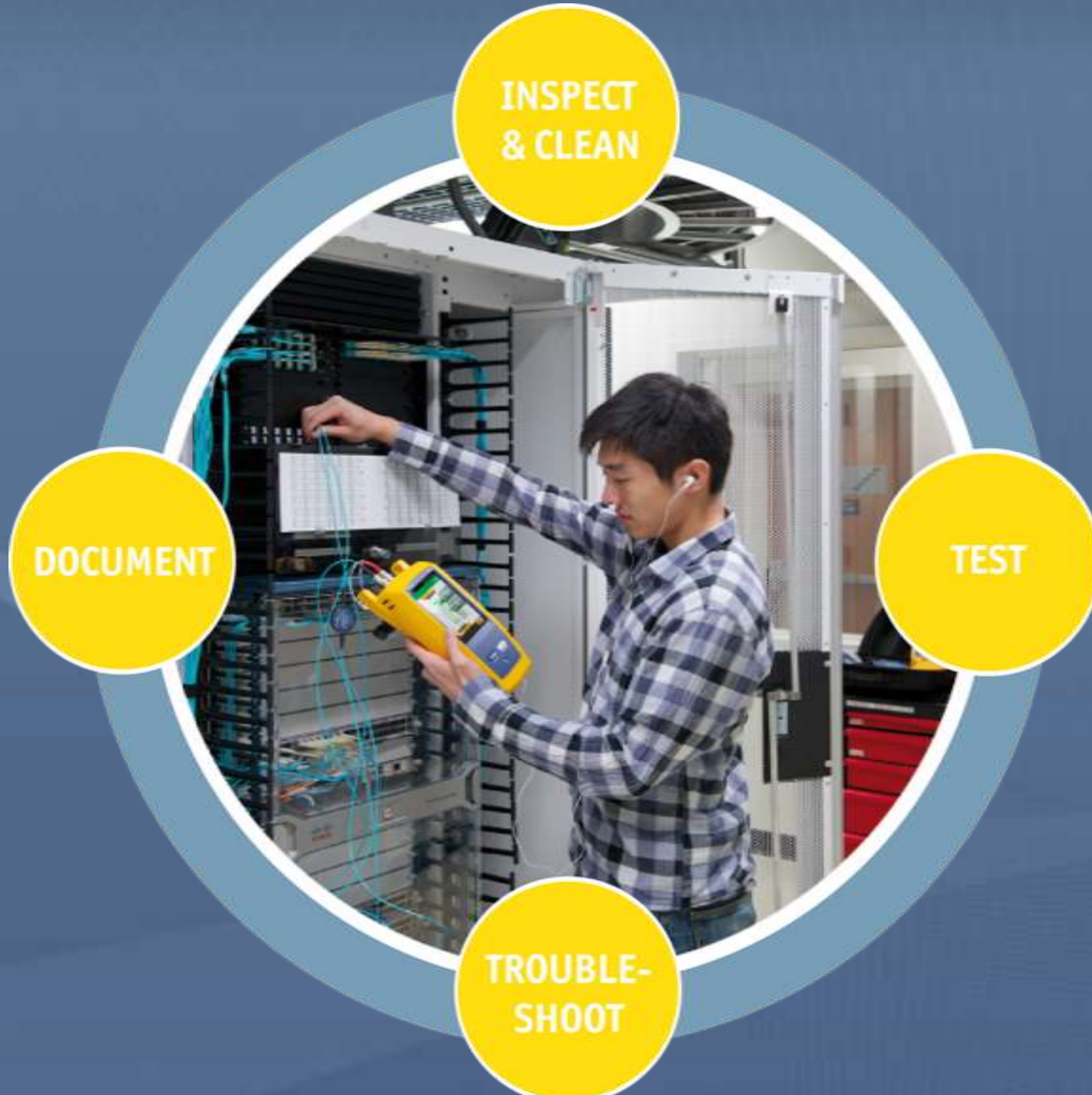
Fiber Excellence Best Practices



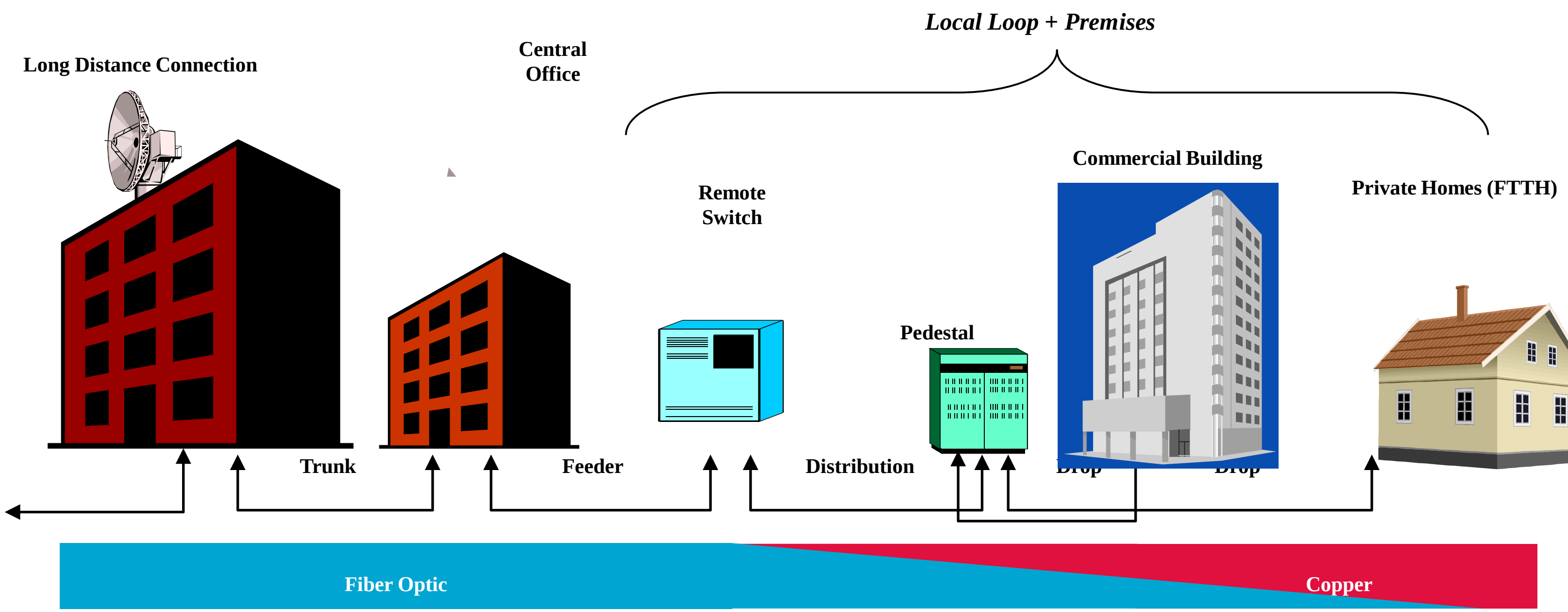
FLUKE networks

Prepared by:
Robert Luijten, Global Field Marketing Manager
Christian Schillab, Senior Product Specialist

Fiber Excellence Agenda

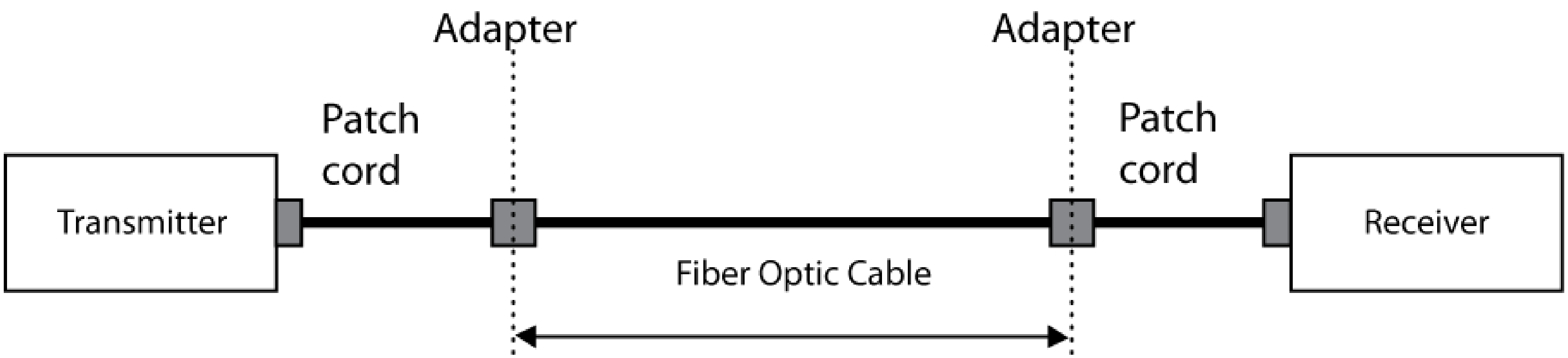
- **Optical Fiber Basics**
- **End-face Inspection and Cleaning**
- **Test - Loss/Length Certification**
- **Fiber Plant Characterization and Troubleshooting**
- **Documentation**

Where's the Optical Fiber ?

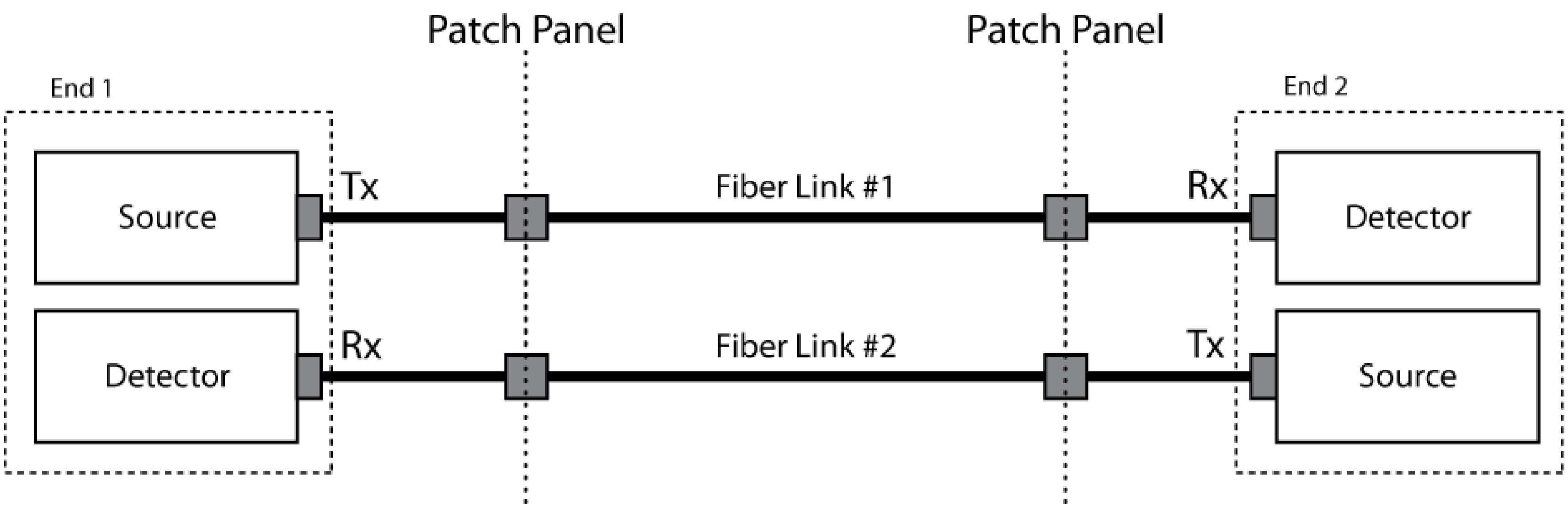


FTTH Connection waiting to be connected to a home in the Netherlands

What is fiber optic transmission?



Fibers Are Usually Used in Pairs

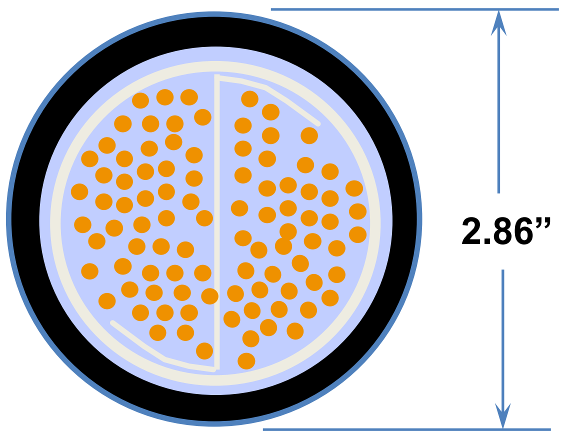


Why Install Fiber Optics

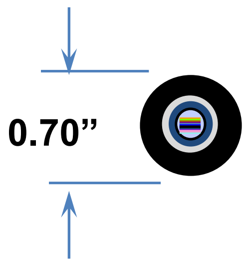
- Low Signal Loss
- High Bandwidth
- Not Affected by EMI or RFI
- Small Size
- Lightweight
- Higher port density on electronics
- Electronics require less power and produce less heat for high bandwidth applications

Why Install Fiber Optics

900 Pair Copper Cable



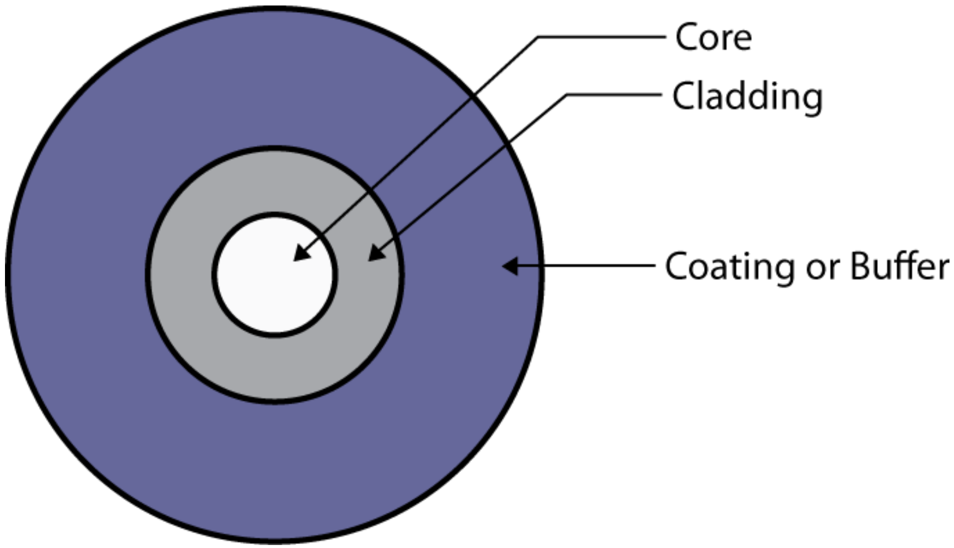
216 Fiber Optical Cable



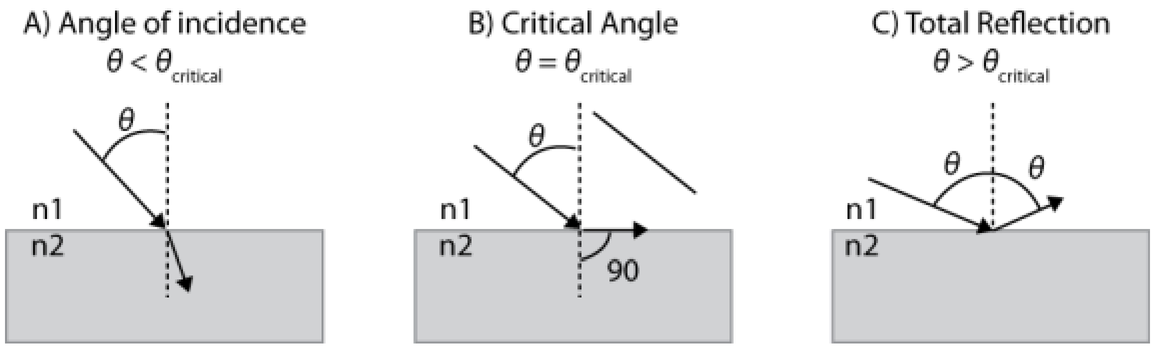
Media Type	22 Gauge Copper	SingleMode Fiber
Weight	4800 lbs / 1000 feet	200 lbs / 1000 feet
Transmission Rate	1.54 MB/sec	40x 10 GB/sec
# 2-way phone calls	10,800	27,869,000
Regenerator Spacing	1.14 miles	72 miles

Optical Fiber

- Uses light pulses instead of electrical signals
- Core & Cladding are composed of glass
  - Cladding prevents light loss in bends: allows complete internal reflection
- Core diameter defines fiber type (MultiMode: 50µm,62.5µm; SingleMode: 9µm)
- Cladding diameter = 125 µm
- Coating of Strengthening Material is UV curable urethane acrylate (2-Layers)
- Coating diameter = 250 µm

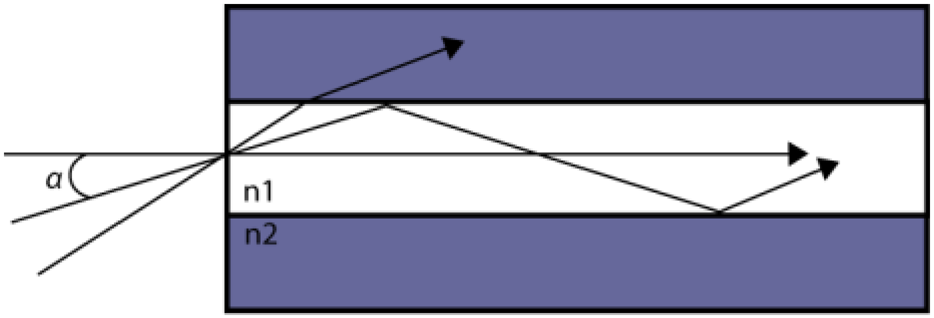


Index of Refraction – How light is kept in the core



- Total internal reflection occurs because light travels at different speeds in different materials.
- The core of the optical fiber has a higher index of refraction than the cladding, that is n1 > n2. see above example C. This allows for total internal reflection.

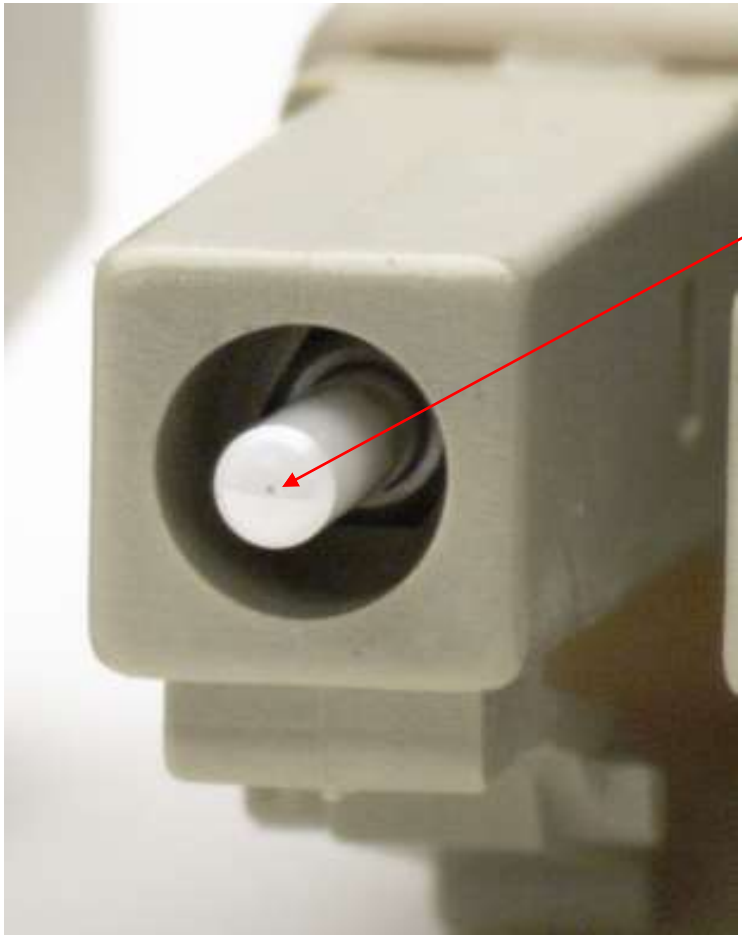
Total Refection – MultiMode Fiber



Core index of refraction n1 = 1.47
Cladding index of refraction n2 = 1.45

- Light that enters at less than the critical angle is guided along the fiber.
- The light reflects at the boundary between the core and the cladding and travels along different paths. A path is also called a mode.
- There are three different rays of light are pictured above:
  - *One mode travels straight down the center of the core.*
  - *A second mode travels at a steep angle and bounces back and forth by total internal reflection.*
  - *The third mode exceeds the critical angle and is refracted into the cladding and lost as it escapes into the air.*

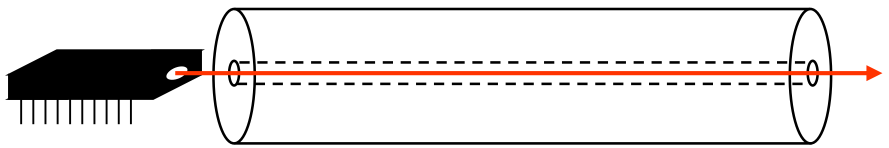
The fiber is VERY small!



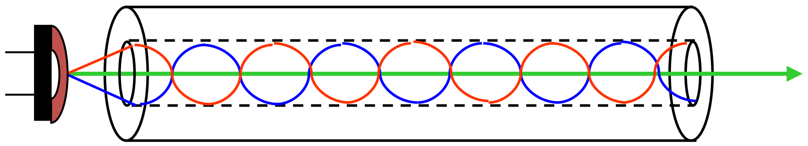
- Can you see the fiber in the center of the ferrule?
- You are actually viewing the cladding and the core. (125µm diameter)

Optical Fiber Types

- SingleMode

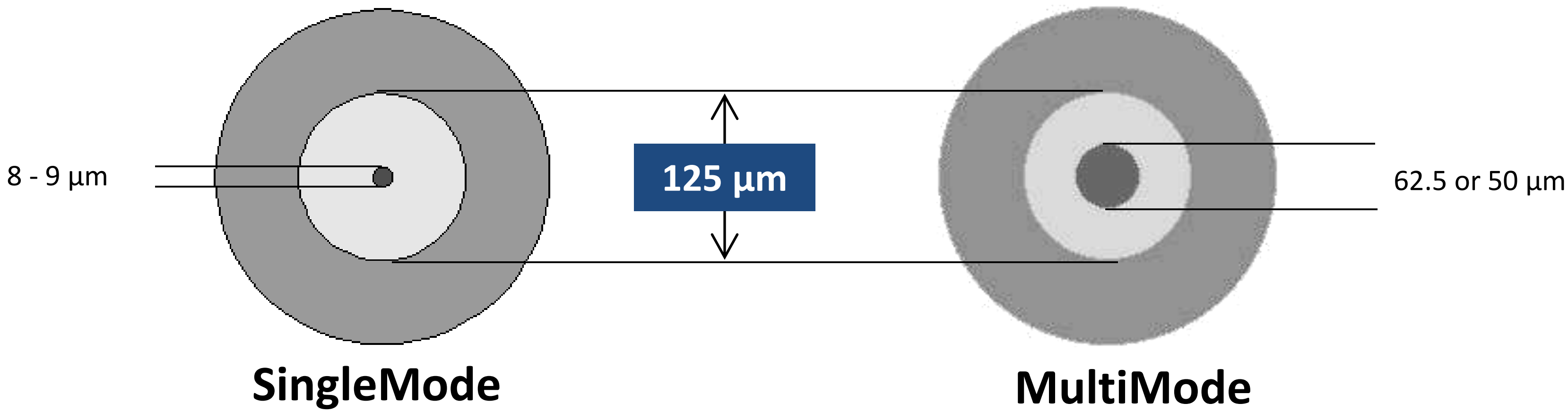


- MultiMode



The radius, r, and index of refraction, n_1, of the core determines the number of modes allowed to propagate:
Number of Modes ≈ $\Delta(2\pi n_{core} r_{core}/\lambda)$

Optical Fiber Types



Media Type	SingleMode Fiber	MultiMode Fiber
Cost	Inexpensive	Expensive
Core diameter / splicing cost	Very small core; expensive splicing	Large core; inexpensive splicing
Attenuation / Distance	Low attenuation; longer distance	Higher attenuation; shorter distance
Bandwidth / Capacity	Higher bandwidth; high capacity	Lower bandwidth; lower capacity
Transmitter Cost	High	Low

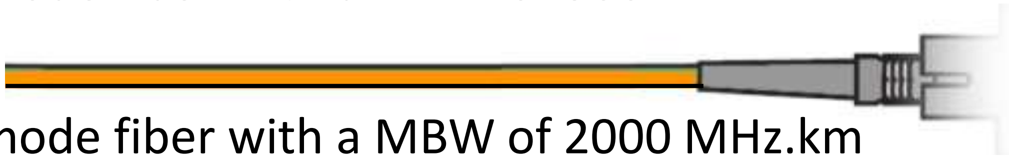
MultiMode Optical Fiber Types

		Cable attenuation coefficient (dB/km)		Minimum modal bandwidth (MHz•km)		
				Overfilled		Laser
Wavelength (nm)		850	1300	850	1300	850
Optical fiber type	Core diameter (µm)					ISO/IEC 11801 Ed.2.2 (2011)
OM1	50 or 62.5	3.5	1.5	200	500	Not specified
OM2	50 or 62.5	3.5	1.5	500	500	Not specified
OM3	50	3.5	1.5	1500	500	2000
OM4	50	3.5	1.5	3500	500	4700

Designation

The following now applies to ANSI/TIA-568-C and ISO/IEC 11801:2010

- **OM1**: 62.5 µm multimode fiber with a MBW of 200 MHz.km
- **OM2**: 50 µm multimode fiber with a MBW of 500 MHz.km



- **OM3**: 50 µm multimode fiber with a MBW of 2000 MHz.km

- **OM4**: 50 µm multimode fiber with a MBW of 4700 MHz.km

- **OS1**: 9 µm singlemode fiber

Factors Affecting Optical Fiber Performance

- Factors Affecting Light Losses or Attenuation
  - Intrinsic
  - Bending Losses
  - Splice Losses
- Factors Affecting Light Pulse Broadening (= bandwidth limiting)
  - MultiMode Dispersion
  - Chromatic Dispersion
  - Polarization Mode Dispersion

FLUKE networks

Attenuation

- Attenuation is amount of signal (light) that is lost as the light travels along the fiber.
- Attenuation is measured in Decibels (dB) per Kilometer (km) at specified wavelengths, measured in nanometers (nm).
- Typical Attenuation for various types of optical fiber

Fiber Type	850 nm	1310 nm	1550 nm
SingleMode	N/A	0.35 dB/km	0.25 dB/km
MultiMode	3.5 dB/km	1.5 dB/km	N/A

Sources of Attenuation

Attenuation in optical fiber is caused by several intrinsic and extrinsic factors:

- Two intrinsic factors are scattering and absorption.
- Extrinsic causes of attenuation include cable manufacturing stresses, environmental effects, and physical bends in the fiber.

Sources of Attenuation - Intrinsic

Raleigh Scattering

– Is caused by microscopic non/uniformities in the optical fiber. They cause the light to partially scatter as it travels through the fiber

- Rayleigh scattering increases sharply at short wavelengths.
- Strongest source of attenuation in modern fibers

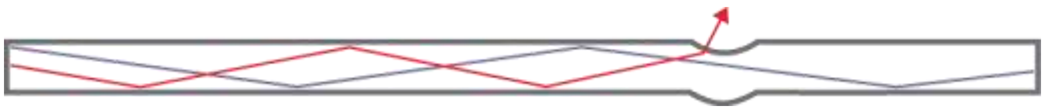
Absorption

– These are material impurities that absorb the optical energy an dissipate it as a small amount of heat.

- It contributes little to the overall loss.

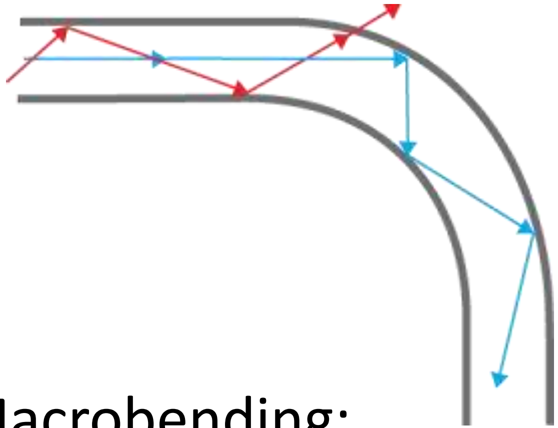
Note: Poor glass quality includes bubbles in glass, impurities and glass density changes.

Sources of Attenuation – Extrinsic



Microbending:

- *Is caused by microscopic imperfections in the geometry of the fiber resulting from the manufacturing process such as rotational asymmetry, minor changes in the core diameter, or rough boundaries between the core and cladding.*
- *Can be induced during installation due to point pressures.*



Macrobending:

- *Some light in the higher order mode groups is no longer reflected and guided within the core.*
- *Affects long wavelengths first.*
- *Affected mostly by fiber design.*
- *The standards actually describe the bend radius limits.*

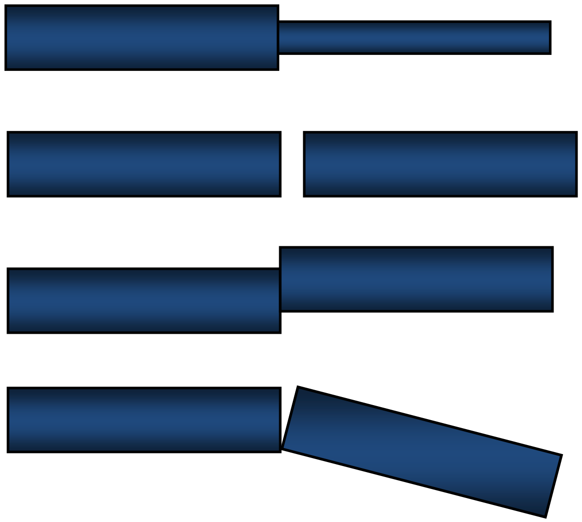
Splice / Fusion Loss:

- Fusion: core alignment
- Mechanical: core alignment, dirt on end face, reflection

Sources of Attenuation: Coupling Losses

Losses at splices and connectors, including test equipment connectors:

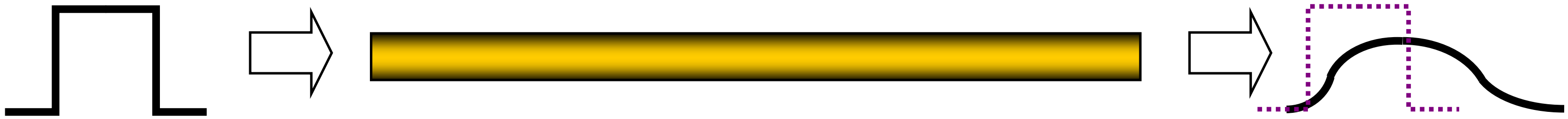
- *Area mismatch*
- *Spacing loss*
- *Axis misalignment*
- *Angular misalignment*



Keep in mind there can also be core diameter differences and core/cladding concentricity errors.

NOTE: Coupling loss is the dominating contributor to the the overall link loss in premise and Data Center cabling.

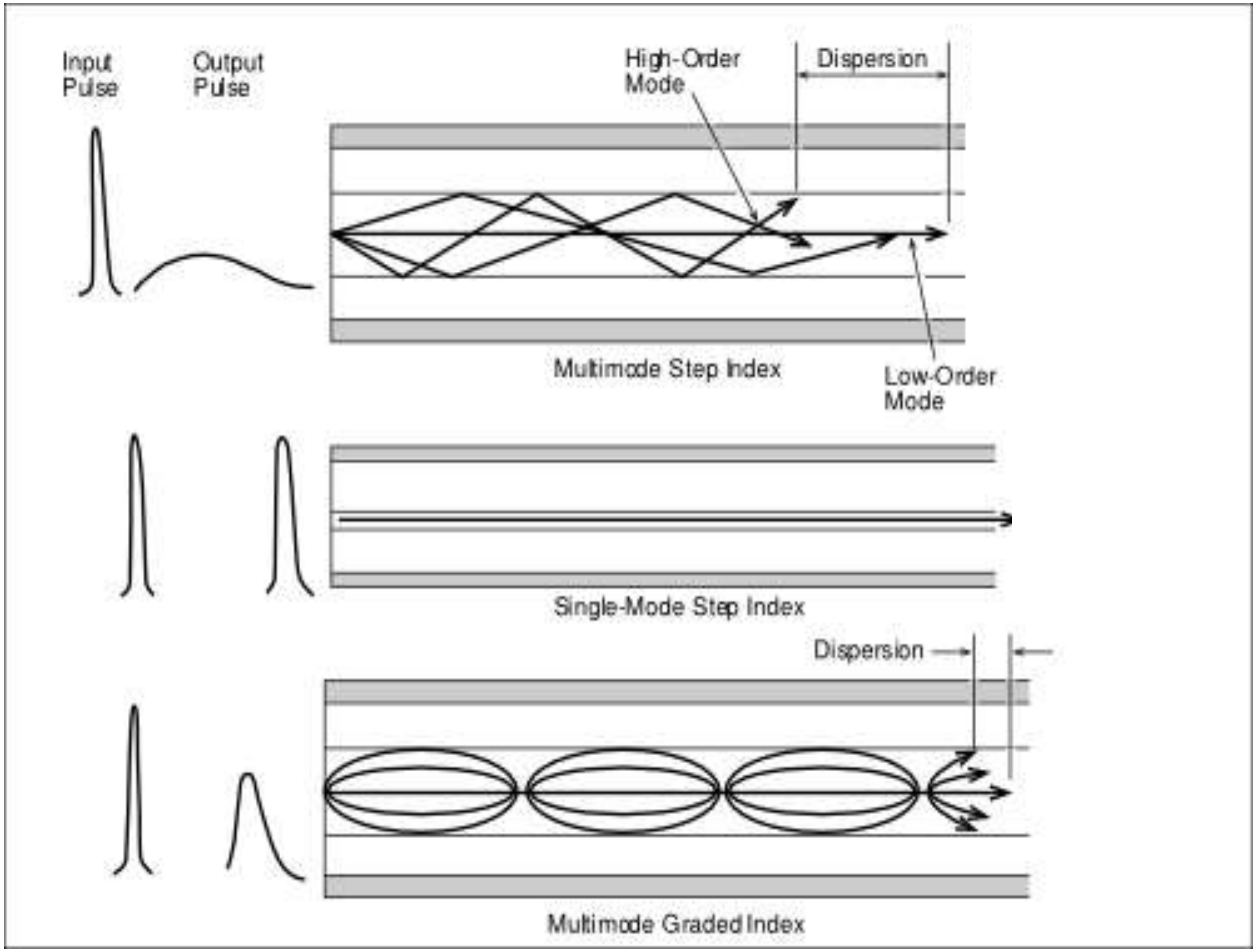
MultiMode Dispersion



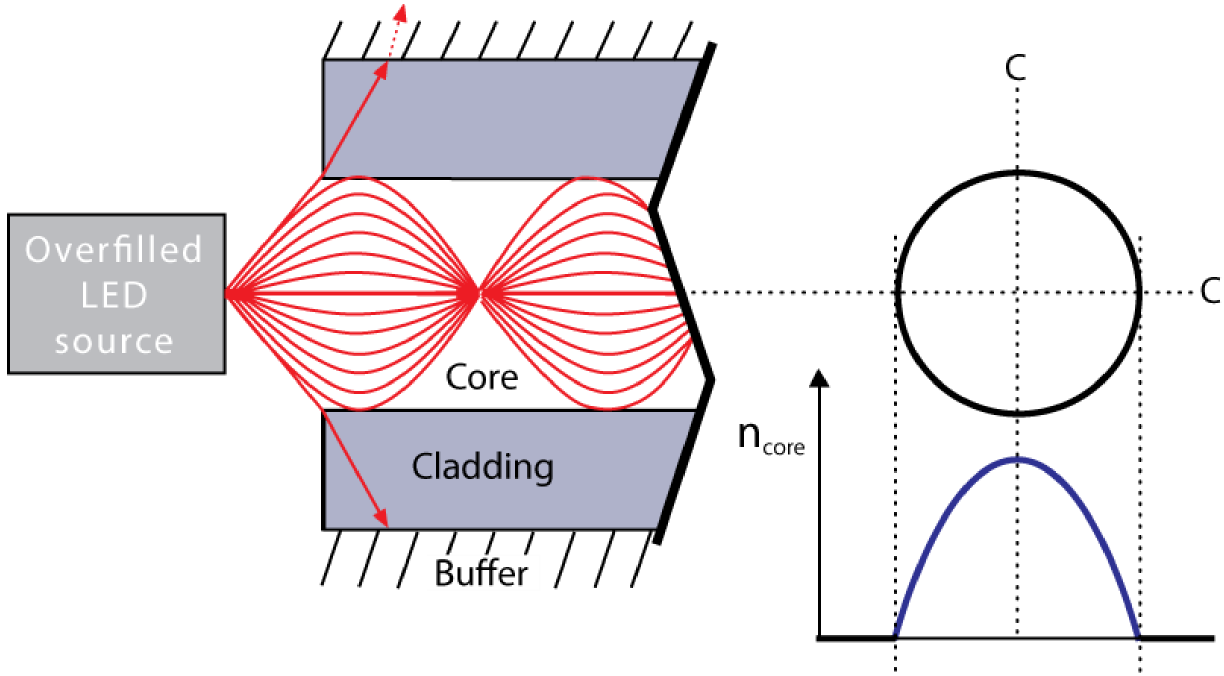
- Spreading of the pulses of light as they travel along the fiber link
- Multimode optical fiber guides the light along multiple paths or modes. The light that enters at the wider angle takes more bounces and travels a longer way. It represents the higher order modes.
  - *This disparity between arrival times of the different light rays is known as dispersion*
  - *The result is a muddied signal at the receiving end.*
  - *Imperfect core structure causes modes to have different speeds*
- Dispersion can be reduced:
  - *Use smaller core diameter – reduces the number of modes*
    - *Graded-index fiber*
    - *SingleMode fiber*

NOTE: Dispersion is the reason for length limits in the standards and is not a common field measurement in premise cabling due cost / effort and relevance.

MultiMode Dispersion



Graded Index Multimode Fiber

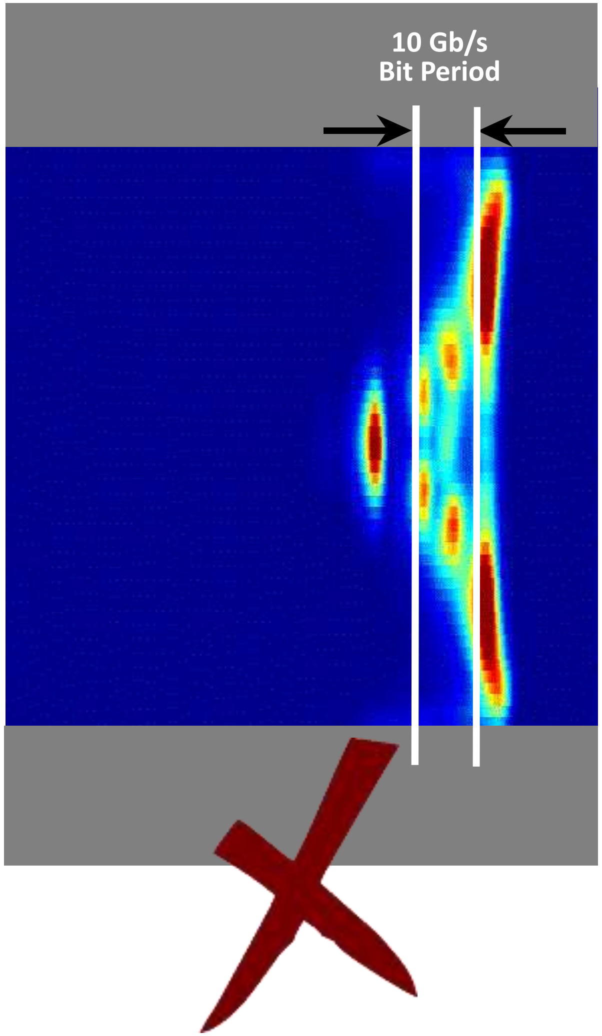


The refraction index of the core changes throughout the core. It is highest in the center and gradually decreases toward the boundary with the cladding.

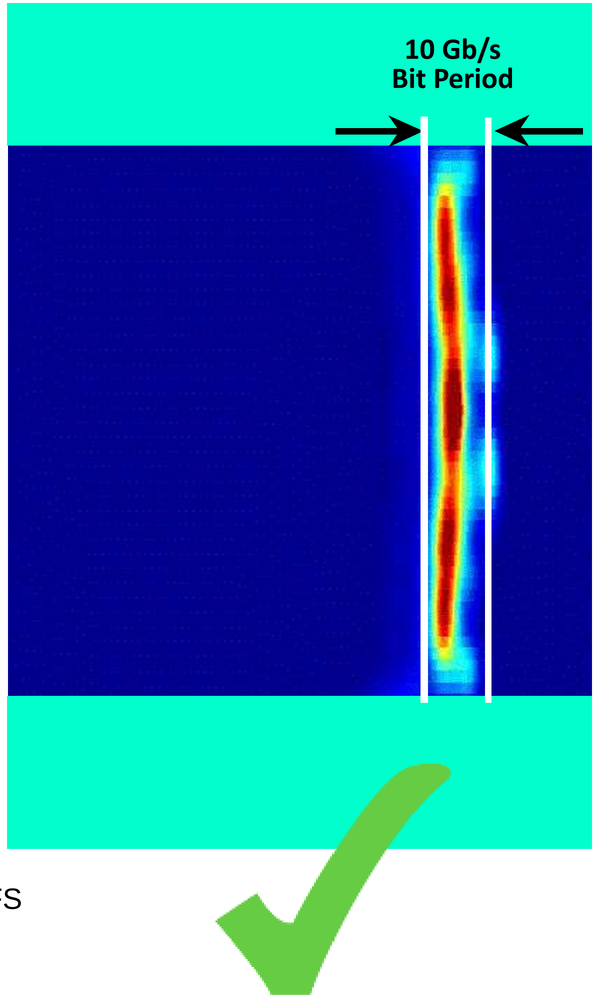
- *Graded index multimode fiber therefore provides better bandwidth thanks to curvature and smoothness.*

MultiMode Dispersion

Standard 62.5 µm vs. Laser Optimized 50 µm Fiber:
Received pulse at 10 Gb/s over 300 meters



Fiber Core Center



Graphics courtesy of OFS

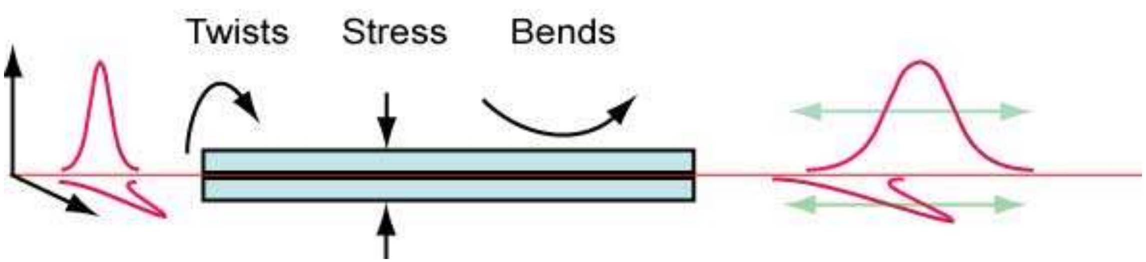
Chromatic Dispersion

- A Laser output is a distribution of wavelengths. These different wavelengths or "colors" propagate at different speeds, *even within the same mode*. This causes smearing of the received optical signal
  - There is dispersion compensating fiber
- This dispersion is wavelength dependant: standard fiber, both MultiMode and SingleMode, has zero dispersion as 1310nm.
  - If you an operate a fiber at the zero dispersion wavelength with a monochromatic light source, the bandwidth of the fiber will be very large.

Graphic courtesy of The Fiber Optic Association

Polarization Mode Dispersion (SingleMode only)

- Complex optical effect.
- Most single-mode fibers support two perpendicular polarizations of the original transmitted signal. If a fiber was perfect, i.e. perfectly round and free from all stresses, both polarization modes would propagate at exactly the same speed.
  - Radial imperfections of the core cause the two perpendicular polarizations to travel at different speeds and consequently they arrive at the end of the fiber at different times



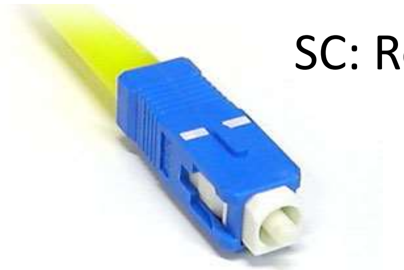
Graphic courtesy of The Fiber Optic Association

Applications limited by dispersion

				10GBASE-SR	40GBASE-SR4 and 100GBASE-SR10
Optical fiber type	Core diameter (µm)	Minimum modal bandwidth	850 nm fixed loss (dB)	Length (m)	Length (m)
OM1	62.5	160	2.6	26	N/A
		200	2.5	33	N/A
		220	2.5	33	N/A
OM2	50	500	2.3	82	N/A
OM3	50	2000	2.6	300	100
OM4	50	4700	2.6	400	150

- 50 /125 µm has less dispersion – it's core is smaller than 62.5/125 µm fiber.
- Your loss may be lower than the allowed fixed loss, but if it exceeds the length found here (IEEE 802.3) there may be errors on the network.
- For further information: **Next Generation 40Gb/s and 100Gb/s Optical Ethernet Study Group**.

Styles Of Connectors



SC: Rectangular, push-push lock, the most rugged

ST: Very popular, bayonet lock, keyed

FC: Screw-on lock, keyed

MIC (designed for FDDI), dual fiber

E2000 (used in DWDM)

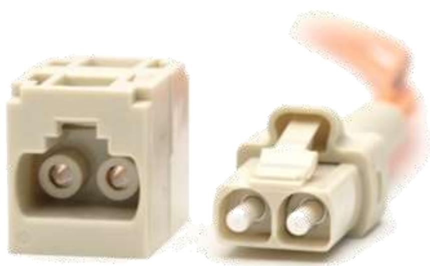
Types of SFF Fiber Connectors

SFF (Small Form Factor): An optical fiber duplex connector with a size approximating that of an 8-position modular outlet/connector.

MT-RJ: Polarized, pinned & unpinned

LC: Non-polarized, 1.25 mm ferrules.
Typically used in Data Centers.

VF-45: Polarized, v-groove connections



FJ: Non-polarized, 2.5 mm ferrules

Other: MU & more

FLUKE networks

MPO / MTP Array Connectors

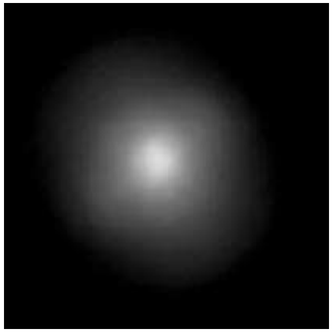
- Connector with 12, 24, 48 …, fibers
- Supports parallel optics … 40 & 100Gl over multi mode fiber

Rapid deployment /
Fiber Cassettes (SC / LC)

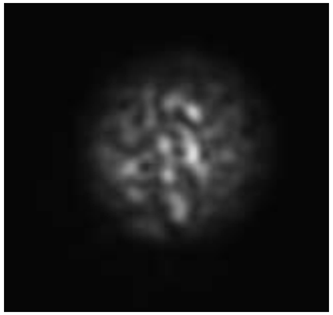
Pinned concept similar to MTRJ

Transmission Sources

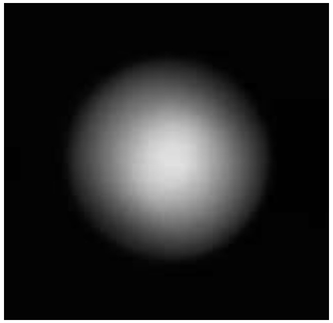
- Fabry-Perot (FP) Laser
  - Used for singlemode: 1310 nm or 1550 nm
  - Narrow spectrum (can be less than 1 nm)
  - Narrow beam width (does not fill multimode fibers)
  - Highest power and fastest switching



- VCSELs
  - Vertical Cavity Surface Emitting Laser
  - Used for multimode at 850 and 1300 nm
  - Quite narrow spectrum
  - Narrow beam width (does not fill multimode fibers)
  - Much less expensive than FP or DFB lasers



- Light Emitting Diodes (LED)
  - Used for multimode: 850 nm or 1300 nm
  - Wide beam width fills multimode fibers
  - Wider spectrum (typically 50 nm)
  - Inexpensive
  - Cannot modulate as fast as lasers



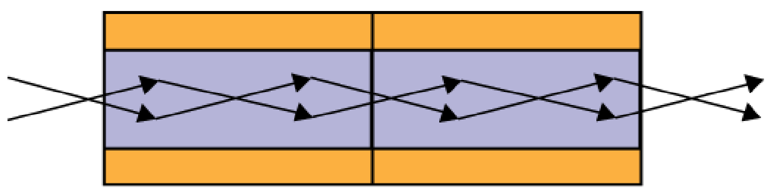
Always Test MultiMode with Overfilled LED

To be standards compliant…

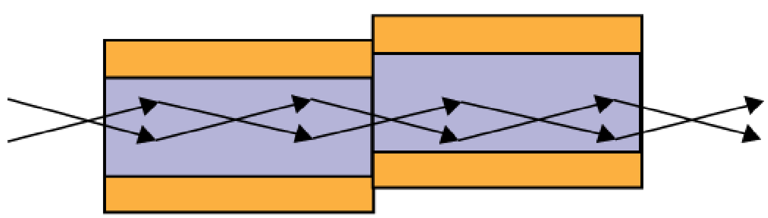
- You need a light source with characteristics identical to those of the over-filled LED.
  - ANSI/TIA-526-14-B specifies the source must have a spectral width of between 30 nanometers (nm) and 60 nm, which is easily achieved with an LED source.
  - VCSEL's show a random distribution of modes and "spotty" illumination and can therefore not be used for certification purposes.

In the Real World …

- *Testing the two connections shown with under-filled launch conditions may not detect the misalignment problem in the optical cable.*
  - A VCSEL source has a spectral within the region of just 0.65 nm, which is not even close to the required 30 nm, making its use a violation of some industry standards.



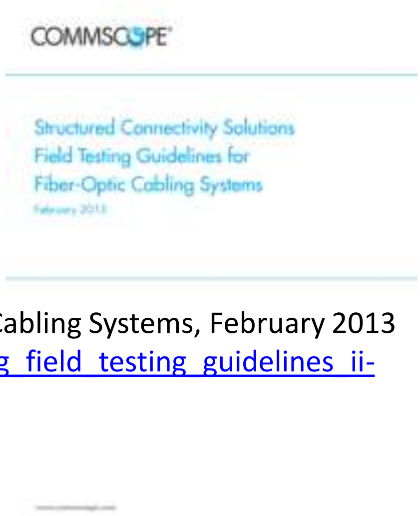
Connection (a) – Properly aligned



Connection (b) – Improperly aligned

The Important Requirement is Warranty

- Multimode horizontal link segments should be tested
  - in one direction
  - at EITHER 850 nm or 1,300 nm wavelength
  - the use of optical test equipment that provides Encircled Flux compliant launch condition is strongly recommended
- Single-mode horizontal link segments should be tested
  - in one direction
  - at EITHER 1,310 nm
  - or 1,550 nm wavelength.


COMMSCOPE
Structured Connectivity Solutions
Field Testing Guidelines for
Fiber-Optic Cabling Systems

CommScope: Field Testing Guidelines for Fiber-Optic Cabling Systems, February 2013
http://www.commscope.com/docs/structured_cabling_field_testing_guidelines_ii-106524.pdf

The Important Requirement is Warranty

- E.2.2 Tier 1
- When conducting Tier 1 testing, each optical fiber link is measured for its attenuation with an OLTS.
- Fiber length verification may be obtained from cable sheath markings or via the OLTS (if the OLTS has length measurement capability).
- Polarity can be verified with the OLTS while performing attenuation tests.
- Testing can be conducted at one or more wavelengths and in one or both directions.
- A published standard should be referenced to identify the wavelength(s) and direction(s) required for the test.

When testing choose the right limit ….. It's not simple

Loss Budget

Channel Limits

Application Limits

Link Limits

ISO / IEC

IEEE

Generic Cabling

Component Requirements

Maximum Channel Length

Patched Channel

Standards Based Limits

- There are two types:
  - Application standards
    - These include IEEE 802.3z 1000BASE-SX
    - The optical loss allowed is a fixed value
  - Cabling standards
    - These include ANSI/TIA-568-C.0 and ISO/IEC 11801 (ISO/IEC 14763-3)
    - The loss allowed depends on the number of adapters, splices and length of the cable

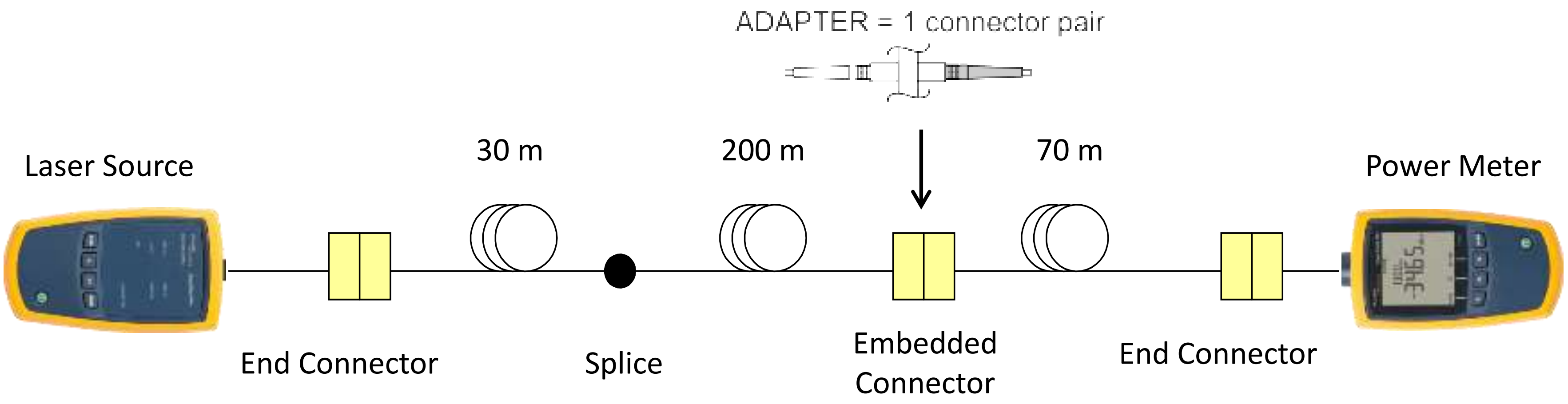
Standards Overview

Region	Channel / Link / Component - Requirements	Field Testing Requirements
International	• ISO/IEC **11801** 2002 AMD2 (2009) Information technology – Generic cabling for **customer** premises • ISO/IEC **24702** …- Generic Cabling for **Industrial** premises • ISO/IEC **24764** …- Generic Cabling for **Data center** premises • ISO/IEC **15018** …- Generic cabling for **homes**	ISO/IEC **14763-3** (June 2006) Information technology – Implementation and operation of customer premises cabling – Part 3: Testing of optical fiber cabling.
Europe	EN 50173-**x** "Family" Amd AB:2010 Information technology - Generic cabling systems • 50173-**1**…Part 1: **General** requirements • 50173-**2**…Part 2: **Office** premises • 50173-**3**…Part 3: **Industrial** premises • 50173-**4**…Part 4: **Homes** • 50173-**5**…Part 5: **Data Centers**	EN **50346**:2002 A2:2009 Information technology - Cabling installation – Testing of installed cabling. (Refers to 14763-3 for all technical details)
USA	ANSI/TIA-568-**C.0**-2009 **Generic** Telecommunications Cabling for Customer Premises **C.1 Commercial** Building …. **C.2 Balanced Twisted-Pair** …Components Standards **C.3 Optical** Fiber Cabling … Components Standard	ANSI/TIA-455-78-B-2002, Optical Fibers Part 1-40: Measurement Methods and Test Procedures – Attenuation ANSI/TIA/EIA-455-8-2000, Measurement of Splice or Connector Loss and Reflectance Using an OTDR

Standards Based Limits

Type		λ (nm)	Loss-Limit	Units / Comment
Applications	IEEE 802.3: 10GBASE-SR/SW	850	2.6 dB	requires OF-300
	IEEE 802.3: 10GBASE-LR/LW	1310	6.2 dB	requires OF-2000
….the transmission path has to comply with the application or channel requirements	ISO/IEC 8802-3: 1000BASE-SX	850	3.56 dB	requires OF-500
	ISO/IEC 8802-3: 1000BASE-LX	1300	2.35 dB	requires OF-500
		1310	4.56 dB	requires OF-2000
	ISO/IEC 8802-3: 100BASE-FX	1300	11 dB	requires OF-2000
	ISO/IEC 14165-111: Fibre Channel (FC-PH) @1 062 Mbit/s e,	850	4.0 dB	requires OF-500
List is not complete!		1310	6.0 dB	requires OF-2000
Channels *… consists of 1 or more links + equip. /patch cords*	OF-300 / OF-500 / OF-2000 Multi M. (max.300m/500m/2000m)	850	2.55 / 3.25 / 8.5	dB
		1300	3.25 / 2.25 / 4.5	
	OF-300 / OF-500 / OF-2000 Single M. (max. 300m/500m/2000m)	1310	1.8 / 2.0 / 3.5	
		1500	1.8 / 2.0 / 3.5	
Links	The loss limit is dependent on λ, length and connector/splice count. (min. 3 Components)			
Component	Fiber: OM1/ -2/ -3/ -4	850	3.5	dB / km
		1300	1.5	
	Fiber: OS1 / OS2	both	1.0 / 0.4	
	Splice: all	all	0.3	dB / Splice
	Connector or Adapter: (Adapter = Connector pair) All	both	0.75 dB (for 100% of cases) 0.5 dB (95%) and 0.35 dB (50%)	
Requirement for Field Testing	TRC (Test Reference Cord) & Random Connector @ Link Ends	850/1300	0.3	dB / Connection
		1310/1500	0.5	
ISO/IEC only	TRC & TRC (periodic Check)	850/1300	0.1	dB / Connection
		1310/1500	0.2	

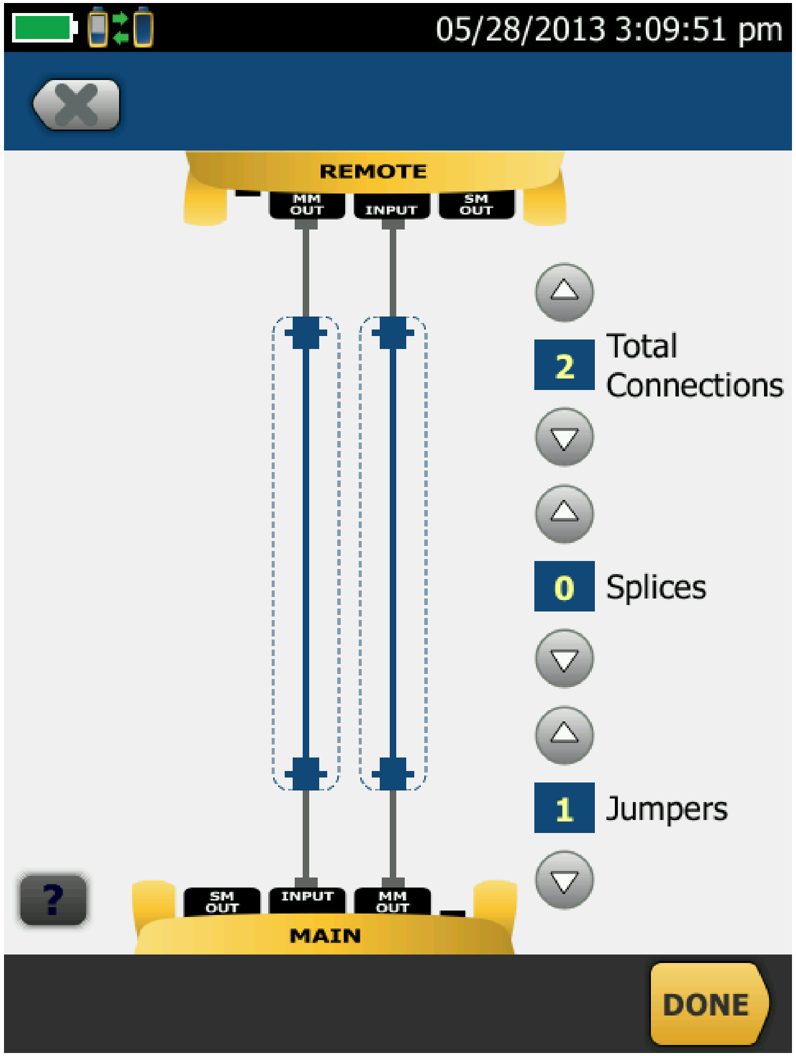
Calculating a Optical Loss "Budget"



	Limits defined by ISO 11801 AMD2 & ISO/IEC 14763-3	Allowable Loss
300 meter Fiber 50µm/125µm	3.5 dB/km	1.05 db
2 "end" connectors	0.3 dB/connector	0.60 dB
1 „embedded" connector pair	0.75 dB/adapter	0.75 dB
1 splice	0.3dB/splice	0.30 dB
	Total	**2.70 dB**

Note: Calculation based on theoretical maximum for a MM fiber at 850 nm wavelength

Calculating a Optical Loss "Budget"



Note: Make sure the tester is set to the right Cabling Standard/Test Limit.

Measuring Optical Loss

dB Loss	P_{out} as a % of P_{in}	% of power lost	Ratio P_{out} / P_{in}
1	79%	21%	
2	63%	37%	
3	50%	50%	1/2
5	32%	68%	
6	25%	75%	1/4
7	20%	80%	1/5
10	10%	90%	1/10
15	3.2%	96.8%	~1/30
20	1%	99	1/100

- Measured in dB
  - Not a linear scale, but a logarithmic scale
- For every 3 dB down, received power drops by a factor of 2
- For every 10 dB down, received power drops by a factor of 10

$$\text{Loss (dB)} = 10 * \text{Log} \frac{\text{Power (received)}}{\text{Power (transmitted)}}$$

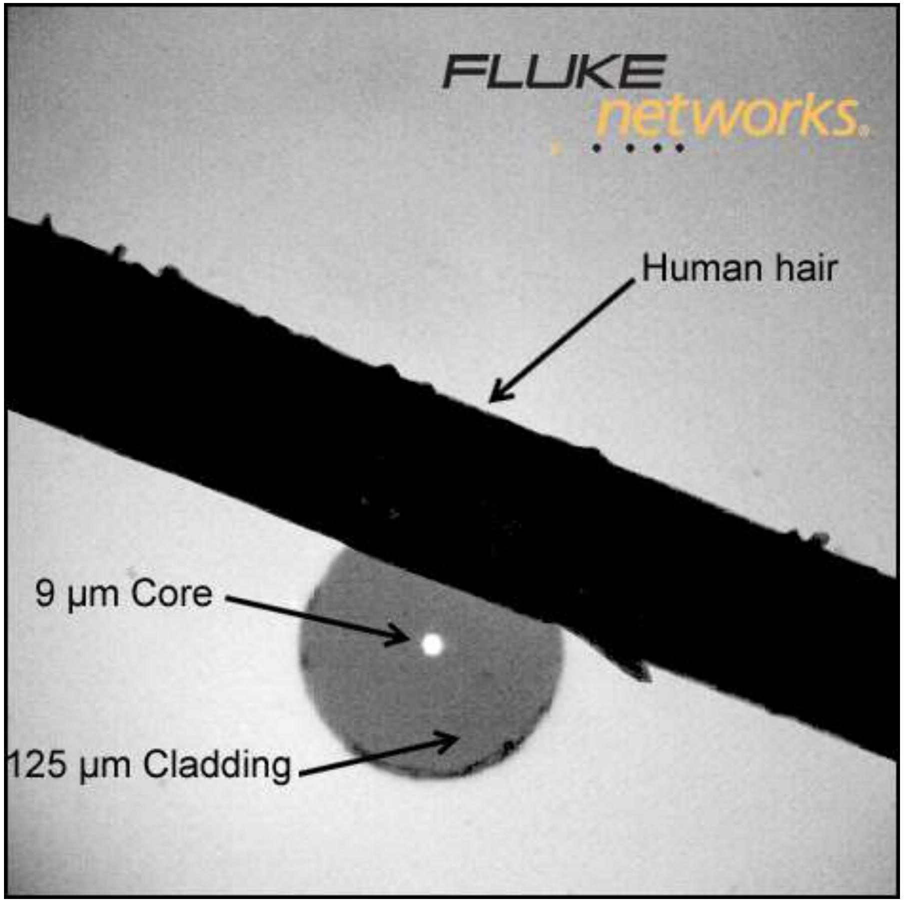
Fiber Excellence Agenda

- Optical Fiber Basics
- End-face Inspection and Cleaning
- Test - Loss/Length Certification
- Fiber Plant Characterization and Troubleshooting
- Documentation


INSPECT
& CLEAN
DOCUMENT
TEST
TROUBLE-
SHOOT
VERSIV
01/10/2014 1:52:01 pm
FAIL
FiberInspector
Connected

Fiber Testing is All About Cleaning

- Without the appropriate cleaning supplies **AND** inspection equipment, you CANNOT test fiber
- Dust in an office is typically between 2.5 µm and 10 µm
- Dirt is everywhere, also inside dust caps!
- All fibers should be inspected and cleaned before being used, even if they are brand new out of the bag
- Dirty end-faces cause 85% of fiber cable failures*



**** Source: Third-party survey commissioned by Fluke Networks***

Safety With Optical Fibers

- To avoid possible exposure to hazardous invisible LED radiation and to prevent eye damage:
  - **NEVER** look directly into the aperture of an energized fiber connector.
  - Do not adjust or modify the source; LED sources may exceed Class 1.
  - Do not use magnification at the fiber connector output unless it contains a safety filter.
- Lasers are more hazardous than LED's!

FLUKE networks

Fiber Optic Cleaning Kit with IBC-OneClick

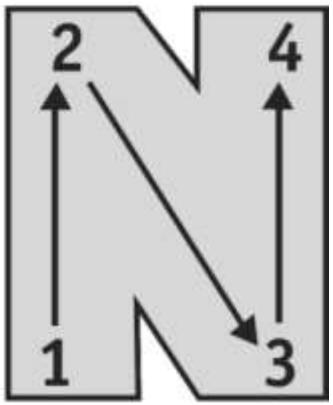
- Great to remove dust
- Cleans Bulkheads and Cords
- Absolutely no training required
- 500+ Cleaning Actions
- Cleans:
  - PC and APC (angled)
    2.5mm Version Cleans: SC, ST, FC, E2000
  - 1.25mm Version Cleans: LC
  - MPO/MTP Version

BUT:

If the fiber is truly dirty, “wet” cleaning is required.

Optimal Cleaning Method

1. Peel cover from unused “N.”
2. Apply a minimal amount of solvent from Fluke Networks Solvent Pen
3. Place end-face perpendicular to card in first corner of unused “N”



4. Swipe through “N” shape using gentle pressure and moving from wet to dry
5. Check end-face with microscope, place cap on test reference cord

Optimal Cleaning Method

Always “wet to dry”

Cleaning Output Ports on a Fiber Module

Make sue you have a bulkhead connector mounted on your Fiber Inspector

Cleaning Ports

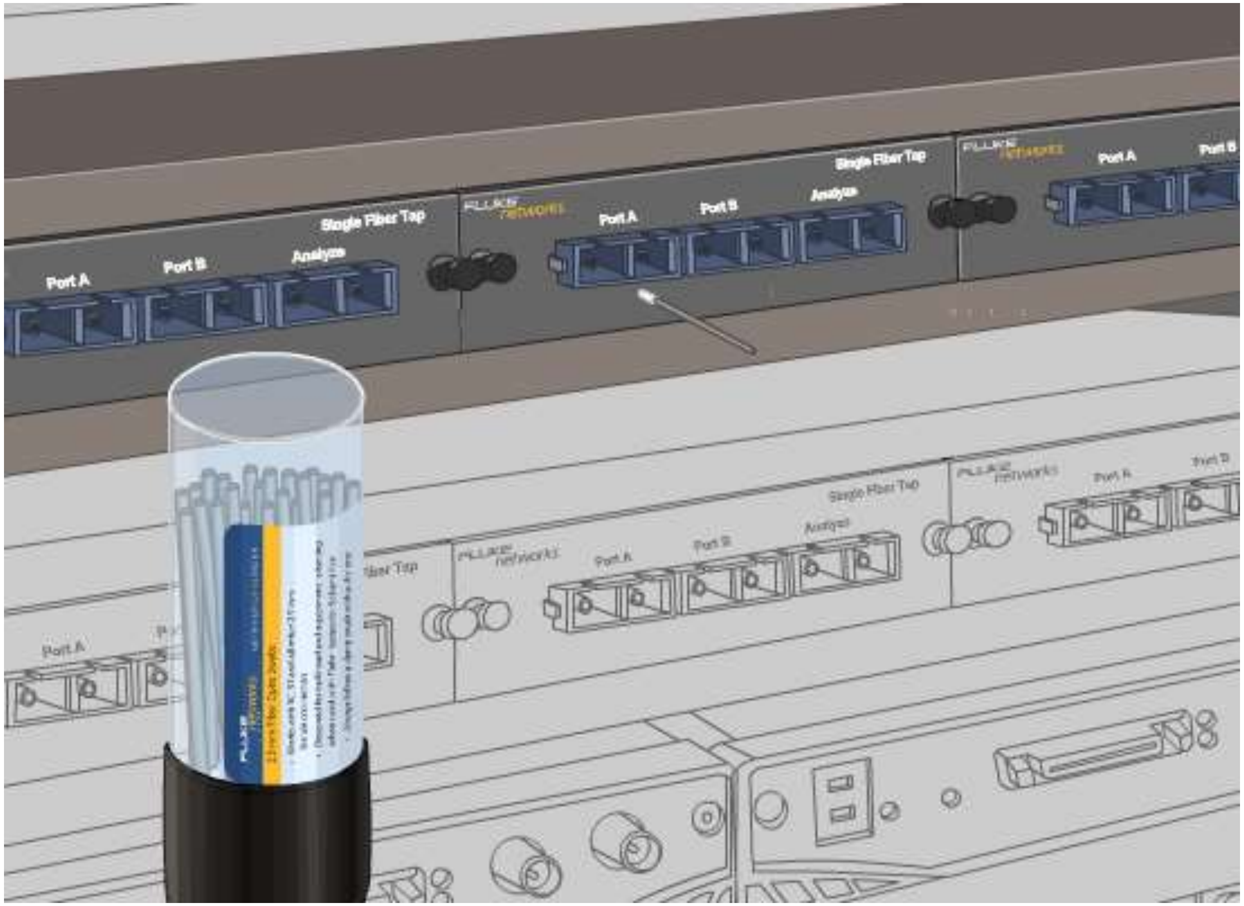
- Dampen the cleaning pad (take minimal quantity)
- Press down gently rotating the foam tip three times

Cleaning Ports

- Insert into port and apply gentle pressure
- Rotate the foam tip three times

Cleaning Ports

- Remove foam tip
- Gently insert gently a new dry foam tip



Source: [Fluke Networks Fiber Cleaning Video]() on YouTube

Fiber Optic Cleaning Kits

NFC-Kit-Case

NFC-Kit-Case-E (Enhanced)

http://www.flukenetworks.com/fibercleaning

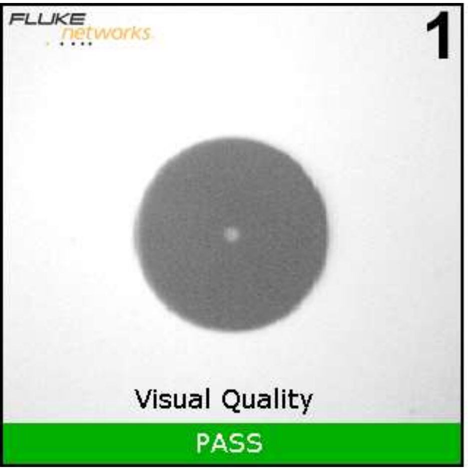
Fiber Microscope Overview

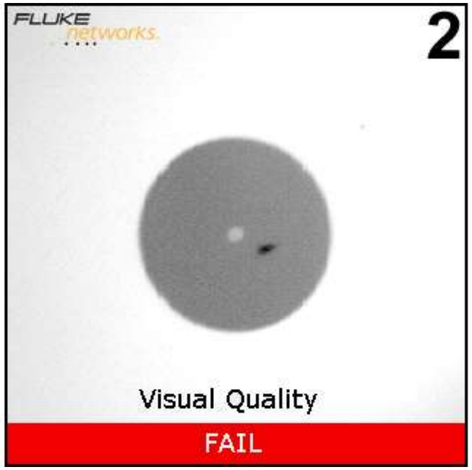
FiberViewer	FiberInspector Mini	FiberInspector Pro
FT120/FT140	FT-500	FI-7000

• Inspect patch cords only
• Rugged, ergonomic form factor
• Most affordable way to inspect an end-face
• 200x and 400x versions
• With 2.5mm Universal Adapter and optional with LC 1.25mm Universal Microscope Adapter
	• Inspect most patch cords and ports (SC, SC/APC, FC, LC, 1.25mm and 2.5mm)
	• Exceptionally compact and convenient
	• Competitive price point for a video microscope
		• Member of the Versiv™ Cabling Certification Product Family
		  • Large Color Touchscreen
		• Inspect widest range of patch cords and port varieties
		  • E2000/APC, FC, LC, MPO, MPO/APC, MPO/MTP, MPO/ MTP APC, MU, SC, SC/APC, ST, 1.25mm, 1.25mm APC, 2.5mm, 2.5mm APC
		• Grades, saves and documents endfaces
		• Test to industry standards
		  • Certification to IEC 61300-3-35

Benefit of Certification to IEC 61300-3-35

- Simple Pass/Fail acceptance testing
  - No more confusion about whether the fiber is good or bad
  - Eliminates human subjectivity from the measurement.
  - Save end face views during certification process to end finger pointing
  - Graphical indication of problem areas
  - Don’t have to worry about “What is considered clean?”





Summary of Best Practices

- Don’t cut corners: always inspect.
- Start with a clean, lint-free wiping surface every time
  - Material left exposed accumulates ambient dust
  - Material used once should not be used again
- Use a minimal amount of specialized solvent
  - Important that solvent be removed after cleaning
  - Move the end-face from the wet spot into a dry zone
    - Cleaning with a saturated wipe will not fully remove solvent
    - Cleaning with a dry wipe will not dissolve contaminants and can generate static, attracting dust
- Proper handling and motion
  - Apply gentle pressure with soft backing behind cleaning surface
  - Hold end-face perpendicular to cleaning surface
- Inspect both end-faces of any connection before insertion
  - If the first cleaning was not sufficient, then clean again until all contamination is removed

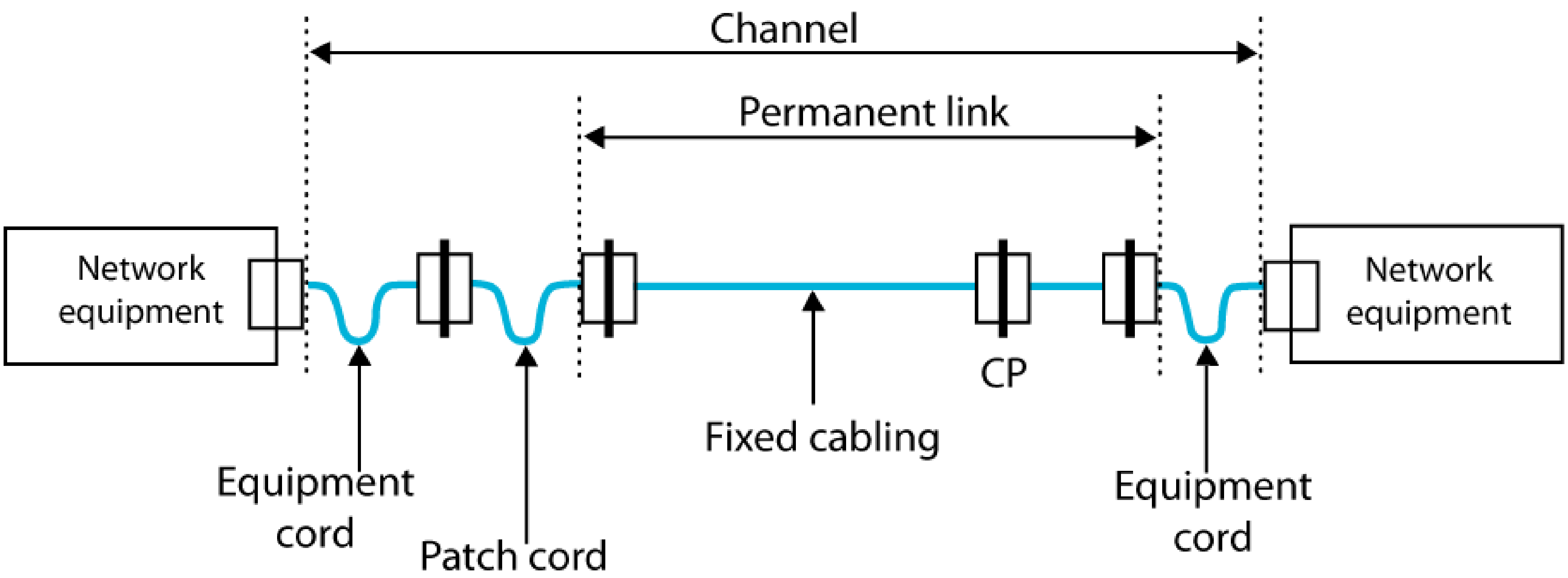
Fiber Excellence Agenda

- Optical Fiber Basics
- End-face Inspection and Cleaning
- Test - Loss/Length Certification
- Fiber Plant Characterization and Troubleshooting
- Documentation


INSPECT & CLEAN
TEST
TROUBLE-SHOOT
DOCUMENT
FLUKE networks
VERSIV
05/28/2013 3:09:25 pm
TEST SETUP
Module: CertiFiber Pro - Quad
Test Type: Smart Remote
Bi-Directional
Off
Fiber Type: OM3 Multimode 50
Fiber Type Settings
Test Limit: ISO/IEC 14763-3
Reference Method: 1 Jumper Method
Connector Type: LC

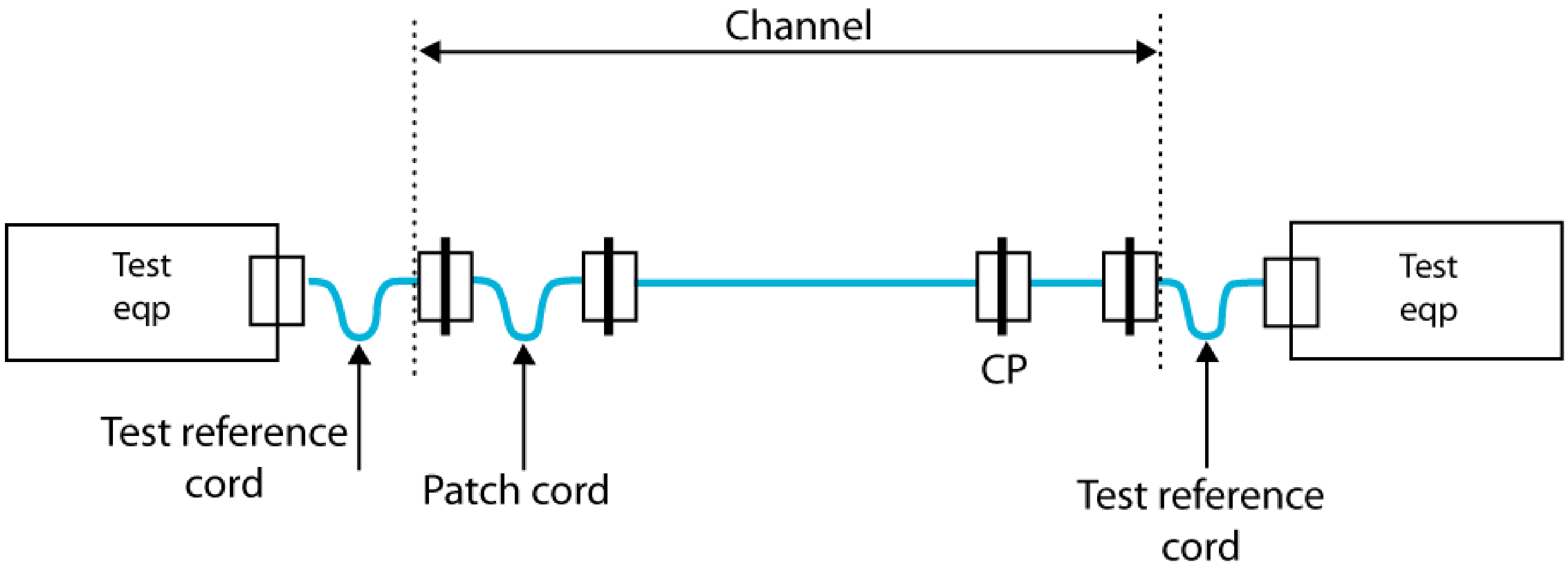
- **Eliminate common problems with good practices during installation and maintenance**
  - Verify continuity, polarity, adequate end-face condition with basic tools to ensure best termination and installation practices
- **Perform complete cable certification**
  - Basic certification (Tier 1)
  - Extended certification (Tier 2)

Difference between Channel and Permanent Link



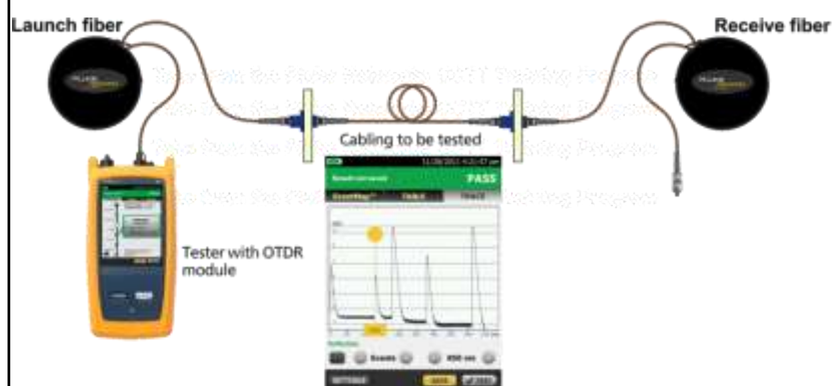
- The channel represents the end-to-end link connecting transmitter and receiver.
- The fixed cabling, a subsegment of the channel, is called the permanent link.
- The figure shows a generic horizontal link model that contains optional connections such as the CP (Consolidation Point).

How Test Equipment is Connected



- *The end connections are now no longer part of the channel specification.*
- *Test Reference Cords (TRCs) with minimal loss (1 m of cord represents 0.0035 dB) are used instead.*

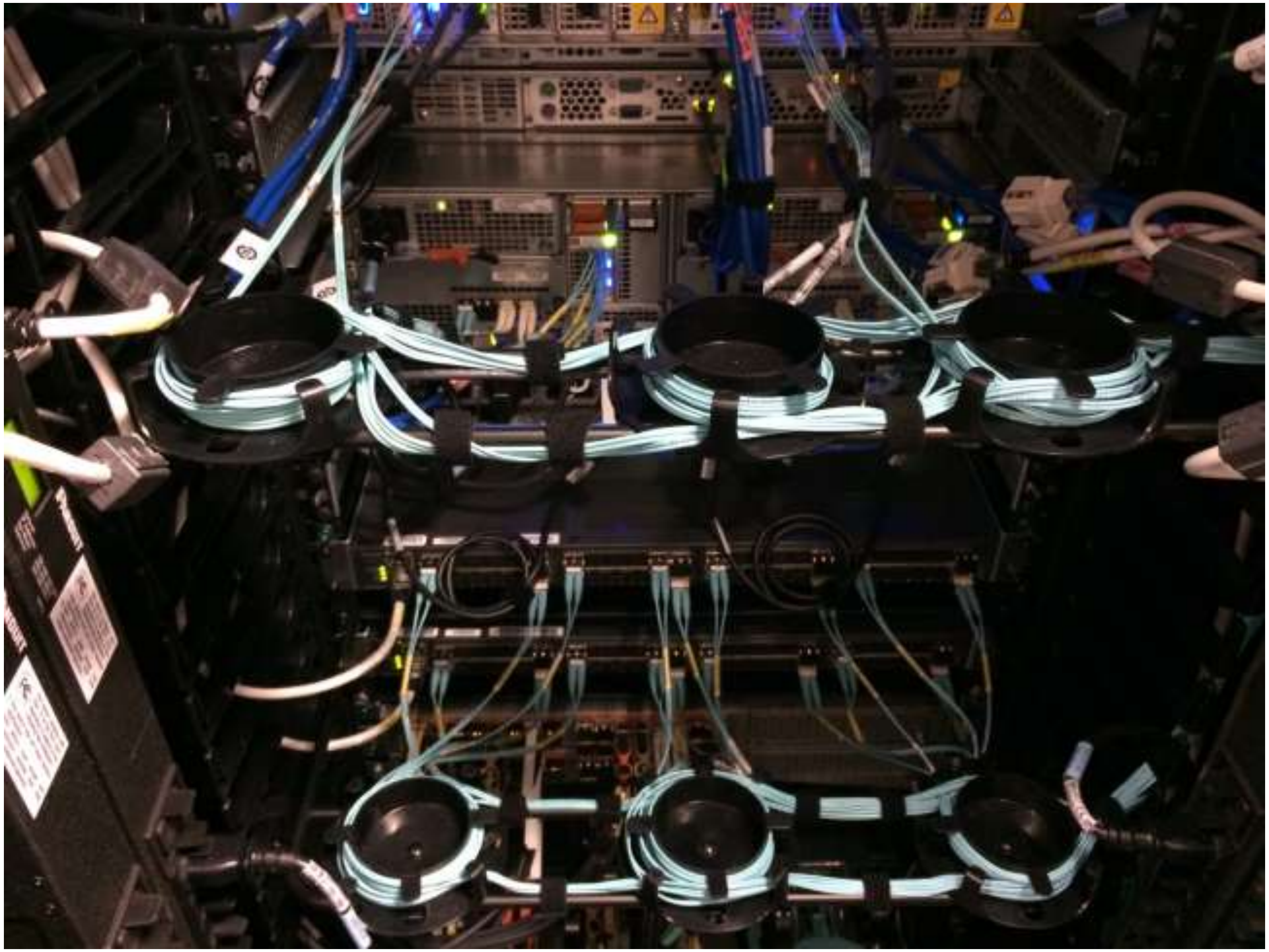
Test Method Overview

Standard	Methods	
TIA	TIA-568-C	
	Tier-1	**Tier-2**
ISO IEC	ISO 11801 AMD.1 / ISO/IEC 14763-3	
	BASIC Test Regime	**EXTENDED** Test Regime
	LSPM: Light Source & Power Meter 	**OTDR**: Optical Time Domain Reflectometer 

- The two methods are <u>complimentary</u> !
  - OTDR based method does not replace the LSPM based solution
  - Tier 1/Basic: Manual calculation of length is allowed.
- Both methods have advantages and limitations

Something about Length

Length is well known in data centers due to pre-terminated trunks

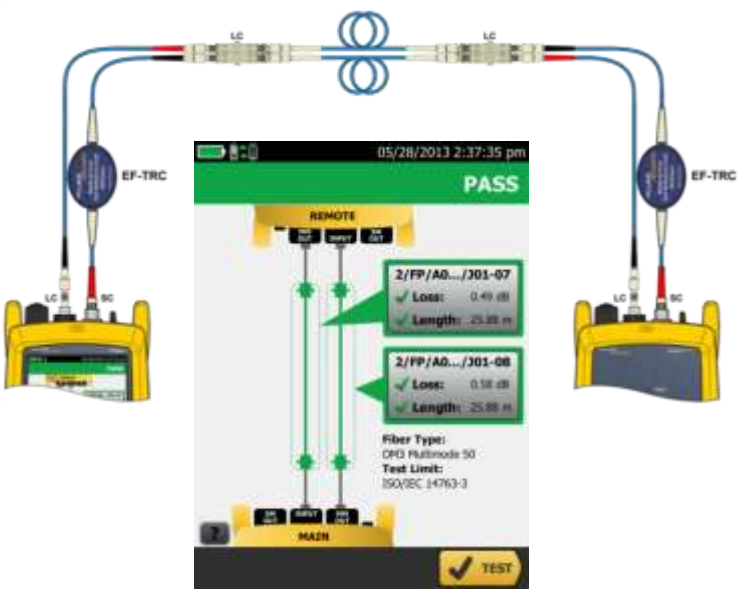


Tier 1/Basic: LSPM versus OLTS

LSPM … Light Source & Power Meter

- Measures the insertion loss of a fiber path
- Length Dependent Limits and Margins need to be calculated manually
- Length needs to be determined manually.

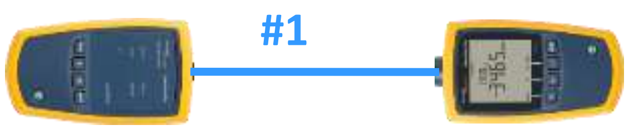
OLTS … Optical Loss Test System

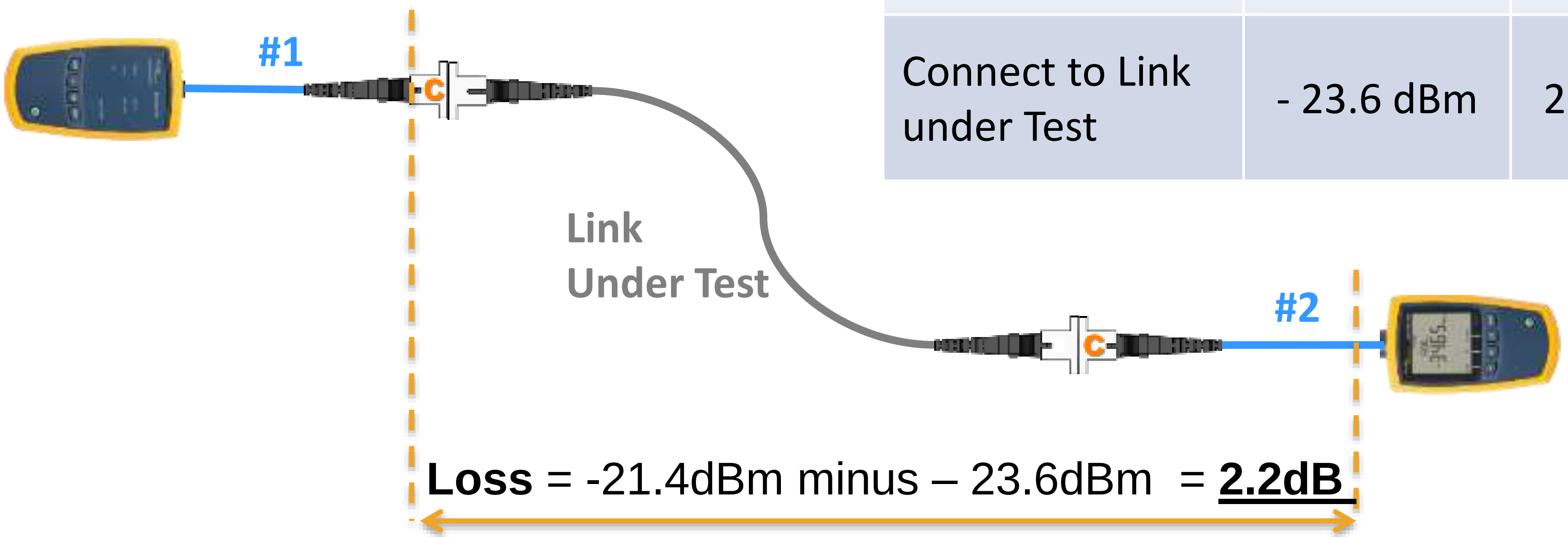


- Measures a duplex fiber in both directions
  1. Measures the length
  2. Calculates the length dependent loss limit
  3. Measures the insertion loss
  4. Calculates the margin
- Optional 2nd step: Measure both fibers in the duplex link in both directions

Set Reference & Power (dBm) vs. Loss (dB)

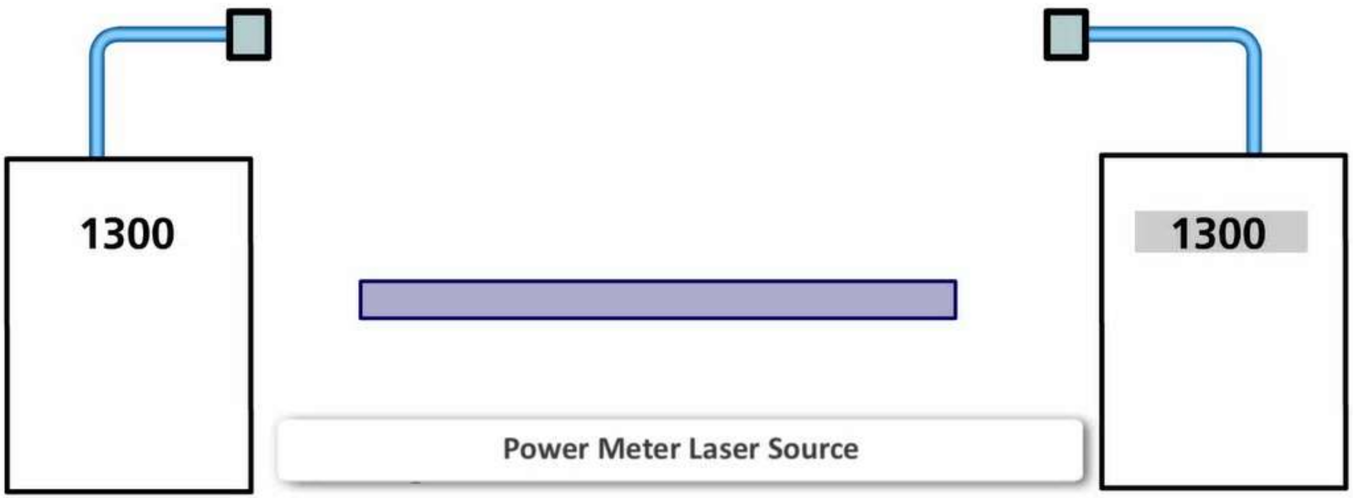
Power Meter can either display a Power (always negative!) or a Loss value





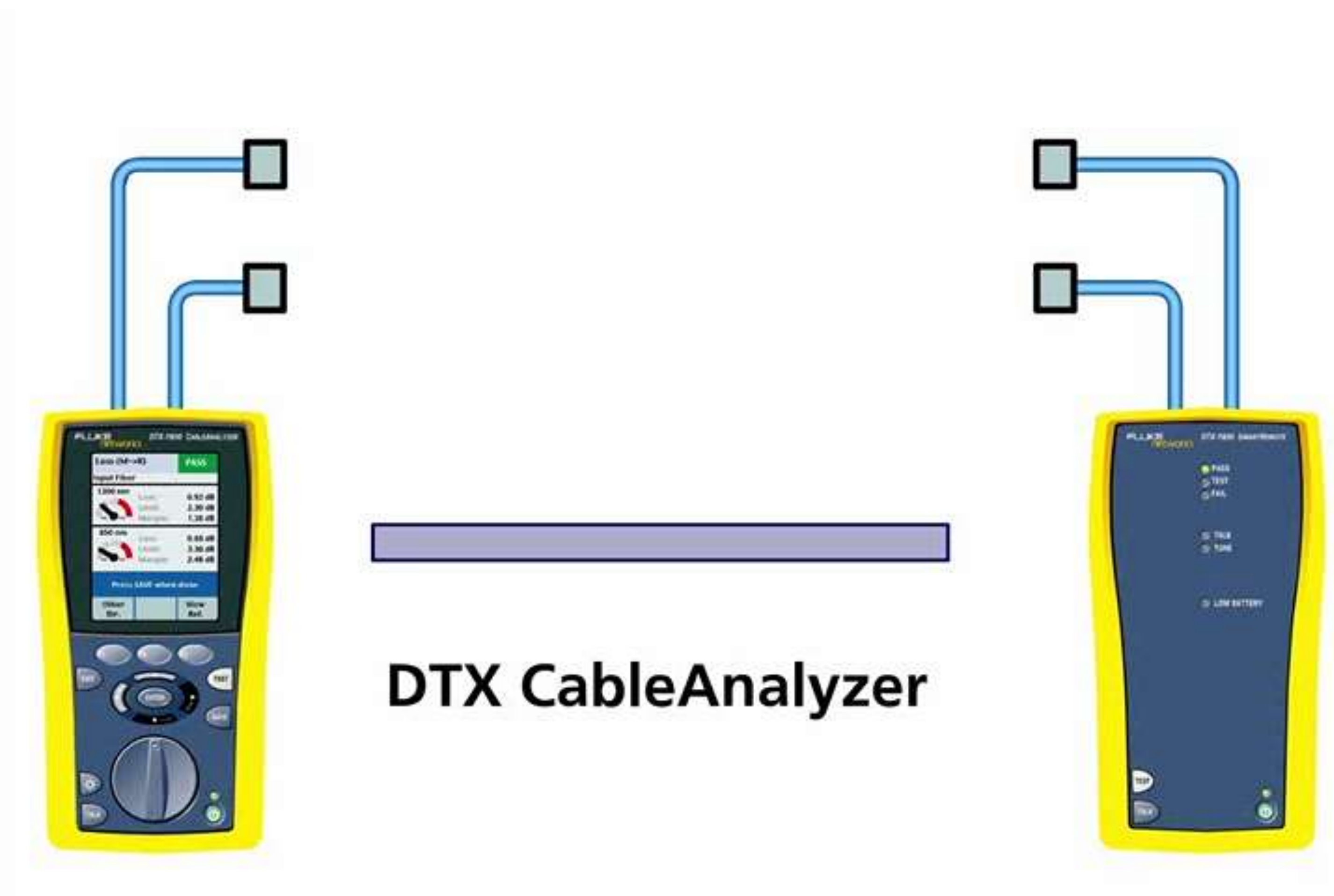
Example → Action	Power dBm (mW)	Loss dB
Connect Source & Power Meter	- 21.4 dBm	XX dB
Set Reference on Meter	- 21.4 dBm	0.0 dB
Connect to Link under Test	- 23.6 dBm	2.2 dB

Power Meter Laser Source (Manual)



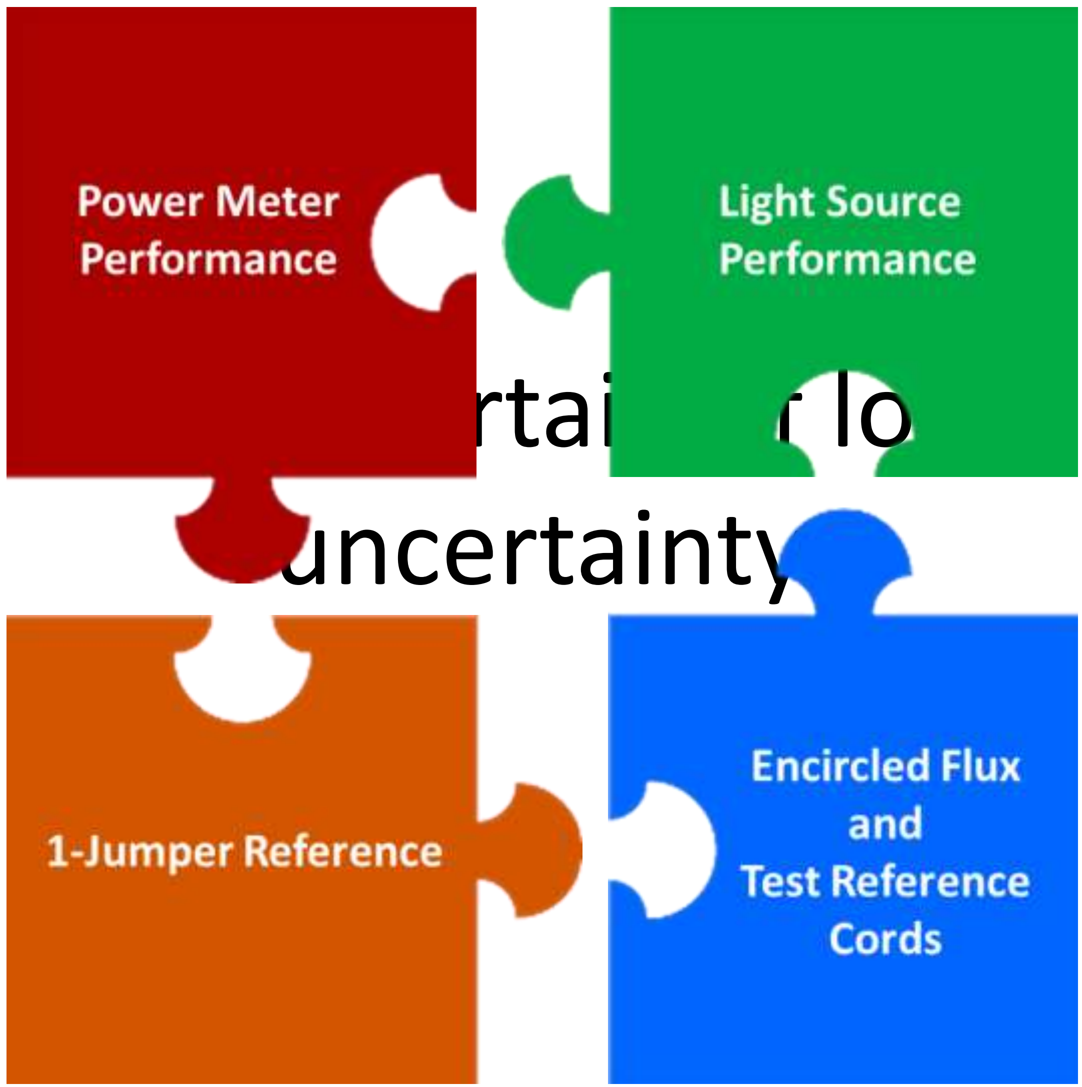
FLUKE networks

Optical Loss Test Set (Automated)

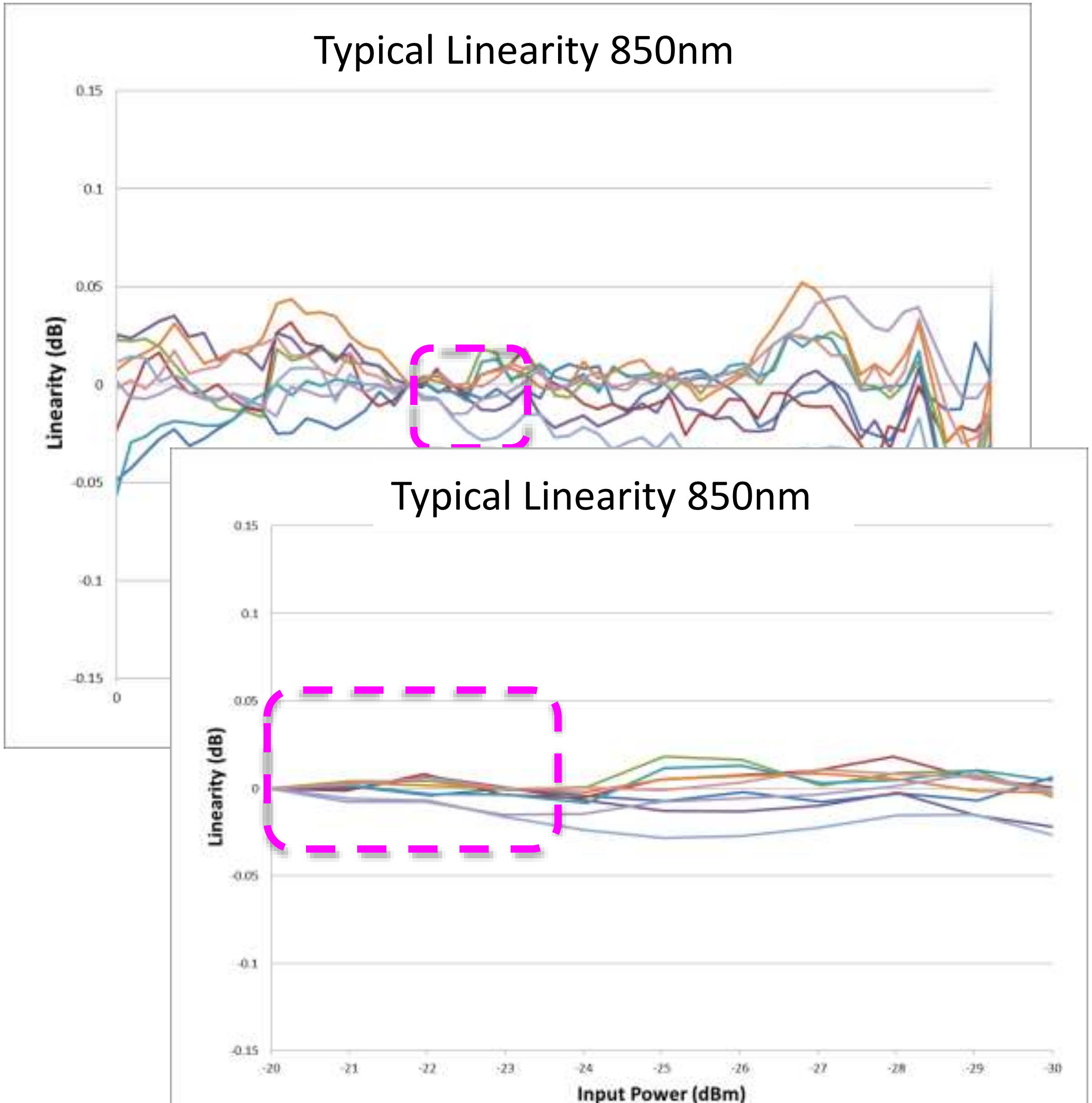


FLUKE networks

The 4 pieces to the jigsaw puzzle that make for a successful Tier 1 optical loss measurement



Power Meter Performance

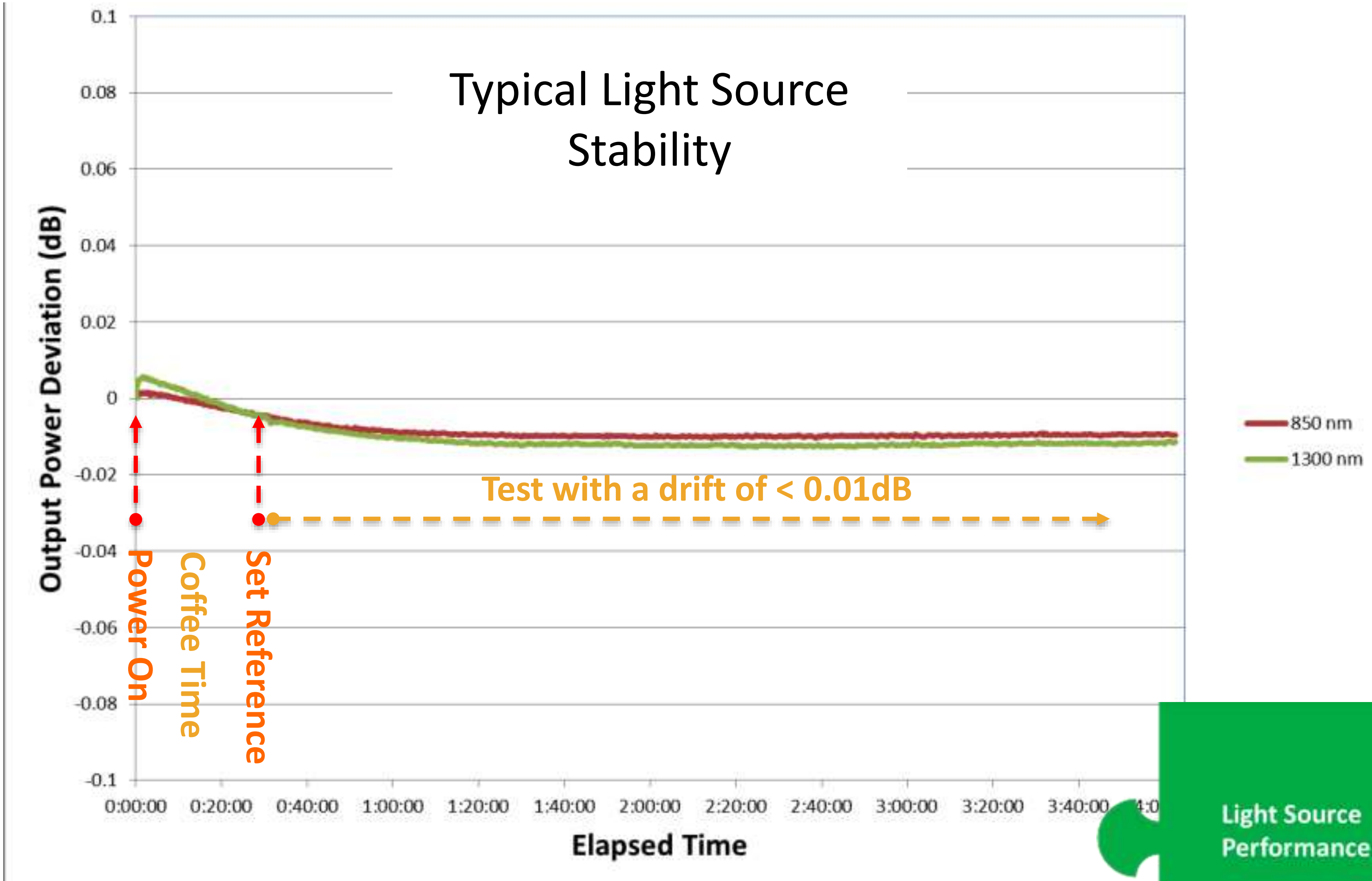


- The parameter of interest is *linearity*
- Recent designs demonstrate excellent performance
- For typical loss values of < 3dB the error is neglectable
  - Typical sample show an error due to non-linearity of less then 0.02dB

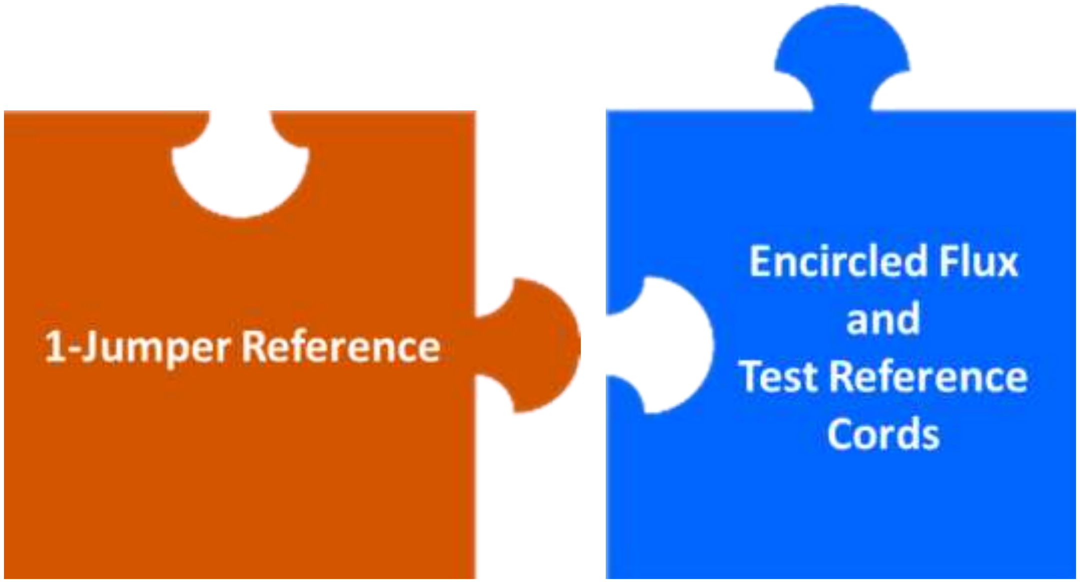
Light source performance

- ANSI/TIA-526-14-B specifies the source must have a spectral width of between 30 nanometers (nm) and 60 nm, which is easily achieved with an LED source.
- Light source stability is the measure of output power variation over time.
- LOSS changes if the light source power changes.
  - If the light source's output power decreases, the measured loss increases.
- Therefore the light source's output must be very stable over time.
- Recent design demonstrate outstanding stability.

Light source stability: Example

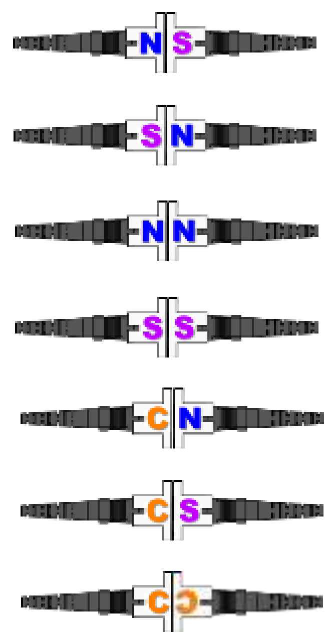


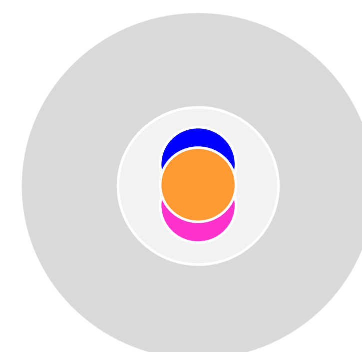
Light Source Performance


1-Jumper Reference
Encircled Flux
and
Test Reference
Cords

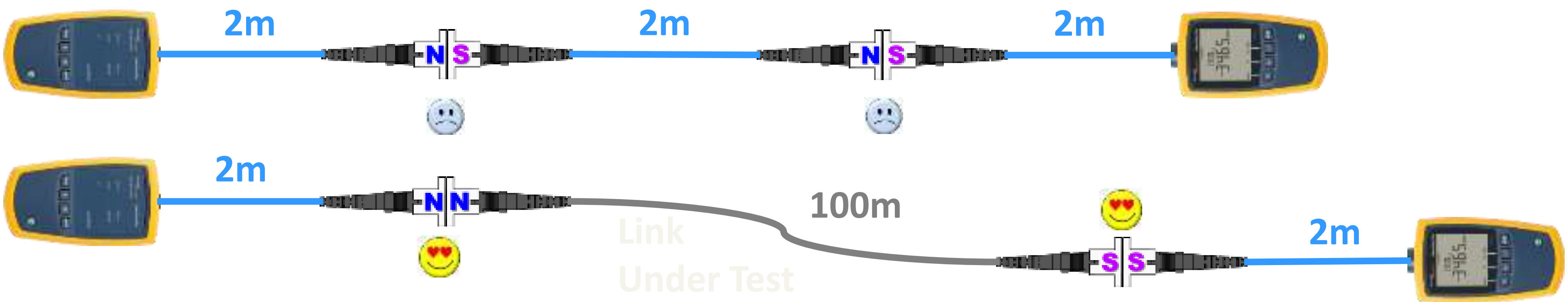
Test Reference Cord (TRC) … An Exercise

- The major source for connector IL (insertion loss) is misalignment
- The fiber is not in the very center of the ferrule.
- We set the reference with 3 jumpers
- For simplicity of the experiment we assume 3 kinds of the misalignments: North, South, Center (none)
- **<u>Scenarios:</u>**
  1. North / South 0.6 dB :
  2. South / North 0.6 dB :
  3. North / North 0.1dB :
  4. South / South 0.1dB :
  5. Center / North 0.3dB :
  6. Center / South 0.3dB :
  7. Center / Center 0.1dB :





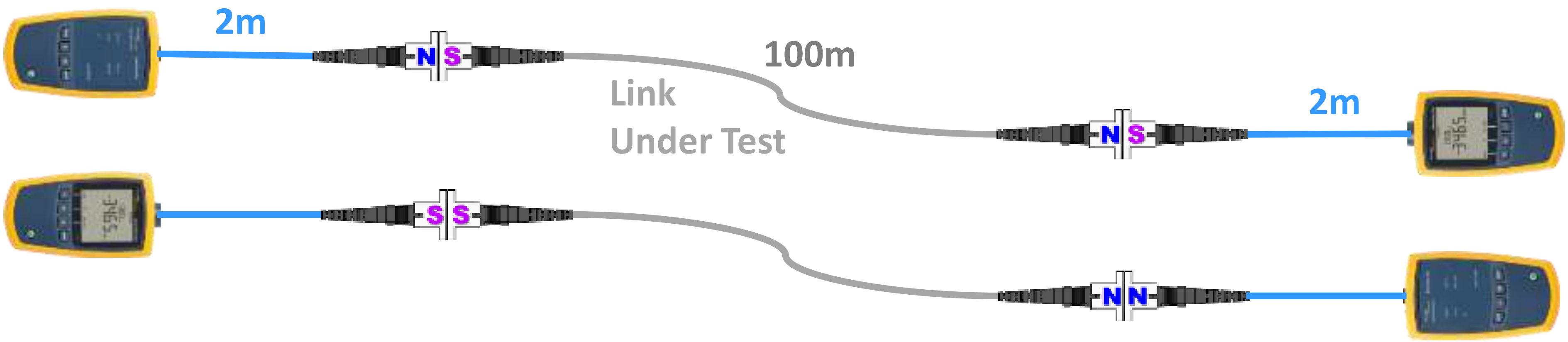
Set Reference with 3-Jumper Method using normal patch cords



	Fiber 1	Conn 1	Fiber 3	Conn 2	Fiber 3	Total	
Set Ref.	2 m	N/S	2m	N/S	2m		
[dB]	0.01	0.60	0.01	0.60	0.01	**1.23**	
Measure	2 m	N/S	100m	N/S	2m		
[dB]	0.01	0.1	0.35	0.1	0.01	**0.52**	- 0.71

- After setting the reference measure a 100m link
- A negative loss is shown … even if the link would be 300m this might happen
- The number one reason for calls into the TAC

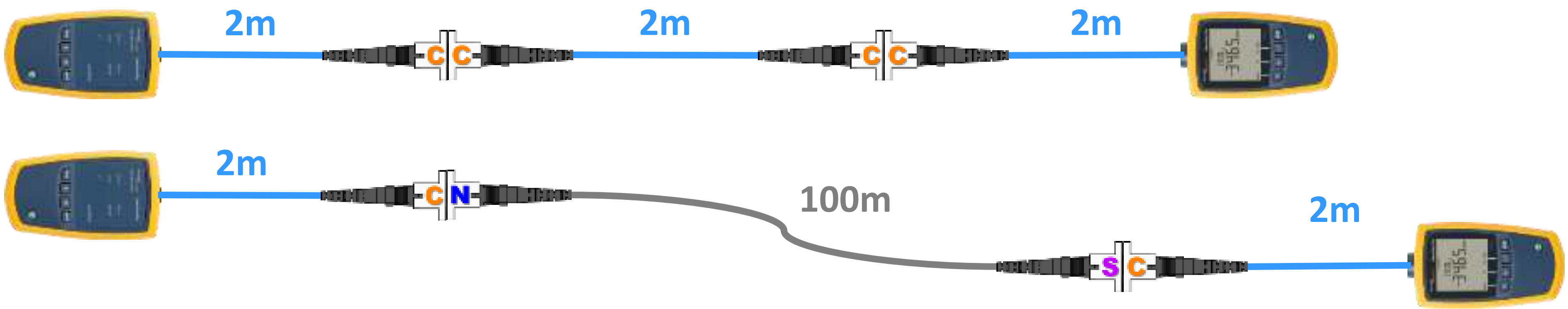
Improve accuracy by measuring from both ends



	Fiber 1	Conn 1	Fiber 3	Conn 2	Fiber 3	Total	Delta
End 1	2 m	N/S	100m	N/S	2m		
[dB]	0.01	0.60	0.35	0.60	0.01	**1.52**	
End 2	2 m	N/S	100m	N/S	2m		
[dB]	0.01	0.1	0.35	0.1	0.01	**0.52**	- 1.00

- The result varies by one dB …. In this case 200% !!!
- Random cords are the reason why many believe it is essential to measure from both ends with an OLTS

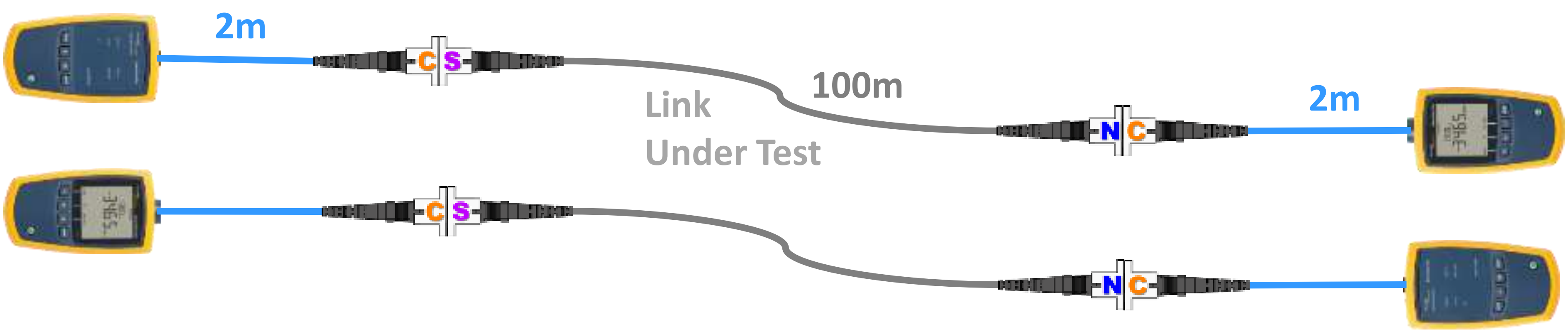
Now use TRCs with “Centered” characteristics instead



	Fiber 1	Conn 1	Fiber 3	Conn 2	Fiber 3	Total	IL
Set Ref.	2 m	N/S	2m	N/S	2m		
[dB]	0.01	0.1	0.01	0.1	0.01	**0.23**	
Measure	2 m	N/S	100m	N/S	2m		
[dB]	0.01	0.30	0.35	0.30	0.01	**0.97**	0.74

- We a measure a 100m link
- It’s possible but not likely to see a negative loss if the process is executed correctly

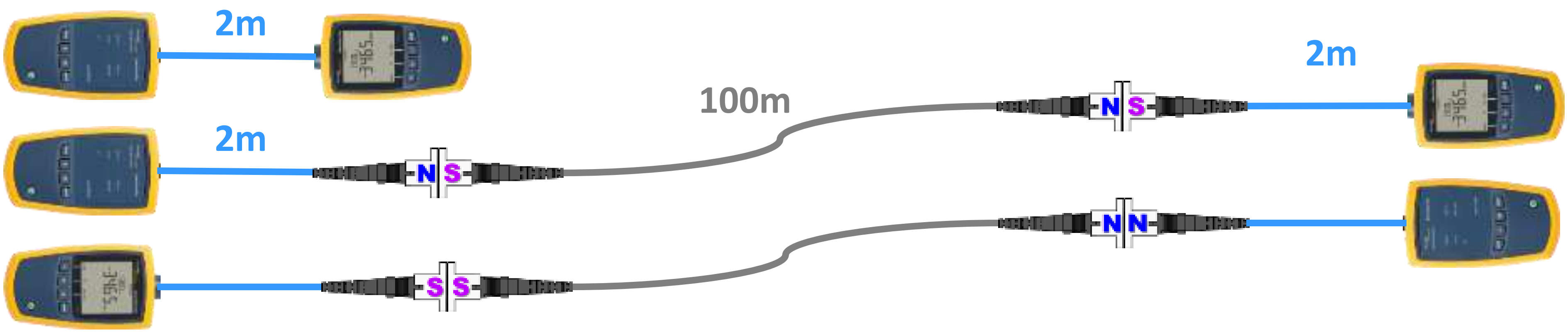
Does measuring from both ends Improve accuracy if you use TRC's?



	Fiber 1	Conn 1	Fiber 3	Conn 2	Fiber 3	Total	Delta
End 1	2 m	N/S	100m	N/S	2m		
[dB]	0.01	0.30	0.35	0.30	0.01	**0.92**	
End 2	2 m	N/S	100m	N/S	2m		
[dB]	0.01	0.30	0.35	0.30	0.01	**0.92**	- 0.00

- The result does not vary significantly. We should see a variation of less then 0.1dB 0.15dB being the exception

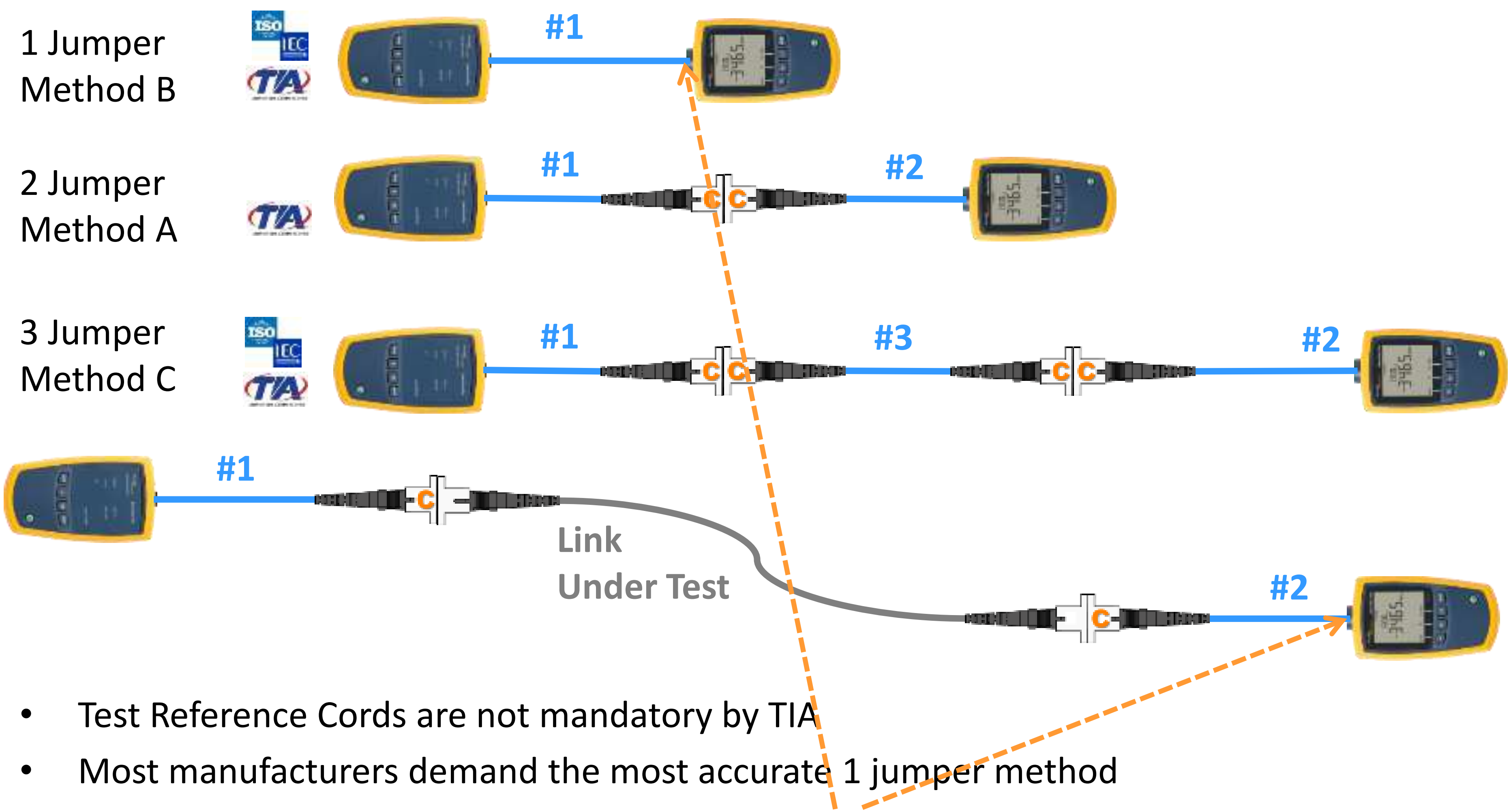
Setting the Reference with the 1-Jumper Method (Method B)



	Fiber 1	Conn 1	Fiber 3	Conn 2	Fiber 3	Total	IL
Set Ref	2 m	The meter uses a non critical connection					
[dB]	0.01		0			**0.01**	
Measure …	2 m	N/S	100m	N/S	2m		
… End 1 [dB]	0.01	0.6	0.35	0.6	0.01	**1.57**	**1.56**
… End 2 [dB]	0.01	0.1	0.35	0.1	0.01	**0.52**	**0.51**

- The requirement is that the meter has a non-critical connector (large surface detector) It is neutral to connector misalignments
- The result still varies by one dB but we will never see a negative loss
- **We now understand why the ultimate measurement combines the “1 jumper method” with TRCs!**

Reference Methods



- Test Reference Cords are not mandatory by TIA
- Most manufacturers demand the most accurate 1 jumper method
- The one jumper method always require a "non-critical" connection on the meter

Use ICA’s on the Meter or if the Link has Different Endfaces on Either End

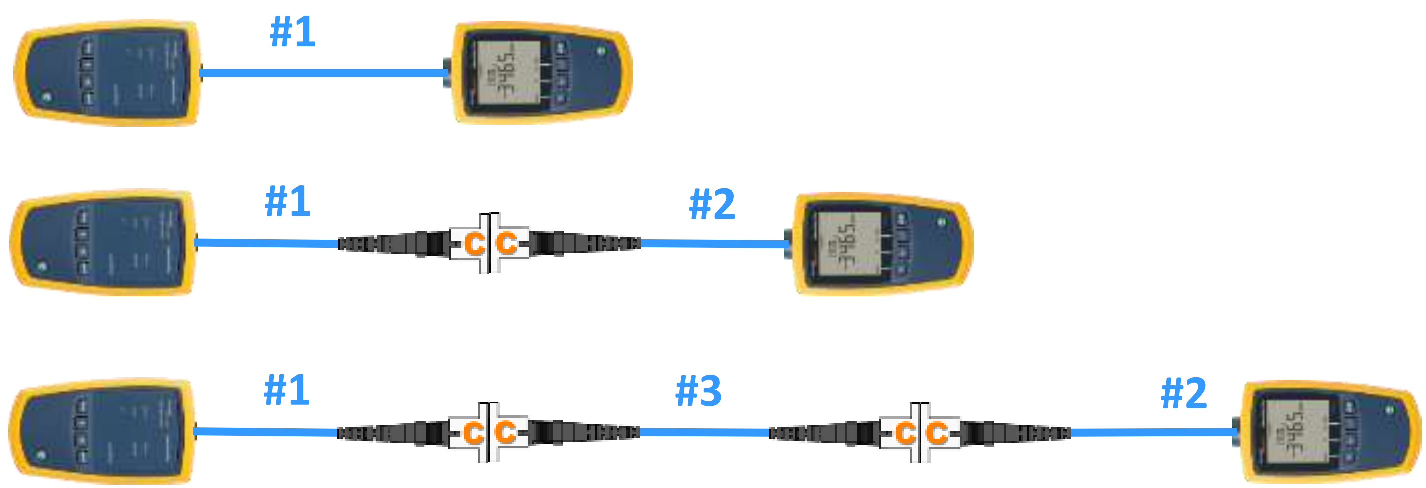
Different Interchangeable Adapters are available to enable 1-Jumper Reference Setting

Accuracy of the three reference methods

1 Jumper Method B

2 Jumper Method A

3 Jumper Method C



Cords /Ref. Method	1 Jumper	2 Jumper	3 Jumper
Reg. Patch Cords			
Test Reference Cords			

"Negative Loss Free" Zone

High risk of negative loss results !

FLUKE networks

1-Jumper Reference Setting is Preferred

12 Backbone Optical Fibre Testing

Single and Multi mode backbone links shall be tested at both wavelength and in both directions in accordance with BS/ISO/IEC 14763-3.Testing of the fibre optic cabling using the One Jumper Reference Method using Light Source and Power Meter with reference grade test cords and couplers.

12.2 OTDR Testing

Backbone, horizontal and centralised links shall be tested at the appropriate operating wavelengths for anomalies and to ensure uniformity of cable attenuation and connector insertion loss.

- Each fibre link and channel shall be tested in both directions wavelengths
- A launch cable shall be installed between the OTDR and the first link connection.
- A tail cable shall be installed after the last link connection.

12.3 Length Measurement

- The length of each fibre shall be recorded.

Source: Excel Encyclopaedia on Cabling Infrastructure Solutions

TRCs Need To Be Checked On A Regular Basis

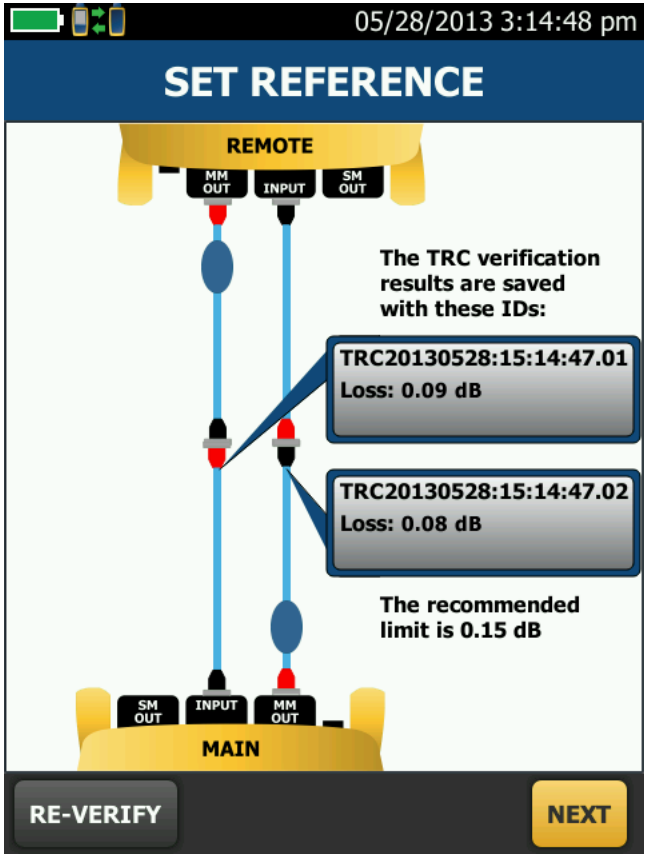
- TRCS many not have the required performance out of the bag
- TRCS wear over time. Eccentricity won't change but the end-face will suffer
- The best time to check them is when setting the reference
  - The one jumper method is the only method to check a TRC
  - It requires a non-critical connection on the meter
  - It requires an Inter-changeable Adapter to match the connector type on the patch panel
  - The process adds < 60 sec to the set reference process

... Test is performed in < 1% of all projects

... Consultants should but don't insist on it

Is there any hope ?

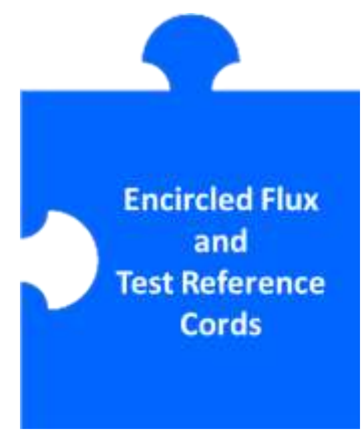
New “Wizards” help users through the reference setting process



Encircled Flux
Reducing multimode uncertainty

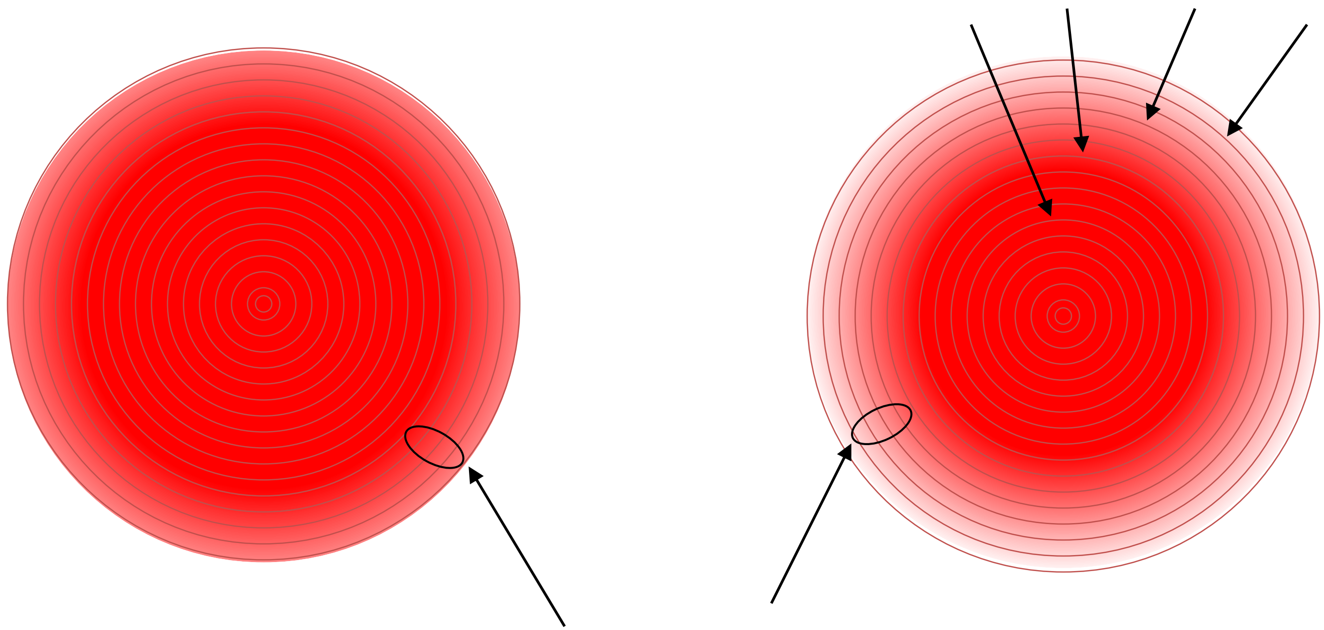
- Encircled Flux (EF) is a way to define launch conditions…the final piece in the puzzle to reducing measurement uncertainty in the field.
  - The consistent launch conditions improve loss measurement uncertainty from 40% to less than 10%.
    - This testing ability eliminates false failures when testing with tight loss budgets.
  - In 2010 EF was approved by the Standards:
    - In TIA with the publication of ANSI/TIA-526-14-B Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant.
    - In ISO with the publication of ISO/IEC 14763-3-am1 Ed1 that led the revision of ISO/IEC 14763-3 Ed1. Main change was the introduction of IEC 61280-4-1, Fiber-optic communication subsystem test procedures – Part 4-1: Cable plant and links – Multimode fiber-optic cable plant attenuation measurement, in which it is stated that in order to provide a more reliable and repeatable result the measurement technique for multimode links should be based on EF.

- Encircled Flux is also the test method that is specified in the IEEE 802.3ba Standard for 40 Gb/s Ethernet (40GBASE-SR4) and 100 Gb/s Ethernet (100GBASE-SR10).



Encircled Flux: Launch Conditions Do matter!

EF specifies power throughout core using multiple control radii.



EF provides tight tolerance on mode power distribution in the outer radii enabling improved agreement between EF-compliant test instruments.

Source 1
Over-filled

Source 2
Restricted or Under-filled

Encircled Flux – Why Comply?

1. Reduces link loss variation
2. Will ensure more “Passes” and minimize finger-pointing
3. Is already strongly recommended by leading cabling manufacturers and will soon become mandatory.

CommScope fiber solutions require the use of power meters that accept plugs of the type used to terminate the cabling system under test. CommScope recommends all multimode launch cord performance verifications and link attenuation measurements to be performed with the Encircled Flux launch condition as defined in TIA-526-14-B and IEC 61280-4-1 ed. 2. See Appendix A for more information.

Caution: Laser light sources, including Vertical Cavity Surface Emitting Lasers (VCSELs), cannot meet the minimum spectral width requirements defined by TIA-526-14-B for LSPMs. Therefore, laser and VCSEL sources are not accepted for certifying multimode fiber systems.

CommScope fiber solutions require all single-mode cord performance verifications and link attenuation measurements to be performed with a launch test cord containing a single loop < 30 mm (1.2 inches) in diameter to suppress multimode propagation. This loop may be created by either wrapping the cord around a mandrel or in free space by securing the cord to itself.

www.commscope.com 8

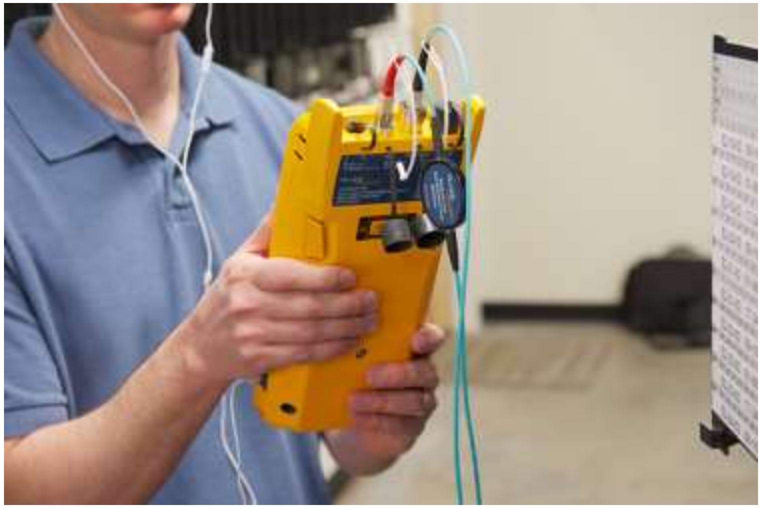
Source: CommScope Structured Connectivity Solutions Field Testing Guidelines for Fiber-Optic Cabling Systems, February 2013

An "open" (expensive) solution and a "proprietary" (very cost-effective) solution

Method 1: External mode controller

Note: When that LC connector breaks or wears out, it cannot be re-terminated in the field.

Method 2: Matched Source and test reference cords

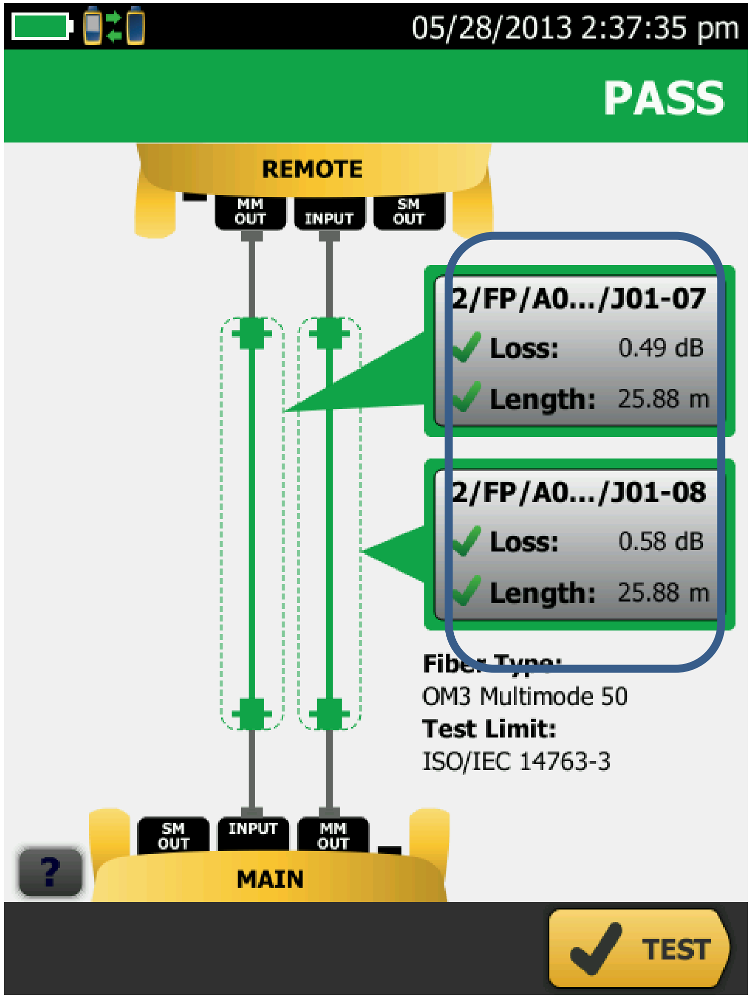


Encircled Flux Test Reference Cords

The new Encircled Flux Test Reference Cords eliminate the requirement to use a mandrel (source side only) or the use of the expensive and bulky conditioners.

Summary - Basic (Tier 1) Certification

- Required for standards compliance
- Uses absolute power/loss measurement
- Best for measuring TOTAL (end-to-end) loss of a fiber channel
- Test against loss limits based on industry standards for current application



FLUKE networks

Testing MPO…
Let us first understand the reason for MPO

MPO (Multi-fiber Push-On) connector drivers:

- Storage growth, virtualization, new fabric architectures driving significant growth in the use of MPO in data centers
- Standard cabling solution for 40 Gbps+ multimode fiber which rely on parallel optics
  - Pre-terminated assemblies becomes de facto
  - Avoid have to spend money on making splices

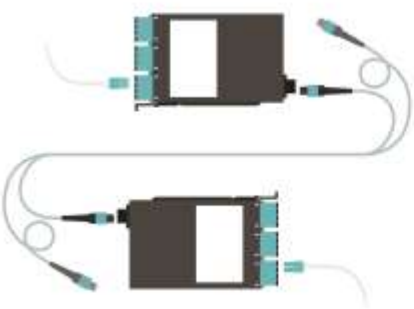
MPO Connectors

**MPO
Cable with Cassette**

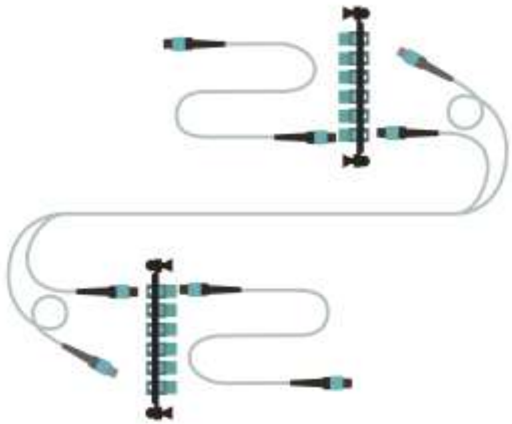
MTP® = Multi-fiber Termination Push-on is a specialized version of MPO connector; trademarked by US Conec

MPO Cable - Future Proof Technology

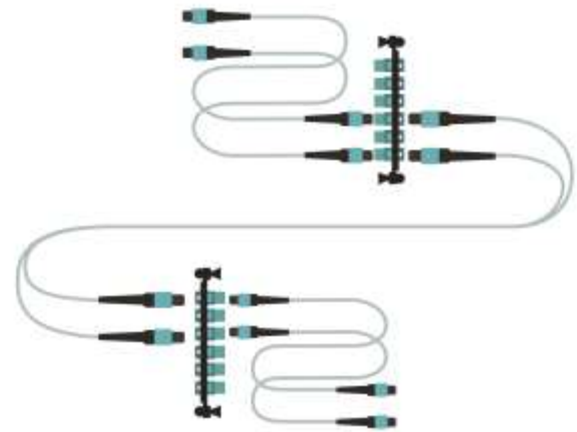
Reuse the same MPO Trunk Cable



1G or 10G Cabling



40G Cabling

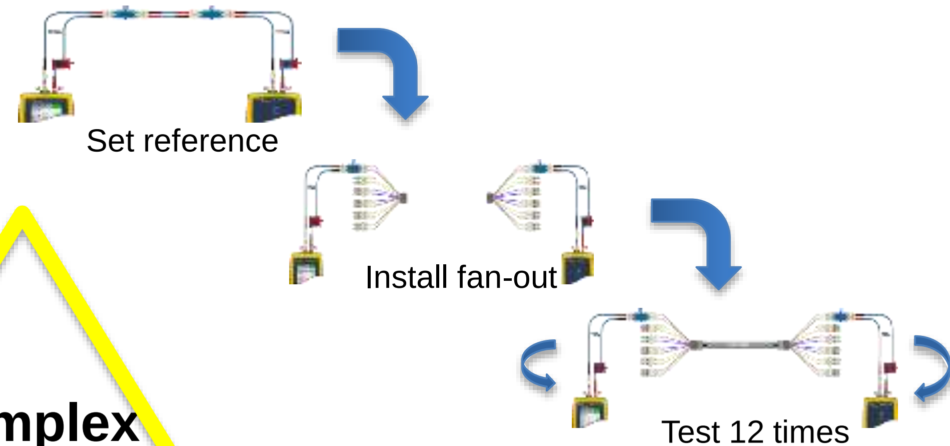


100G Cabling

Lowers the barriers to migrating from 10 GbE towards 40/100 GbE backbones

How are MPO Cables Tested Today?

With PMLS, fan-out cables



Repeat all tests

Complex

Incomplete **Tedious**

Polarity?

Test to Limit?

Documentation?

Testing MPO Cables with MultiFiber Pro

- The first comprehensive MPO 12-fiber Power Meter and Light Source field tester
  - SingleMode and MultiMode
- Semi-automated certification
  - User settable limits based upon international standards
  - Automated loss measurement on all 12 fibers simultaneously
  - Automated Pass/Fail analysis
  - Validates polarity to ensure correct end-to-end connectivity of MPO/MTP links.
    - per TIA-568-C.0
- Can be used to test trunk cables, patch cords and cassettes

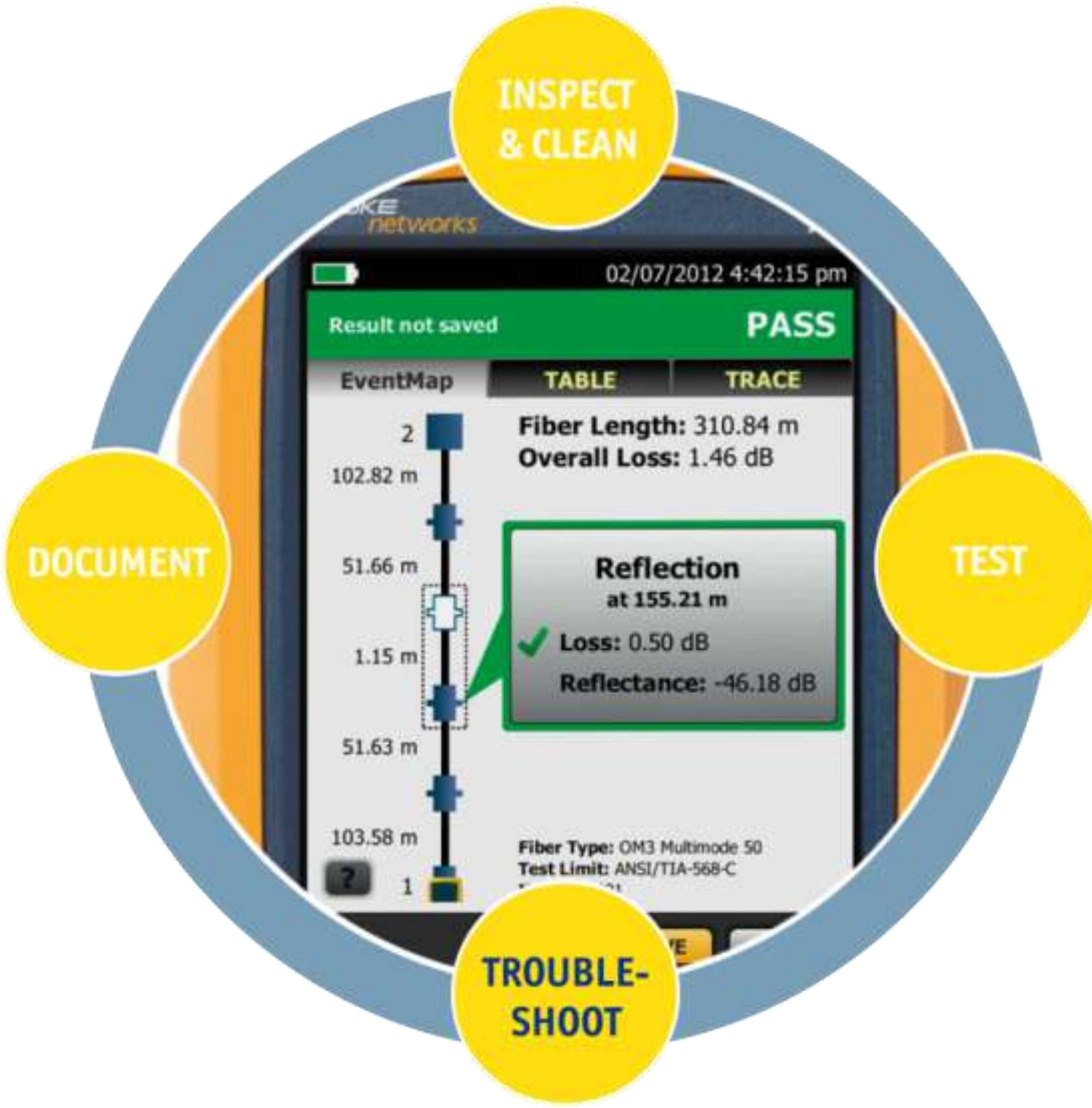
MultiFiber Pro Efficiency

- Takes 20 seconds* per MPO fiber
  - Tests all 12 fibers at once
  - Takes 6 minutes or more for other single fiber testers
- LinkWare Data Management Software consolidates results for all 12 fibers

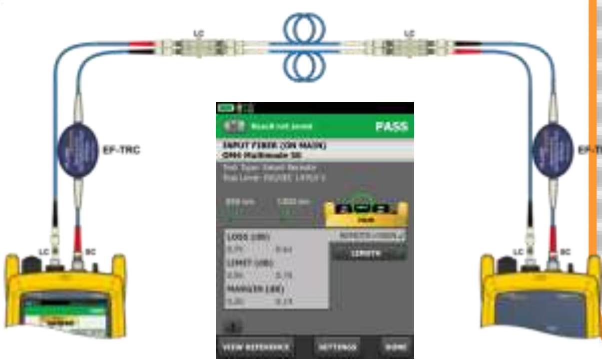
*Actual test acquisition time on MultiFiber Pro is only 6 seconds. 20 seconds include moving testers from one cable to another.

Fiber Excellence Agenda

- Basic Fiber Optic Theory
- End-face Inspection and Cleaning
- Test - Loss/Length Certification
- Fiber Plant Characterization and Troubleshooting
- Documentation


INSPECT & CLEAN
TEST
TROUBLE-SHOOT
DOCUMENT
02/07/2012 4:42:15 pm
Result not saved
PASS
EventMap
TABLE
TRACE
Fiber Length: 310.84 m
Overall Loss: 1.46 dB
2
102.82 m
51.66 m
1.15 m
51.63 m
103.58 m
1
Reflection
at 155.21 m
Loss: 0.50 dB
Reflectance: -46.18 dB
Fiber Type: OM3 Multimode 50
Test Limit: ANSI/TIA-568-C

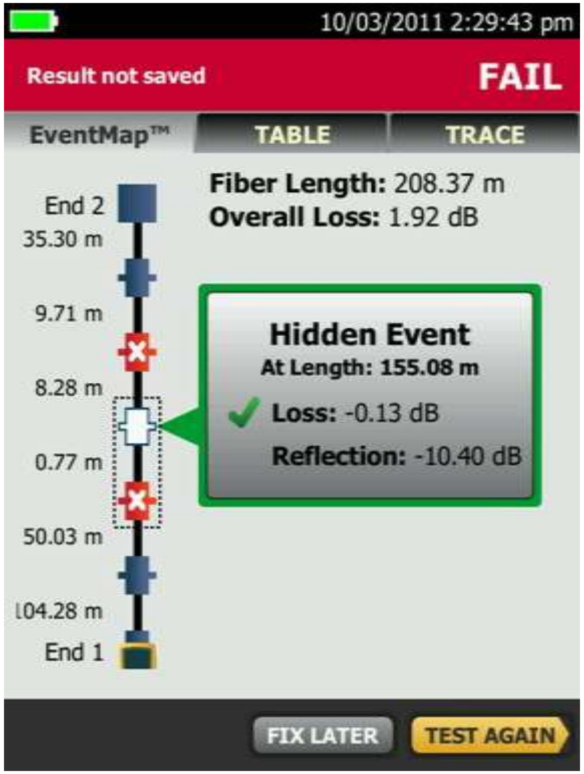
Test Method Overview

Standard	Methods	
TIA	TIA-568-C	
	Tier-1	**Tier-2**
ISO IEC	ISO 11801 AMD.1 / ISO/IEC 14763-3	
	BASIC Test Regime	**EXTENDED** Test Regime
	LSPM: Light Source & Power Meter **OLTS:** Optical Loss Test Set  	**OTDR**: Optical Time Domain Reflectometer 

- The two methods are <u>complimentary</u> !
  - OTDR based method does not replace the LSPM based solution
- Both methods have advantages and limitations

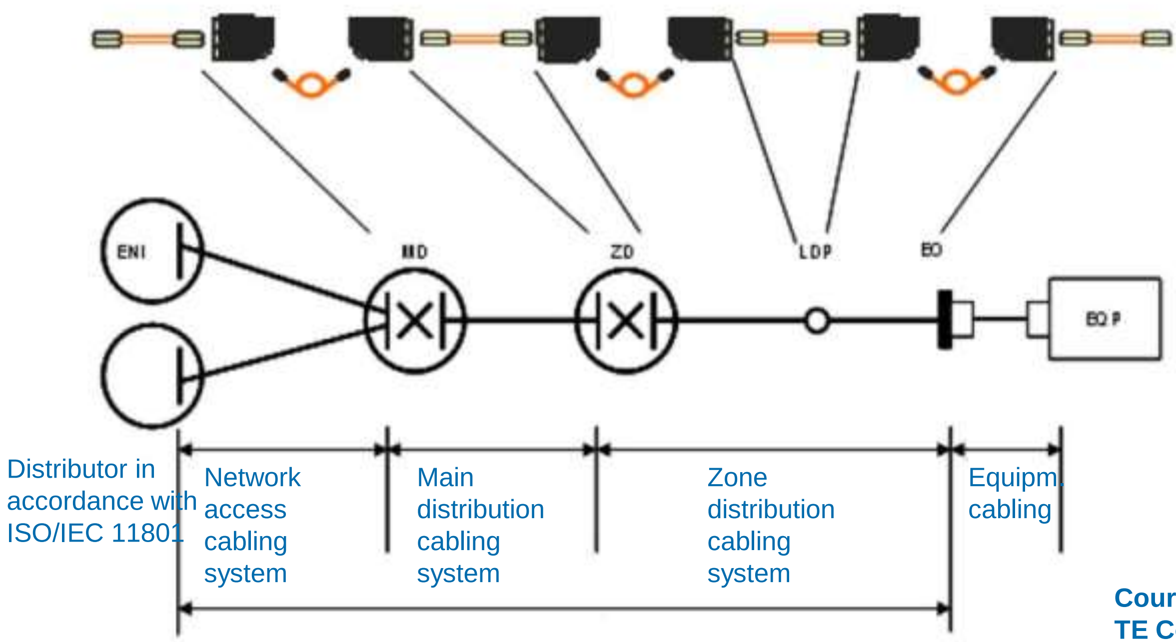
Extended (Tier 2) Fiber Certification

- Complements Tier 1 fiber certification
- Ensure that the fiber link meets expectations for current and future applications
- Reflectance is defined by the amount of light reflected compared to the power of the light being transmitted down the fiber
  - 1% reflectance is -20 dB,
  - A top quality connector, like the APC connector, will have around -60 dB reflectance (1 ppm of light is reflected)



Complex Channels…The Drivers

- “Zoned Data Centers”
- The standards define a “Patched Channel” which consists of multiple segments/links



Courtesy:
TE Connectivity

Testing a Complex Channel

- Assumptions:
  - Complex channel consists of 4 segments
  - One connection is very poor (1.00dB)
  - All other connections 0.25dB and fiber 3.0dB/km

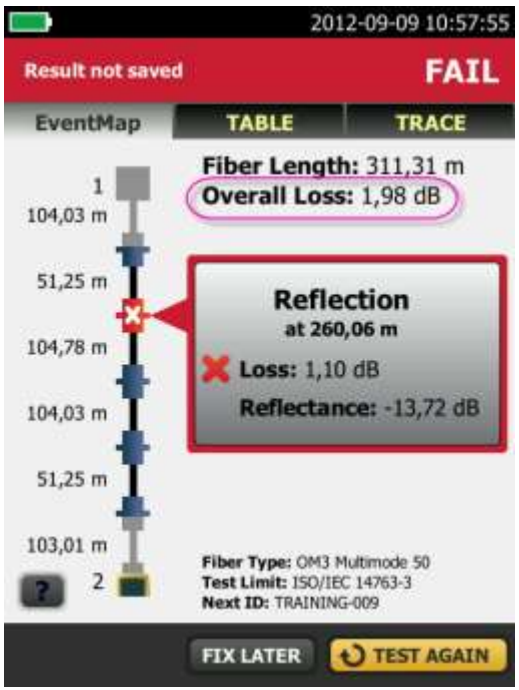
	Conn. #1	Fiber #1	Conn. #2	Fiber #2	Conn. #3	Fiber #3	Conn. #4	Fiber #4	Conn. #5	Total
L (m)		30		30		30		30		120
	0.30	0.105	0.75	0.105	0.75	0.105	0.75	0.105	0.30	**2.40**
Value	0.25	0.09	0.25	0.09	0.25	0.09	**1.00**	0.09	0.25	**2.32**

Take Away:

- Tier1/BASIC LSPM Testing: The good connections may cover up for one very poor one
- Only an OTDR can find the “unnecessary” bottle neck

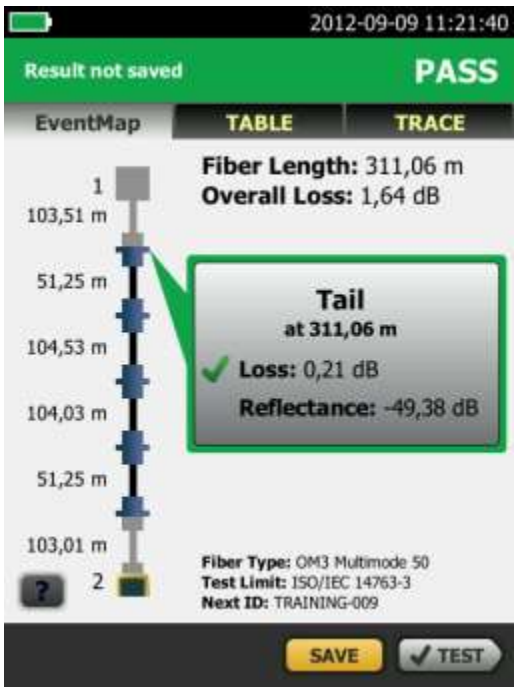
Example: Locating A Bottle Neck

- The overall loss of 1.98dB is well within the limit
- The unnecessary bottle neck is 260m



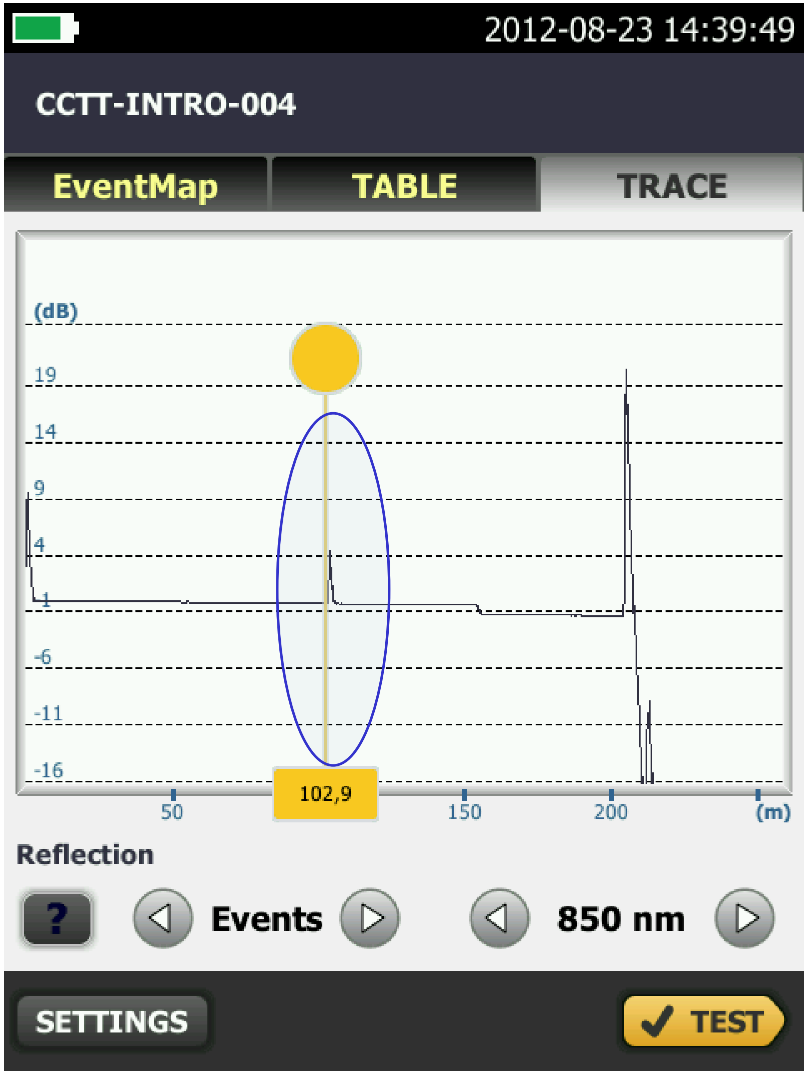
Example: Locating A Bottle Neck

- The problem was resolved by cleaning the end face
- The unnecessary bottle neck is 260m



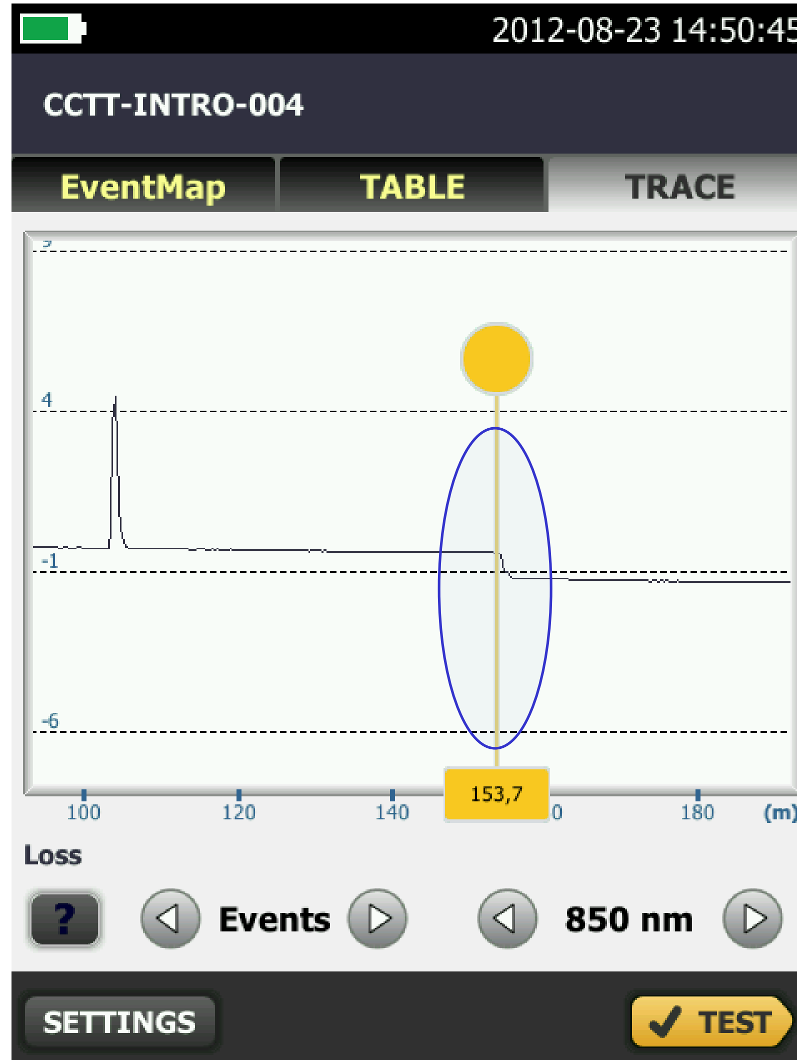
Understand OTDR plots: Reflective events

- Almost always two mated fiber connectors
- Could be a bad mechanical splice too
- On the OTDR trace, they are characterized as a spike



Understand OTDR plots: Non-Reflective events

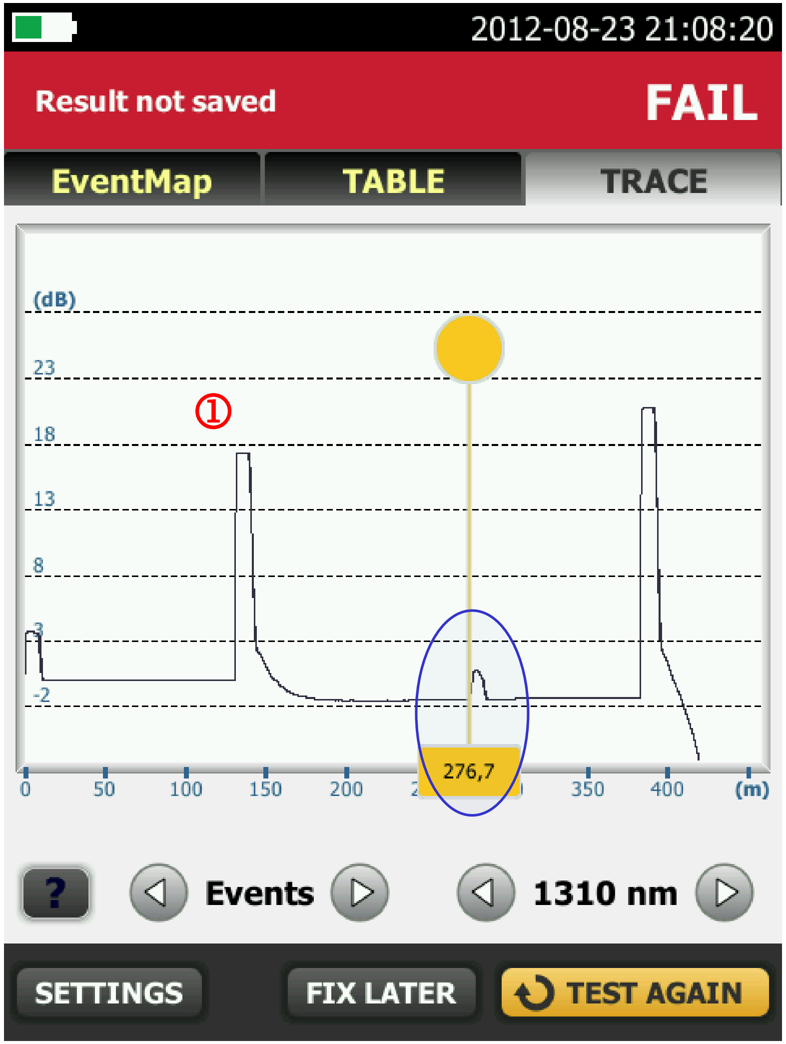
- Almost always a splice, could also be a very good APC connection
  - APC Connectors has almost no reflection
- On the OTDR trace, they are characterized as a dip in the trace
- If you only see it at 1300nm (MM) or 1550 nm (SM), then it is a bend in the fiber



Understand OTDR plots: Ghosts

- Events that don't really exist
- Caused by connections with poor reflectance
- Typically have a near 0 dB loss

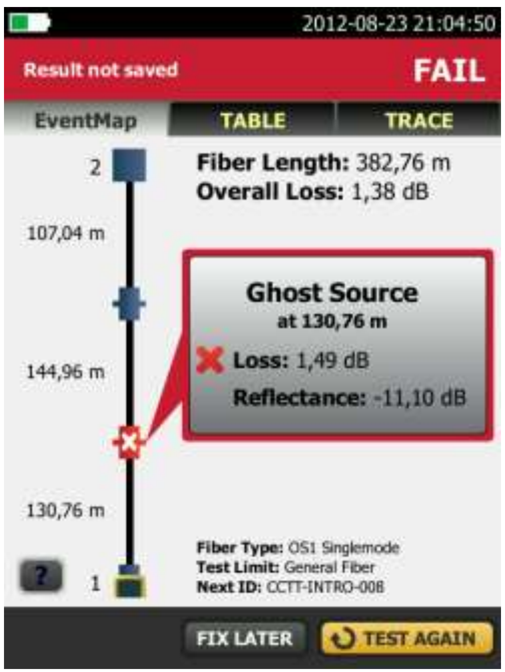
This ghost is caused by some of the light which is reflected from connector ① being reflected back from the OTDR port into the system under test. This is then reflected back again from connector ①. It therefore shows up as a spike on the trace twice as far down the fiber as the real reflection from the connector pair.
That's why we want good reflectance, even at the OTDR port.



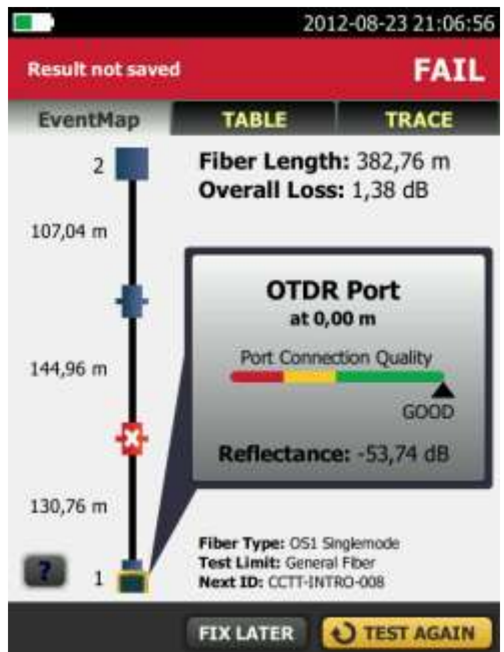
Understand OTDR plots: Ghosts ….. Help for the user

- Understanding what cause the Ghost is key
  - Poor connections in the link under test
  - The OTDR and Launch Fiber

1.) This is causing the ghost



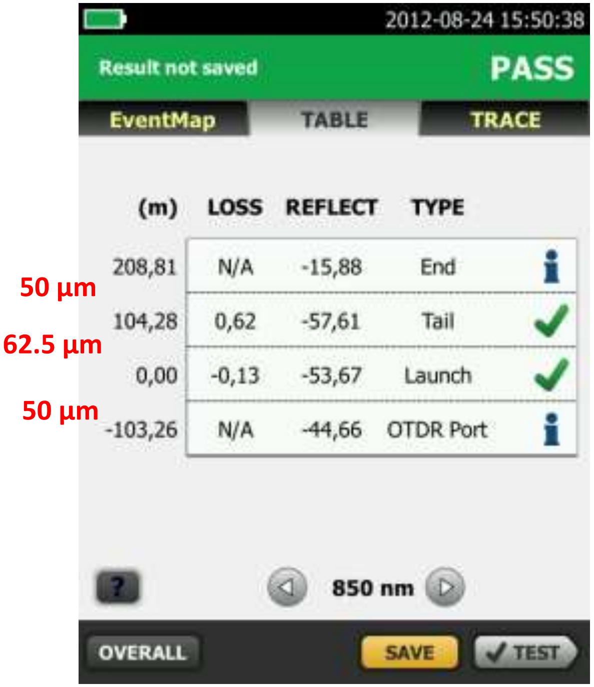
2.) The OTDR port is not to blame

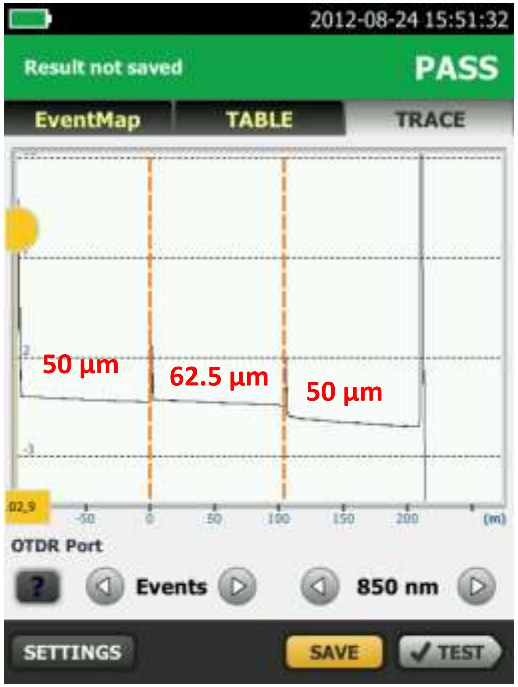


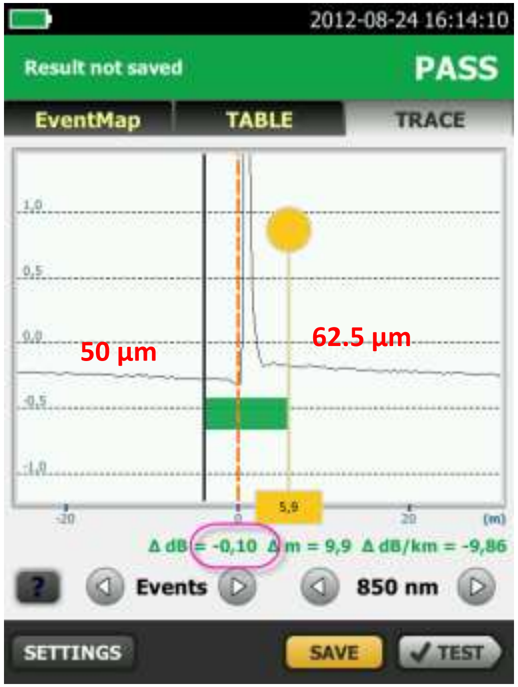
3.) Cause & Effect on one screen

Understanding Gainers: Mixing Different Fibers

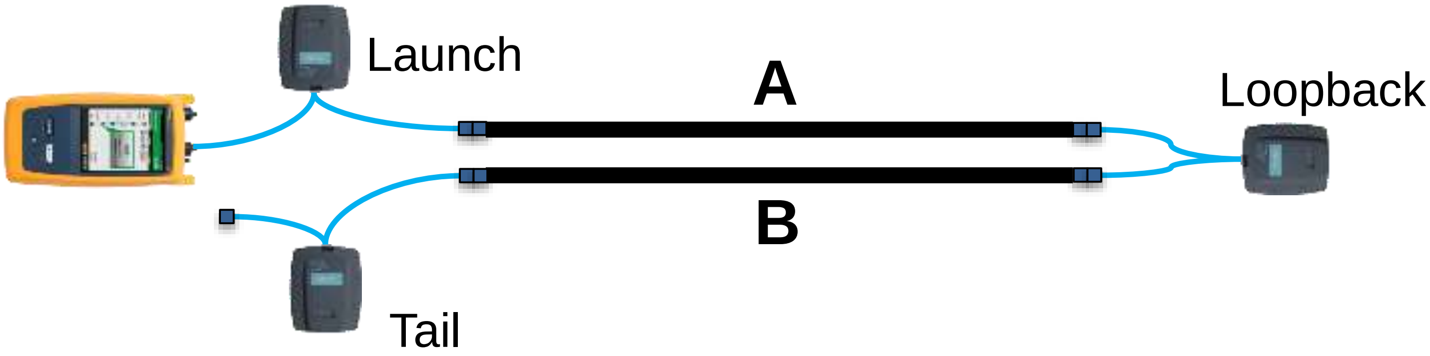
- If you see a significant loss followed by a significant gain or vise versa:
  - Excessive loss would be 62.5 µm into a 50 µm fiber
  - Excessive gain would be 50 µm into a 62.5 µm fiber
- The effect is seen less significant but can't be ignored for matching diameters





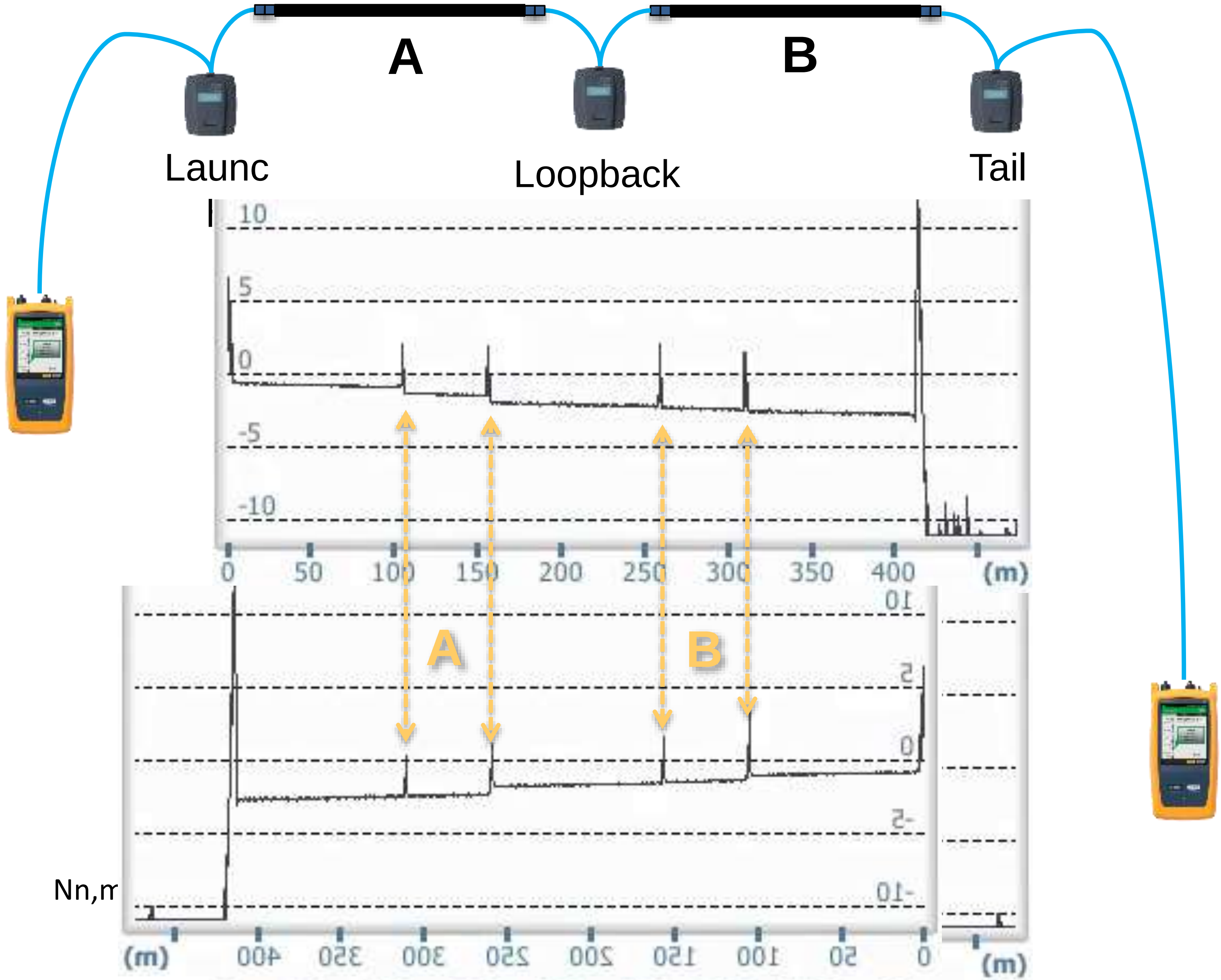


Alternative Method Using a Loop



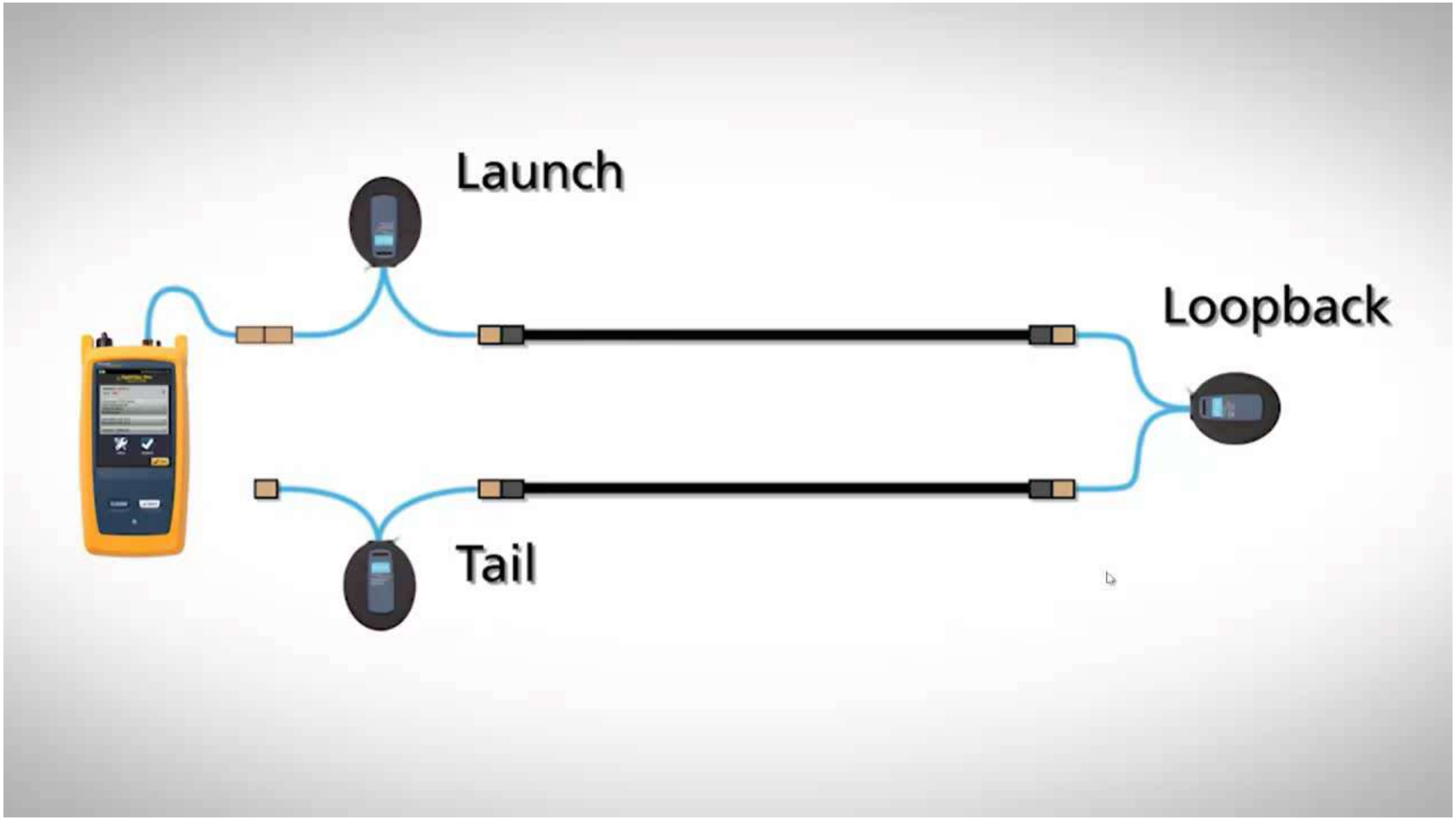
1. Tests A and B fiber simultaneously
2. In a second step from the other direction
3. The individual segments need to be identified in the trace

Alternative Method Using a Loop



- Nn,m

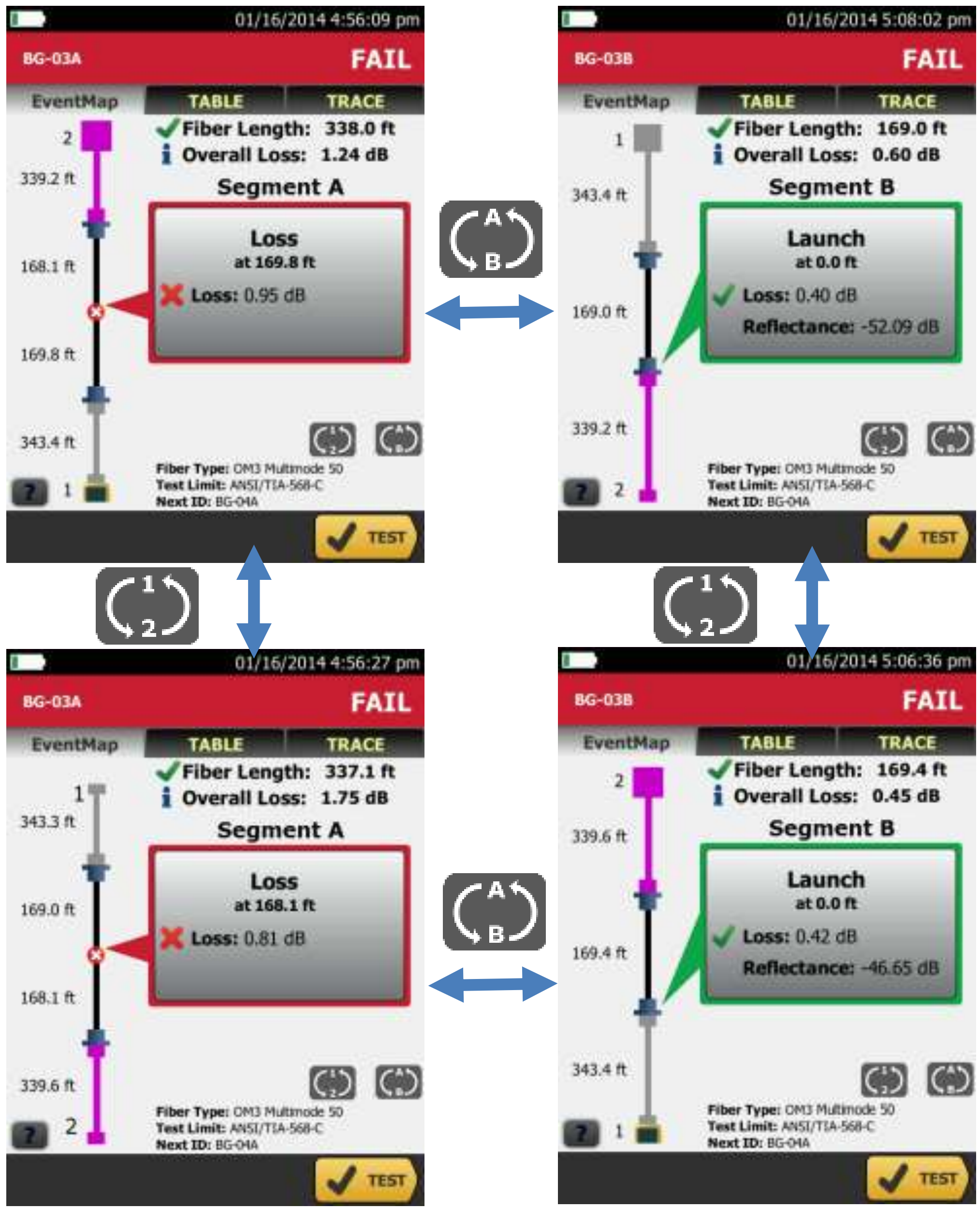
SmartLoop Function – Measuring 2 fibers at the same time



FLUKE networks

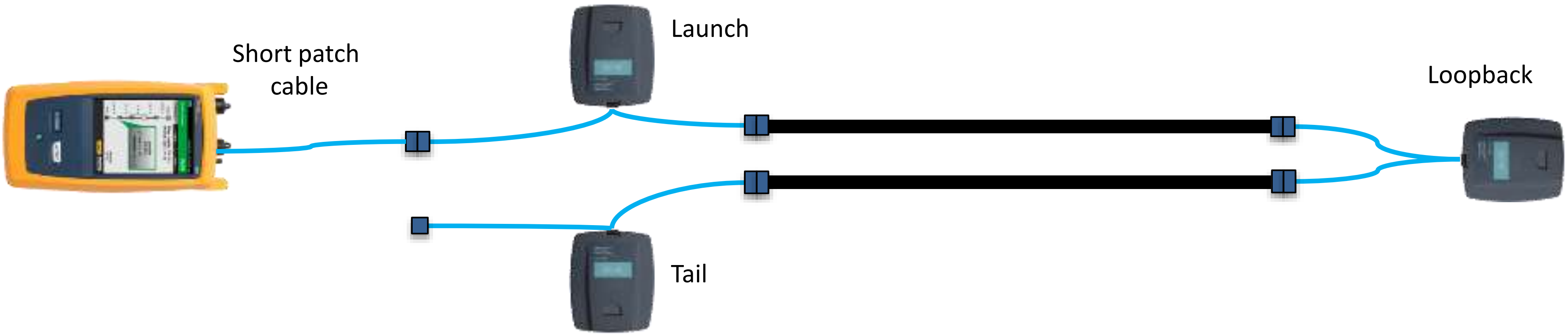
Test Results Navigation

- Tap [A/B icon] to toggle between fibers A and B
- Tap [1/2 icon] to toggle between Ends 1 and 2
- The loopback fiber is always End 2



Protect your OTDR port

- When preforming bi-directional OTDR testing, you need to leave the launch and tail cords attached to the link under test.
- This means that you are frequently connecting and disconnecting from your OTDR's port
- Protect your OTDR port by using a short patch cord in front of your launch/tail fiber
  - This short patch cord, 1 foot (1/3 meter), is within the OTDR's event deadzone so it will not affect your measurement results
  - This is not the same as using a short patch cord between the launch cord and link under test



Is it possible to troubleshoot without an OTDR?

Troubleshooting a fiber break with a Visual Fault Locater

- Start at one end and work to the other
- Use VFL to shine light into fiber (turn off the room lights)
- Open patch panel and look for VFL light
- Walk along fiber path looking for the VFL light
- Pinch the fiber at a point to see if the VFL light is getting that far
- Take off port covers look for light
- Open patch panel and look for VFL light
- Use an end face inspector on the connector
- Use an OTDR (or call someone with an OTDR)

Eliminate trial and error with (MultiMode) Fiber QuickMap

- Connect Fiber QuickMap to troubled fiber
- Press "Test"
- Go to fault location!

Hands-on: Interpreting a Series of Readings

- 1st of 4 incidents detected
- Reflective incident flagged at 98.7 ft
- Measurement of -41 dB
  - Threshold set at -35 dB (= more than 3% of light is reflected)
- Analysis?

Hands-on: Interpreting a Series of Readings

- 2nd of 4 incidents detected
- Reflective and Loss incidents flagged at 141.2 ft
  - Reflective measurement of -32 dB
  - Loss threshold set at 0.5 dB
- Analysis?

Hands-on: Interpreting a Series of Readings

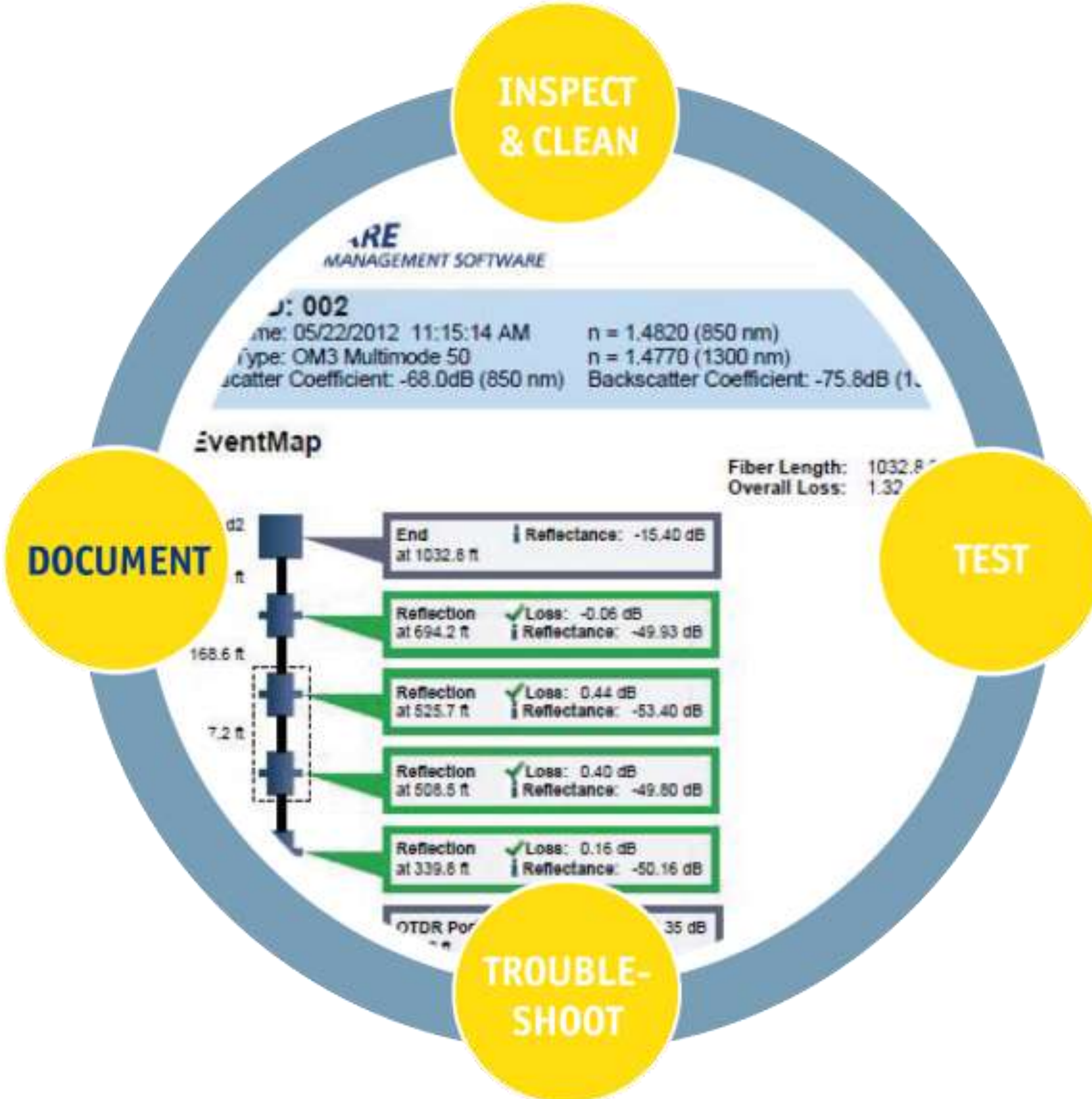
- 3rd of 4 incidents detected
- Reflective incident at 147.6 ft
  - Reflective measurement of -40 dB
  - Reflective and Loss thresholds not tripped
- Analysis?

Hands-on: Interpreting a Series of Readings

- 4th of 4 incidents detected
- Reflective incident flagged at 178.2 ft
  - Reflective measurement of -20 dB
  - –Loss threshold not tripped
- Analysis?

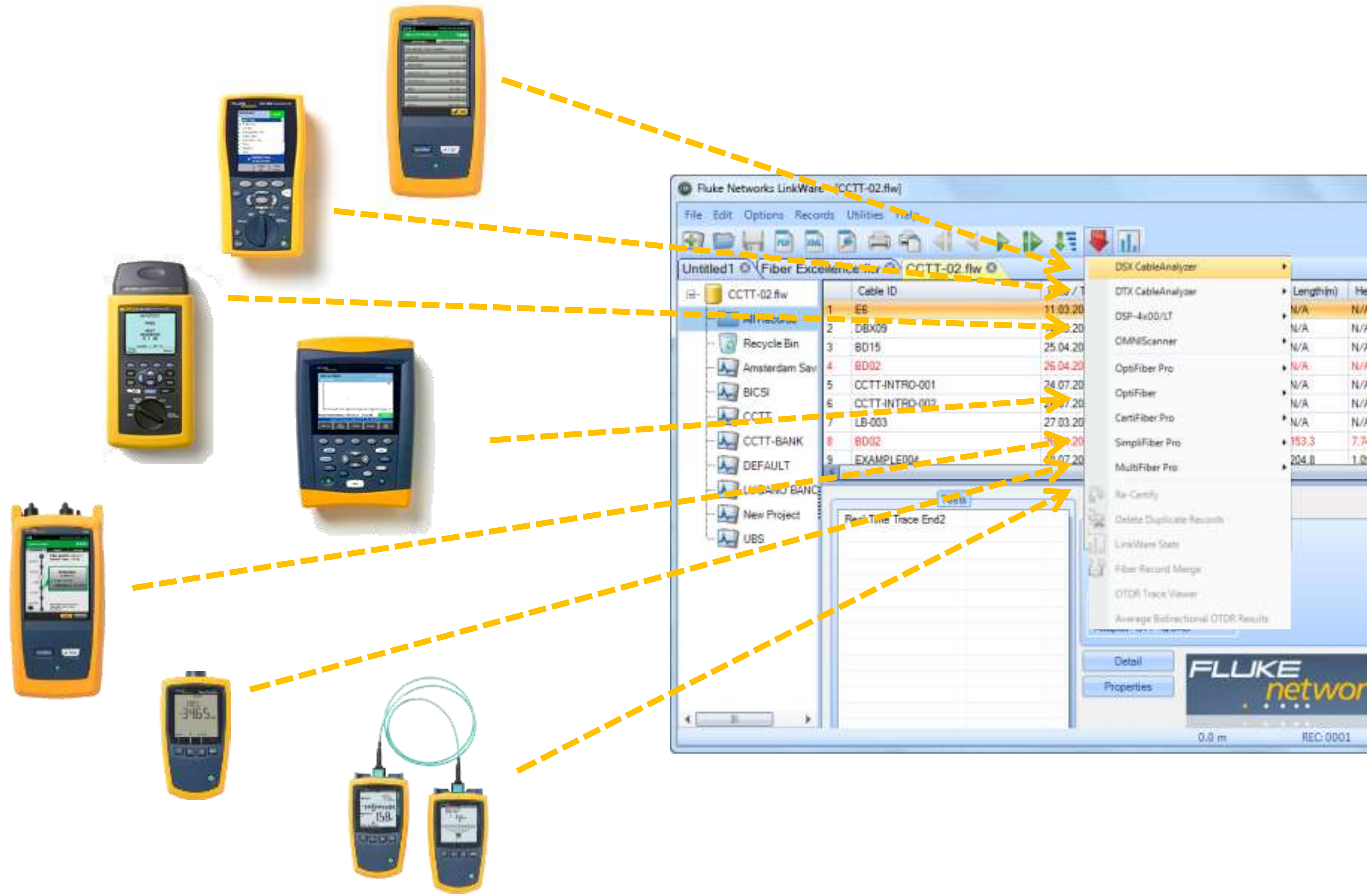
Fiber Excellence Agenda

- **Basic Fiber Optic Theory**
- **End-face Inspection and Cleaning**
- **Test - Loss/Length Certification**
- **Fiber Plant Characterization and Troubleshooting**
- **Documentation**


INSPECT & CLEAN
MANAGEMENT SOFTWARE
n = 1.4820 (850 nm)
n = 1.4770 (1300 nm)
EventMap
Fiber Length:
Overall Loss:
End at 1032.8 ft Reflectance: -15.40 dB
Reflection at 694.2 ft Loss: -0.06 dB Reflectance: -49.93 dB
Reflection at 525.7 ft Loss: 0.44 dB Reflectance: -53.40 dB
Reflection at 508.5 ft Loss: 0.40 dB Reflectance: -49.80 dB
Reflection at 339.8 ft Loss: 0.16 dB Reflectance: -50.16 dB
168.6 ft
7.2 ft
DOCUMENT
TEST
TROUBLE-
SHOOT

Comprehensive, professional-quality documentation of the test results of installed network cabling.

LinkWare Works With Multiple Fluke Networks Testers

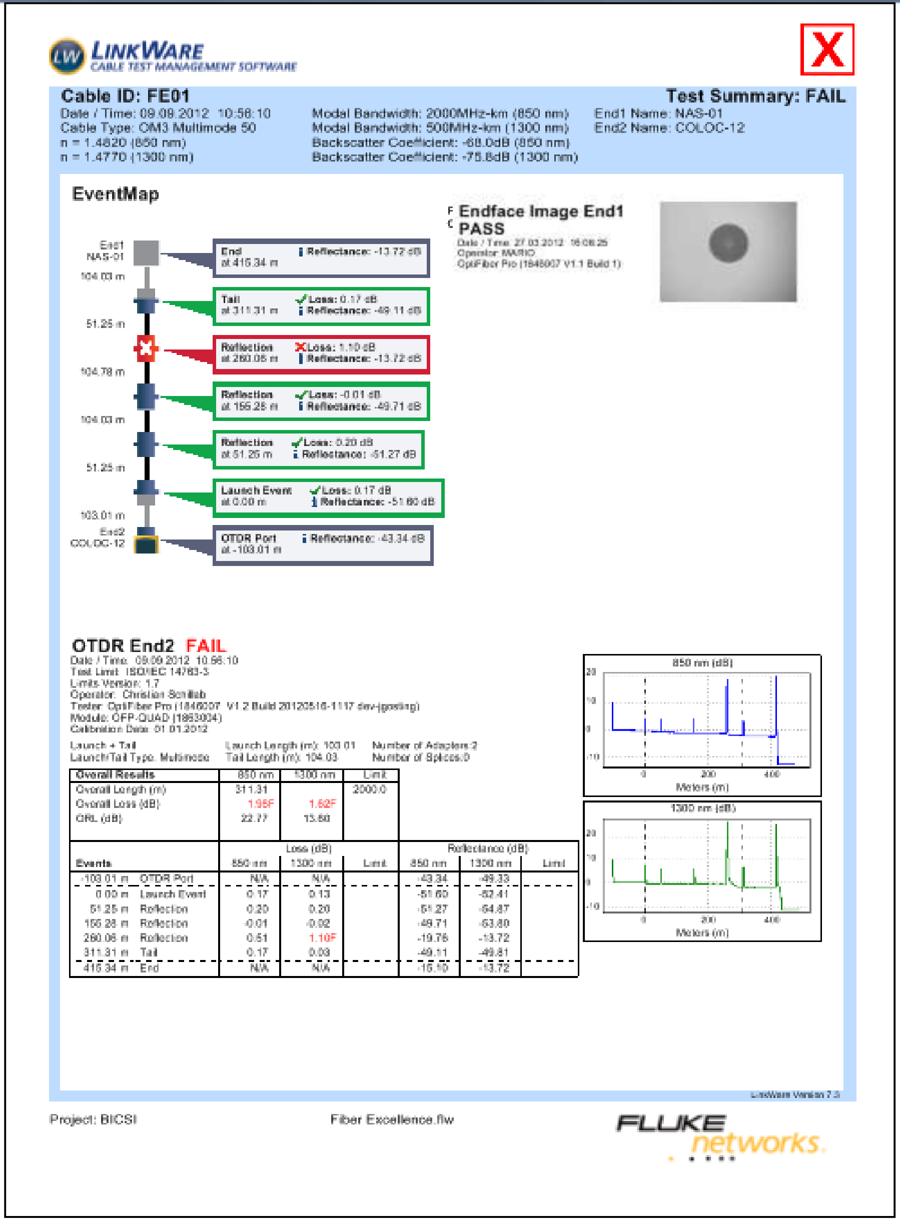


Documentation

Why document?

- Good record-keeping
  - *Always a smart practice*
- Enforces installation accountability and integrity
  - *Required in certain projects*
  - *Helps resolve contractor/client project disputes*
- Facilitates more efficient troubleshooting
  - *Locate potential problem areas more quickly*

– Useful during (preventative) maintenance



LINKWARE
CABLE TEST MANAGEMENT SOFTWARE

Cable ID: FE01 **Test Summary: FAIL**

Date / Time: 09.08.2012 10:56:10
Cable Type: OM3 Multimode 50
n = 1.4820 (850 nm)
n = 1.4770 (1300 nm)

Modal Bandwidth: 2000MHz-km (850 nm)
Modal Bandwidth: 500MHz-km (1300 nm)
Backscatter Coefficient: -68.0dB (850 nm)
Backscatter Coefficient: -75.8dB (1300 nm)

End1 Name: NAS-01
End2 Name: COLOC-12

EventMap

End1 NAS-01
End at 416.34 m — Reflectance: -13.72 dB
104.03 m
Tail at 311.31 m — Loss: 0.17 dB, Reflectance: -49.11 dB
51.25 m
Reflection at 260.06 m — Loss: 1.10 dB, Reflectance: -13.72 dB
104.78 m
Reflection at 156.28 m — Loss: -0.01 dB, Reflectance: -49.71 dB
104.03 m
Reflection at 51.25 m — Loss: 0.20 dB, Reflectance: -51.27 dB
51.25 m
Launch Event at 0.00 m — Loss: 0.17 dB, Reflectance: -51.60 dB
103.01 m
End2 COLOC-12
OTDR Port at -103.01 m — Reflectance: -43.34 dB

Endface Image End1 PASS
Date / Time: 27.03.2012 16:08:25
Operator: MARIO
OptiFiber Pro (1846007 V1.1 Build 1)

OTDR End2 FAIL
Date / Time: 09.09.2012 10:56:10
Test Limit: ISO/IEC 14763-3
Limits Version: 1.7
Operator: Christian Schillab
Tester: OptiFiber Pro (1846007 V1.2 Build 20120516-1117 dev-(gosling)
Module: OFP-QUAD (1863004)
Calibration Date: 01.01.2012

Launch + Tail — Launch Length (m): 103.01 — Number of Adapters:2
Launch/Tail Type: Multimode — Tail Length (m): 104.03 — Number of Splices:0

Overall Results	850 nm	1300 nm	Limit
Overall Length (m)	311.31		2000.0
Overall Loss (dB)	1.95F	1.62F	
ORL (dB)	22.77	13.60	

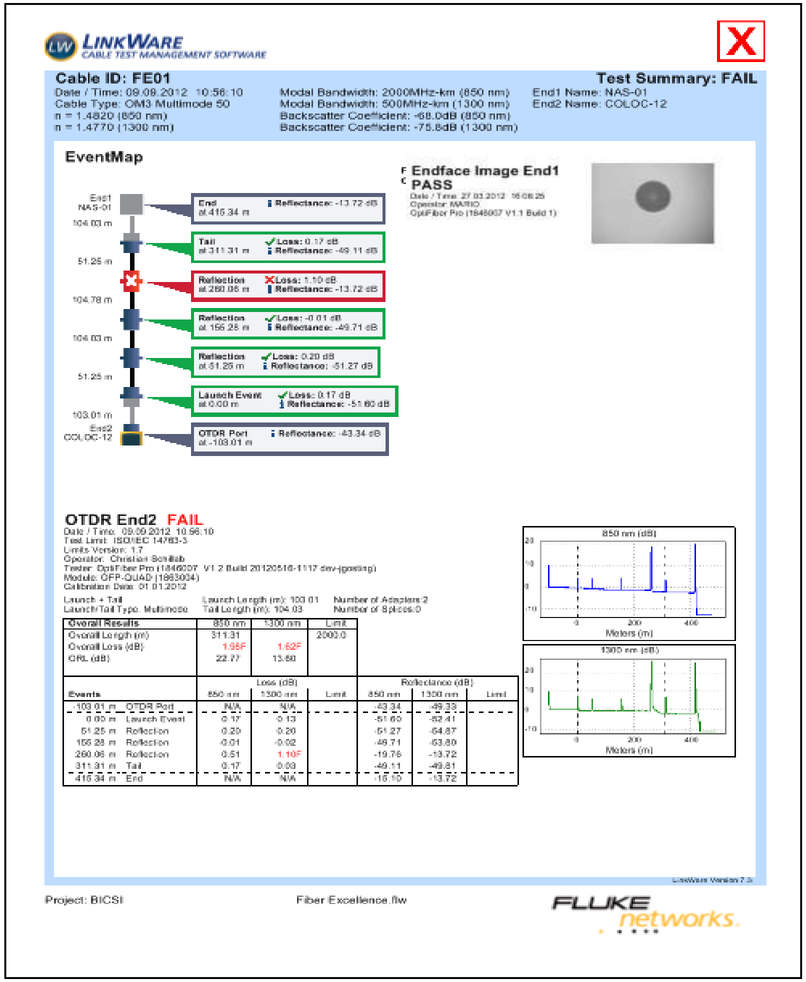
Events		Loss (dB) 850 nm	Loss (dB) 1300 nm	Loss (dB) Limit	Reflectance (dB) 850 nm	Reflectance (dB) 1300 nm	Reflectance (dB) Limit
-103.01 m	OTDR Port	N/A	N/A		-43.34	-49.33	
0.00 m	Launch Event	0.17	0.13		-51.60	-52.41	
51.25 m	Reflection	0.20	0.20		-51.27	-54.87	
156.28 m	Reflection	-0.01	-0.02		-49.71	-53.80	
260.06 m	Reflection	0.51	1.10F		-19.76	-13.72	
311.31 m	Tail	0.17	0.03		-49.11	-49.81	
416.34 m	End	N/A	N/A		-16.10	-13.72	

850 nm (dB) — Meters (m)
1300 nm (dB) — Meters (m)

Project: BICSI — Fiber Excellence.flw

FLUKE networks

Multiple Result Views For Each Fiber



Cable ID: FE01 — Test Summary: FAIL

Date / Time: 09.09.2012 10:56:10
Cable Type: OM3 Multimode 50
n = 1.4820 (850 nm)
n = 1.4770 (1300 nm)

Modal Bandwidth: 2000MHz-km (850 nm)
Modal Bandwidth: 500MHz-km (1300 nm)
Backscatter Coefficient: -68.0dB (850 nm)
Backscatter Coefficient: -75.8dB (1300 nm)

End1 Name: NAS-01
End2 Name: COLOC-12

EventMap

End1 NAS-01
End at 415.34 m — Reflectance: -13.72 dB
104.03 m
Tail at 311.31 m — Loss: 0.17 dB, Reflectance: -49.11 dB
51.25 m
Reflection at 260.06 m — Loss: 1.10 dB, Reflectance: -13.72 dB
104.78 m
Reflection at 156.28 m — Loss: -0.01 dB, Reflectance: -49.71 dB
104.03 m
Reflection at 51.25 m — Loss: 0.20 dB, Reflectance: -51.27 dB
51.25 m
Launch Event at 0.00 m — Loss: 0.17 dB, Reflectance: -51.60 dB
103.01 m
End2 COLOC-12
OTDR Port at -103.01 m — Reflectance: -43.34 dB

Endface Image End1 PASS
Date / Time: 27.03.2012 16:08:25
Operator: MARIO
OptiFiber Pro (1846007 V1.1 Build 1)

OTDR End2 FAIL
Date / Time: 09.09.2012 10:56:10
Test Limit: ISO/IEC 14763-3
Limits Version: 1.7
Operator: Christian Schillab
Tester: OptiFiber Pro (1846007 V1.2 Build 20120516-1117 dev-(gosling))
Module: OFP-QUAD (1863004)
Calibration Date: 01.01.2012

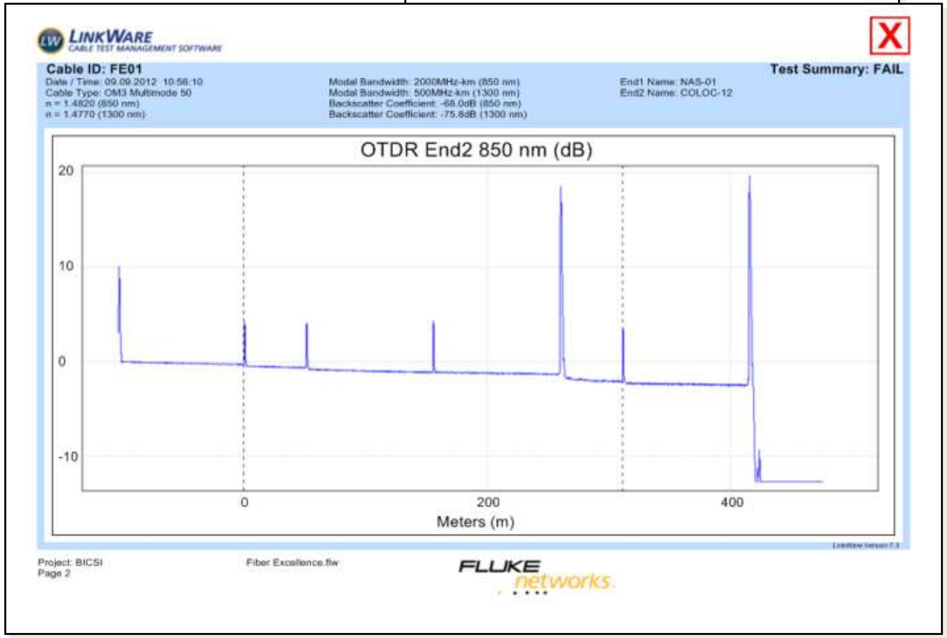
Launch + Tail — Launch Length (m): 103.01 — Number of Adapters: 2
Launch/Tail Type: Multimode — Tail Length (m): 104.03 — Number of Splices: 0

Overall Results	850 nm	1300 nm	Limit
Overall Length (m)	311.31		2000.0
Overall Loss (dB)	1.98F	1.62F	
ORL (dB)	22.77	13.60	

Events		Loss (dB) 850 nm	Loss (dB) 1300 nm	Loss (dB) Limit	Reflectance (dB) 850 nm	Reflectance (dB) 1300 nm	Reflectance (dB) Limit
-103.01 m	OTDR Port	N/A	N/A		-43.34	-49.33	
0.00 m	Launch Event	0.17	0.13		-51.60	-52.41	
51.25 m	Reflection	0.20	0.20		-51.27	-54.87	
156.28 m	Reflection	-0.01	-0.02		-49.71	-53.80	
260.06 m	Reflection	0.51	1.10F		-19.76	-13.72	
311.31 m	Tail	0.17	0.03		-49.11	-49.81	
416.34 m	End	N/A	N/A		-16.10	-13.72	

LinkWare Version 7.3

Project: BICSI — Fiber Excellence.flw



Cable ID: FE01 — Test Summary: FAIL

Date / Time: 09.09.2012 10:56:10
Cable Type: OM3 Multimode 50
n = 1.4820 (850 nm)
n = 1.4770 (1300 nm)

Modal Bandwidth: 2000MHz-km (850 nm)
Modal Bandwidth: 500MHz-km (1300 nm)
Backscatter Coefficient: -68.0dB (850 nm)
Backscatter Coefficient: -75.8dB (1300 nm)

End1 Name: NAS-01
End2 Name: COLOC-12

Project: BICSI
Page 2
Fiber Excellence.flw

Statistical Analysis Of Test Results

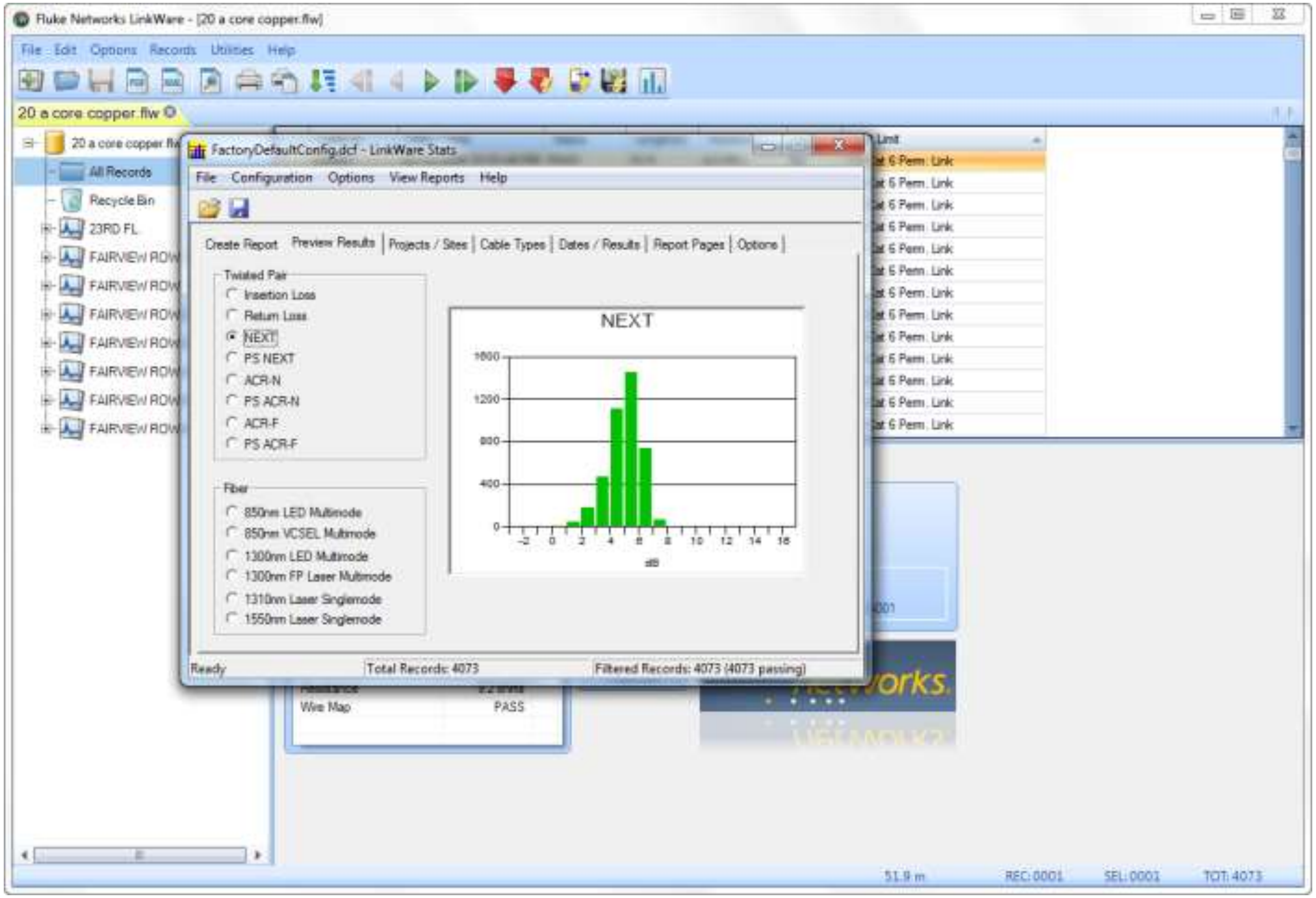
When & Why ?

1. When many results need to be viewed
2. The statistical distribution allows for conclusion about anomalies and deficiencies
3. When data is needed from a reference implementation for a quality plan
4. To monitor the installation quality while an project/installation is still ongoing

Great tool to provide immediate insight into job quality

Linkware Stats: Statistical Analysis

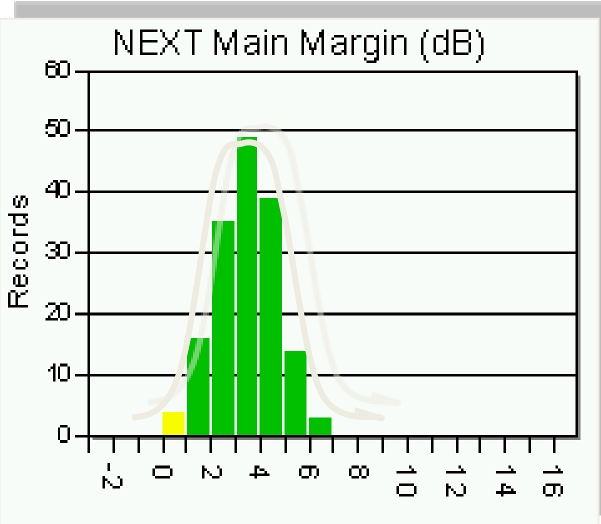
- Included with Linkware



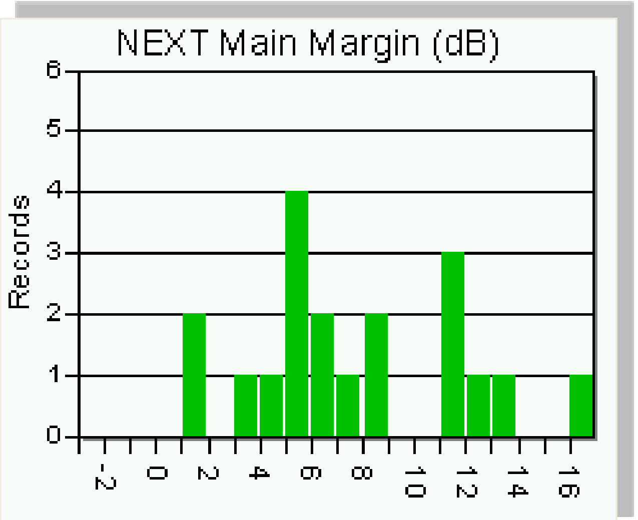
Statistical Analysis Insights

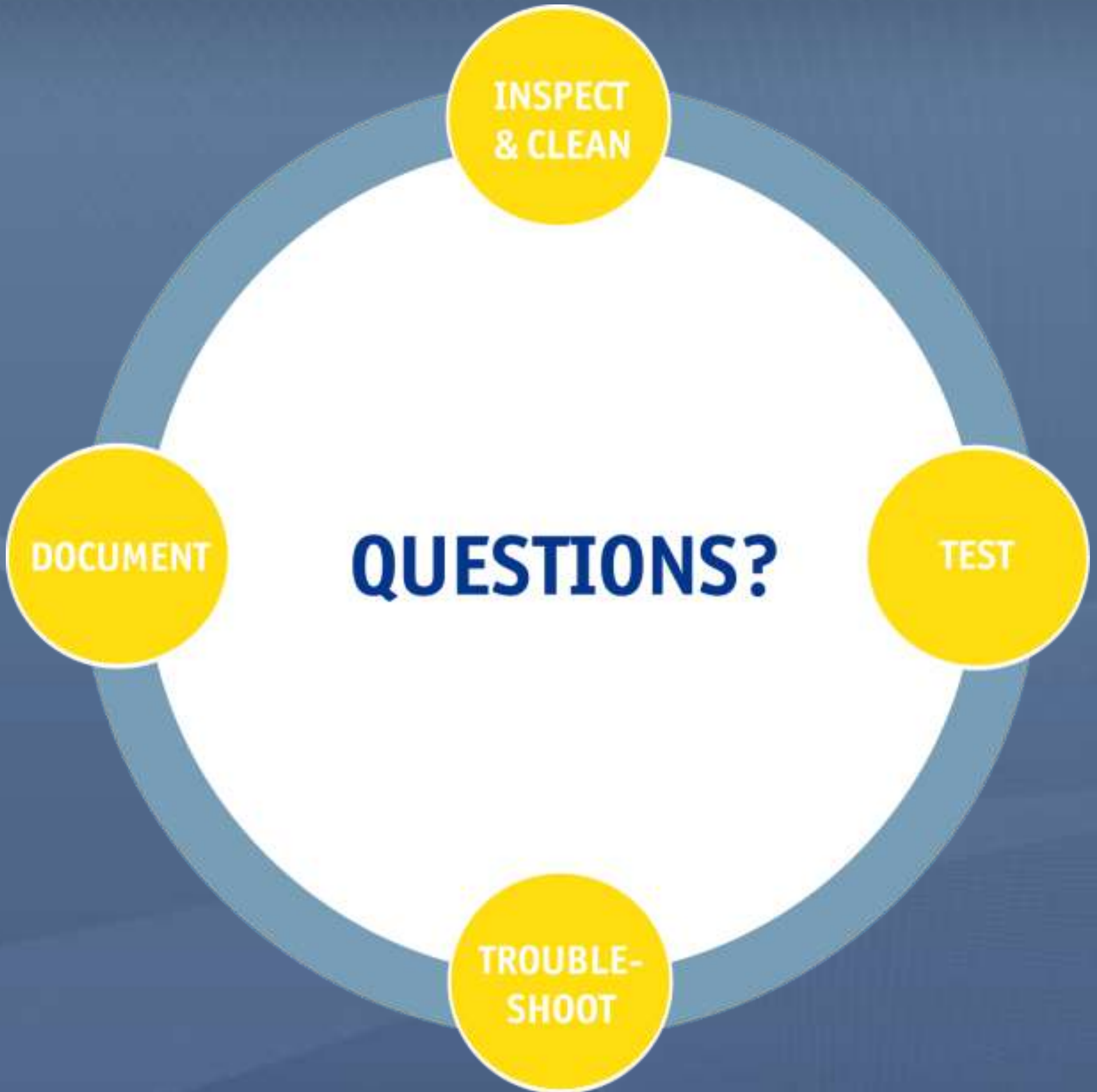
Find what may be „hidden“ in a histogram?

- The margins for NEXT show a normal distribution



- In this case the distribution of NEXT margin is abnormal
  - Material of different quality ?
  - Different installation teams deliver different quality ?
  - Did one team use a damaged/poor test adapter or is a calibration imminent?





FLUKE networks

Prepared by:
Robert Luijten, Global Field Marketing Manager
Christian Schillab, Senior Product Specialist