Is Your Network Ready for 100 Gig?

Specifying Optical Fiber for the Next Generation

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Agenda

- Fiber Market Drivers
- Fiber Types and Standards
- Application Standards
- Multimode Fiber Value Proposition
- Conclusions

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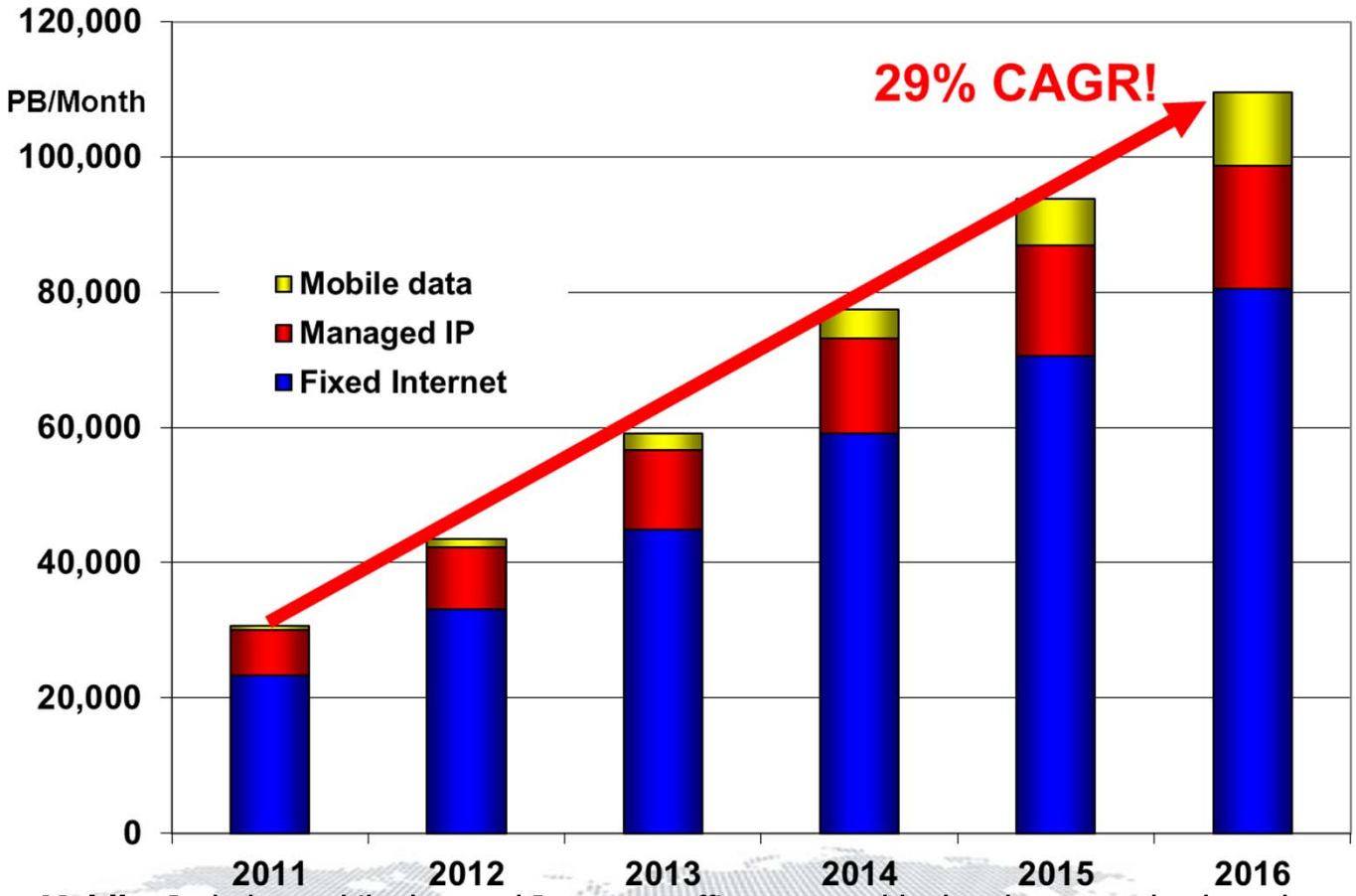
IP Traffic Growth

- Global IP traffic will quadruple from 2011 to 2016
- Annual global IP traffic will reach 1.3 zettabytes ($1.3x10^{21}$ bytes) by the end of 2016
- 31% of traffic will be from non-PC devices by 2016
- In 2016 wired devices will account for 39% of IP traffic, while Wi-Fi and wireless devices will account for 61%
- By 2016 the number of IP devices will be nearly 3x the global population

Cisco Visual Networking Index:
Forecast and Methodology, 2011-2016
May 30, 2012

IP Traffic Growth



Cisco Visual Networking Index:
Forecast and Methodology, 2011-2016
May 30, 2012

Mobile: Includes mobile data and Internet traffic generated by handsets, notebook cards, and mobile broadband gateways
Internet: Denotes all IP traffic that crosses an Internet backbone
Managed IP: Includes corporate IP WAN traffic, IP transport of TV/VoD

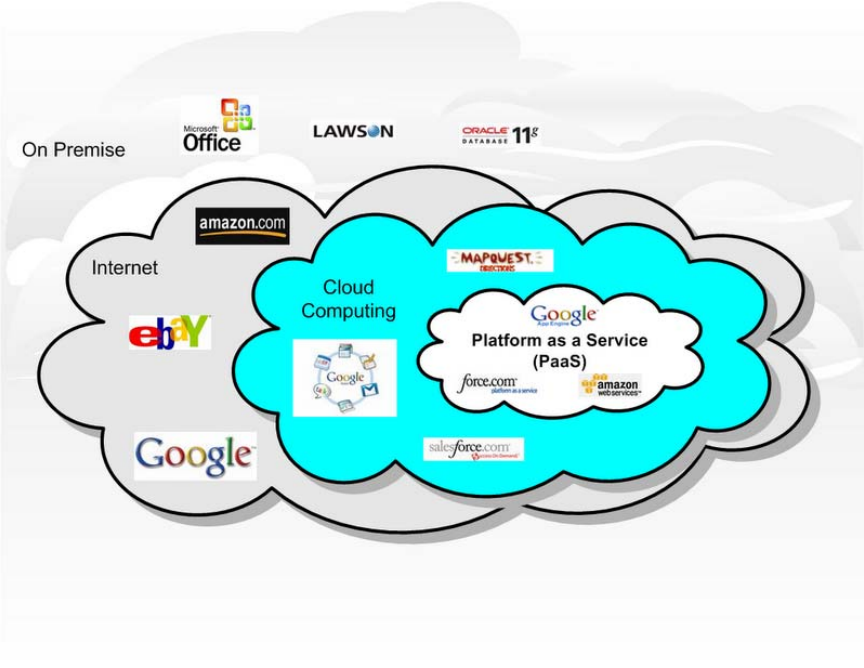
Internet Applications

- **YouTube**
  - ✓ August 2012 – 72 hours of video uploaded every minute [1]
  - ✓ August 2012 – 3 billion hours of video watched/month [1]
- **Apple**
  - ✓ July 2012 – Apple sells 17 million new iPads and 26 million iPhones in 2Q2012[2]
  - ✓ March 2012 – Apple iTunes hits 25 billion app downloads [2]
- **Facebook**
  - ✓ June 2012 – 955 million active users, 552 million daily users

[1] http://www.youtube.com/t/press_statistics/
[2] http://www.apple.com/pr/library/
[4] http://newsroom.fb.com/content/default.aspx?NewsAreaId=22

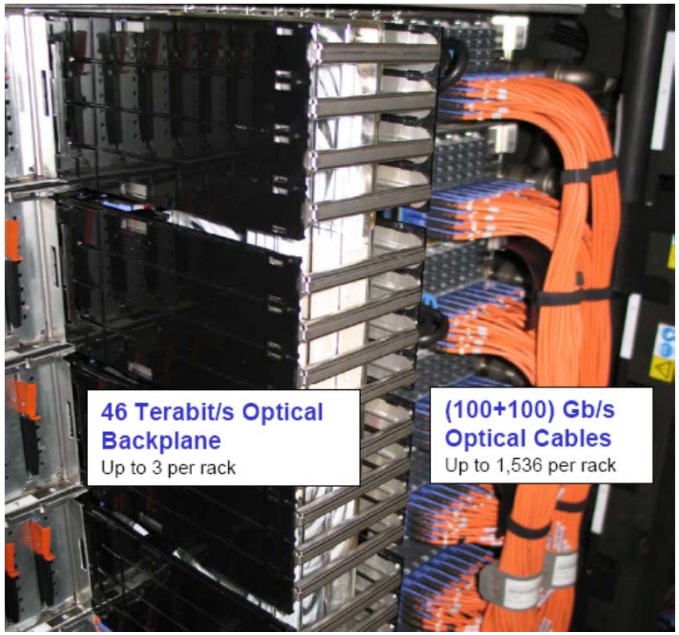
What is happening today

- **Cloud Computing**
  - Migration to hosted services



http://www.princeton.edu/~ddix/cloud-computing.html

- **High Performance Computing**
  - Increased optical density – 40x over previous generations



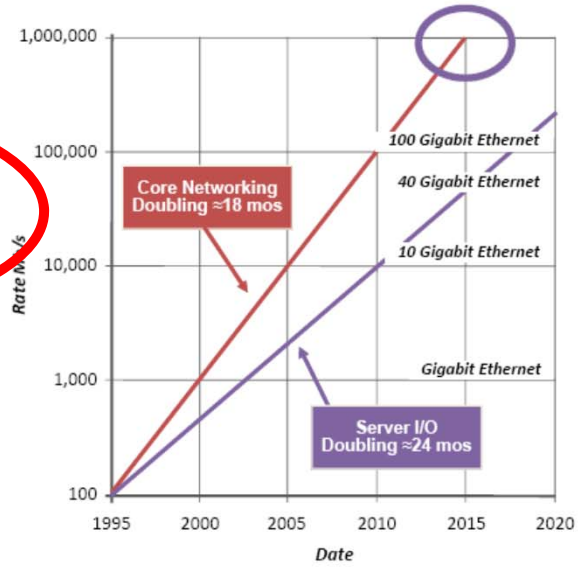
"Optical Interconnect Opportunities in Supercomputers and High End Computing"
OFC 2012 Tutorial
March 6, 2012
Alan Benner

Bicsi

Next Generation Speeds Coming!

Life after IEEE P802.3ba

- End-users through the prior HSSG: The next speed of Ethernet must begin when 100GbE done!
- HSSG Bandwidth Forecast for "Core Networking"
  - 2013: 400 Gb/s
  - 2015: 1 Tb/s
- Other bandwidth trends?
- 2011 Formation of:
  IEEE 802.3 Industry Connections Ethernet Bandwidth Assessment Ad Hoc



IEEE 802.3 Industry Connections Ethernet Bandwidth Assessment Ad Hoc
July 2012 IEEE 802 Plenary, San Diego, CA, USA

Page 8

- IEEE 802.3 Ethernet Bandwidth Assessment Report approved by IEEE 802.3 Working Group – July 2012
- Next step - initiation requested of a Higher Speed Ethernet Consensus Industry Connections activity

http://www.ieee802.org/802_tutorials/2012-07/BWATutorial_D1_12_0716.pdf

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- Multimode Fiber Value Proposition
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Fiber Types

Fiber Type	Industry Standards			
	ISO/IEC 11801 ANSI/TIA-568-C.3 (cable)	IEC 60793-2-10 (fiber)	TIA/EIA (fiber)	ITU-T (fiber)
62.5/125	OM1[1]	A1b	492AAAA	---
50/125	OM2[2]	A1a.1	492AAAB	G.651.1
50/125	OM3	A1a.2	492AAAC	---
50/125	OM4	A1a.3	492AAAD	---
Std SM	OS1	B1.1	492CAAA	G.652.A or B
Low Water Peak SM	OS2[5]	B1.3	492CAAB	G.652.C or D

[1] *OM1 is typically 62.5µm, but can also be 50µm*

[2] *OM2 is typically 50µm, but can also be 62.5µm*

[5] *OS2 is referenced in the standard* **ISO/IEC 24702** *"Generic Cabling for Industrial Premises"*

Multimode Fiber Types, Performance Grades

Fibre Type	Wavelength (nm)	Max Loss (dB/km)	Min Bandwidth (MHz· km)	
			OFL BW	EMB
OM1 62.5 µm	850 1300	3.5 1.5	200 500	n.a. n.a.
OM2 50 µm	850 1300	3.5 1.5	500 500	n.a. n.a.
OM3 50 µm	850 1300	3.5 1.5	1500 500	**2000** n.a.
OM4 50 µm	850 1300	3.5 1.5	3500 500	**4700** n.a.

OFL BW =

Overfilled Launch Bandwidth

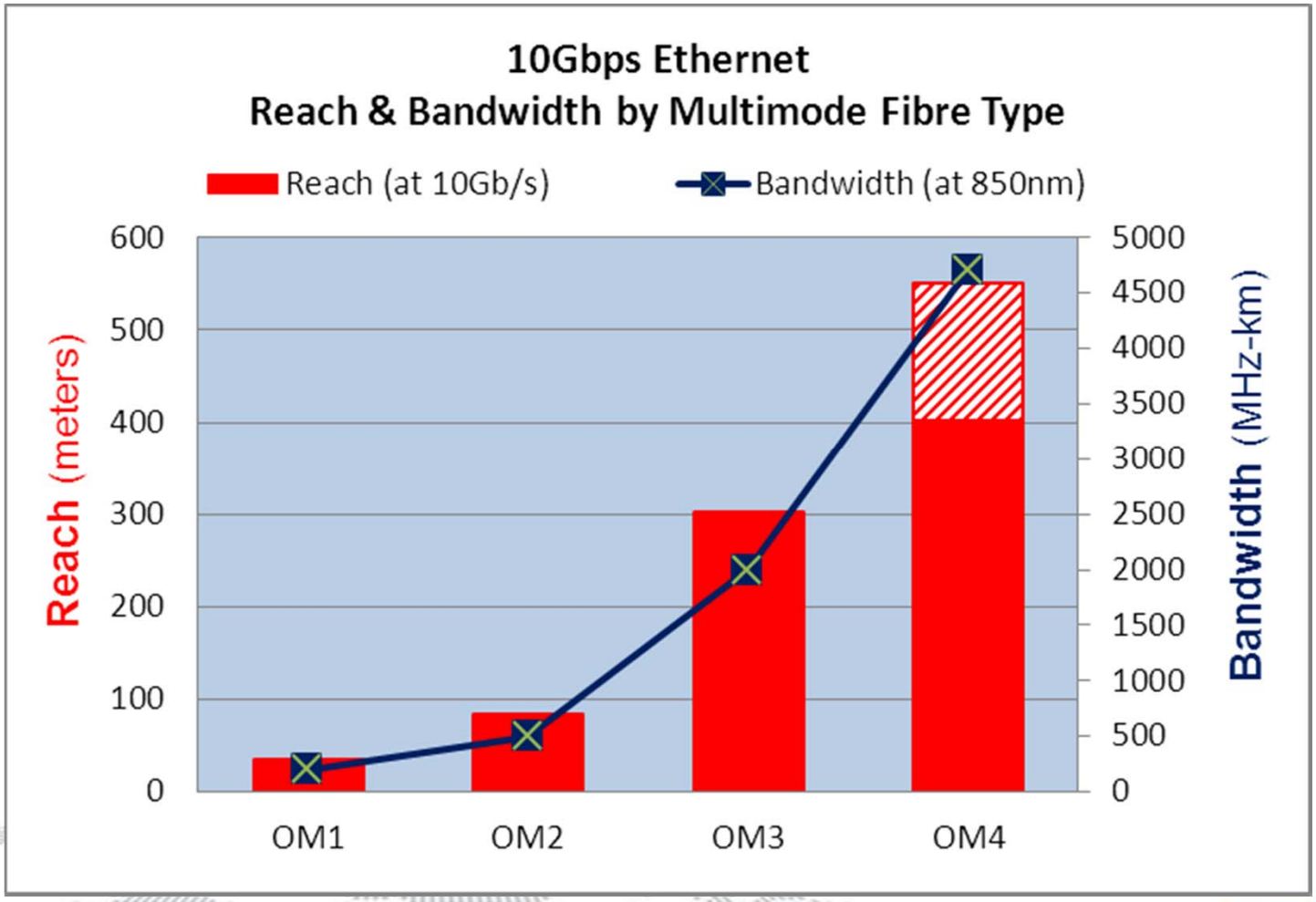
EMB =

Effective Modal Bandwidth

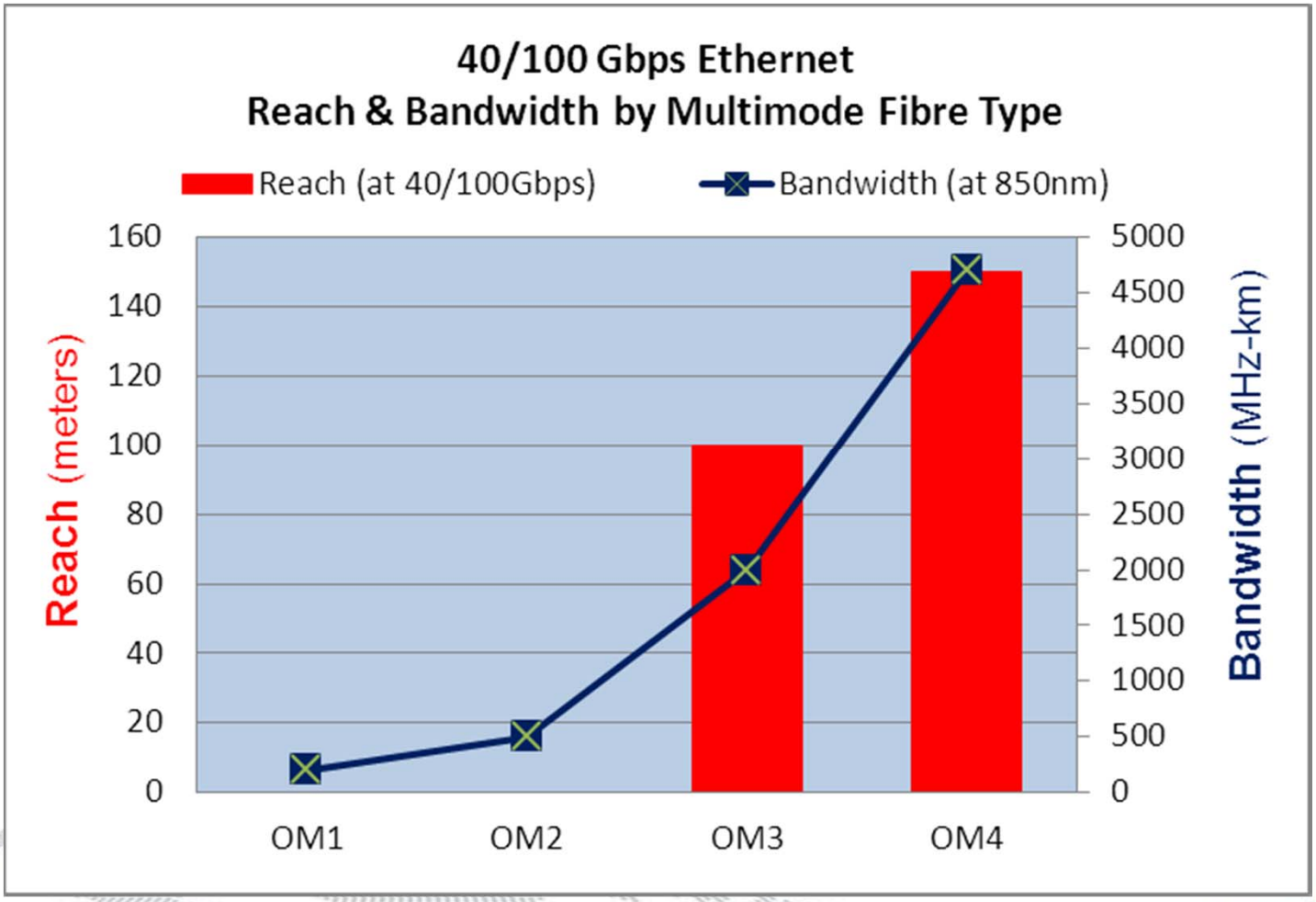
(*also known as "Laser" BW*)

OMx designations are from ISO/IEC 11801 International Cabling Standard

Multimode Fiber Types and Reach

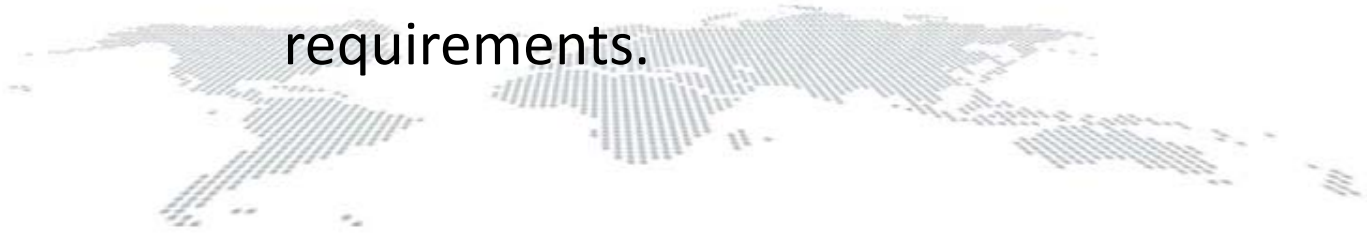


Multimode Fiber Types and Reach



TIA-942 Telecommunications Infrastructure Standard for Data Centers

- **Revision TIA-942-A published August 2012**
  - Major modifications from ANSI/TIA-942 in **Optical**
    - OM3 and OM4 are now the only recognized multimode media types. OM4 is recommended. OM1 and OM2 fibers are no longer recognized.
    - LC connector is the recognized single fiber (simplex and duplex fiber) connector.
    - MPO is the recognized multi-fiber connector
    - Removed 100 m length limitation on optical fiber horizontal cabling. Now based on individual application requirements.



BICSI

So What Is Going On With Bend-Insensitive Multimode Fibers (BIMMF)?

BICSI

Benefits of Bend-Insensitive Multimode Fiber

- Bend-insensitive multimode fiber (BIMMF) provides an opportunity to re-design cable management for improved space efficiency
- Denser, more compact trays and shelves improve airflow and cooling in data center racks and cabinets
- Smaller bend radii allow shorter distances between an adapter faceplate and door front
- BIMMF provides relief from strict cable management policies for standard multimode fiber, *but bend radius control and good installation and routing practices* must not *be abandoned!*

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Bend-Insensitive Multimode Fiber Simplified

Macrobend Test	Diameter	Standard 50/125 Fiber	Bend-Insensitive Multimode Fiber
100 turns 37.5 mm radius	 36.8 mm radius Baseball	850 nm ≤ 0.5 dB 1300 nm ≤ 0.5 dB	850 nm ≤ 0.5 dB 1300 nm ≤ 0.5 dB
2 turns 15 mm radius	 22.4 mm radius Golf Ball	850 nm ≤ 1.0 dB 1300 nm ≤ 1.0 dB	850 nm ≤ 0.1 dB 1300 nm ≤ 0.3 dB
2 turns 7.5 mm radius	 9.0 mm radius Dime	NOT DEFINED	850 nm ≤ 0.2 dB 1300 nm ≤ 0.5 dB

What is the Status of Bend-Insensitive Multimode Fiber?

IEC/TIA Standardization process is well underway

- Joint IEC/TIA Task force chaired by OFS' Dave Mazzarese is leading standardization effort
  - Currently reviewing multimode core diameter and Numerical Aperture (NA) measurement procedures
    - IEC60793-1-43 Numerical Aperture Draft under review
    - IEC60793-1-20 Core Diameter
      - » Round Robin underway
  - Reviewing system performance of BIMMFs to determine if current EMB measurement and characterization methods are adequate
    - IEC60793-1-49 DMD Specification being revised to account for leaky modes
  - Documents will be adopted as TIA FOTPs

Significant progress is being made!

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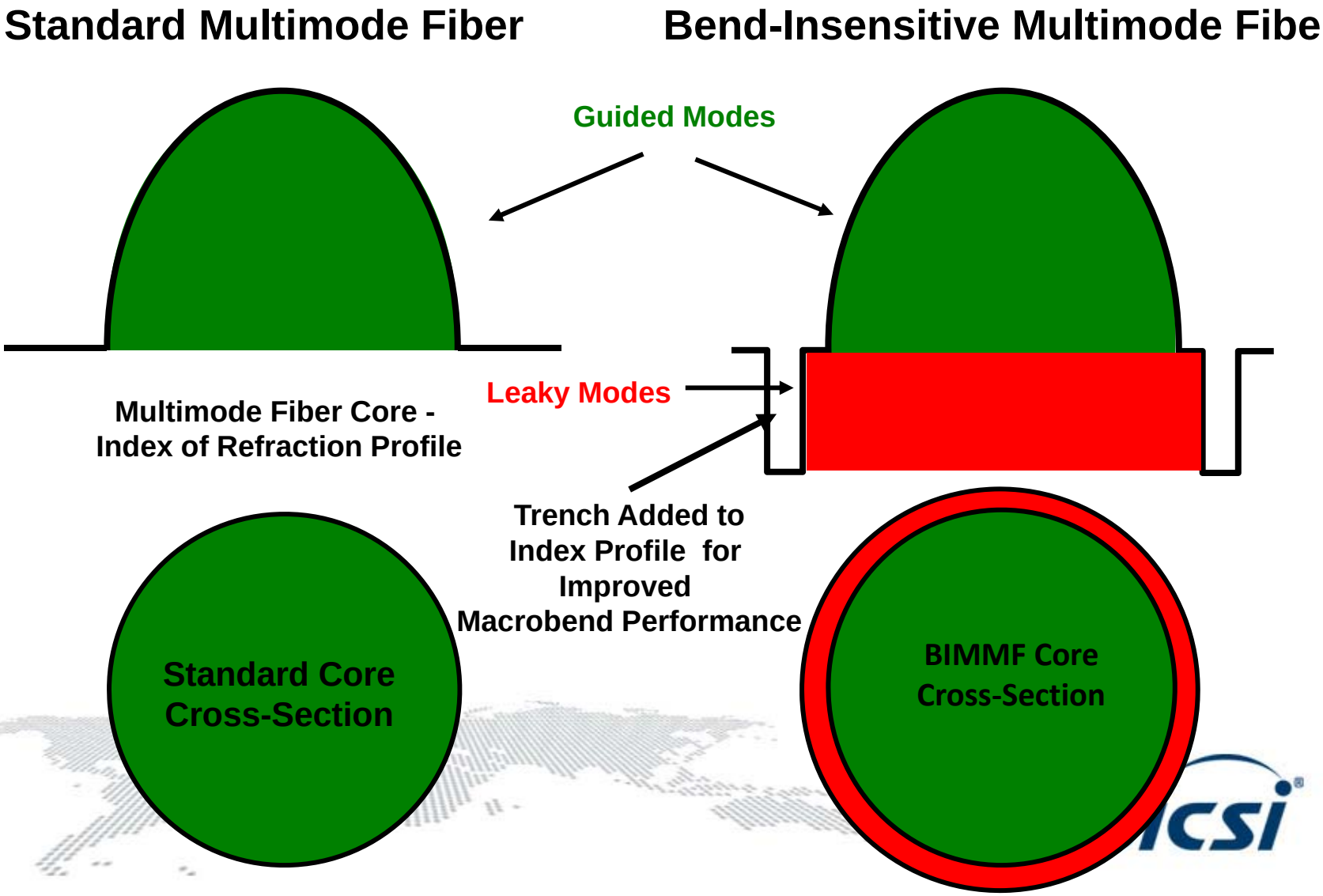
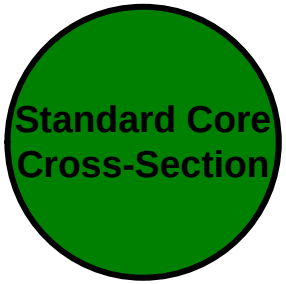
Comparison of Waveguides

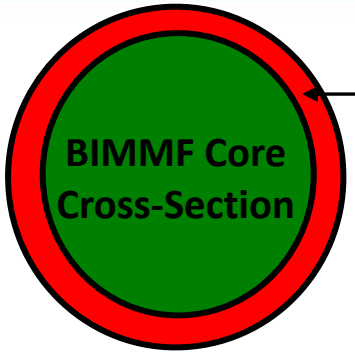


Standard Multimode Fiber and BIMMF Fiber Appearance



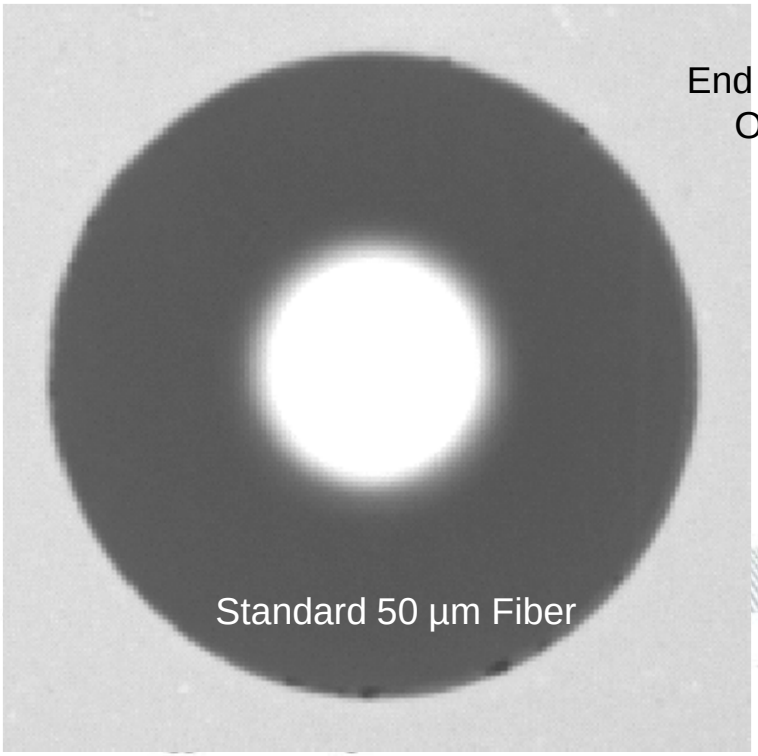
"Halo" provides a visual indicator of BIMMF

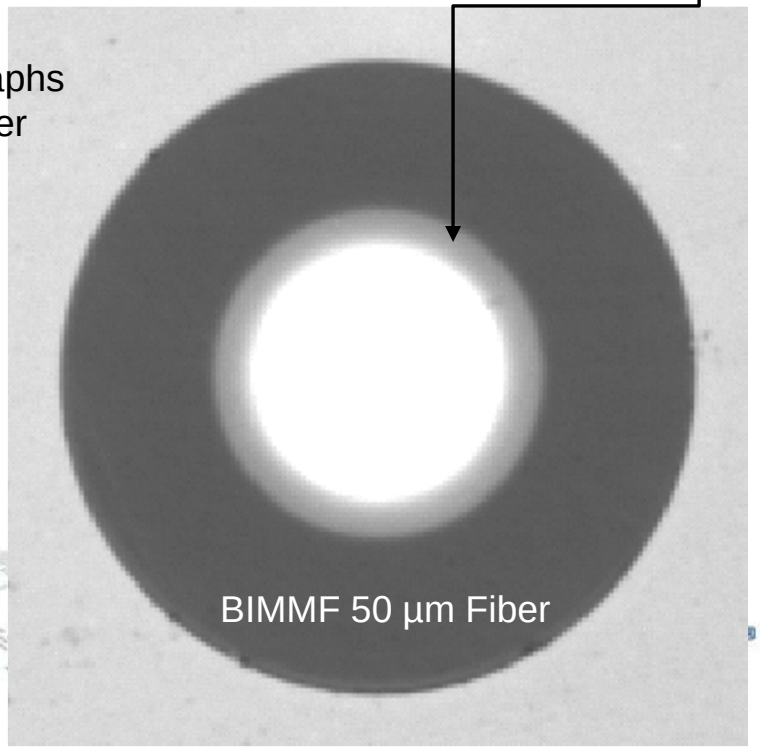
A properly designed BIMMF trench has no effect on system performance!



BIMMF "Halo"

End Face Photographs Of Standard Fiber And BIMMF





What parameters impact system performance?

- Interoperability / Connection properties
- Bandwidth
- Reliability

It is desirable for optical fibers to be **optimized** for system performance

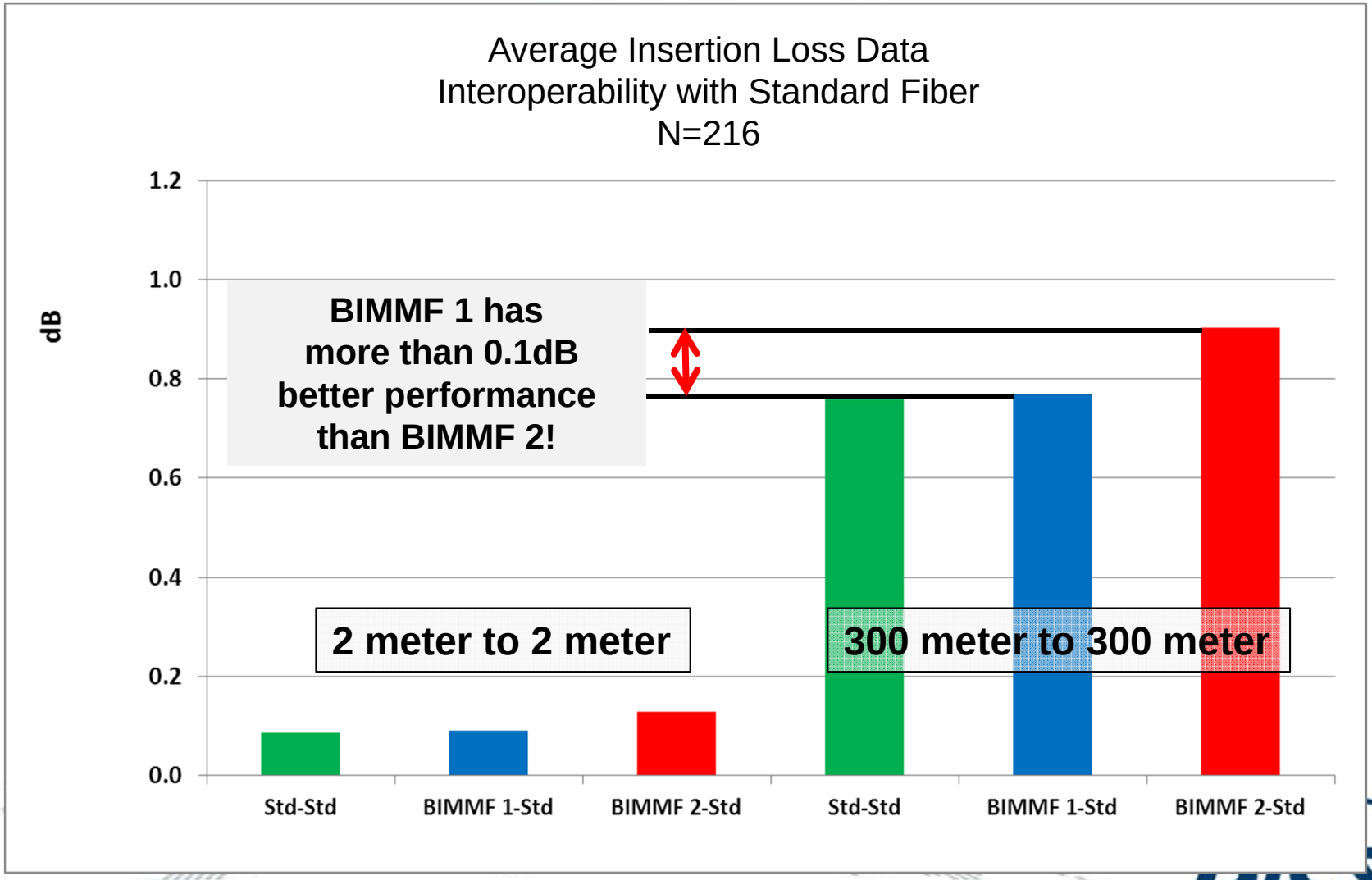
Matching Core Size and Numerical Aperture is essential for low loss connections!

Fiber Design	Core Diameter		NA	
	2m	1000 m	2m	1000 m
Standard 50 µm	50 µm	50 µm	0.20	0.20
BIMMF Design 1	51 µm	50 µm	0.21	0.20
BIMMF Design 2	50 µm	49 µm	0.21	0.19

Matching long length core diameter and NA provide best connection performance

Leaky modes distort short-length Core Diameter and NA values in BIMMFs

Matched Long Length Measurements Provide Best Compatibility!



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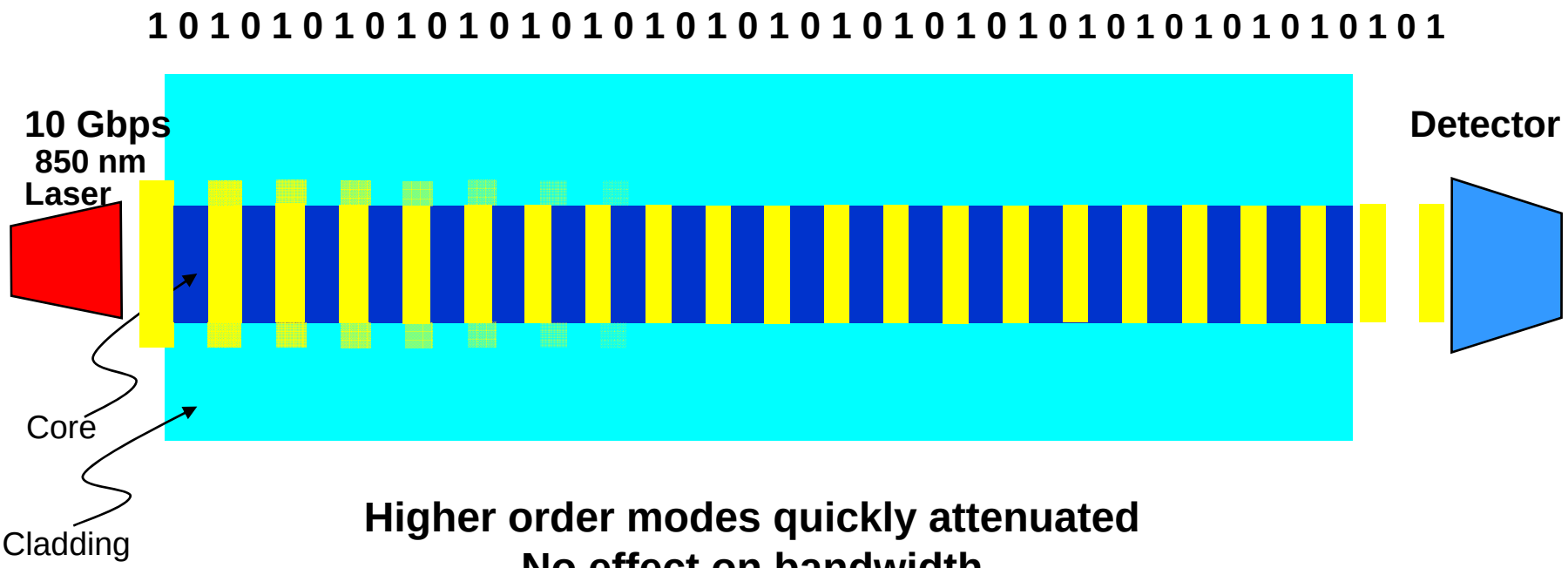
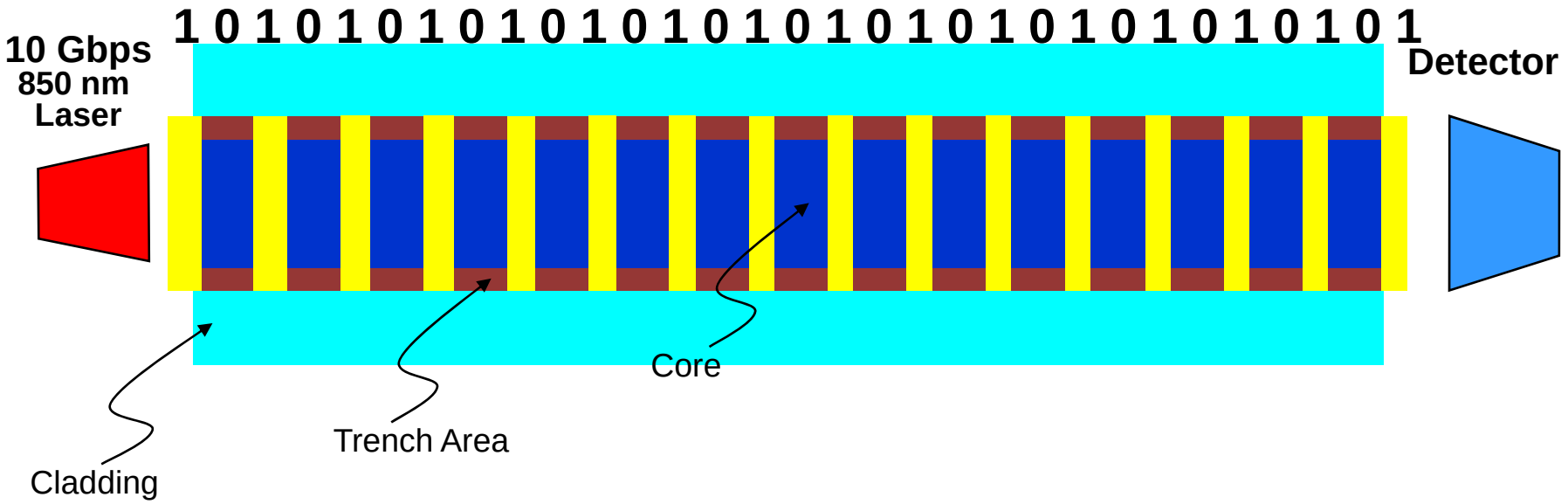
Standard Multimode Fibers



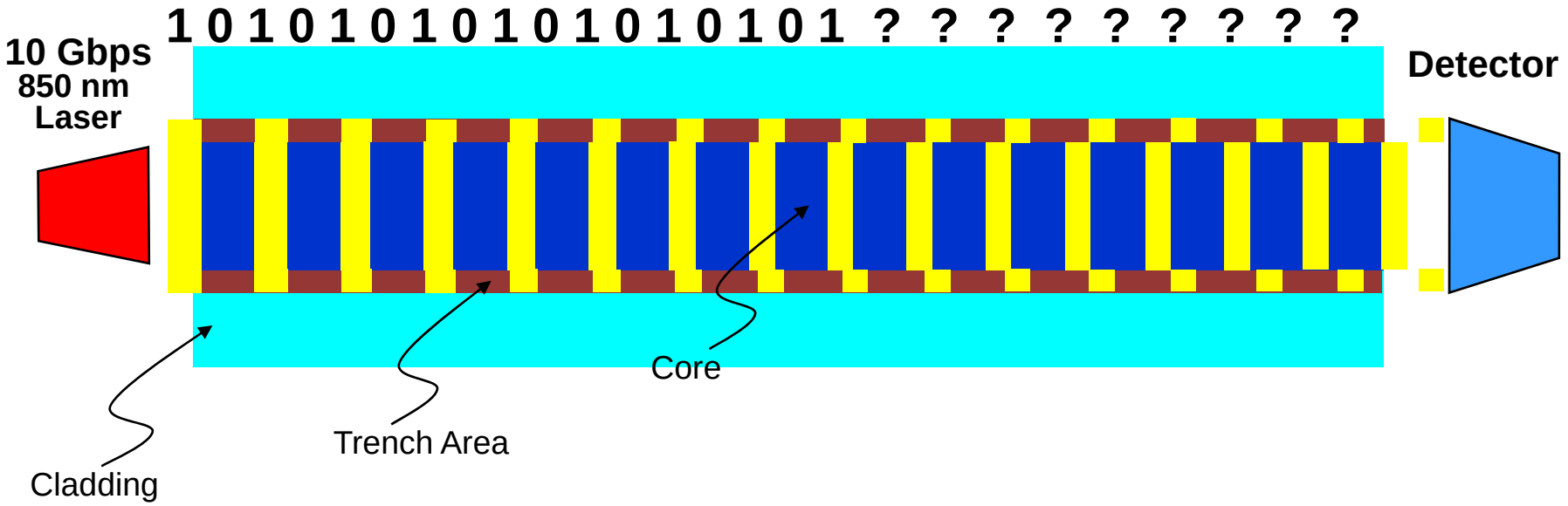
Higher order modes quickly attenuated
No effect on bandwidth
Maximum transmission distance!

Good BIMMFs control leaky mode behavior!

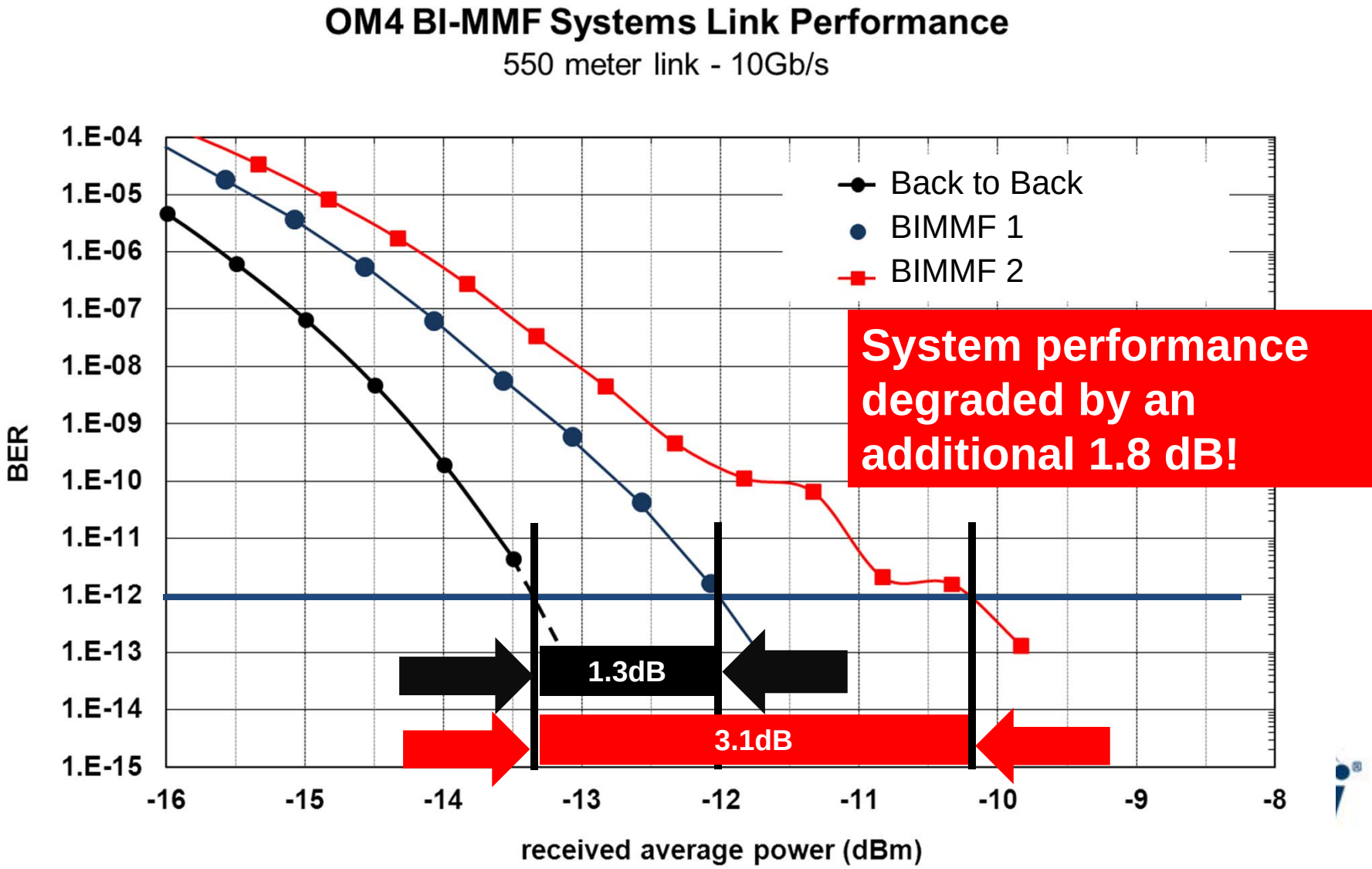


Leaky Modes Propagate in all BIMMF designs

Poor leaky mode control can degrade bandwidth and jeopardize system performance!



System Performance is not comparable for these fibers!



What parameters impact system performance?

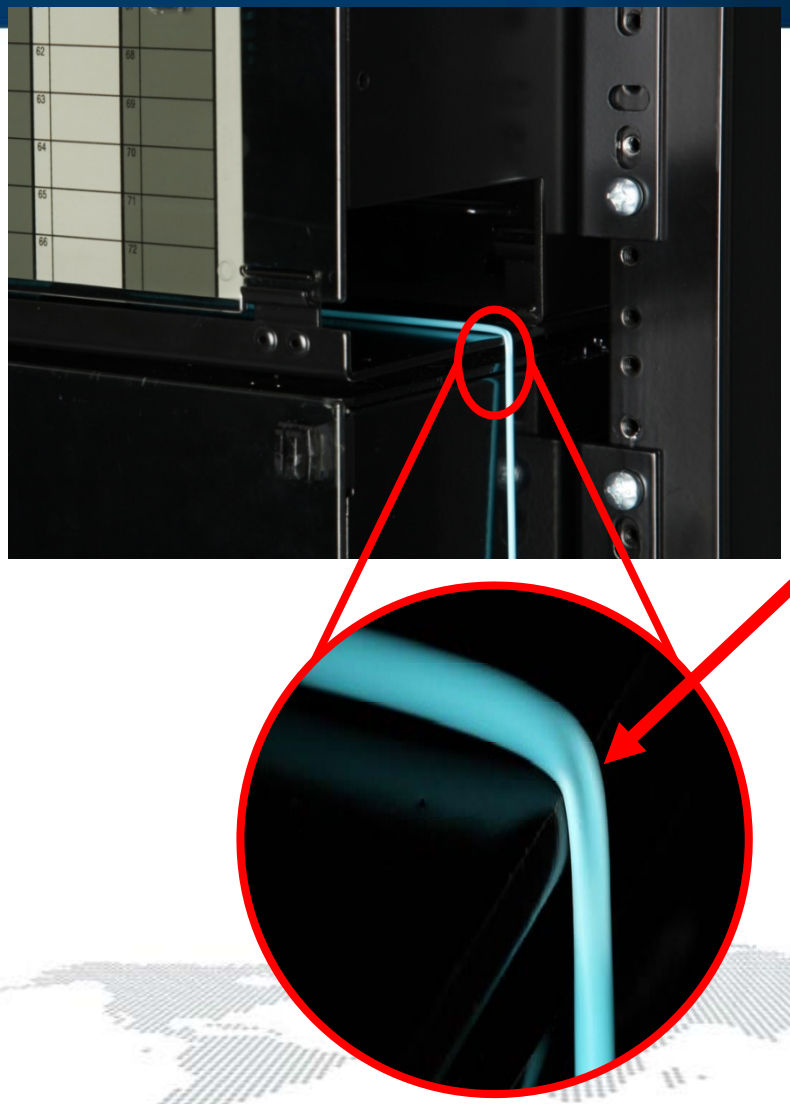
- Interoperability / Connection properties
- Bandwidth
- Reliability

It is desirable for optical fibers to be **optimized** for system performance

Fiber Reliability is Critical!

- Fiber reliability is a function of:
  - Mechanical Reliability
    - Inherent glass quality – intrinsic strength
    - Proof test level – extrinsic strength
    - Packaging – cable design
    - **Deployment**
  - Optical Reliability
    - Maintaining optical signal through the link
    - Sufficient bandwidth to support future system upgrades

Should you do this?



- What is the expected lifetime of this jumper?

Fiber bend radius approximately 1-2 mm

Expected time to mechanical failure

1 mm bend ~ 1 month

2 mm bend ~ 5 years

Summary of Bend-Insensitive Multimode Fiber

- Bend-insensitive fibers offer significantly improved bending loss, and can improve cable management problems in today's high density interconnects
- It is prudent to balance macrobend performance with other fiber parameters including bandwidth and interoperability to optimize system performance
- Bend-insensitive multimode fiber standardization is currently underway
  - Significant progress is being made and technical content completion is targeted for the end of 2012
- Bend-insensitive fiber is **NOT** a substitute for proper cable management

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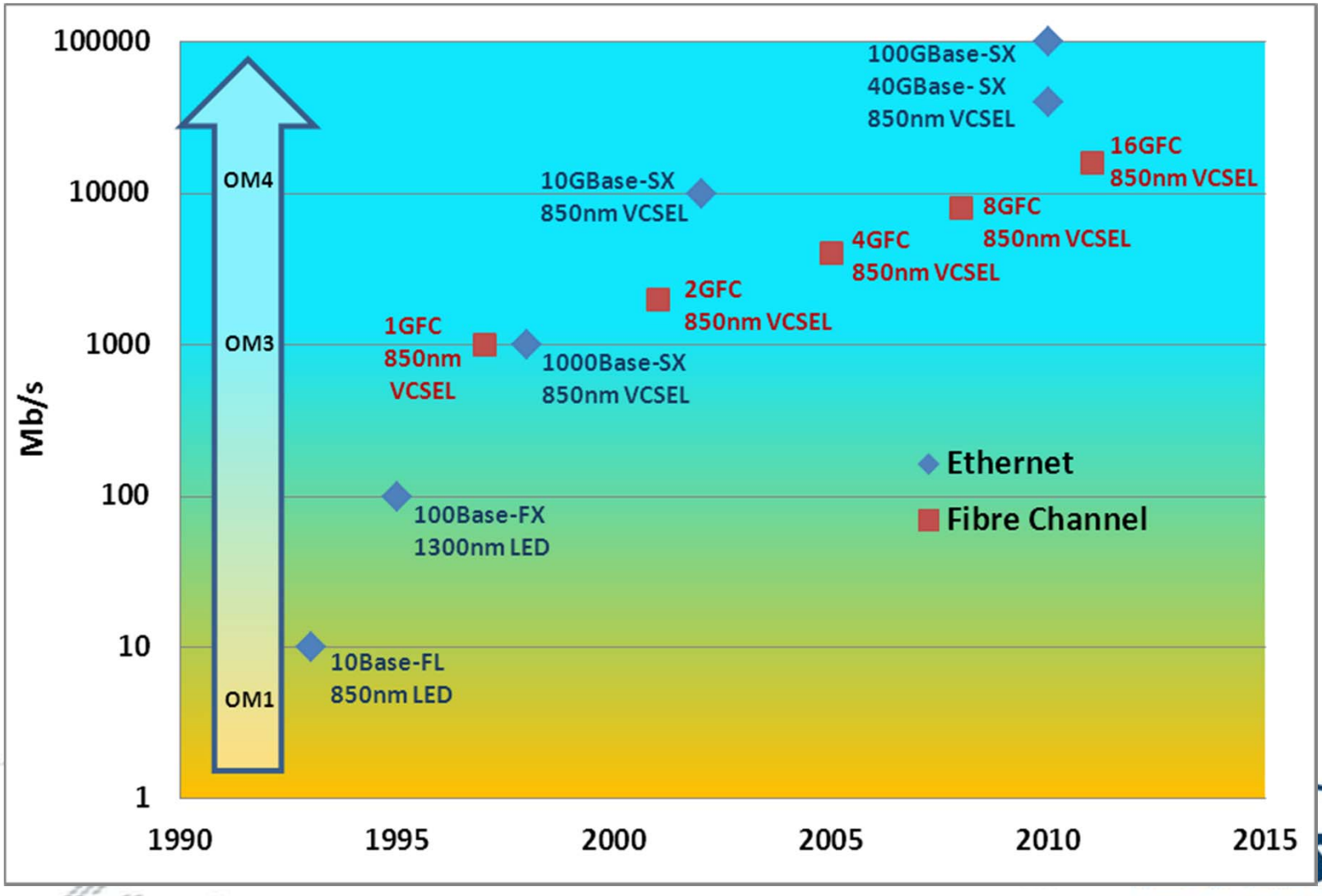
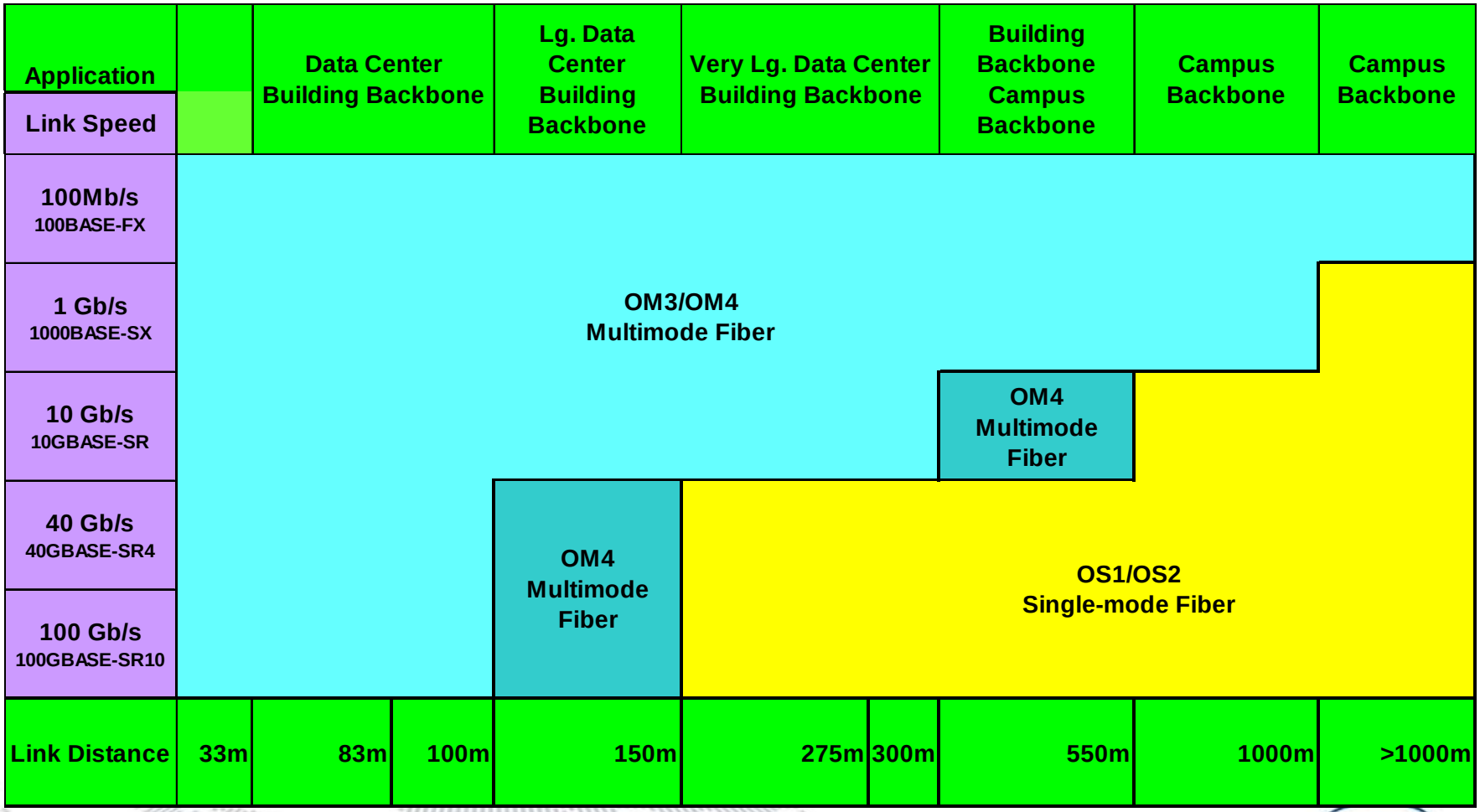
Evolution of Short Reach Applications



Ethernet Link Distance/ Application Mapping



40G & 100G Ethernet (IEEE 802.3ba)

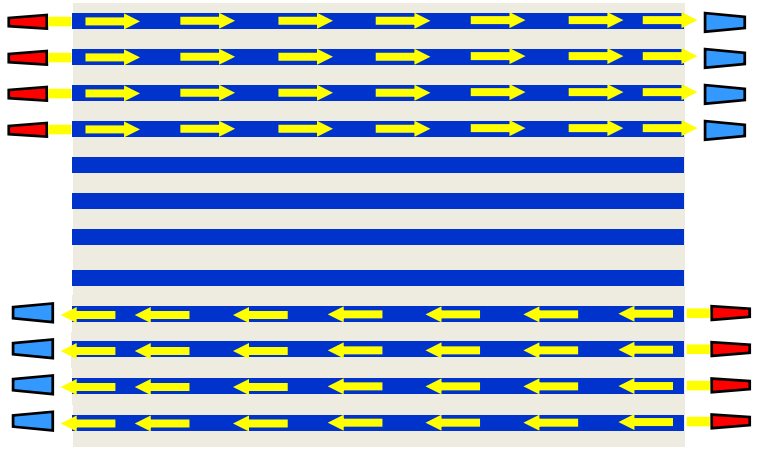
Reach & Media:

- ✓ **40 Gb/s** for servers, HPC, SAN, NAS
  - **10 km** on SMF (1310nm) — **40GBASE-LR4**
  - **100 m** on OM3 MMF (850nm) — **40GBASE-SR4**
  - **150 m** on OM4 MMF (850 nm) — **40GBASE-SR4**
  - **7 m** over copper — **40GBASE-CR4**
  - **1 m** over backplane — **40GBASE-KR4**
- ✓ **100 Gb/s** for switching, routing, aggregation
  - **40 km** on SMF (1310nm) — **100GBASE-ER4**
  - **10 km** on SMF (1310nm) — **100GBASE-LR4**
  - **100 m** on OM3 MMF (850nm) — **100GBASE-SR10**
  - **150 m** on OM4 MMF (850nm) — **100GBASE-SR10**
  - **7 m** over copper — **100GBASE-CR10**

High Speed Short Reach Technologies: Multiple Fiber Parallel Systems

<u>for 40G</u>:

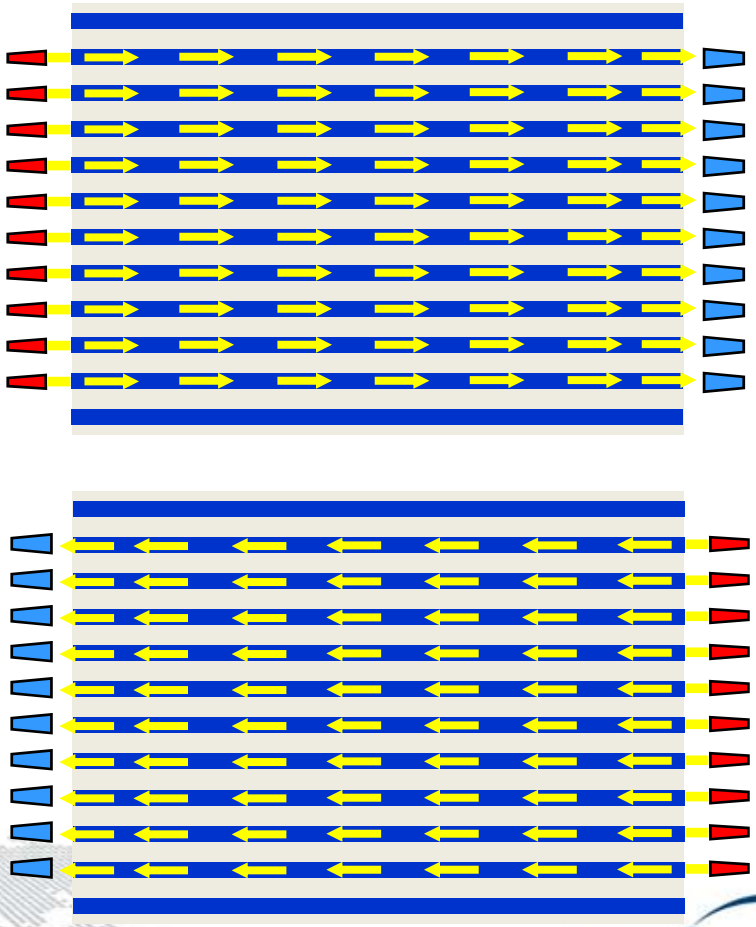
- One 12-fiber cable
  - duplex link
  - 8 active fibers
- 12 fiber MPO connector
- One wavelength per fiber
- 4 x 10 Gb/s



High Speed Short Reach Technologies: Multiple Fiber Parallel Systems

for 100G:

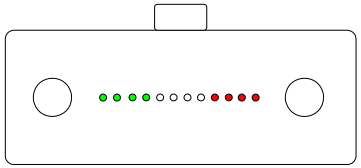
- Two 12 fiber cables, or 24 fiber Cable
  - 20 Active
  - Duplex link
- MPO connector
  - 2 x 12 fiber
  - 1 x 24 fiber
- One wavelength per fiber
- 10 x 10 Gb/s



40G & 100G Ethernet – MDI Recommendations

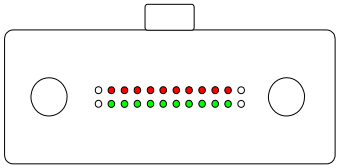
References MPO interface req's/specs of IEC 61754-7.

40GBASE-SR4



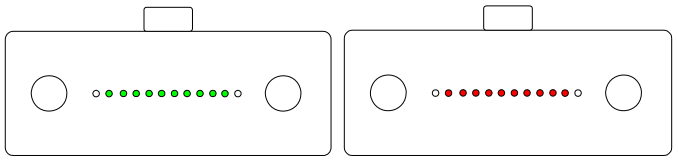
Left 4 fibers are Tx
Right 4 fibers are Rx
(inner 4 fibers unused)

100GBASE-SR10



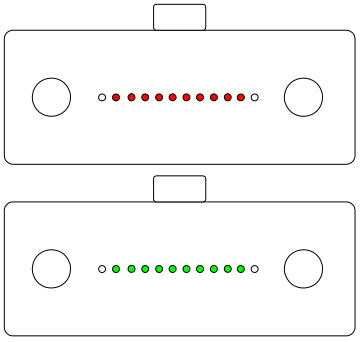
Inner 10 fibers, Top Row are Rx
Inner 10 fibers, Bot Row are Tx
(outermost fibers both rows unused)

Option A
(recommended)



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

Option B



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

Option C

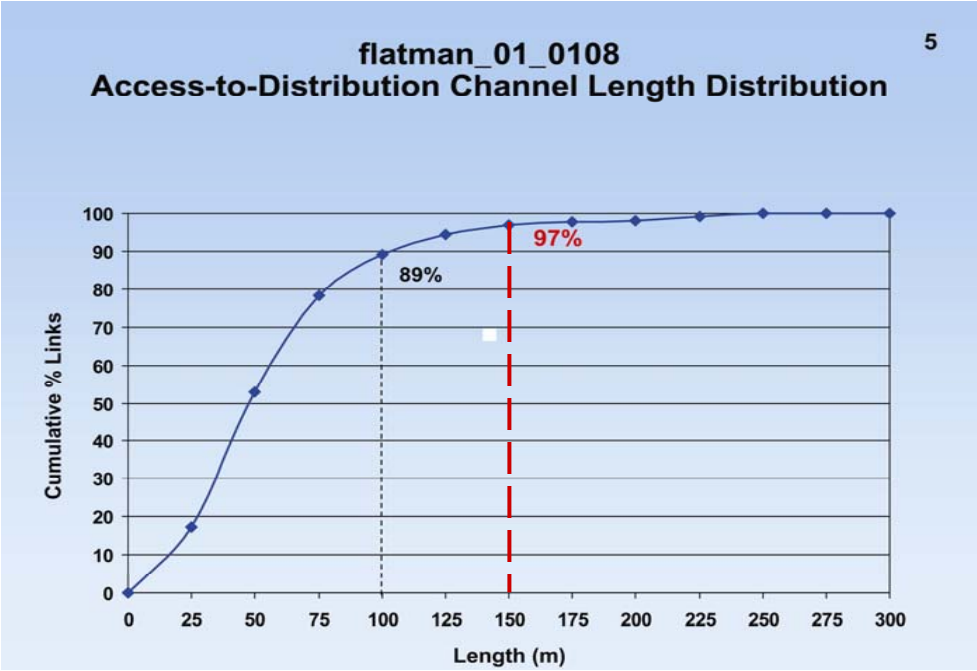
40G & 100G Ethernet *(continued)*

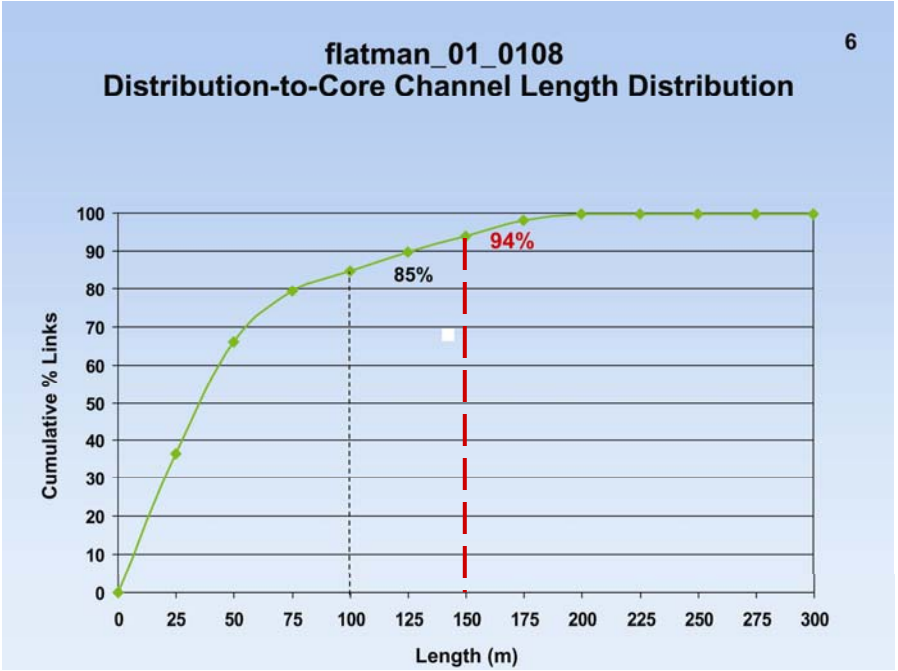
- Reduced reach of 100 m on OM3, 150 m on OM4 compared to 10G (300 m on OM3, 550 m on OM4) is due to relaxation of transmitter spectral width:
  - from 0.45 to 0.65 nm

  There have been no changes to the fiber itself!

- 150 m on OM4 expected to support 95%+ of Data Center links.

Why is OM4 important to 100G?





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

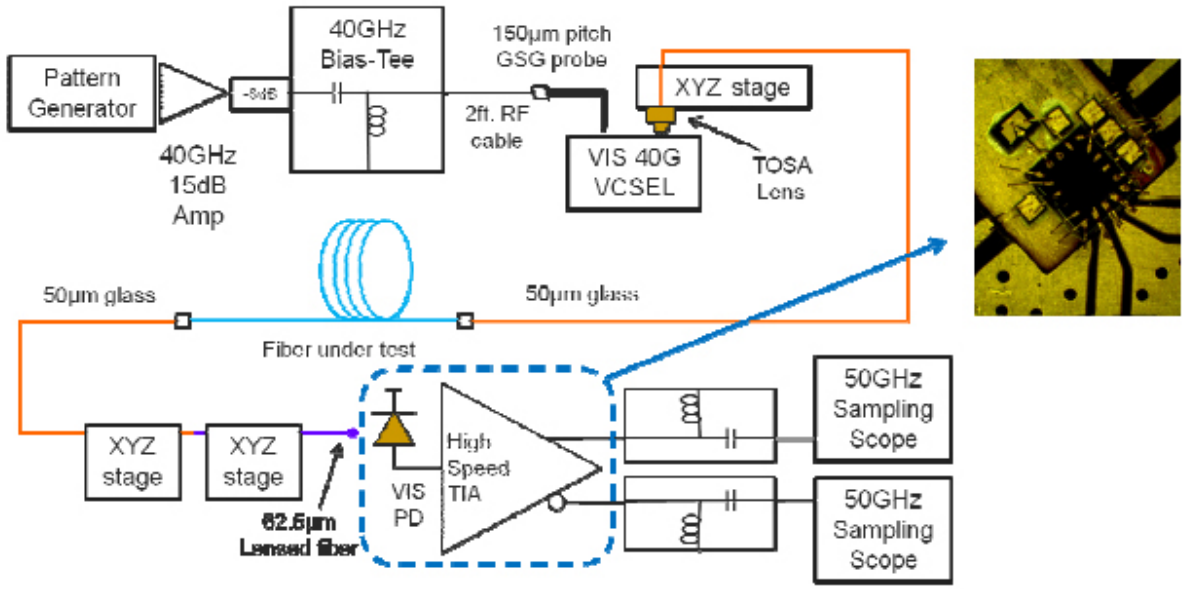
Ethernet – Next Generation

- Next Generation 100 Gb/s Optical Ethernet Study Group
  - **4x25 Gb/s transmission**
  - **Different options discussed – not all will be chosen**

	SM/MM	Wavelength (nm)	Comments
Parallel	MM	850	100-150 m
Parallel	SM	1310	0.5-2 km
Duplex	SM	1310	8/16 level signaling
WDM	SM	1310/1550	Integrated Photonics

Can Multimode Fiber Transmit 25 Gb/s?

25 Gb/s Test bed at GA Tech

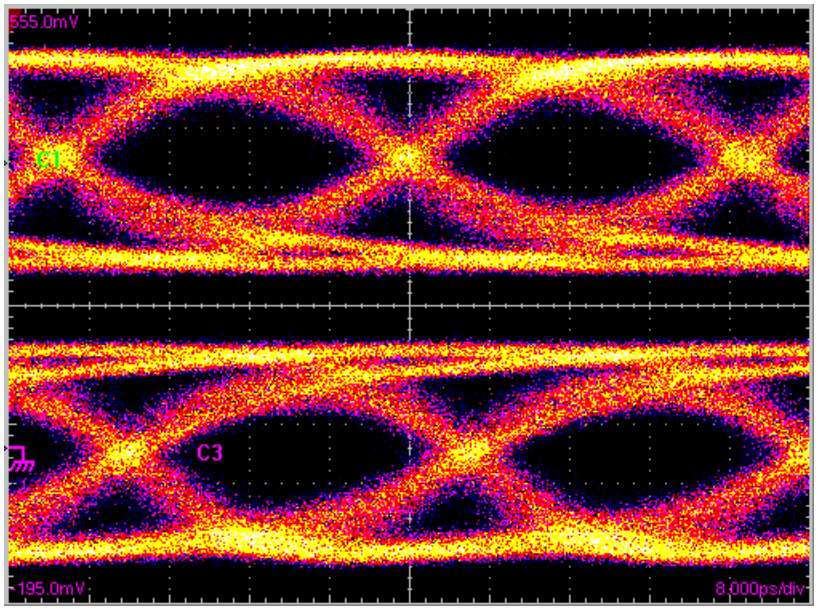


Georgia Tech College of Engineering

C. Patrick Caputo- Georgia Institute of Technology
Stephen E. Ralph – Georgia Institute of Technology
Yi Sun – OFS

ofs
A Furukawa Company

Early 25 Gb/s Transmission Test Results



Open Eye Diagram

25 Gb/s transmission over **200 m** OM4 fiber!!!

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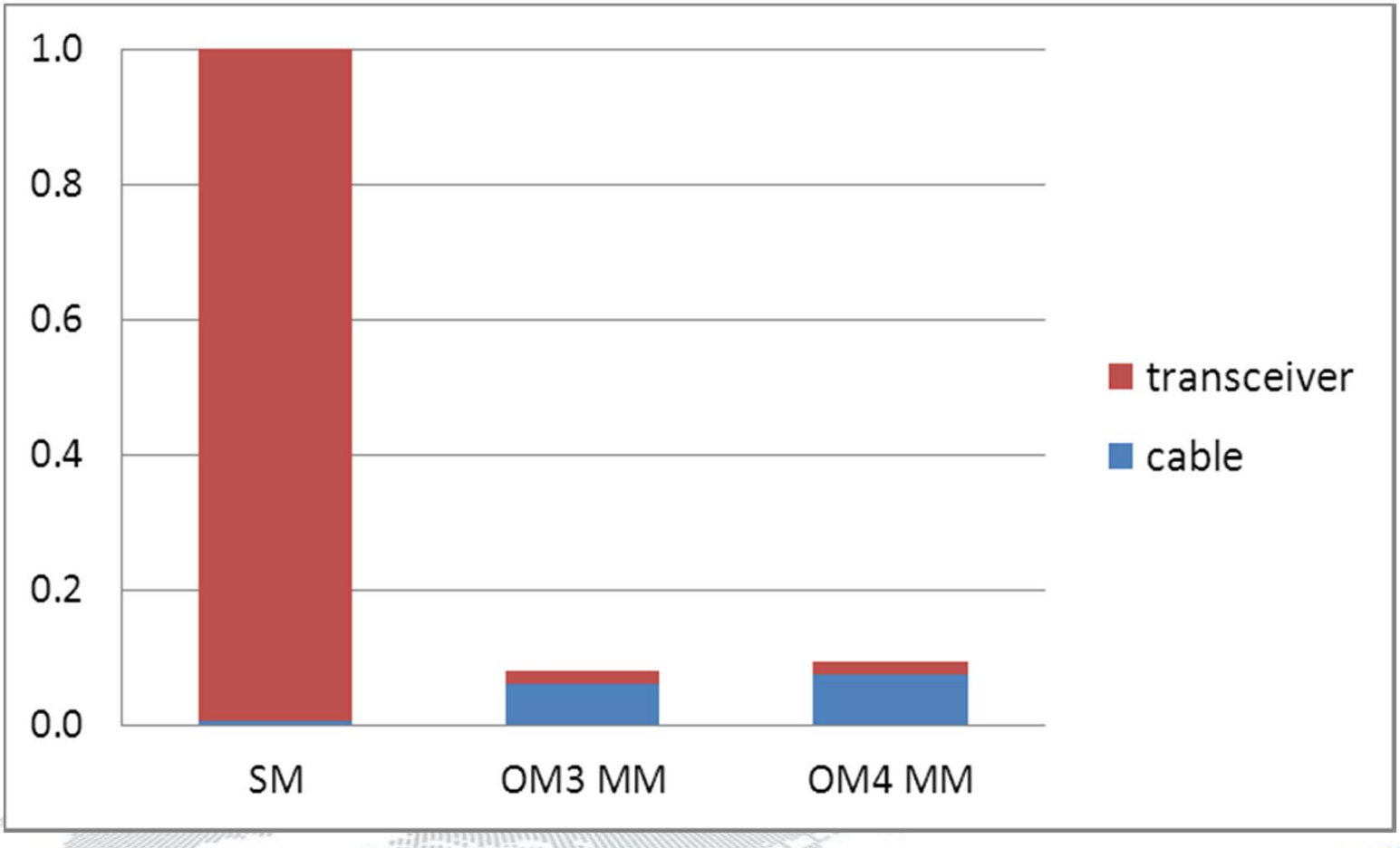
Comparison between Single-mode and Multimode Fiber Systems

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

- **Single-mode CWDM system**
  - **Pro: Lower cabling cost**
  - **Con: Significantly higher transceiver cost**
  - **Con: Higher power consumption**
  - **Con: Larger size**

- **OM3 and OM4 multimode parallel systems**
  - **Pro: Much lower transceiver cost using existing 10 Gb/s VCSELs**
  - **Pro: Lower power consumption**
  - **Pro: Smaller footprint**
  - **Con: Higher cabling cost**

100 Gb/s Link Cost Comparison
SM vs MM



Source data: SanSpot.com August 2012
PEPPM.org, last update June 2012

BICSI

Power Consumption

- Lower power consumption critical as link density and speed increase
  - 100G CFP single-mode transceivers consume 20+ watts
  - 100G CXP multimode transceivers consume ~5 watts

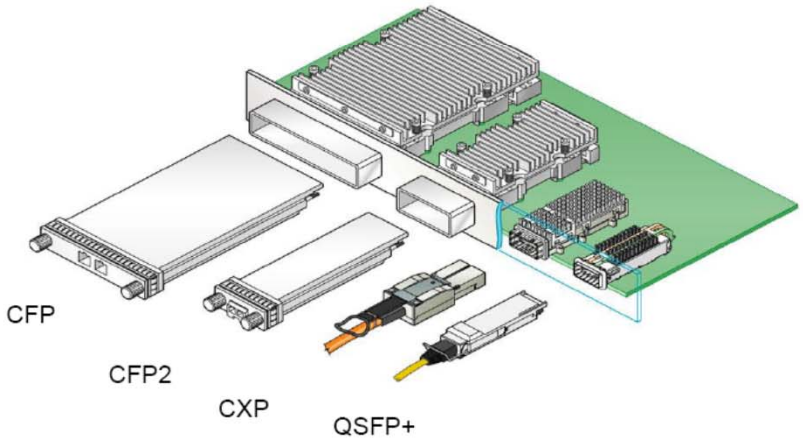
- **Savings ~ 15 watts/transceiver**
- ***Cooling – another 15 watts/transceiver***

Single-mode vs. Multimode Module Size

- Significantly larger footprint for single-mode CFP module
- Much lower faceplate density
  - 4 single-mode modules in 1U footprint vs. 16-32 multimode modules!

100Gbps Form Factor Comparisons

Solutions		Module Form factor	Module Dimensions (mm) (within the chassis)			Maximum Number of 100 Gbps Ports/1U	
# of Channels	Distance		Length	Width	Height	Single	Stacked
10 Channels	10Km or 40 Km	CFP	130	77	13.6	4	-
	100G CR10 0-7m or 100G SR10 0-150m	CXP	25	21	9.8	16	32
4 Channels	10Km or 40 Km	CFP2	92	25	13.6	8	16
	100G CR10 0-7m or 100G SR10 0-150m	QSFP+	52	18.4	8.5	18	36



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Jay Neer Apr 12, 2011

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Agenda

- Fiber Market Drivers
- Fiber Types and Standards
- Application Standards
- Multimode Fiber Value Proposition
- Conclusions

Conclusions

- **OM3 and OM4 Multimode Fiber is the media of choice for short reach 100 Gb/s transmission rates**
  - **In the data center and enterprise “sweet spot”**
  - **Only multimode fibers recognized in ANSI/TIA-942-A**
    - **OM4 fiber recommended**
- **100 Gb/s 4X25 solution could be a painless infrastructure upgrade from 40 Gb/s 4x10 technology**

Thank You!