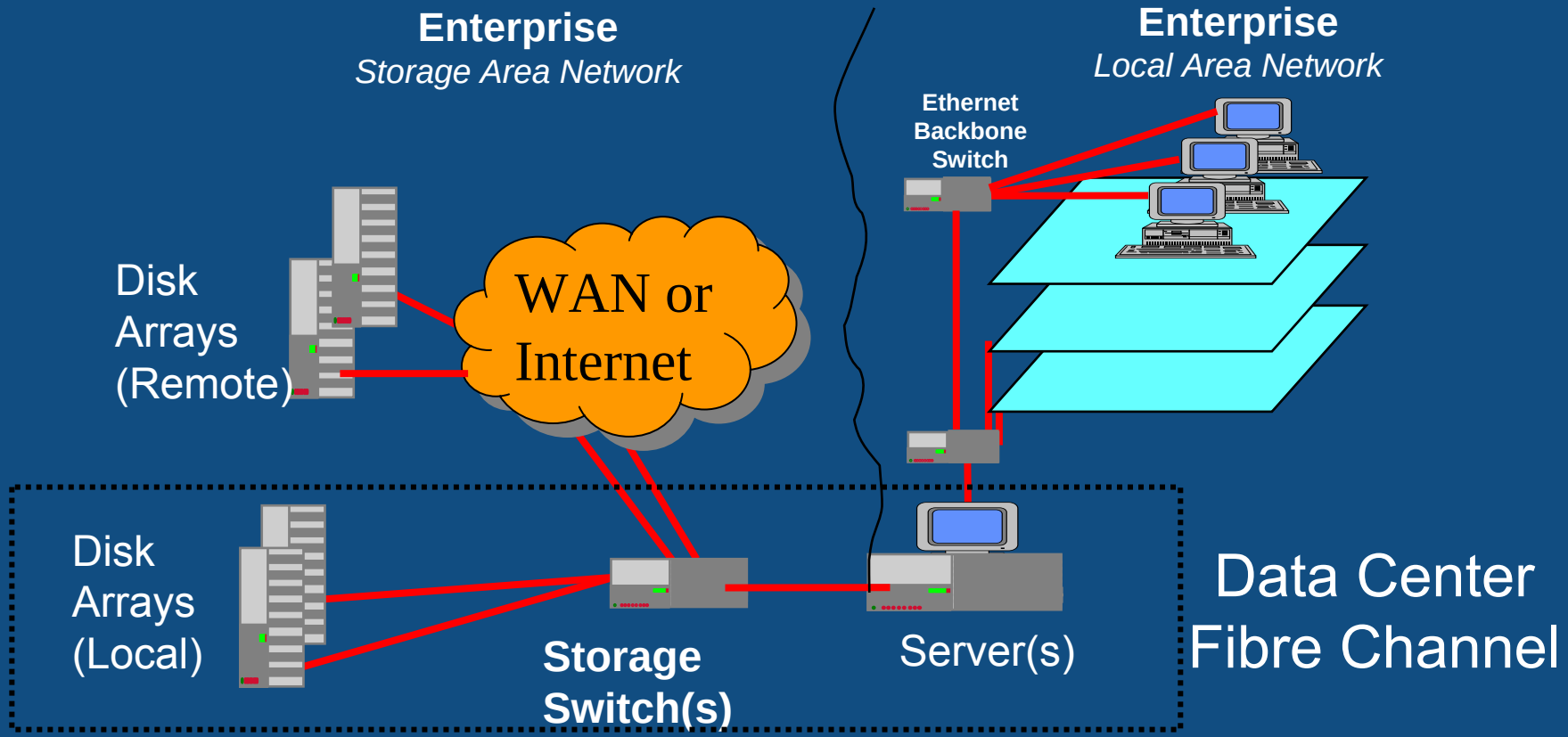
Storage Applications

Fibre Channel

Most widely deployed storage interconnect technology



Fibre Channel Standards (SANs)

Naming Convention:

FC-PI **123-AA-BB-C**

Where,

123 = Speed

AA = Medium Type

BB = Transmitter (LED, Laser, long vs. short λ)

C = Distance

Fiber Type	Speed							
	133 Mbps	266 Mbps	533 Mbps	1.063 Mbps	2.125 Gbps	4.250 Gbps	8.5* Gbps	10 Gbps
62.5um (LED)	1500m	1500m						
62.5um (Laser)				300m	150m	70m		33m
50um (Laser)		2000m	1000m	500m	300m	150m		82m
50um OM3 (Laser)				860m	500m	270m		300m
SM (Laser)		10km	10km	10km	10km	10km		10km

* Under Development

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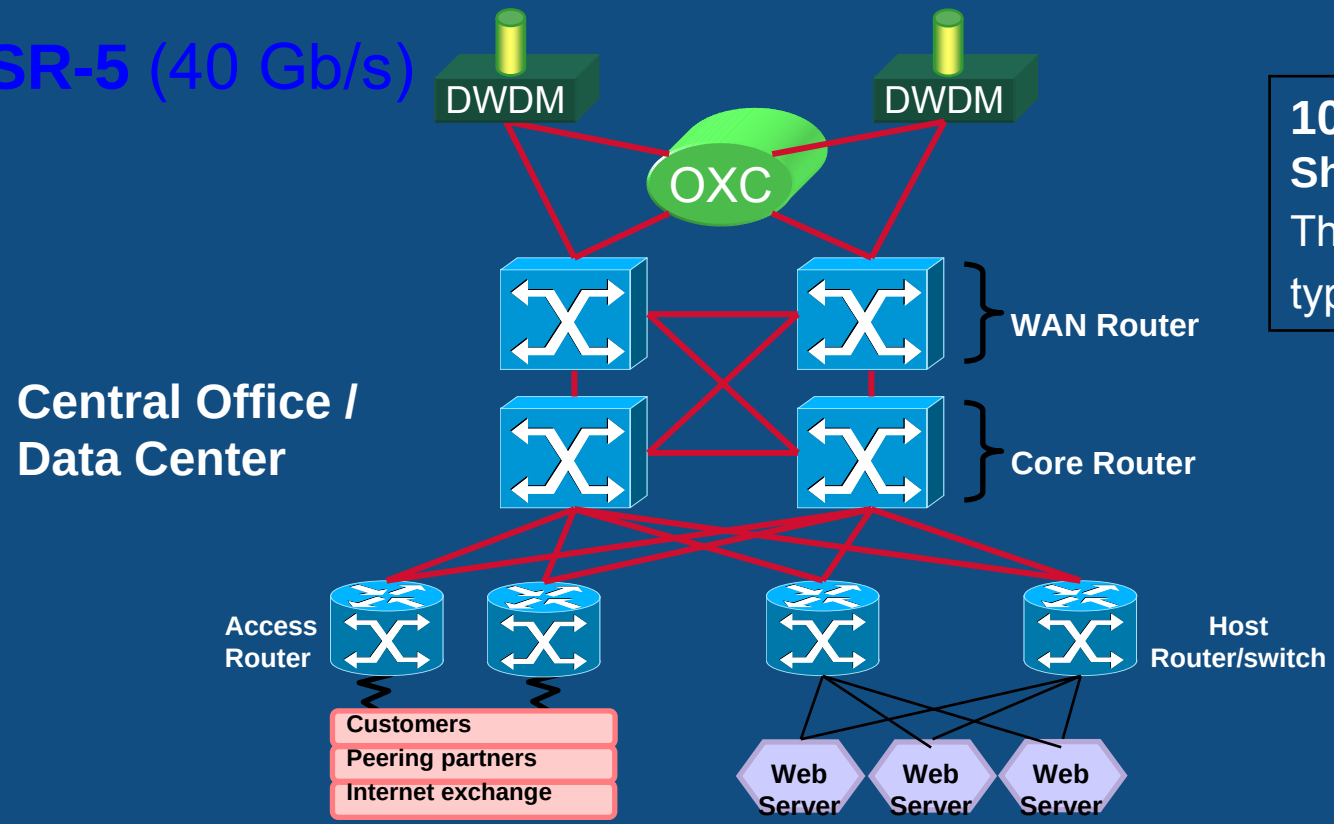
OIF for Central Offices / Data Centers

- **Optical Internetworking Forum -** interoperability agreement
- for short reach, high speed connections between components
- OC-192 (10 Gb/s) supports any protocol (ATM, SONET/SDH, Ethernet, etc)

➢ **VSR-4** (10 Gb/s)

➢ **VSR-5** (40 Gb/s)



10 Gb/s
Short Links
Thousands in a typical CO !

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Tomorrow’s Technology

Must support exploding bandwidth

- Consumers
  - Increasing penetration
  - Increasing bandwidth
  - Personalized Content
- Content
  - Increasing bandwidth requirements

Networking

- Carriers
- Service Providers
- Internet eXchanges

- Private Users
  - Supercomputing / High Performance Computing (HPC)
  - Data Centers
  - Research & Development
  - Medical

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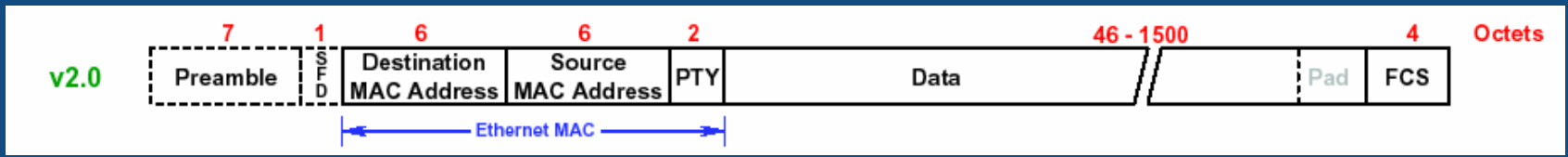
Future Ethernet Speeds

HSSG (High Speed Study Group) formed in IEEE to investigate next Ethernet speed

8 Objectives adopted at Nov 2006 IEEE 802.3 Plenary:

- Full-duplex operation only
- Preserve 802.3 / Ethernet frame format



- Preserve min and max Frame Size of current 802.3 Std
- Speed of 100 Gb/s
- 10km min reach on SMF (1310nm)
- 40km min reach on SMF (1550nm)
- 100m min reach on OM3 MMF
- BER better than or equal to 10^{-12}

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Can we Aggregate?

Link Aggregation (LAG – 802.3ad)
is a complex, temporary fix.

- Difficult to plan for capacity and traffic engineering
  - Harder to manage and troubleshoot multiple physical links
- Uneven distribution of traffic
  - Limitations in the standard
  - Inefficient distribution of large flows

Better Solutions Required!

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Considerations for 100G

- **Short Term → Data Centers, HPC's** (at least 100m)
  - Seen as the first application areas
  - Tx mfr's focused on supporting PMD's for these applications
  - Served by OM3 Multimode
- **Mid Term → Campus Backbones** (2000m)
  - Served by SMF
- **Long Term → Riser Backbones (300m)**
  - Not expected to be necessary for 10+ years
  - IEEE could establish an OM3 option at a later date

- **Fiber Considerations**
  - SMF and OM3
  - OM1 and OM2 will not be supported
- **Transceiver Considerations**
  - Will leverage existing fiber and Tx technologies (Parallel and CWDM)

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HSSG Fiber Optic Ad Hoc Proposals

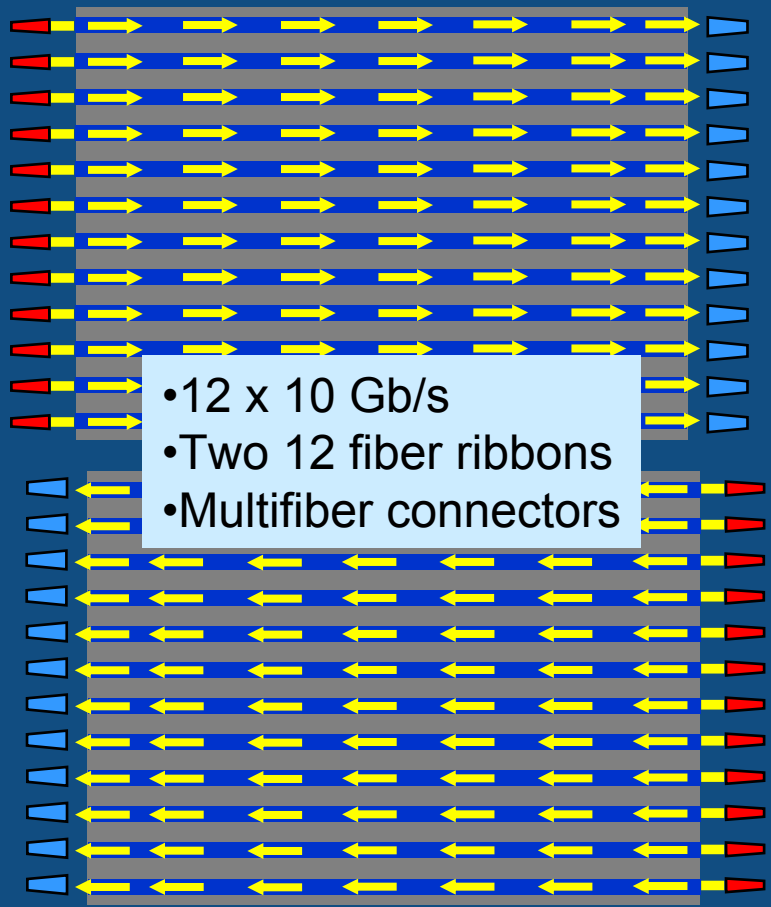
OM3 Multimode

Objective	λ	# Lanes	~Lane Rate (Gb/s)	Source	Cable	Mux
100m MMF OM3	850 nm	12 (8B/10B)	10	VCSEL	MPO ribbon (12 x 2)	12xSDM
	850 nm	10 (64/66)	10	VCSEL	MPO ribbon (12 x 2)	10xSDM
	840/860 nm	10 (64/66)	10	VCSEL	MPO ribbon (12 x 1)	2xWDM and 5xSDM
	840/860 nm	12 (8B/10B)	10	VCSEL	MPO ribbon (12 x 1)	2xWDM and 6xSDM
	835/850/865 nm	12 (8B/10B)	10	VCSEL	MPO ribbon (12 x 1)	3xWDM and 4xSDM

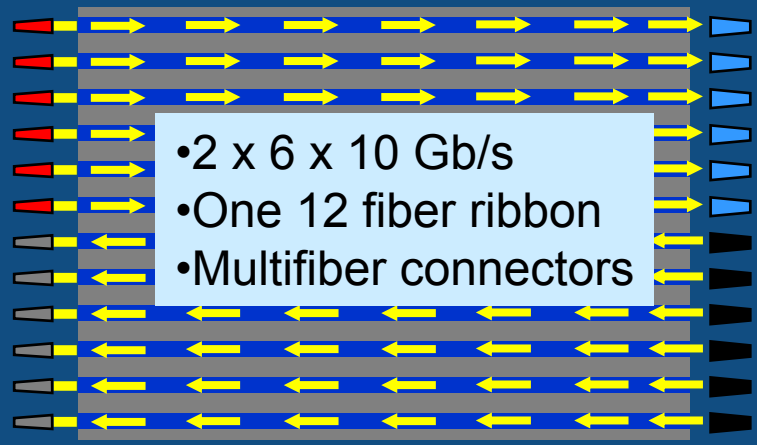
Parallel Systems Technology

Using 850 nm VCSEL arrays for Future Speeds

12x2 Channel Duplex
1 Lambda



12x1 Channel Duplex
2 Lambda



- OM3 multimode to at least 100 meters
- Ribbon cable, or “Ribbonized” Ends
- MPO Connectors
- Very high density
- Ideal for Data Center Trunk cabling

Makes sense to increase density in Data Center applications

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HSSG Fiber Optic Ad Hoc Considerations

Single Mode

Options	Wavelength	Channels	Rate	Source
10 x 10 Gb/s	1550 nm	10	10 Gb/s	EML
5 x 20 Gb/s	1310 nm	5	20 Gb/s	EML
5 x 20 Gb/s	1310 nm	5	20 Gb/s	DML
4 x 25 Gb/s	1310 nm	4	25 Gb/s	EML
4 x 25 Gb/s	1310 nm	4	25 Gb/s	DML
2 x 50 Gb/s	1310 nm	2	50 Gb/s	I/Q ML

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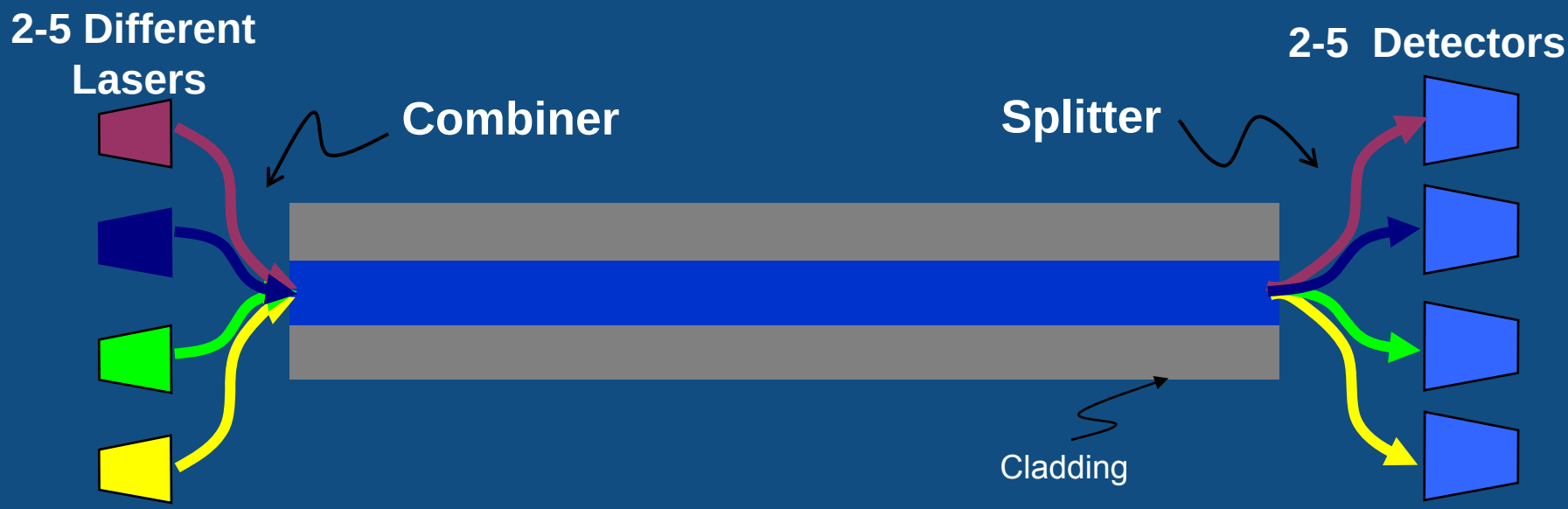
CWDM
(Coarse Wavelength Division Multiplexing)



High cost SM packaging, plus more parts and complexity

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Cost Implications

- **SM CWDM Systems**
  - Work continues to define technical and economic feasibility of designs being considered
  - Pro: Low cable cost
  - Con: High Transceiver cost, requires development
- **OM3 Multimode Parallel Systems**
  - 10 Gb/s VCSELS already available
  - Pro: Low cost, readily available parts
  - Con: High cable cost and sensitive to length
- Traditionally, cost of electronics drive cost comparisons between MM and SM
- Preliminary cost analysis suggests that 2λ x 5 fiber provides lowest cost for short reach situations

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Next Steps

- Finalize objectives
- Validate 5 Criteria
  - Broad Market Potential
  - Compatibility
  - Distinct Identity
  - Technical Feasibility
  - Economic Feasibility
- Submit PAR (Project Authorization Request)
- IEEE likely begin writing 100G std in 2007 and publish in 2010

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Maximizing Performance

Channel Insertion Loss Budgets Decreasing

Due to Ever Increasing Speeds

Year	Application	Data Rate	Designation	Standard	Insertion Loss Budget (db)
Early 80's	Ethernet	10 Mbps	10BASE-FL	IEEE 802.3	12.5
Early 90's	Fast Ethernet	100 Mbps	100BASE-FX	IEEE 802.3	11.0
Late 90's	Short Wavelength Fast Ethernet	10/100 Mbps	100BASE-SX	TIA/EIA-785	4.0
2000	1 Gigabit Ethernet	1,000 Mbps	1000BASE-SX	IEEE 802.3z	3.56
2004	10 Gigabit Ethernet	10,000 Mbps	10GBASE-SR*	IEEE 802.3ae	2.60

Same thing happening in Fibre Channel standards

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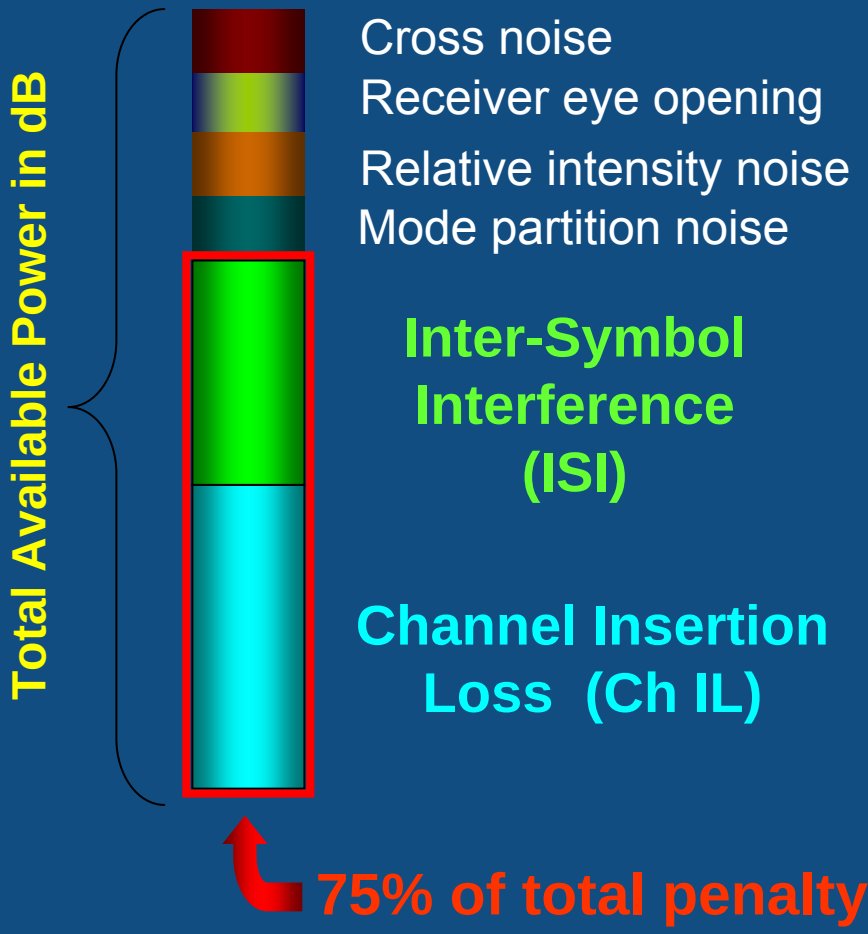
Power Budget Allocations

Power budget consumed by various impairments

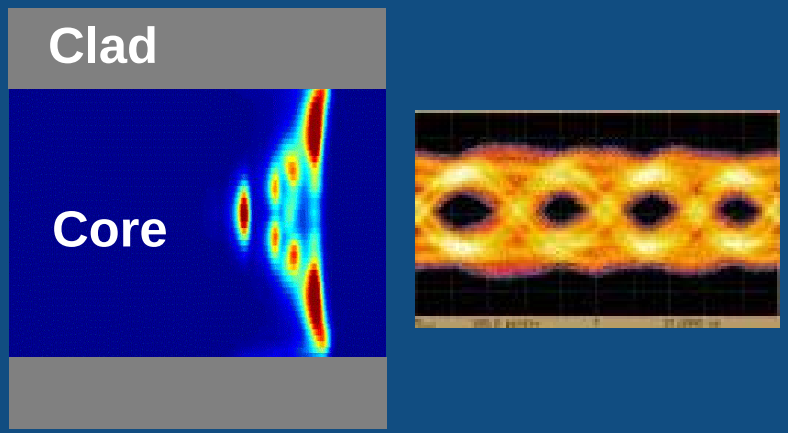


ISI and **Ch IL** Dominate Power Budget

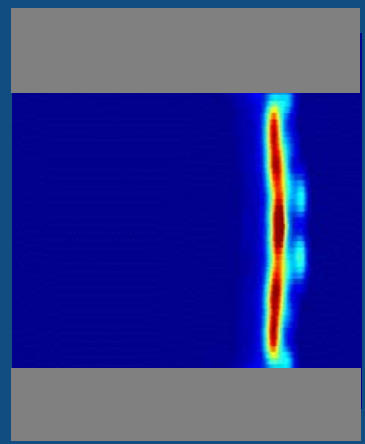
What are Ch IL and ISI?

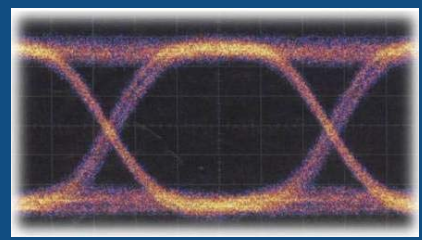
Ch IL: Penalty due to Cable Loss plus Connection & Splice Loss

ISI: Penalty due to bits running together, caused by fiber's DMD



High ISI Penalty





Low ISI Penalty

Low DMD = High Bandwidth = Low ISI Penalty

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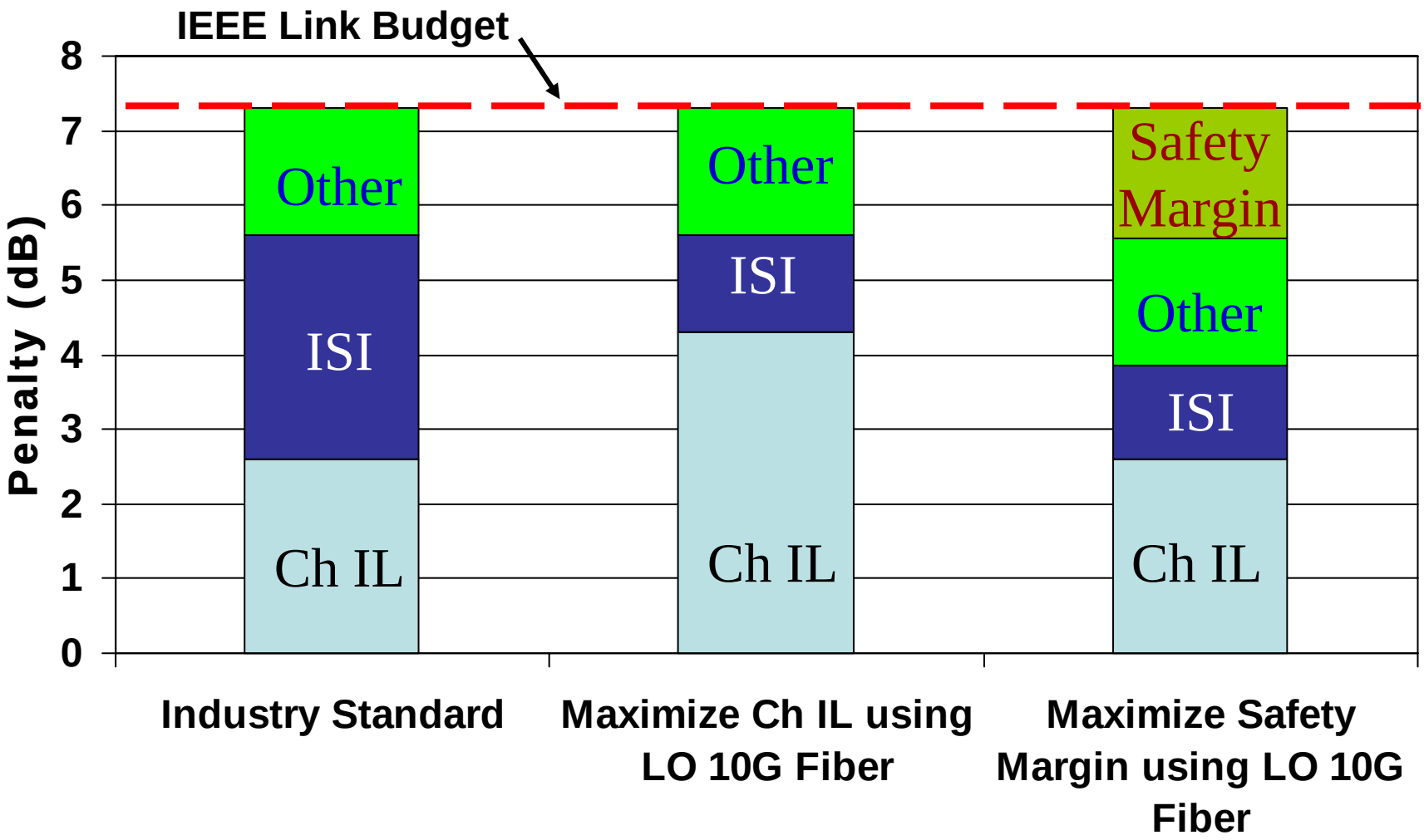
Obtain More Margin by…

- Reducing Ch IL
  - Low loss fiber & cable
  - Low loss connections & splices
    - Low loss connectors
    - Tight fiber geometry tolerances
- Reducing ISI
  - Utilize low DMD (high bandwidth) fiber, even at shorter than rated distances

Trading ISI for Ch IL or Safety Margin



Summary

- Data rates keep rising due to large file sizes, demand for bandwidth
  - Prepare now for 10 Gb/s capability in LANs, SANs, Data Centers
- Laser Optimized 10G 50 um (OM3) multimode fiber provides the needed bandwidth
- Multimode continues to be the most cost-effective solution for short reach LAN, Data Center and CO applications
- OM3 Multimode will support 100Gb/s to continue to provide low-cost options
- Standards provide minimum acceptable levels of performance
  - Exceeding standards offers options to improve link reliability and performance

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Thank you …

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