How Bend Insensitive Multimode Fiber is Affecting Installation and Testing of Enterprise and Data Center Cabling

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Learning Objectives:

- What is bend insensitive multimode fiber
- What is the status of standardization for bend insensitive multimode fiber
- Interoperability of bend insensitive and standard multimode fiber
- Special considerations for testing links and components with bend insensitive multimode fibers.

Outline

- Deployment of fiber by type
- Difference between standard 50/125 fiber and bend insensitive 50/125 fiber
- How was macrobend performance improved
- Standardization efforts/status/what is still to come
- Characterizing BIMMF to assure interoperability
- Test methods for characterizing BIMMF links and components
- Next generation standardization challenges - Wide band fiber

Bandwidth Drivers & Market Deployment of Multimode Fiber

Today's Network

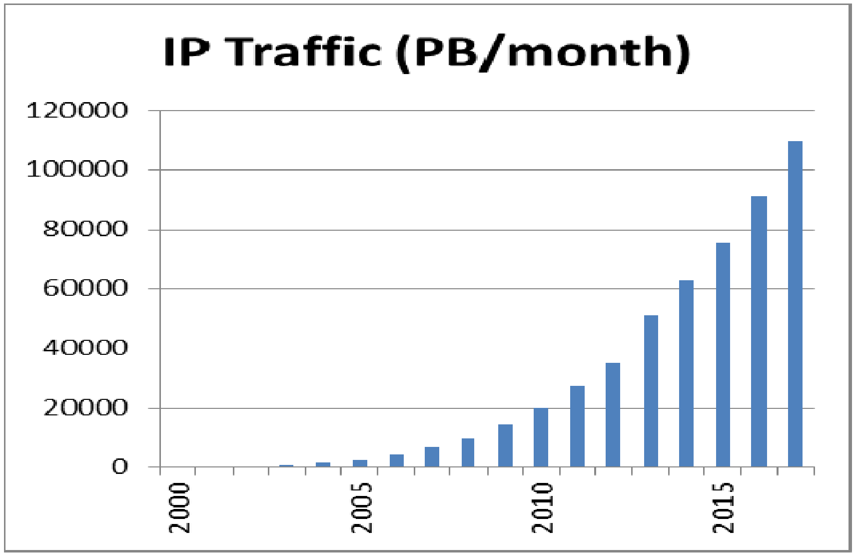
Superfast broadband

- **Facebook**
  - ✓ March 2014 – 1.28 billion monthly users, 802 million daily users[1]
  - ✓ March 2014 – 802 million daily active users on average[1]
- **Netflix**
  - ✓ March 2014 – 48 million members[2]
  - ✓ March 2014 – 1 billion hours of video watched per month [2]

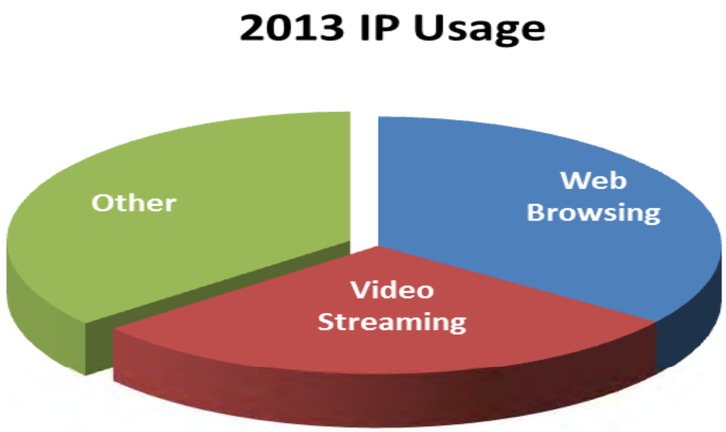
[1] http://newsroom.fb.com/Key-Facts
[2] http://ir.netflix.com/index.cfm

Data traffic trends

Internet growth is explosive

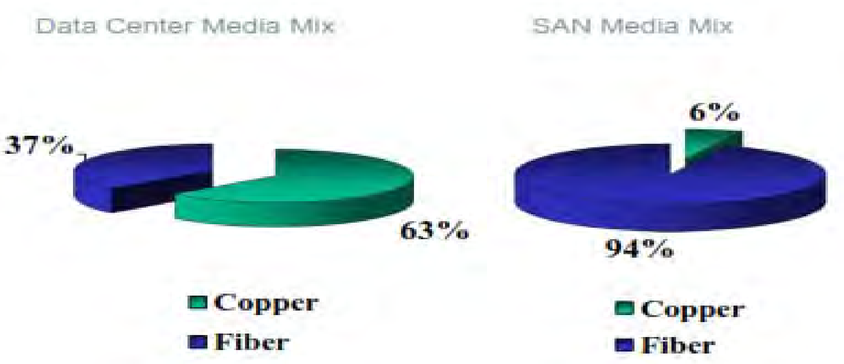


Source: Cisco Visual Networking Index (VNI):
May 29, 2013



Driven by common applications

2012 Data Center Cabling Mix Based on Revenue

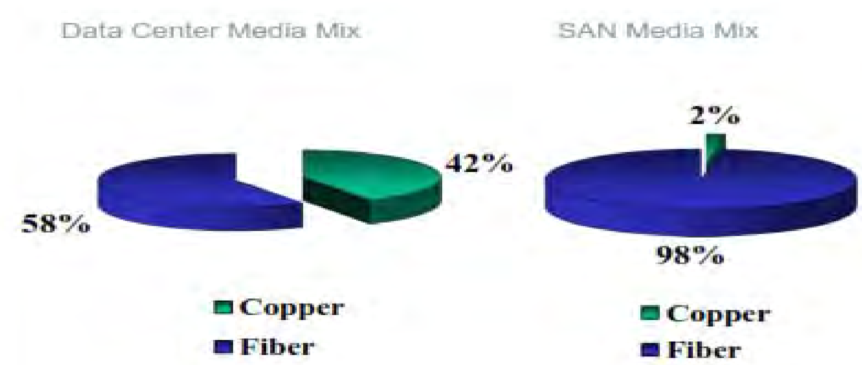


Source: DataCenterStocks.com 2013 Research

March 9, 2014

OFC 2014

2017 Data Center Cabling Mix Based on Revenue



Source: DataCenterStocks.com 2013 Research

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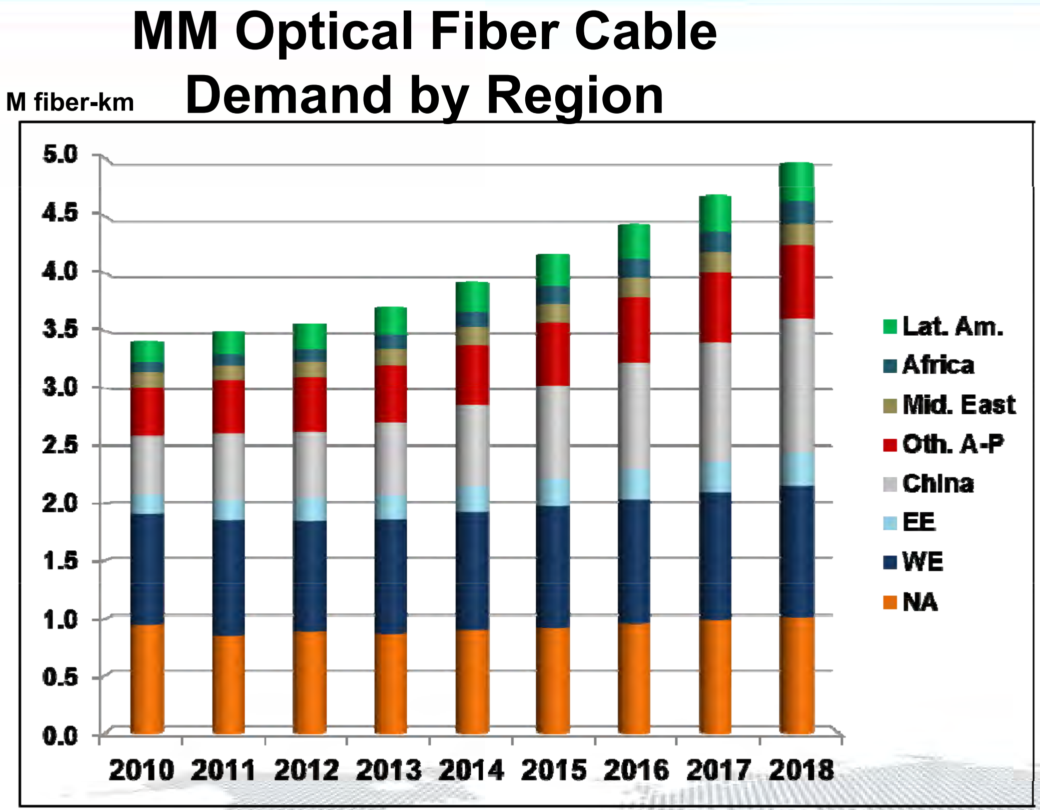
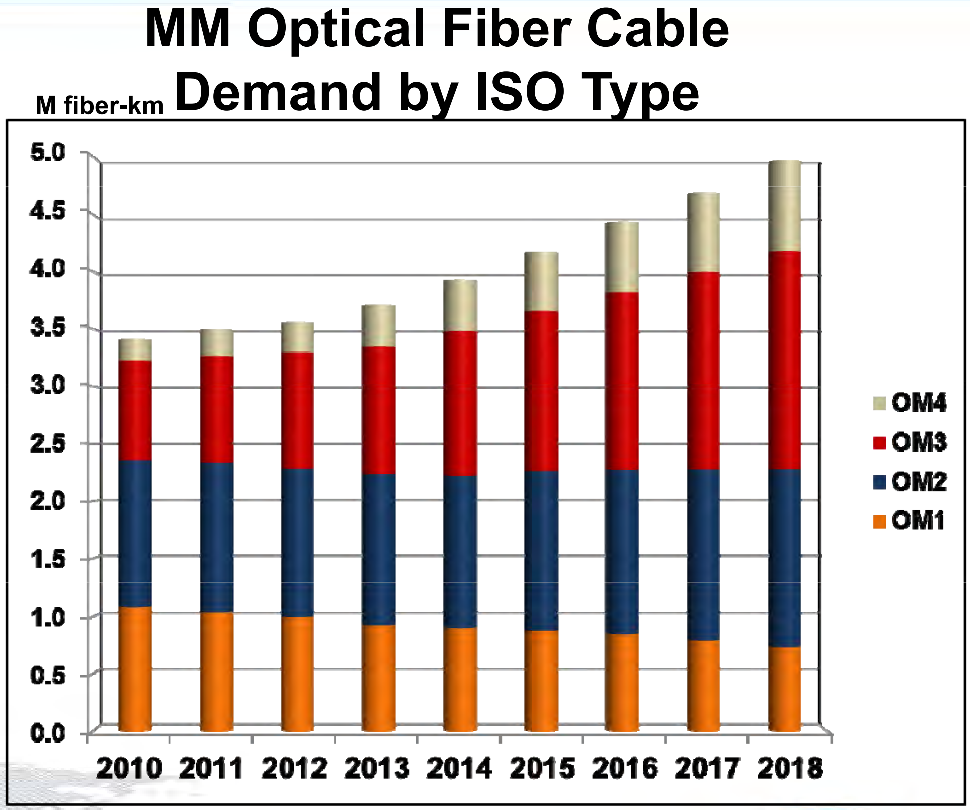
OFC 2014

DataCenterStocks.com

90

Multimode Optical Cable Overview, 2010-2018





Data: CRU International, Feb. 2014

More laser optimized OM3 and OM4 fiber to improve ISI penalty

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Why Multimode?

- Supports most data center links
- Lower initial costs
- Lower power consumption

Transmission media	Max link distance At 10 G	Power Consumption (Baera, 2012)	Transceiver cost
Cat 5-7 Copper	100 m	2-5 Watt	$
OM3 or OM4 multimode fiber	400 m (550m*)	0.7 Watt	$$
OS1 or OS2 single-mode fiber	10 km	0.7 Watt	$$$

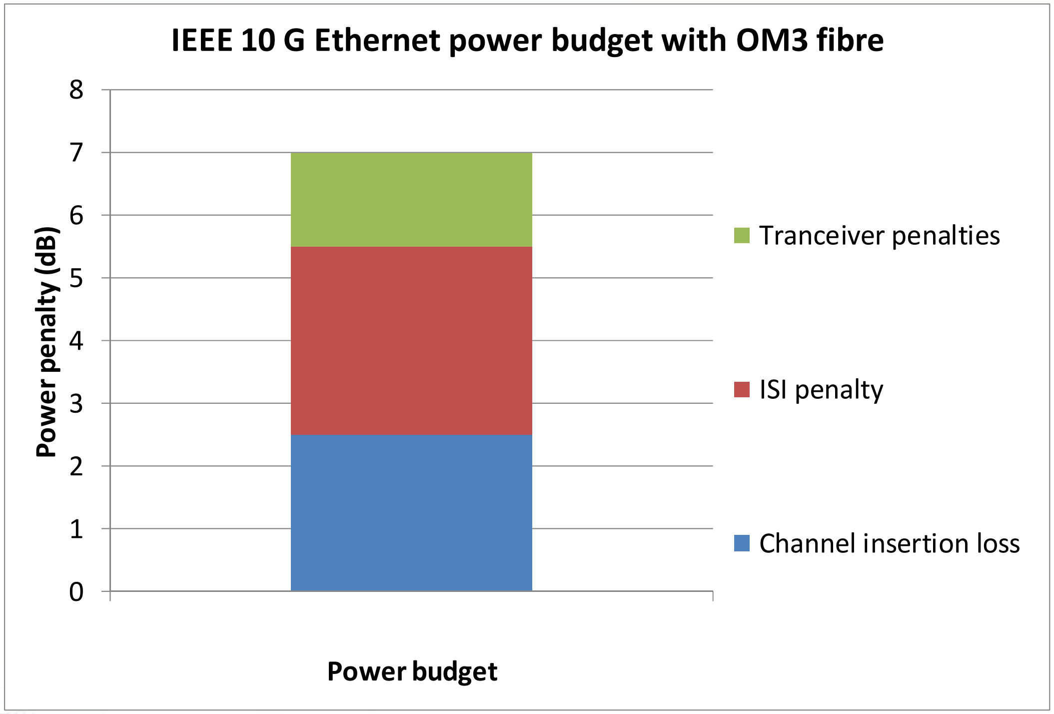
Comparison of 10G Ethernet transmission options for Data Centers

Near term transmission options for data center links.

Data Center Size/ Application Speed	Small to Medium Data Centers		Large data centers
1 G	Copper		OM3/OM4 Fiber Duplex
10 G	Copper	OM3/OM4 Fiber Duplex	OS1/OS2 Single-mode Duplex
40 G	OM3/OM4 Multimode 4 x 10 Parallel		OS1/OS2 Single-mode Duplex
100 G	OM3/OM4 Multimode 10x10 Parallel **4x25 Parallel**		OS1/OS2 Single-mode Duplex **4x25 Parallel**
Link Distance (m)	1	10	100 / 1000

Data center link budget

- ISI penalty
  - System penalty due to bandwidth of the fiber.
- Channel insertion loss
  - Connection loss
  - Cabled attenuation
  - Macrobend loss



Available Insertion Loss Budget

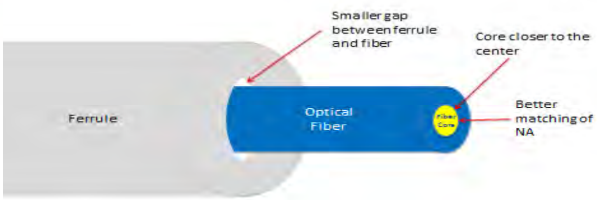
Ethernet

Transmission Speed	Chanel Insertion Loss
1 Gb/s	3.56 dB
10 Gb/s	2.6 dB
40 and 100 Gb/s	1.9 dB

Fibre Channel

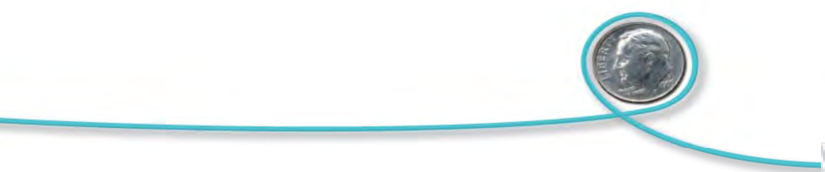
Transmission Speed	Chanel Insertion Loss
8GFC	2.05 dB
16GFC	1.95 dB
32GFC	1.86 dB

Improving the channel insertion loss



Tighter geometries to lower connection loss

Lower fiber attenuation for lower cable attenuation



Improved macrobend performance to assure loss budget is maintained

Difference Between Standard 50/125 Fiber and Bend Insensitive 50/125 fiber

Bend-Insensitive Multimode Fiber

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	 20 mm radius Ping Pong 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

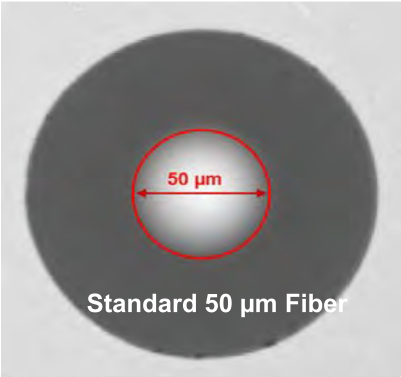
Identification of Bend insensitive Multimode fiber

Method 1: read the jacket printing

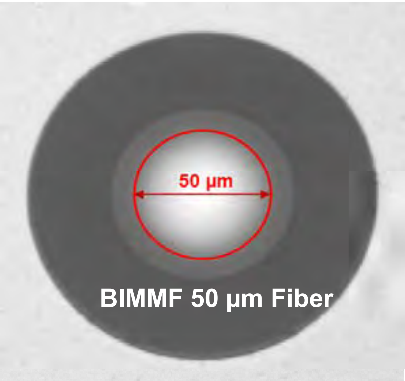
This method is easy, but it does not guarantee what fiber is actually inside

Identification of Bend insensitive Multimode fiber

Method 2: Look at the Illuminated end face of the fiber



Connector end face photographs of standard fiber and BIMMF



Prominence of the halo is dependent on the illumination source and length of the jumper

Identification of Bend insensitive Multimode fiber

Method 3: Test the jumper

Two turns around a 10 mm radius mandrill

- Attenuation less than 0.2 dB → Bend insensitive Multimode Fiber
- Attenuation greater than 0.2 dB → Standard Multimode Fiber

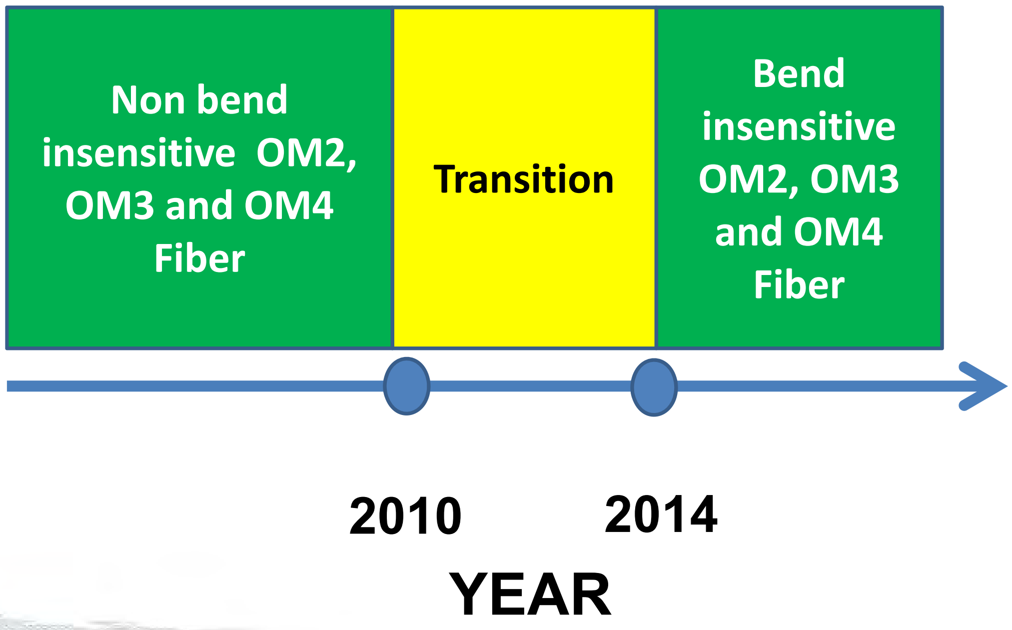
This method is the best way to validate if a jumper is bend insensitive

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!*

Most multimode fiber made today is bend insensitive

- First bend insensitive multimode fibers introduced in 2010
- By 2014 all major fiber manufacturers had switched to bend insensitive multimode fiber as their standard offering



What is the Status of Standardization for Bend Insensitive Multimode Fiber

Standardization

Performance standards

- ISO/IEC 11801 (OM2, OM3 and OM4 requirements)
  – No changes for bend insensitive multimode fiber

- TIA 568 C→D
  – Refers to TIA 492 AAAB, AAAC and AAAD
  – No changes for bend insensitive multimode fiber

Standardization

- **60793-2-10 MMF Detail Product Specification**
  – All technical comments have been resolved
  – Currently at CDV ballot stage
  – Expected completion March 2015
  – Equivalent to TIA 492 - AAAB, AAAC, AAAD

- **60793-1-20 ed2 Core Diameter Measurement**
  - **Approved for publication (Dec 2014)**
  - Equivalent to TIA 455-58 – Expected publication date June 2015

- **60793-1-43 Numerical Aperture (NA) Measurement**
  - **Published**
  – Equivalent to TIA 455-177 Expected publication date June 2015

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Standardization

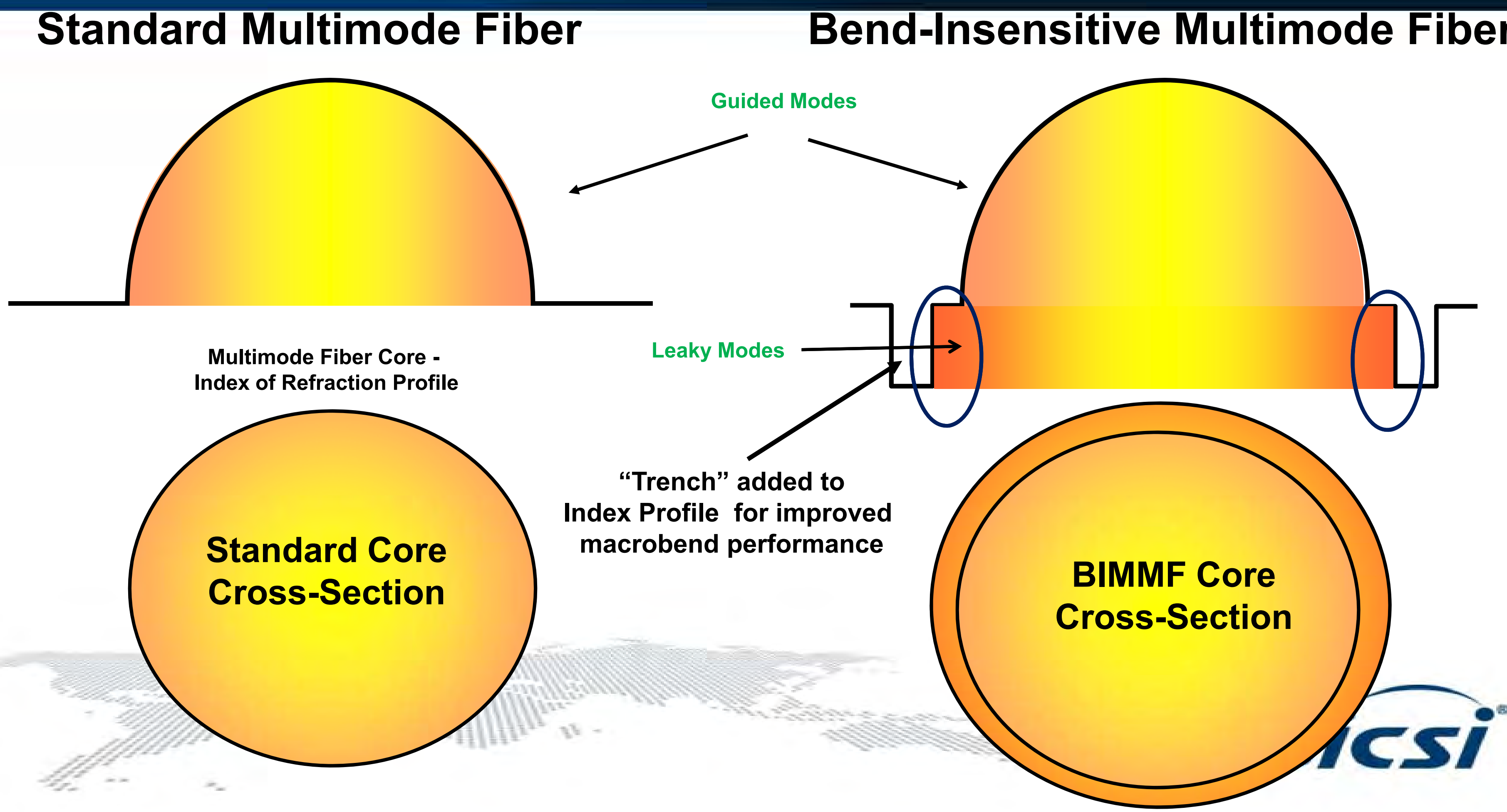
Measurement and testing of bend insensitive multimode fiber components

- IEC IEC 61300-3-4/Ed3: fiber optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-4: Examinations and measurements - Attenuation
- TIA FOTP 171

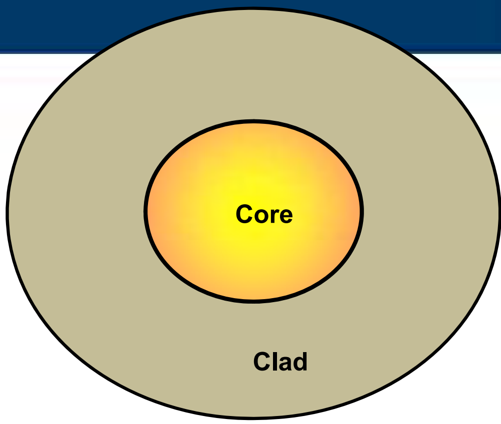
Proposals to revise these documents are being discussed in working groups IEC SC86B and TIA 42.13. This will be discussed later in this presentation as well

How Was Macrobend Performance Improved?

Comparison of Waveguides

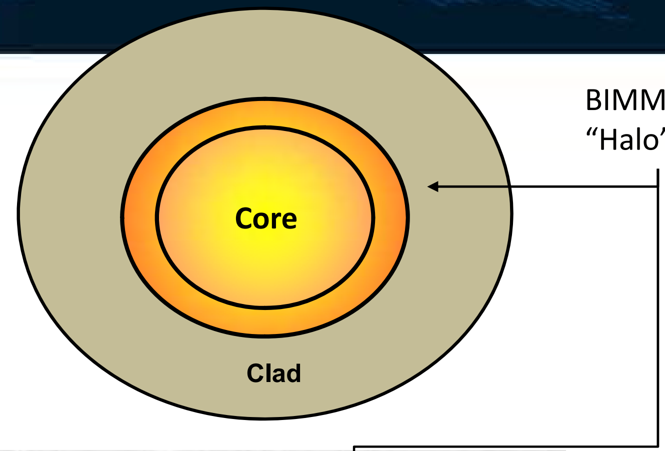


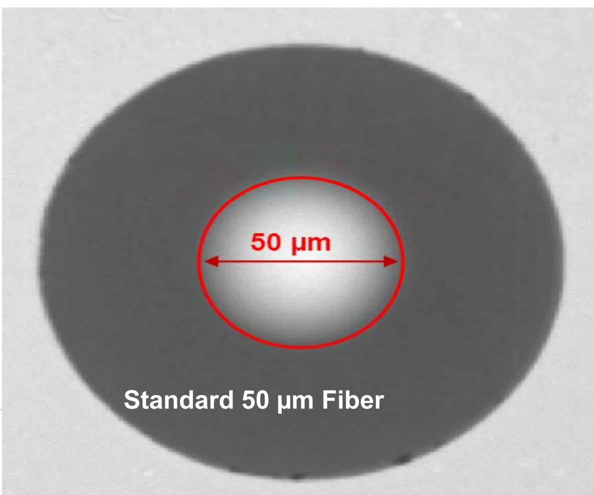
Standard Multimode Fiber and BIMMF Fiber Appearance



“Halo” provides a visual indicator of BIMMF

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





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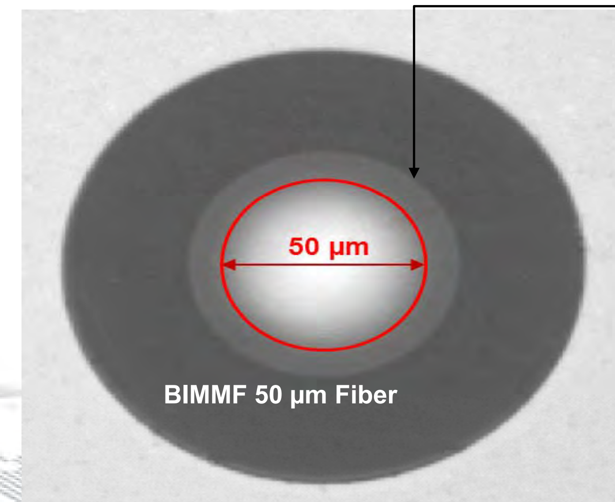
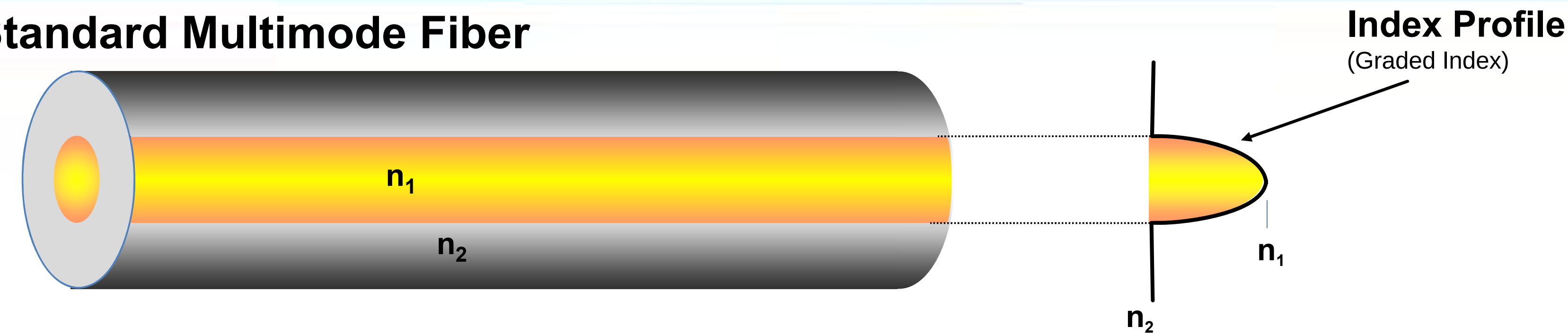
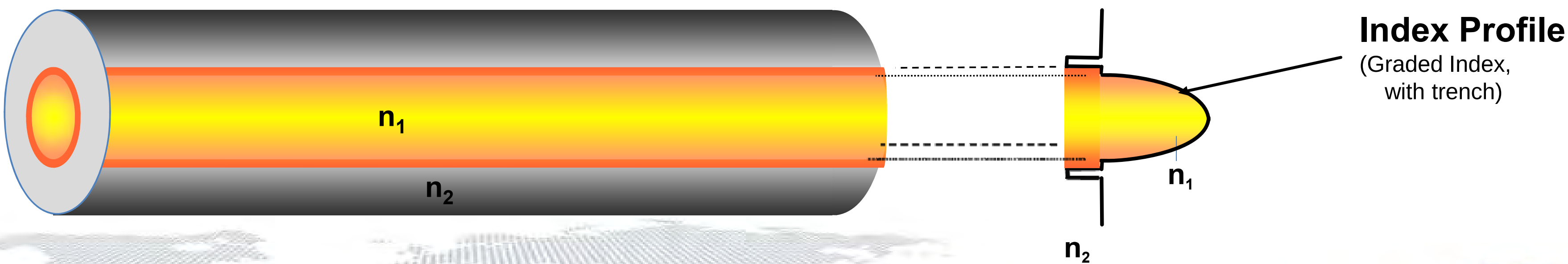


Comparison of Waveguides

Standard Multimode Fiber



Bend-Insensitive Multimode Fiber



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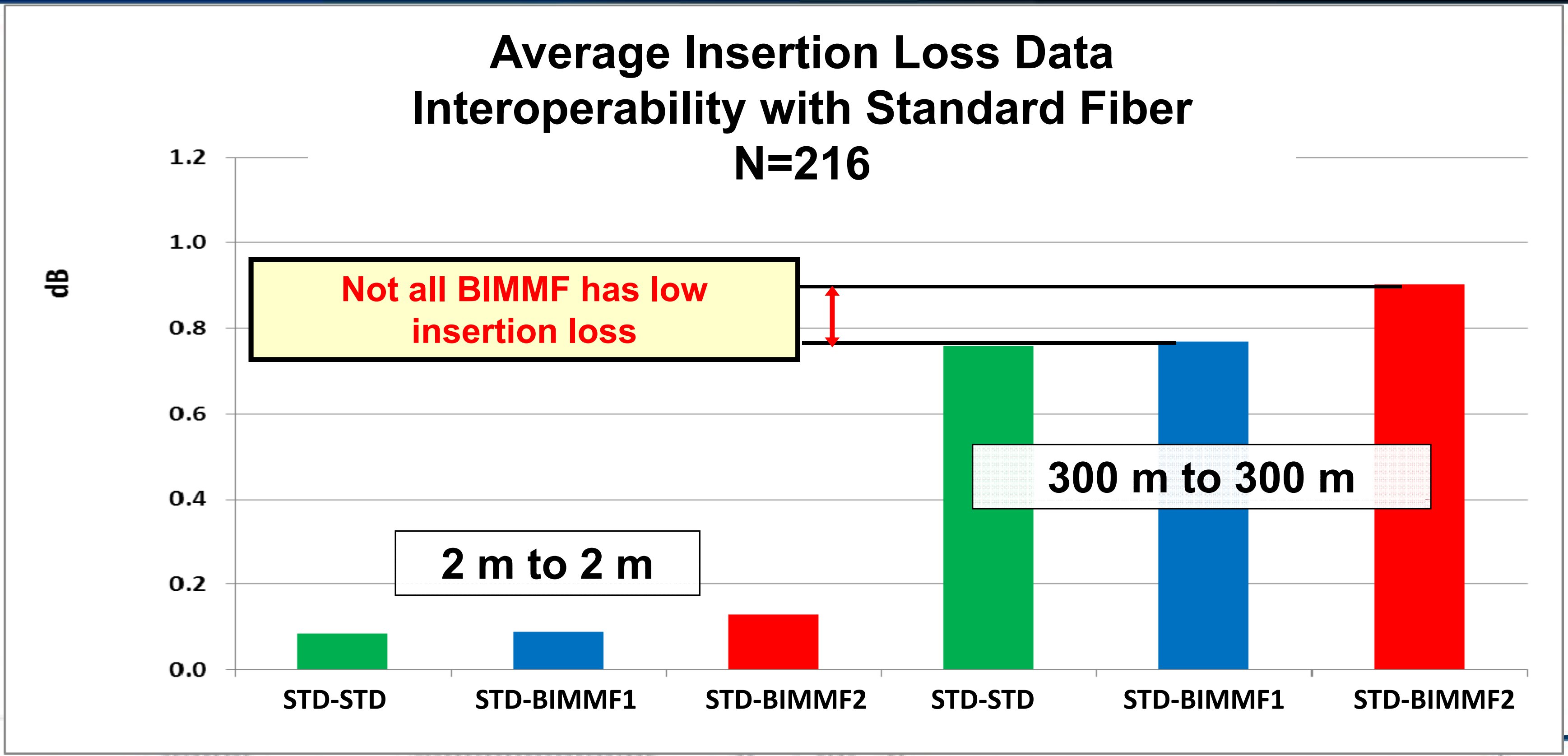
Characterizing BIMMF to Assure Interoperability

Compatibility of BIMMF



Matching Core Size and Numerical Aperture is Essential for Low-Loss Connections!

Fiber Design	Core Diameter		NA	
	2 m	**100 m**	**2 m**	**100 m**
Standard 50 µm	50 µm	50 µm	0.20	0.20
Bend insensitive 50 µm Fiber 1	51 µm	50 µm	0.21	0.20
Bend insensitive 50 µm Fiber 2	50 µm	49 µm	0.21	0.19

- **Matching long-length core diameter and NA provide best connection performance**
  - Outer modes distort short-length Core Diameter and NA values in BIMMF

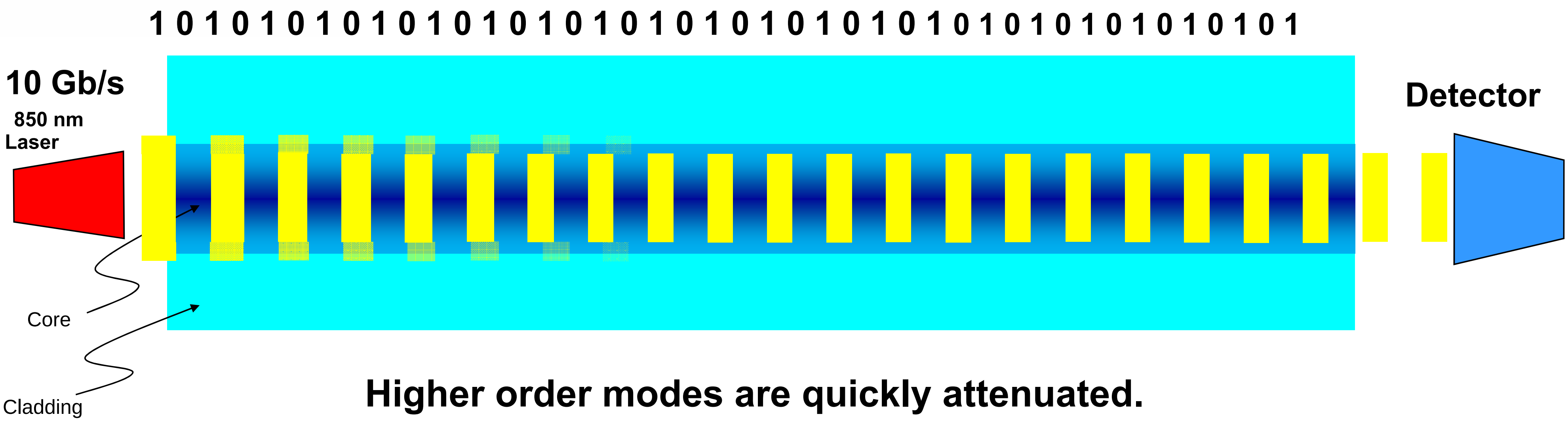
BIMMF Performance Comparison

	Low Bending Loss	Mating Loss and Backward Compatibility
Std. Fiber	X	✓
Bend insensitive 50 µm Fiber 1 (new test method)	✓	✓
Bend insensitive 50 µm Fiber 2 (old test method)	✓	X

This is why geometric measurements were modified for BIMMF

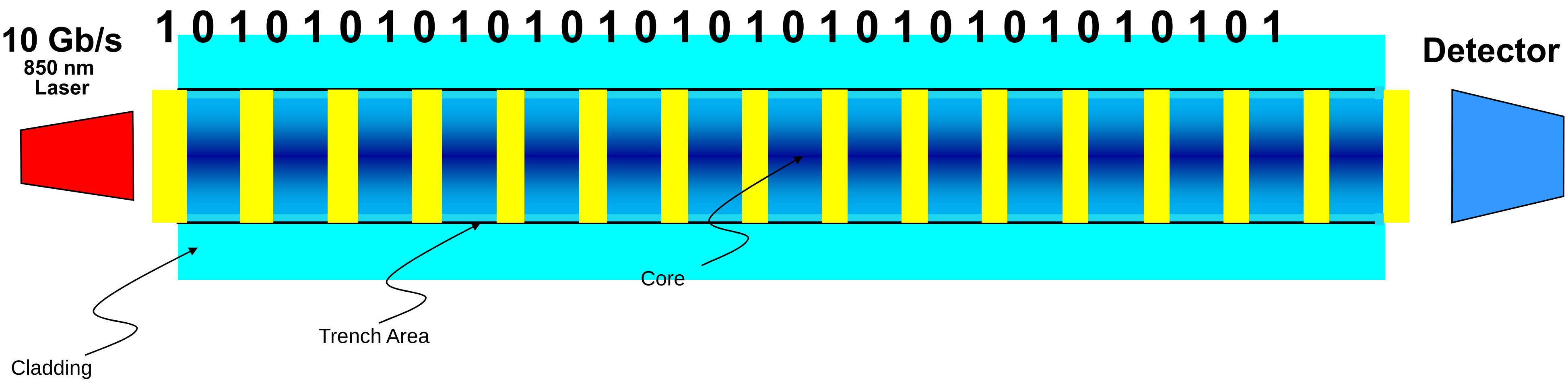
Bandwidth Measurement

Standard Multimode Fiber



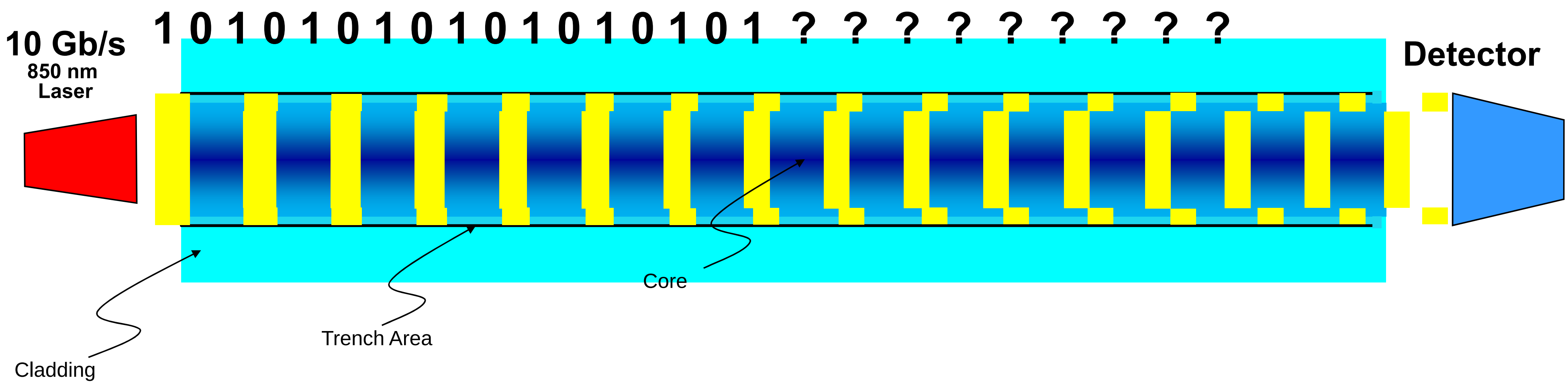
Higher order modes are quickly attenuated.
No effect on bandwidth.
Maximum transmission distance!

Bend insensitive multimode fiber with good high order mode control



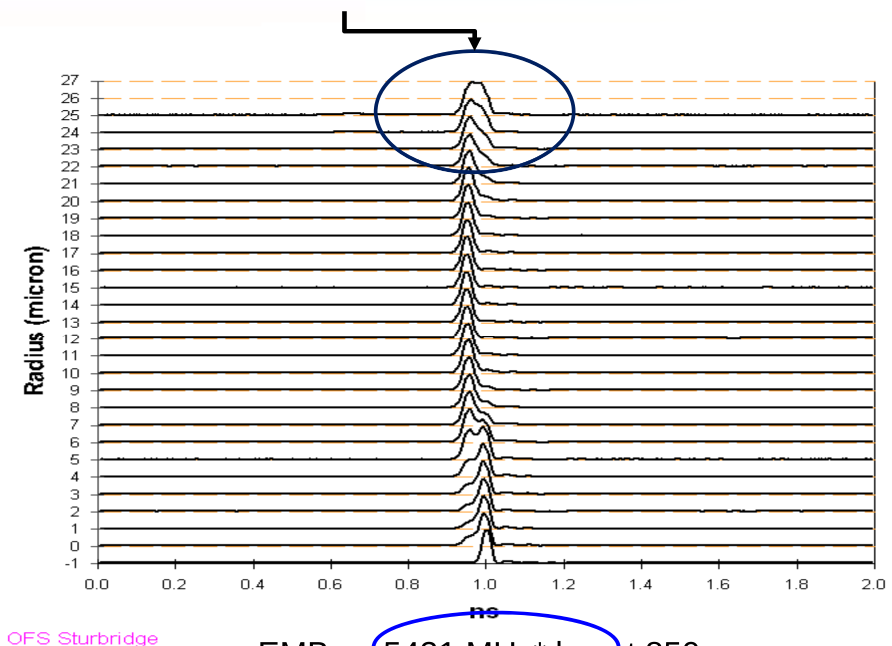
High order modes propagate better in all BIMMF designs

Bend insensitive multimode fiber with poor high order mode control



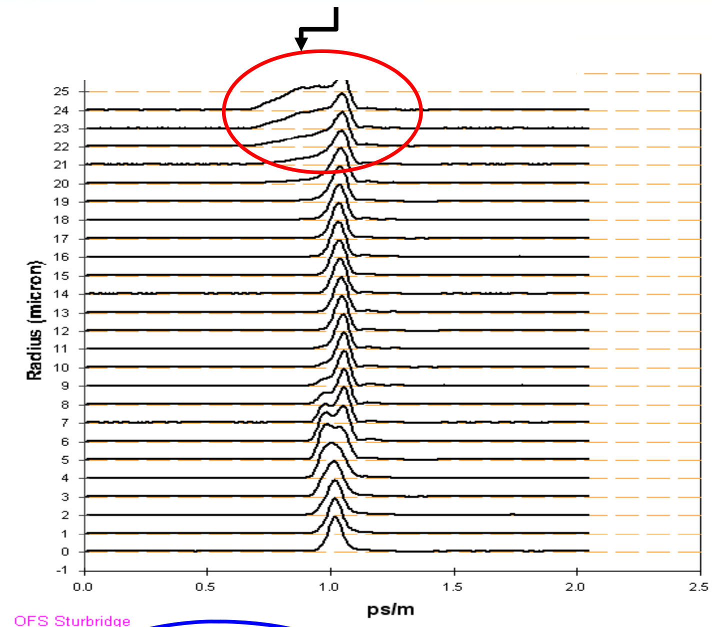
DMD Measurements of Fibers with Comparable EMBc

Good Outer Mode Control



EMBc = 5431 MHz* km at 850 nm
OFL Bandwidth = 5259 MHz* km at 850 nm

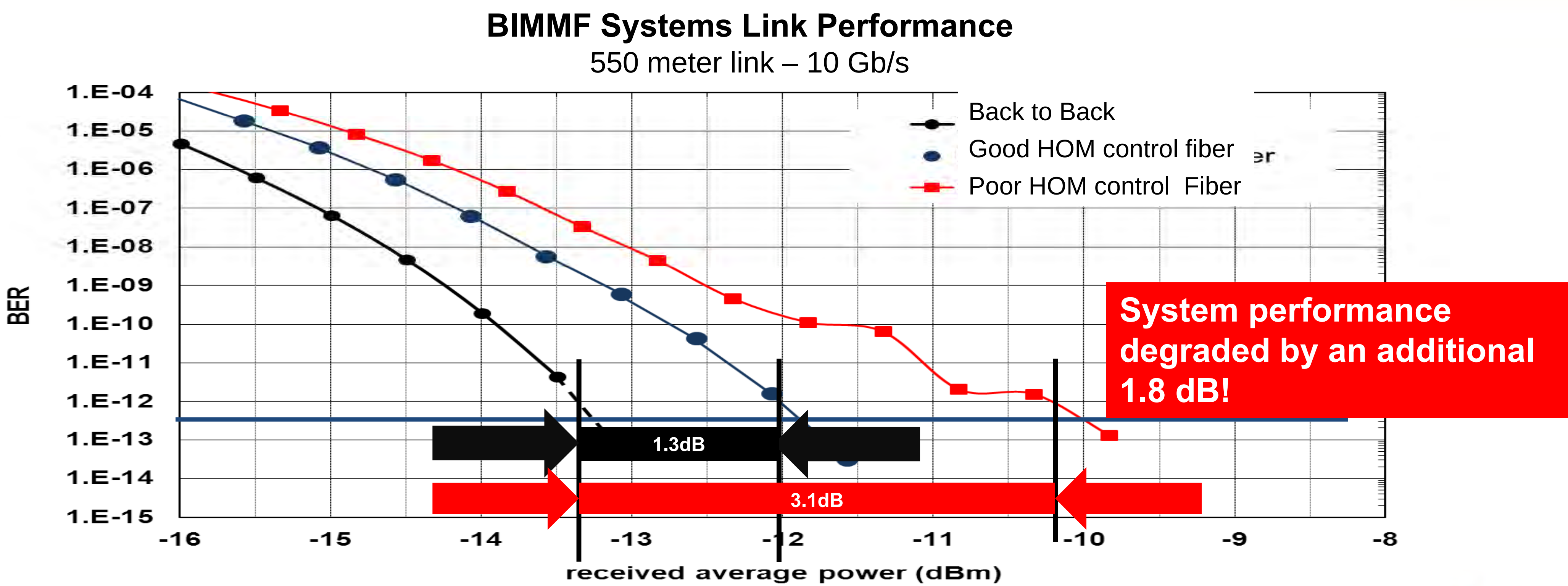
Poor Outer Mode Control



EMBc = 5512 MHz* km at 850 nm
OFL Bandwidth = 3522 MHz* km at 850 nm

Comparable EMBc

EMBc alone is not a reliable indicator of system performance!



New 850 nm bandwidth requirement

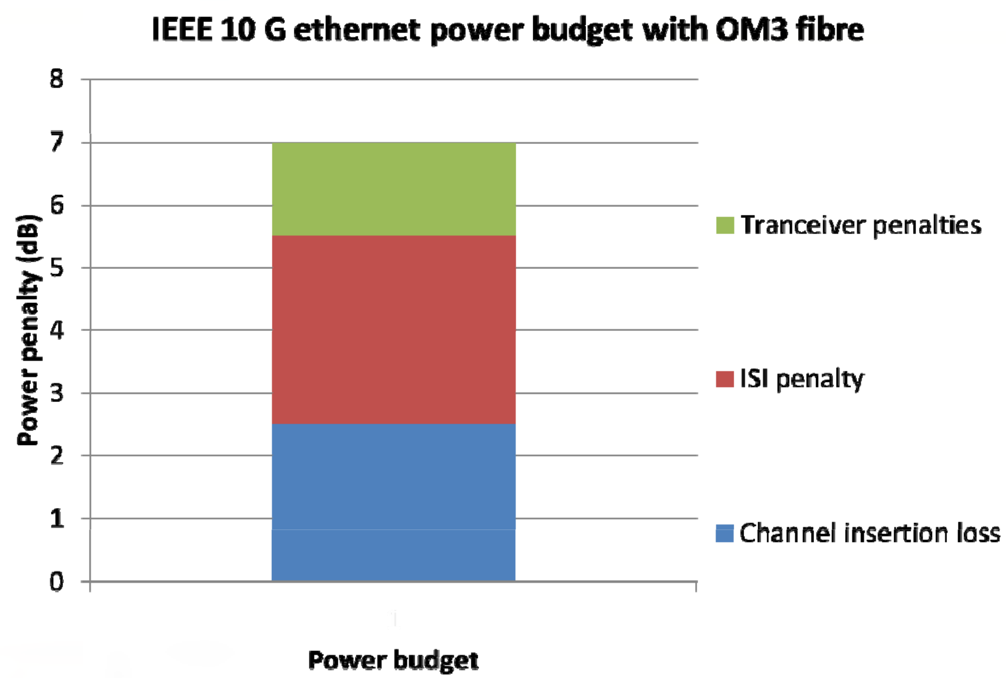
- Measuring high bandwidth fibers using overfilled launch method is challenging
- DMD test method provides similar information with much greater precision
- Reference test method for overfilled bandwidth will change from an overfilled launch measurement to an OMBc measurement

BIMMF Performance Comparison

	Low Bending Loss	Mating Loss and Backward Compatibility	Bandwidth
Std. Fiber	X	✓	✓
Bend insensitive 50 µm Fiber 1 (new test method)	✓	✓	✓
Bend insensitive 50 µm Fiber 2 (old test method)	✓	X	X

Data center link budget

- ISI penalty
  - System penalty due to bandwidth of the fiber.
- Channel insertion loss
  - Connection loss
  - Cabled attenuation
  - Macrobend loss

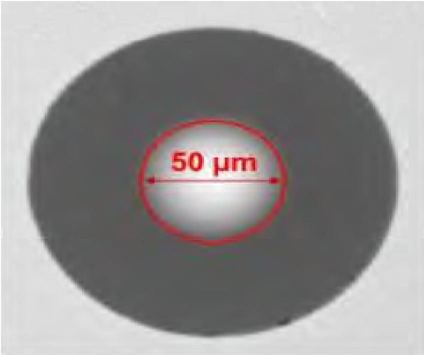


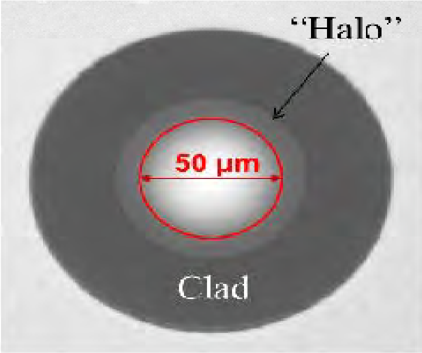
Test Methods for Characterizing BIMMF Links and Components

Measuring insertion loss of 50/125 multimode fiber jumpers

Use Encircled Flux Compliant Launch

- Recommend that all jumpers be tested with Encircled Flux compliant launch





- When using bend insensitive multimode fiber, light in the "halo" region can travel through short jumpers resulting in poor characterization of jumper performance.
- Using an encircled flux compliant launch helps mitigate this effect

Use reference grade test cords

Launch cord

- Reference grade cords help preserve encircled flux condition

Receive cord

- Helps filter any leaky modes that may result in measurement errors
- Ensures that core size and NA of jumper being tested are near nominal target

IEC procedure for testing multimode fiber jumpers

IEC 61300-3-4/Ed3: fiber optic interconnecting devices and passive components

- **Basic test and measurement procedures**
- **Part 3-4: Examinations and measurements - Attenuation**

Several methods are described in this document. The most relevant are:

- Substitution method - Not in FOTP 171
- Insertion method (C2) - Similar to FOTP 171 method D1
- Insertion method (C3) - Similar to FOTP 171 method B1

The current draft of the IEC document is the most recently updated document so it is recommended that we refer to this document when considering testing of jumpers

Substitution method

When using 3 reference patch cords the measurement method works with both standard and BIMMF

Not recommend because it is a relative not absolute measurement of the jumper quality.

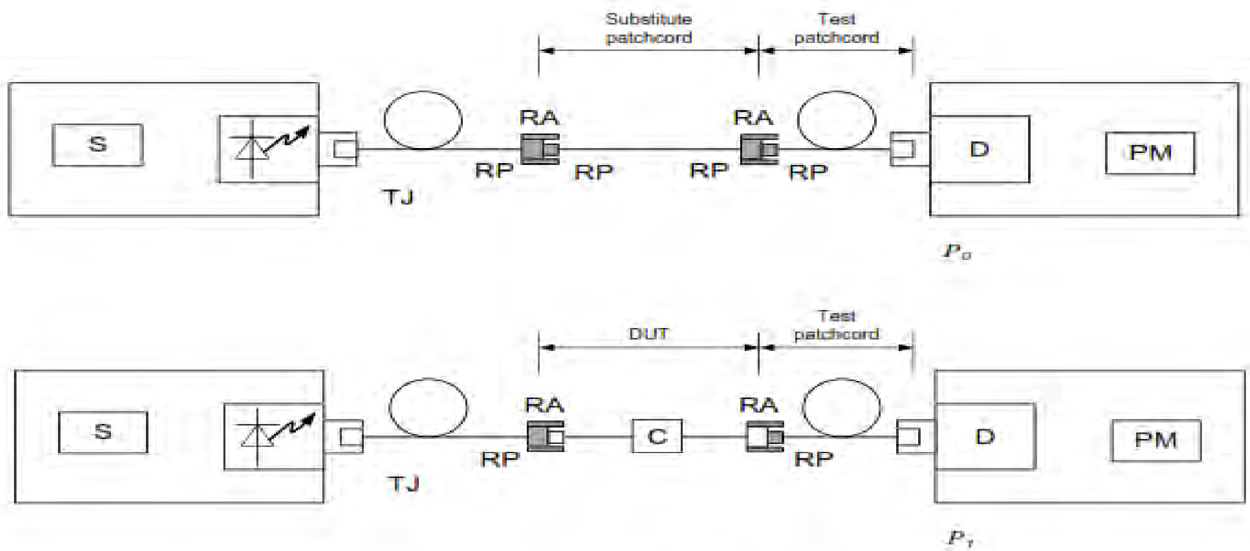


Figure 2 – Substitution method – Type 4 DUT

Insertion method (C2)

Poor method for characterizing BIMMF because it gives an artificially low connection loss when measuring BIMMF

Not recommended. Poor connectors can look good with this method. Connection loss can be off by several tenths of a dB

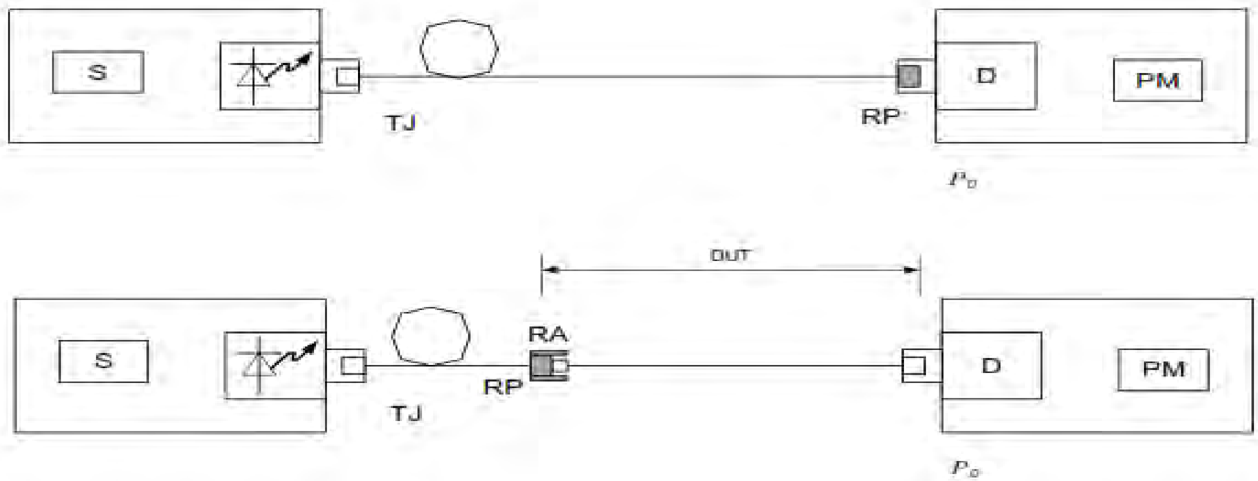


Figure 4 – Insertion method (C2) – Type 5 and Type 6 DUT

Insertion method (C3)

- Preferred method for characterizing BIMMF

- Results are closest to what will be observed in a deployed system.

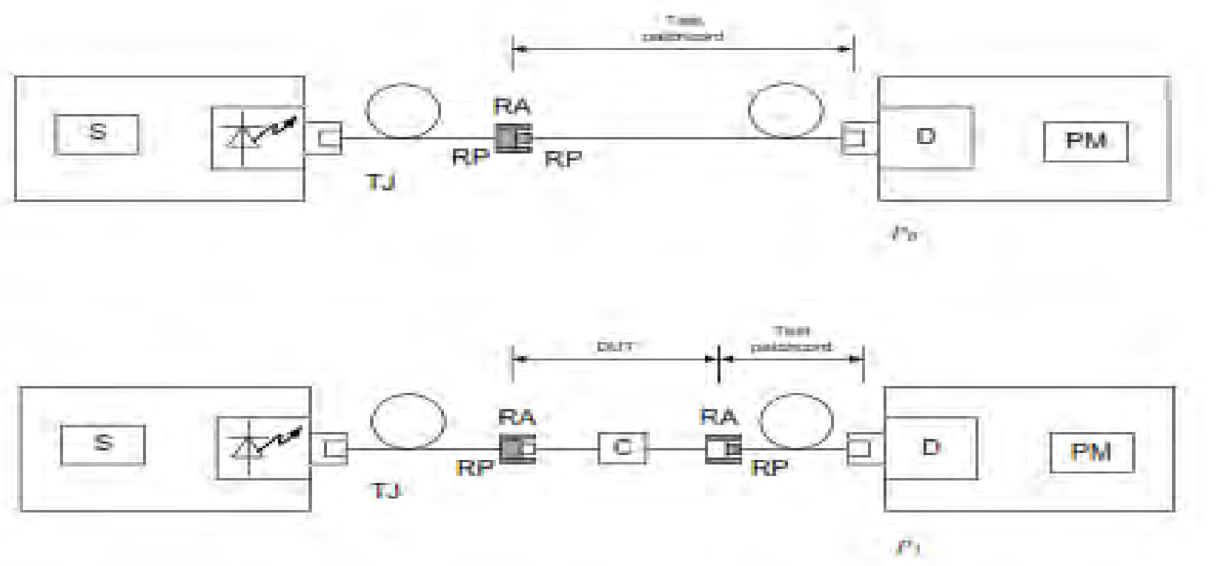


Figure 5 – Insertion method (C3) – Type 4, Type 5, Type 7 and Type 8 DUT

Initial study presented in TIA and IEC

- Methods C2 and C3 produce similar results for standard Multimode fiber
- Methods C2 and C3 differ by ~0.2 dB for Bend insensitive multimode fiber (We need to determine which answer is correct)
- New contributions being presented to IEC and TIA to assure jumper characterization is representative of system performance

Characterizing loss of Bend insensitive multimode fiber links

Use what we learned from testing Jumpers

- Launch is important
  - Use Encircled flux launch (Preferred method)
  - CPR / HOM launches are better than overfilled but not as good as encircled flux launch
- Standard MMF as a test cord
  - Using a BIMMF test lead can result in as much as 0.5 dB error in the loss measurements
- Standard MMF as a receive cord
  - Not using proper receive cord can result in ~0.1 dB error
  - Some vendors recommend the use of BIMMF as a receive cord but we have found that this introduces an optimistic attenuation measurement

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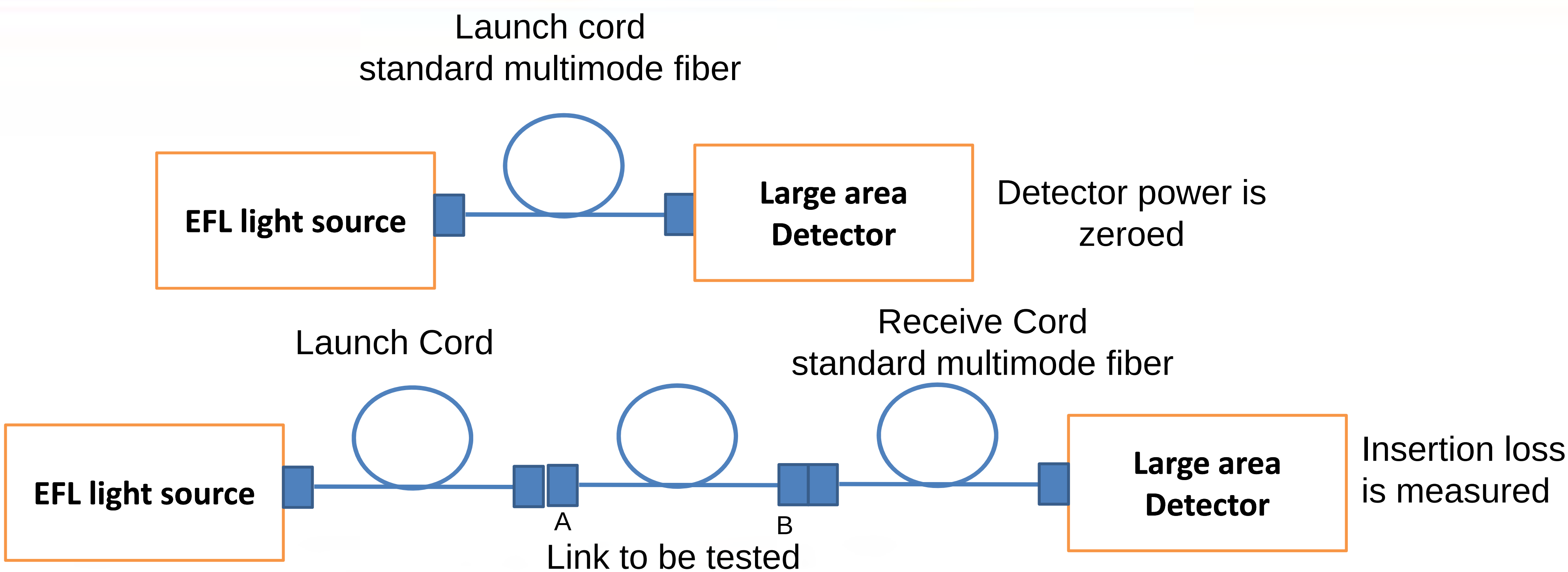
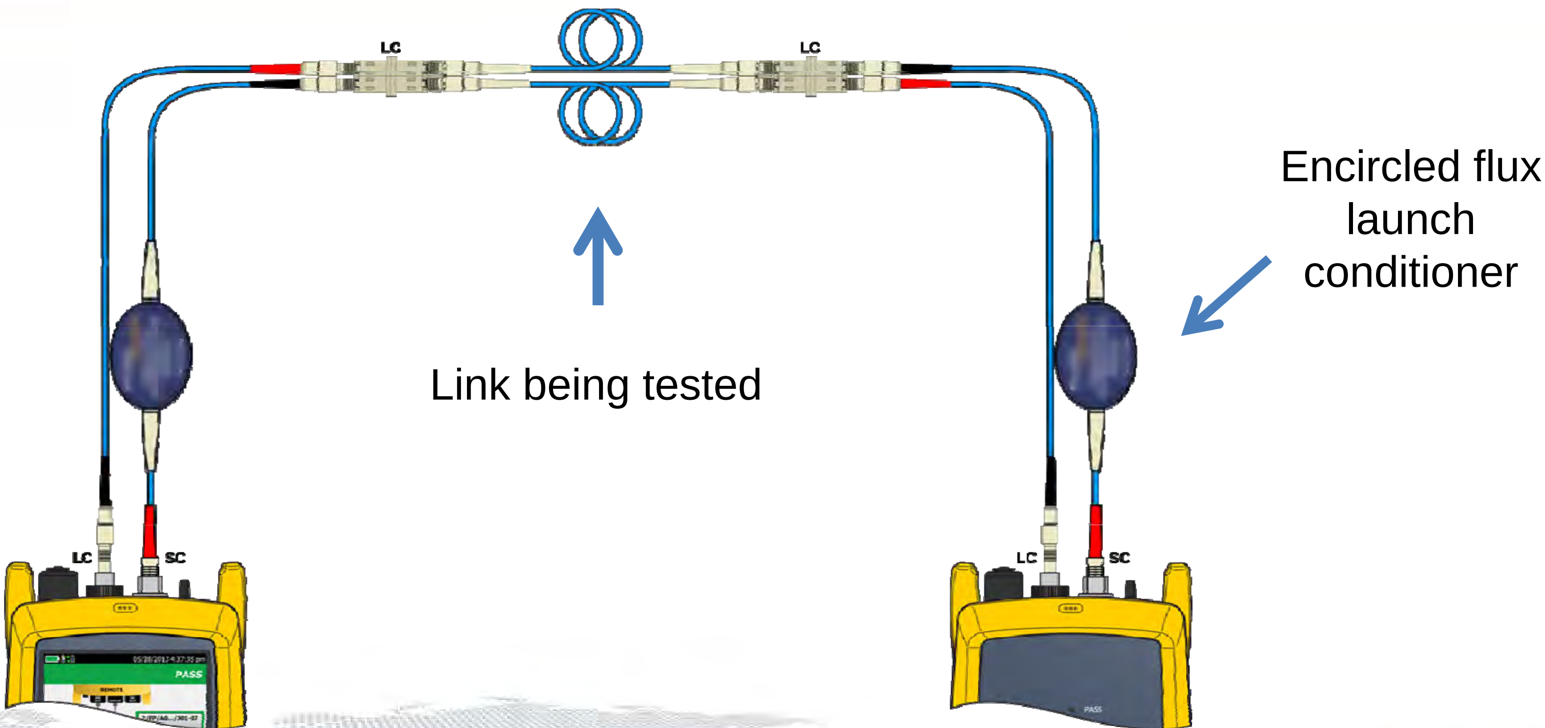
Testing Link with bend insensitive multimode fiber



Example of a duplex link test



What is next with multimode fiber?

Trends in the market

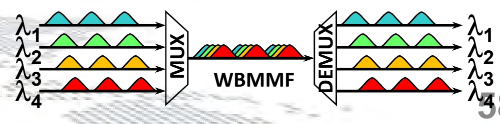
- Parallel transmission
  - **10 G on 1 fiber**
  - **40 G on 4 fibers**
  - **100 G on 10 fibers**
- Higher transmission speeds
  - **1 G**
  - **10 G**
  - **25 G**
- Multiple wavelengths (Something new!)

CDWM on multimode

- Currently active project in TIA with experts from other standards organizations
- Fiber targeted to be backward compatible with OM4 fiber
- Fiber targeted to support ethernet and fiber channel links from 850 nm to 950 nm

MMF Cabling Evolution Map

	10G Parallel Tx Rx	25G Parallel Tx Rx	25G Par + WDM Tx Rx
40G		n.a.	n.a.
100G			
400G	n.a.		



Conclusion

- Bend insensitive fiber standards are technically agreed upon. Published documents will be avialble in the next 6 months in IEC and a 9-12 months in TIA
- Bend insensitive multimode fiber interoperates seamlessly with standard multimode fiber in deployed links
- It is essential that proper test methods are used for characterizing links containing bend insensitive multimode fibers