Eye on Optical Fiber

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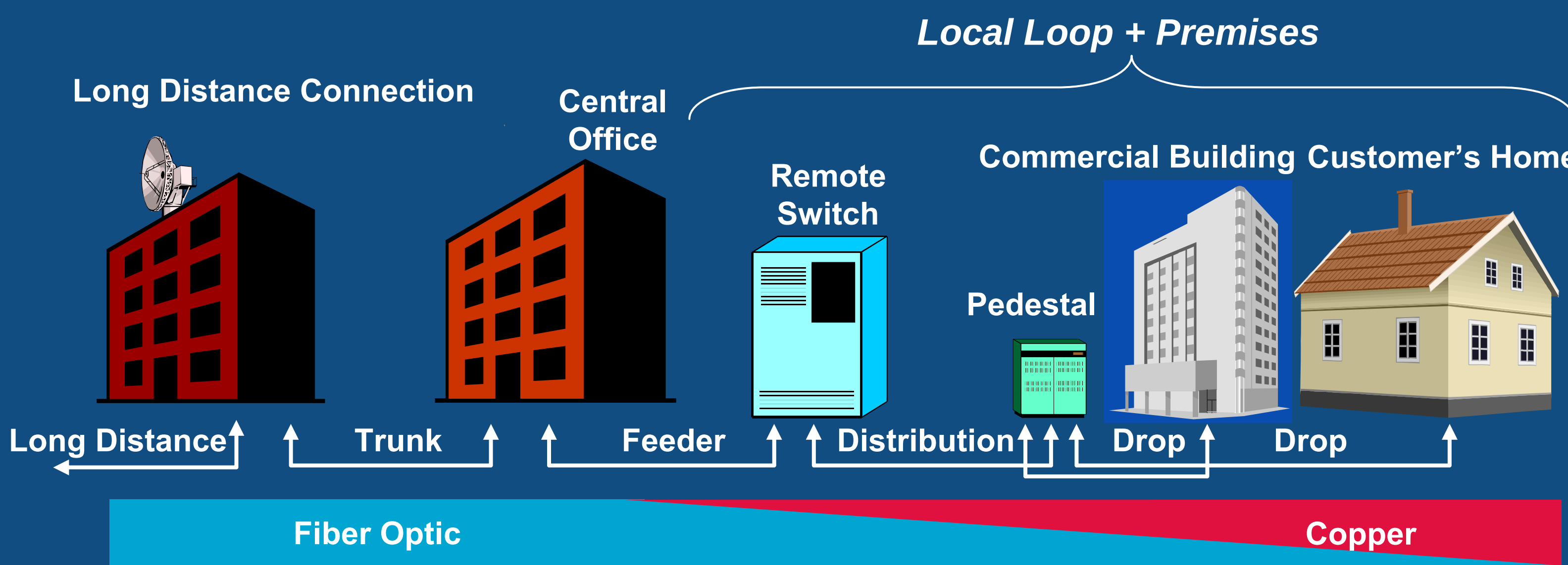
Eye on Optical Fiber

- Introductions
- ABC's of Optical Fiber
- Optical Fiber Standards Review & Update
- Market Update & New Trends
- Optical Fiber Glass, Cable & Connecting Hardware
- Testing 10GB Optical Fiber Networks
- Closing Remarks

ABC's of Optical Fiber

- Where's the Optical Fiber?
- Why Install Fiber Optics?
- Fiber Basics
- Fiber Types
- Factors Affecting Optical Fiber Performance
  - Intrinsic Losses
  - Attenuation/Insertion Loss
  - Dispersion
- Mechanical Reliability

Where's the Optical Fiber?

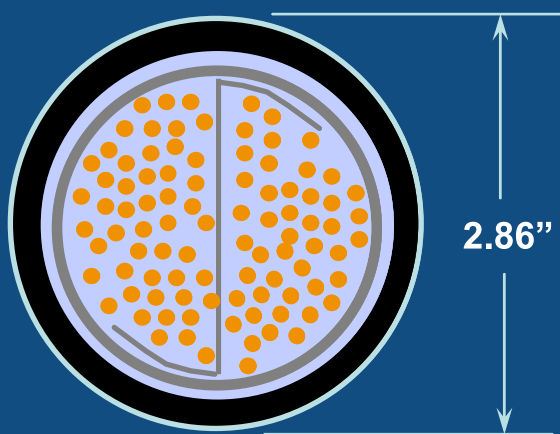


Why Install Fiber Optics?

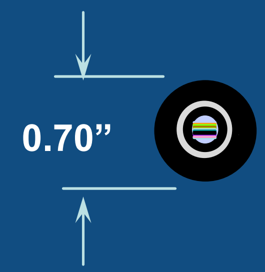
- Low Signal Loss
- High Bandwidth
- Not Affected by EMI or RFI
- Small Size
- Lightweight

Why Install Fiber Optics?

900 Pair Copper Cable



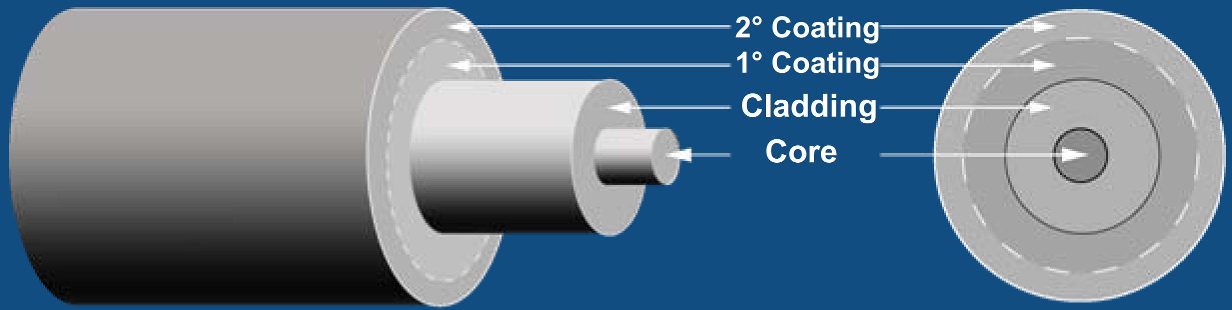
216 Fiber Optical Cable



900 Pair Copper Cable	Type of Medium	216 Fiber Optical Cable
22 Gauge Conductors	Type of Medium	Single Mode fibers
4800 lbs/1000 feet	Weight	200 lbs/1000 feet
1.54 Mb/s	Transmission Rate	40 x 10 Gb/s
10,800	2-Way Phone Calls	27,869,000
1.14 Miles	Regenerator Spacing	72 Miles

Optical Fiber

- Uses light pulses instead of electrical signals
- Core & Cladding are composed of glass
- n1 of the core > n2 of the cladding
- Core diameter defines fiber type
- Cladding diameter = 125 µm
- Coating is UV curable urethane acrylate (2-Layers)
- Coating diameter = 250 µm



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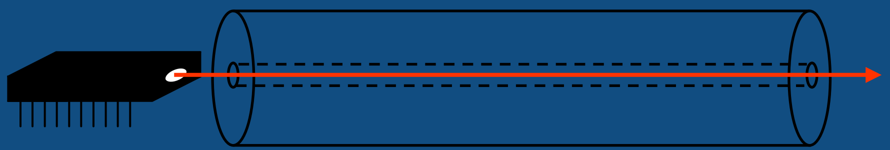
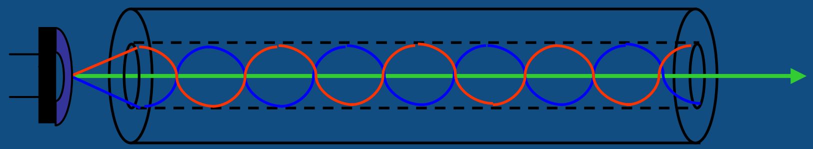
Optical Fiber Types

- Single Mode



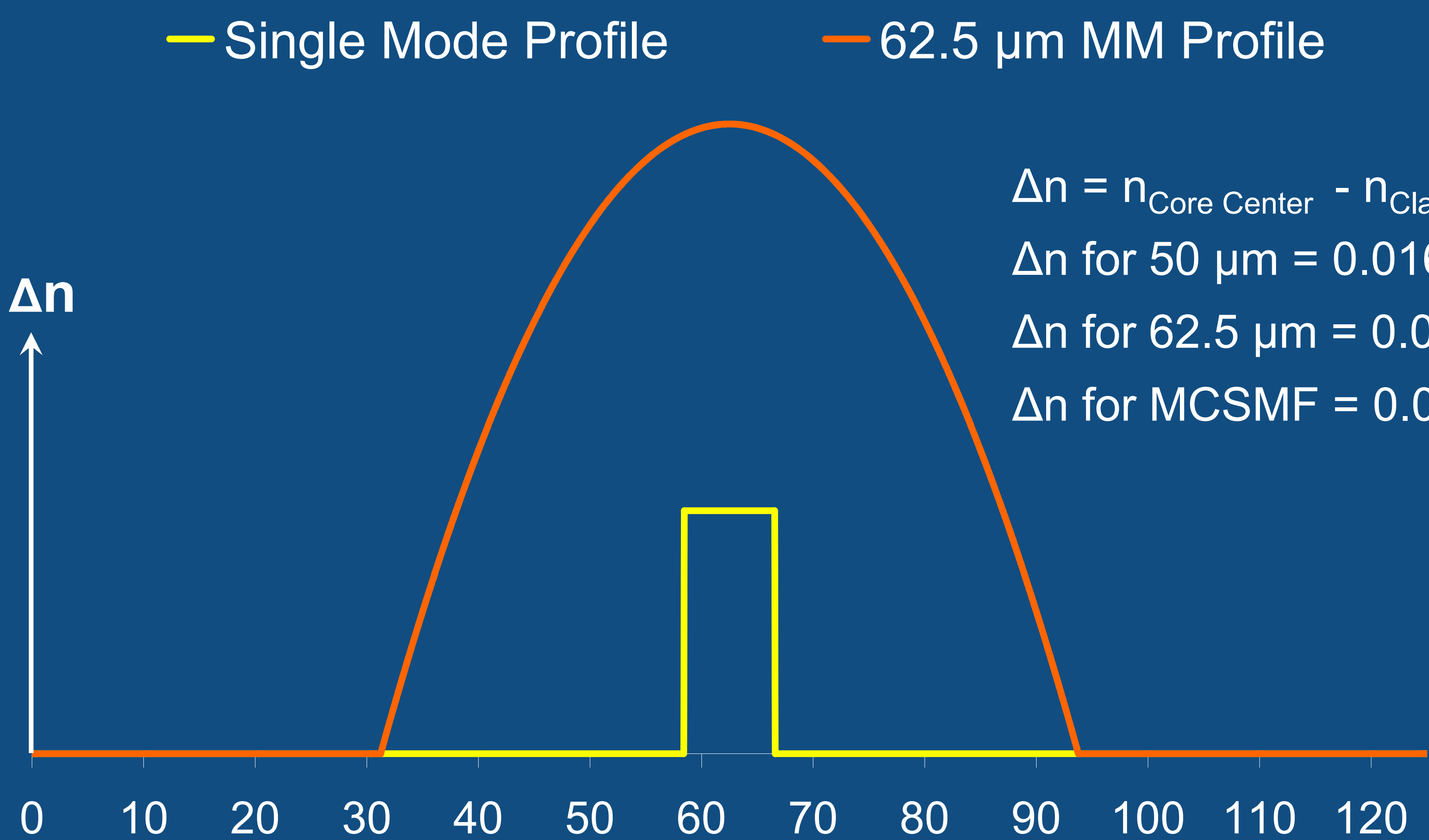
- Multimode



The radius, r, and index of refraction, n_1, of the core determines the number of modes allowed to propagate:

Number of Modes $\approx \Delta(2\pi n_{core} r_{core}/\lambda)$

Index Profile of Fiber Types



$\Delta n = n_{Core\ Center} - n_{Cladding}$

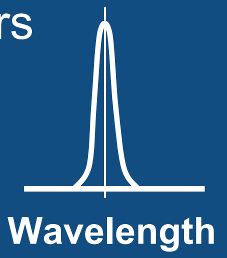
Δn for 50 µm = 0.0165

Δn for 62.5 µm = 0.0285

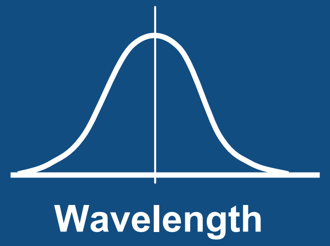
Δn for MCSMF = 0.011

Transmission Sources

- Fabry-Perot (FP) and Distributed Feedback (DFB) Lasers
  - 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
  - Most expensive (especially DFB)



- 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



- VCSEL's
  - 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

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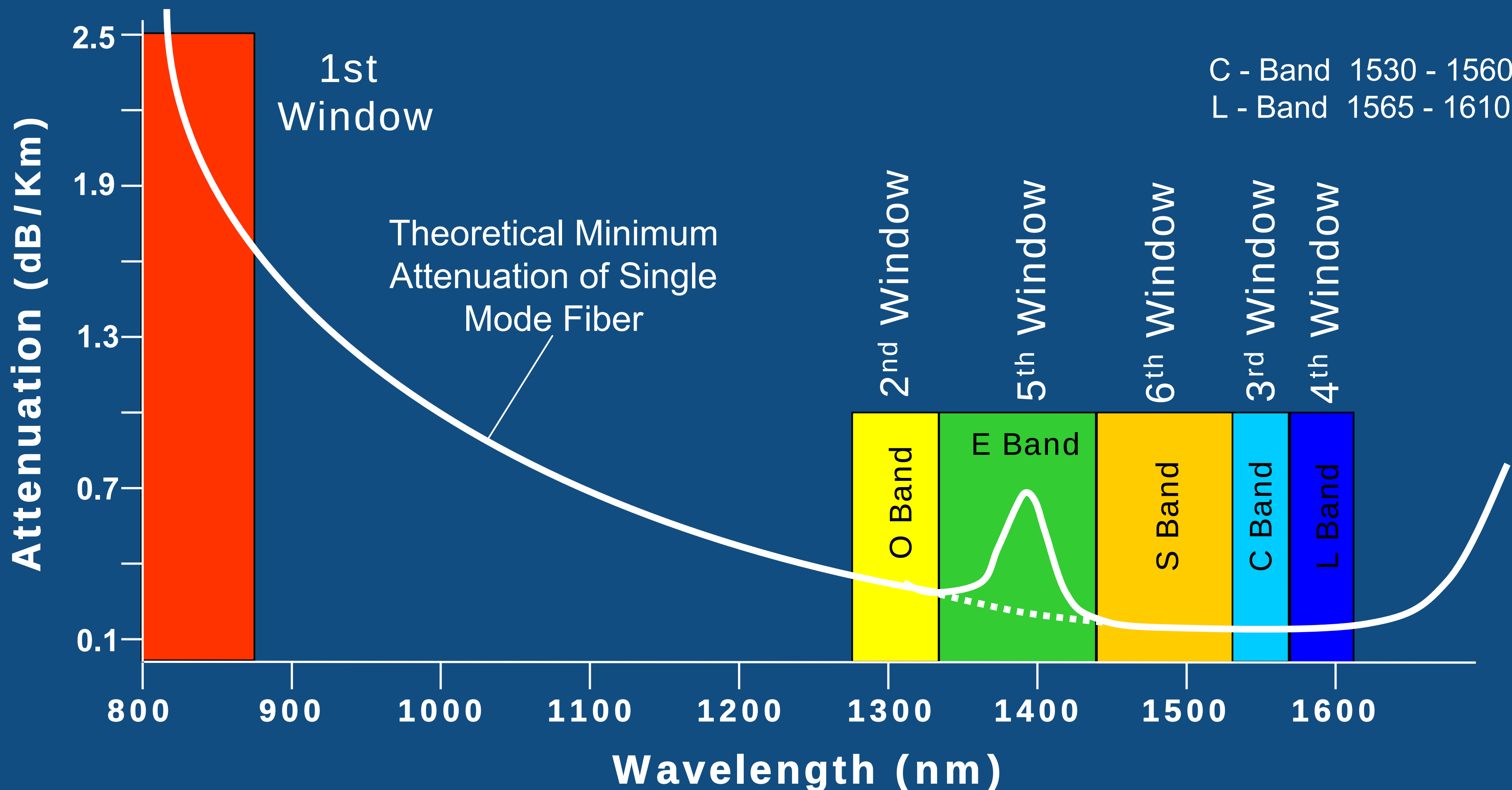
Wavelength Windows Operation

Reference Point: Visible Light is between 450 and 650 nm



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Factors Affecting Optical Fiber Performance

- Factors Affecting Light Losses or Attenuation
  - Intrinsic
  - Bending Losses
  - Splice Losses
- Factors Affecting Light Pulse Broadening (Bandwidth)
  - Chromatic Dispersion
  - Modal Dispersion
  - Polarization Mode Dispersion

Attenuation

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

Attenuation for Fiber Types

Fiber Type	850 nm	1310 nm	1550 nm
Single Mode	N/A	0.35 dB/km	0.25 dB/km
Multimode	3.5 dB/km	1.0 dB/km	N/A

Sources of Attenuation

- Intrinsic
  - Defines fundamental minimum loss
  - Raleigh Scattering
  - Water Peak Absorption (except of zero water peak fiber)
- Splice Loss
  - Fusion: core alignment
  - Mechanical: core alignment, dirt on end face, reflection
  - Mode Field Diameter in Single Mode Fibers
  - Numerical Aperture Mismatch in Multimode Fibers

Sources of Attenuation

- Macrobending (Single Mode Fiber)
  - Bending radius ~ 2 – 15 mm
  - Affects long wavelengths first
  - Affected mostly by fiber design
- Microbending (All Fiber)
  - Bending radius ~ radius of core
  - Can occur during optical fiber manufacturing process
  - Can be induced during installation due to point pressures
  - Affects all wavelengths, but increases slightly with wavelength
  - Order of Sensitivity (least to highest): SM, 62.5 μ, 50 μ
  - Affected by Coating and Cable Design

Dispersion or Pulse Broadening

- Chromatic Dispersion (Single Mode Fibers)
  - Laser output is distribution of wavelengths
  - Different wavelengths travel different speeds
  - Dispersion compensating fiber
- Polarization Mode Dispersion (Single Mode Fibers)
  - Radially imperfect core
  - Causes delay in 1 of 2 Orthogonal Modes
- Modal Dispersion (Multi-mode Fibers)
  - Mode is quantum level in light pulse
  - Each mode occupies different area of core
  - Imperfect core structure causes modes to have different speeds

Measuring Modal Dispersion

- Over-Filled Launch (OFL)
  - Uses LED
  - Completely fills all modes of multimode fiber
- Differential Modal Dispersion
  - Uses Laser
  - Injects pulses of light from one side of the core to the other at micron intervals
  - Measures Pulse Intensity and Time of Arrival
  - Effective Modal Bandwidth (EFL) is determined from this test

Optical Fiber Mechanical Reliability

- Strength of Glass Determined By:
  - Size of Flaws on Surface of Glass
  - Ability of Moisture to Associate with Glass Surface
- Manufacturing Virtually “Flawless” Fiber
  - Typically Proof Tested to 100 kpsi Stress or 1% Strain
  - Glass breaks at flaws
- Most failures occur at splices where stripping the fiber introduces flaws

ABC’s of Optical Fibers

Questions?

Optical Fiber Standards Update

- North American Standards
  - IEEE
  - EIA/TIA
  - ICEA
  - Telcordia
  - FOLS

IEEE 802.3

- 802.3 is the foundation specification for Ethernet Protocol and Physical Layer Definition
- The dominant protocol in the enterprise space
- Seeing increasing use and acceptance in metro area networks

IEEE 802.3 1GB Implementations

- 1000BASE-SX
  - Operates over multi-mode fiber using 850 nm laser
  - 62.5 µm Multimode Fiber
    - Maximum distance 220 m
    - With good quality fiber and terminations, will work over longer distances
  - 50 µm fibers have reach 500 m or more, depending on bandwidth
- 1000BASE-LX
  - Single Mode Fiber
    - Uses 1300 nm laser for up to 2 km over single mode fiber.
    - Can operate correctly over distances up to 10 or 20 km
  - Multimode Fiber (Both 62.5 & 50 µm)
    - Has reach of 550 m
    - For links greater than 300 m, mode conditioning patch cord may be required

IEEE 802.3 10GB Implementations

- 10GBASE-SR (Short Range, Multimode)
  - Range of between 26 m and 82 m depending on fiber type at 850 nm
  - Supports 300 m operation over LO 50 µm with 2000 MHz·km Bandwidth
- 10GBASE-LRM (Long Range Multimode)
  - Distances up to 220 m on FDDI-grade (legacy) 62.5 µm multi-mode
  - Utilizes Electronic Dispersion Compensation
  - Will work with 98% of installed 62.5 µ Fiber
- 10GBASE-LR/ER (Long Range/Extended Range; Single Mode)
  - LR - Serialized Ethernet over 1310 nm up to 10 km – 25 km.
  - ER - Supports distances up to 40 km at 1550 nm.
- 10GBASE-LX4 (WDM over Multimode)
  - Uses wavelength division multiplexing (WDM) & 4 lasers operating at 3.125 Gbit/s on unique wavelengths to support ranges between 240 m and 300 m
  - Also supports 10 km over single-mode fiber using wavelengths around 1310 nm.

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TIA Standards

- TIA 455, includes all the Fiber Optic Test Procedures (FOTP)
- TIA 472, Generic Optical Fiber Specification
- TIA 492, includes detail specifications for fibers
- TIA 526, Optical Fiber Testing
  - 526-7 – SMF
  - 526-14 – MMF (in need of revision)
- TIA 606A – Cabling Administration
  - Currently under revision
  - To include Data Centers
- TIA/EIA-785: Short Wavelength Fast Ethernet Standard
- ANSI/TIA 942 -Telecommunications Infrastructure Standard for Data Centers
- TSB 178 – Re-defining launch conditions
- TIA/EIA 568 C Series

TIA 568-C Update

- 568-C.0
  - New standard for "Generic Structured Cabling"
  - Will cover common aspects of the TR-42 suite of documents
  - Incorporates TSB-140, Tier Level Optical Fiber Testing
  - User-focused document
  - Still in draft stage; not expected until 2008
- 568-C.1
  - Enterprise space cable and cabling
  - User-focused document
  - Still in draft stage; not expected until 2008
- 568-C.2
  - Copper cabling components
  - Manufacturer-focused document
  - No draft created yet
- 568-C.3
  - Fiber cabling components
  - Manufacturer-focused document
  - Expected to be issued by end of year

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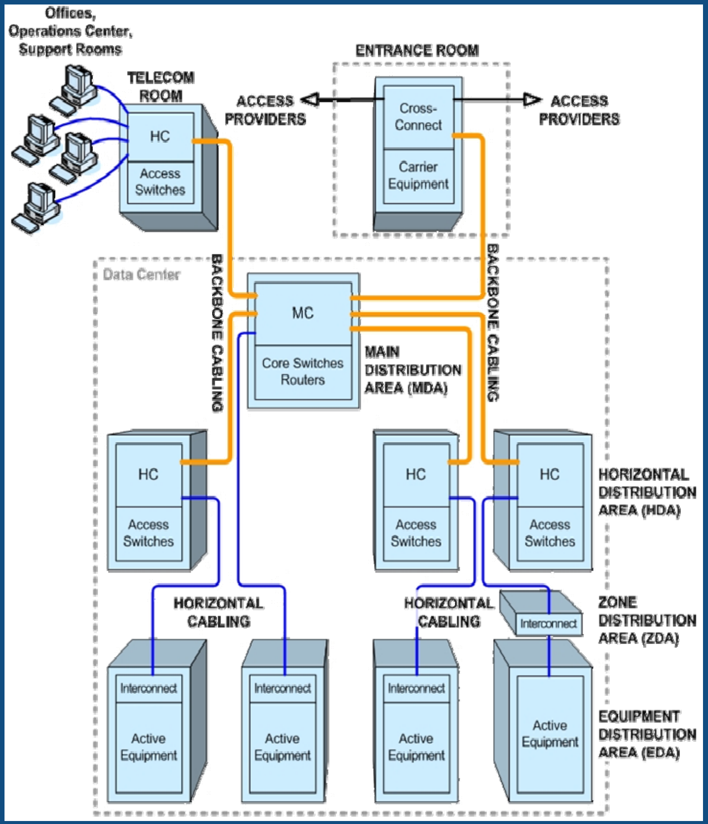
ANSI/TIA 942 –Telecommunications Infrastructure Standard for Data Centers

- Computer Room
- Telecommunications Room
- Entrance Room
- MDA – Main Distribution Area
- HDA – Horiz. Distribution Area
- ZDA – Zone Distribution Area
- EDA – Equip. Distribution Area
- Horizontal Cabling
- Backbone Cabling



Blue = UTP copper cable **Orange = Fiber cable**

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TIA-942 Media Selection Considerations

- Multimode fiber optic cable
  - 62.5/125μm or 50/125μm allowed
  - 50/125μm 850nm laser optimized, OM3, recommended
- Recommendations
  - Insure correct bandwidth of fiber for OM3 compliance
  - Aqua color is not sufficient
  - “Borrowing” loss budget or maximum length from modal bandwidth is not currently supported by North American standards
  - Customers that want to change limits based on supposed headroom of special cable types will have to set their own custom limits

TIA Organizational Update

- TR-42 – Copper Cabling
- FO-4 – Optical Fiber Cabling
- TR-42 and FO-4 Co-locating Meetings for better coordination of standards

ICEA Standards

- S-83-596-01, Standard for Optical Fiber Premises Distribution Cable (under revision)
- S-104-696-01, Standard for Indoor-Outdoor Optical Fiber Cable (2001) (under revision)
- S-87-640-99, Standard for Optical Fiber Outside Plant Communications Cable, Technical Requirements (1999)

Telcordia Standards

- Original Bellcore standards
  - Less Frequently Used Now
- GR-409, Issue 1, 1994, Generic Requirements for Premises Fiber Optic Cable (under revision)
- GR-20, Issue 2, 1998, Generic Requirements for Optical Fiber and Optical Fiber Cables (OSP) (under revision)
- GR-2961 (1998), Generic Requirements for Multi-Purpose Fiber Optic Cable

Fiber Optical LAN Section (FOLS)

- TIA Sponsored Industry Group promoting use of optical fiber in the enterprise space
- Website: www.fols.org
- Includes white papers and standards update
- Cost Model
  - Allows comparison of copper vs. optical fiber system
  - Updated Model Released February 2007

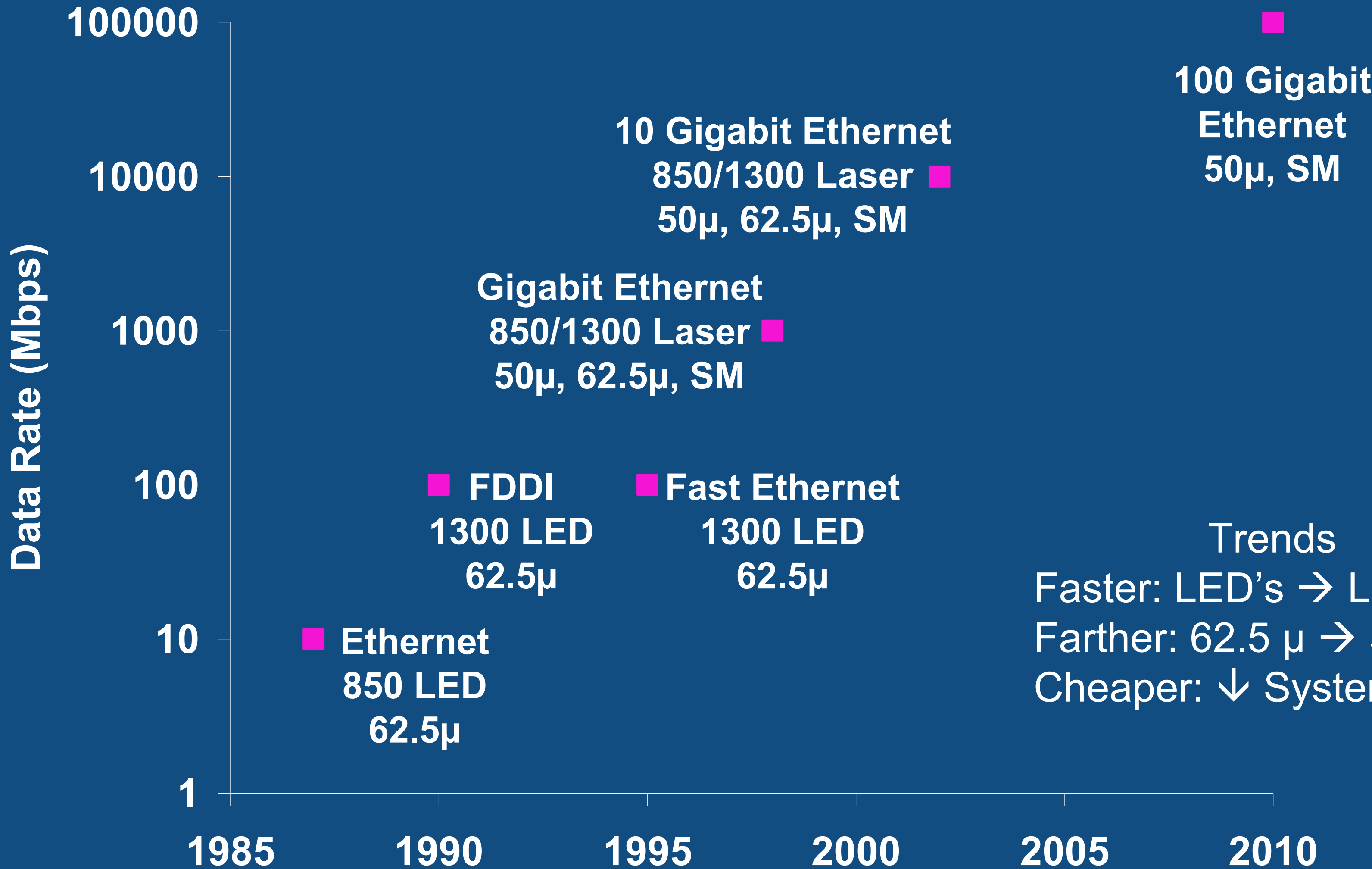
Standards Update

Questions?

Market Update & Trends

- Faster & Farther
- Network Speeds: 2006 vs. 2008
- Optical Fiber Network Cabling: 2006 vs. 2008
- Fiber to the Desk: 2006 vs. 2008
- 10 GBE Port Forecast
- Cost of Migrating
- Multimode Market Shift
- Security: Wireless, Copper and Fiber
- Trends in Applications & Standards

Evolution of Enterprise Ethernet



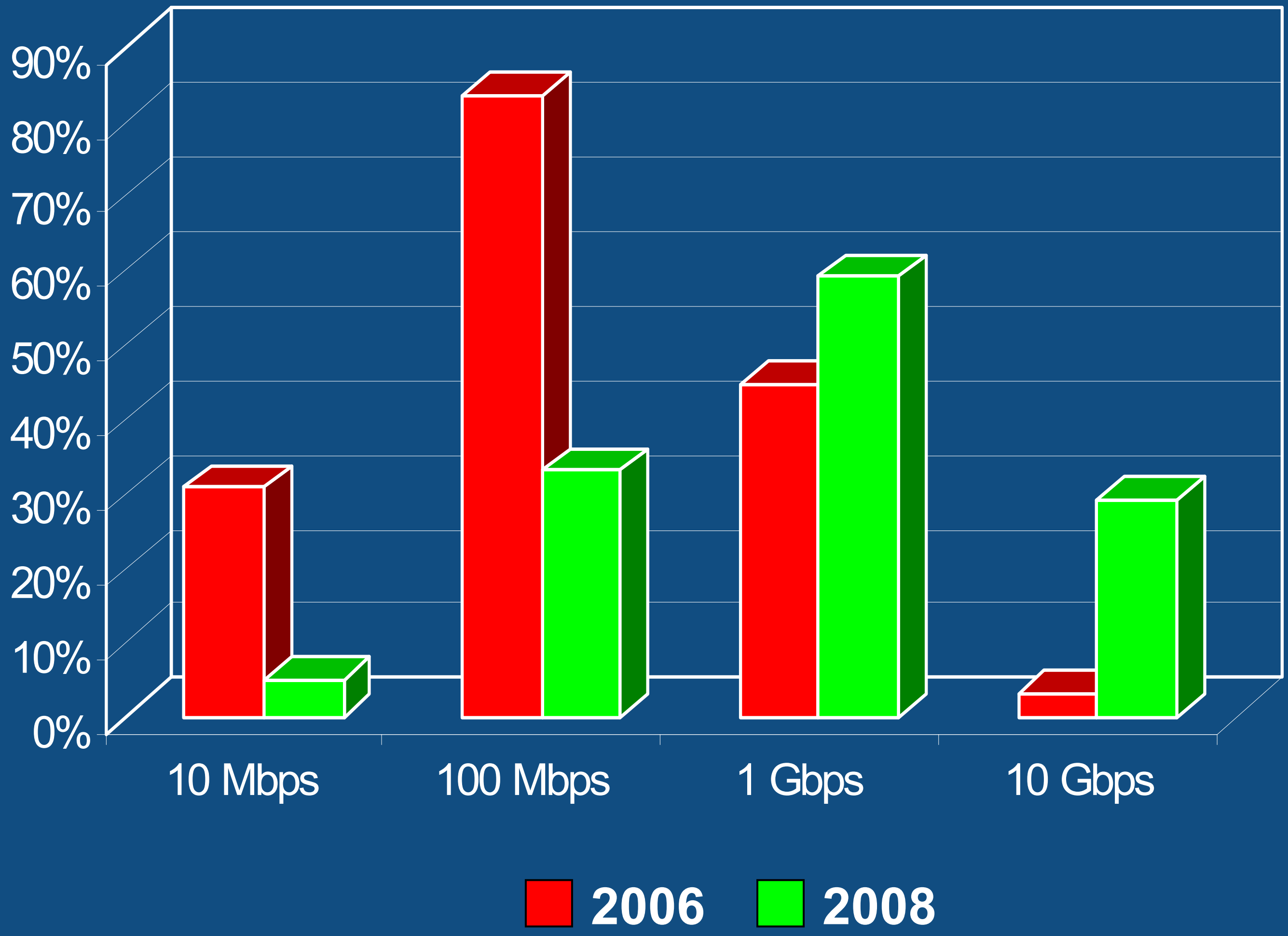
Trends

Faster: LED's → Lasers

Farther: 62.5 µ → 50 µ

Cheaper: ↓ System Cost

Network Speeds: 2006 vs. 2008



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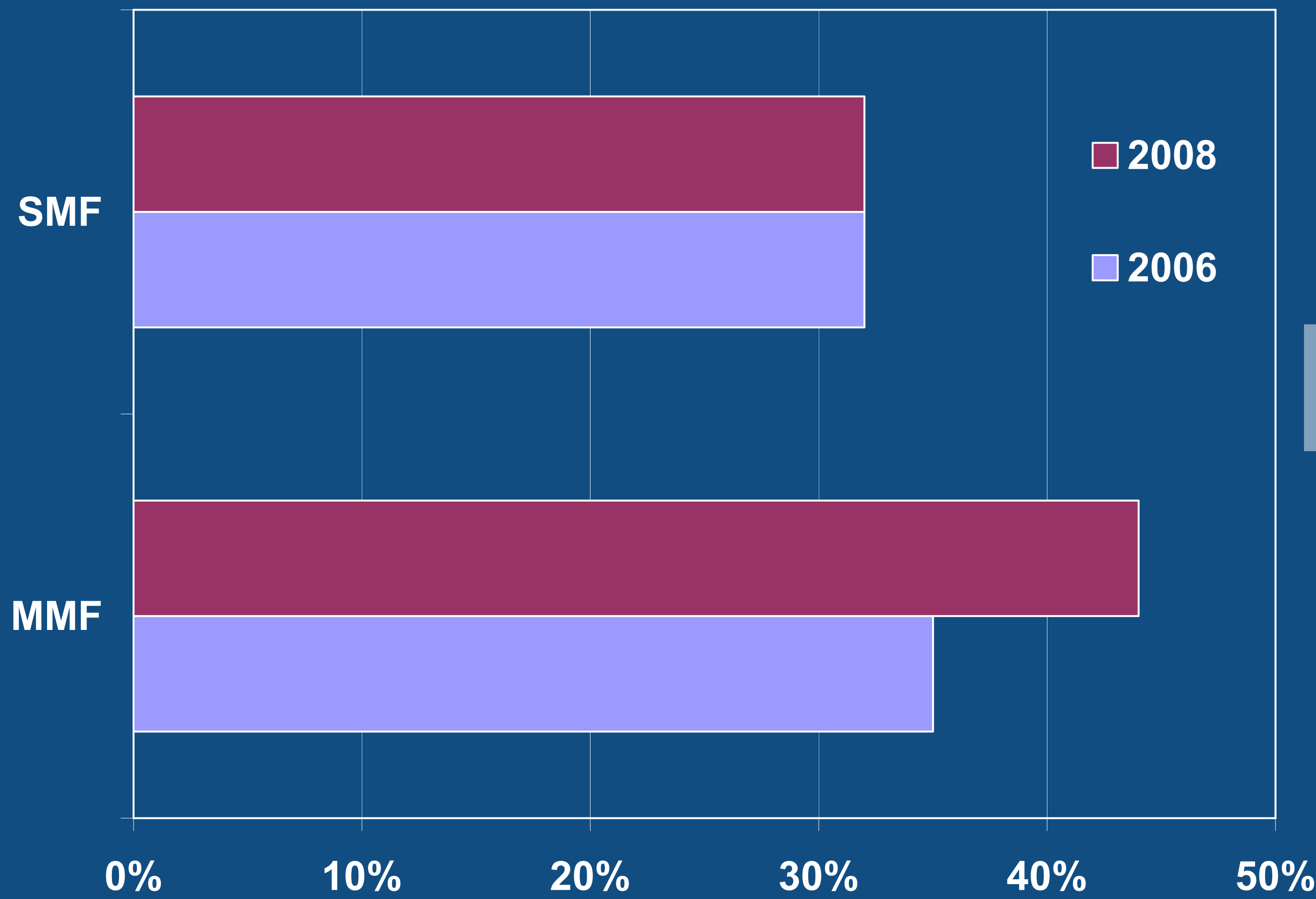
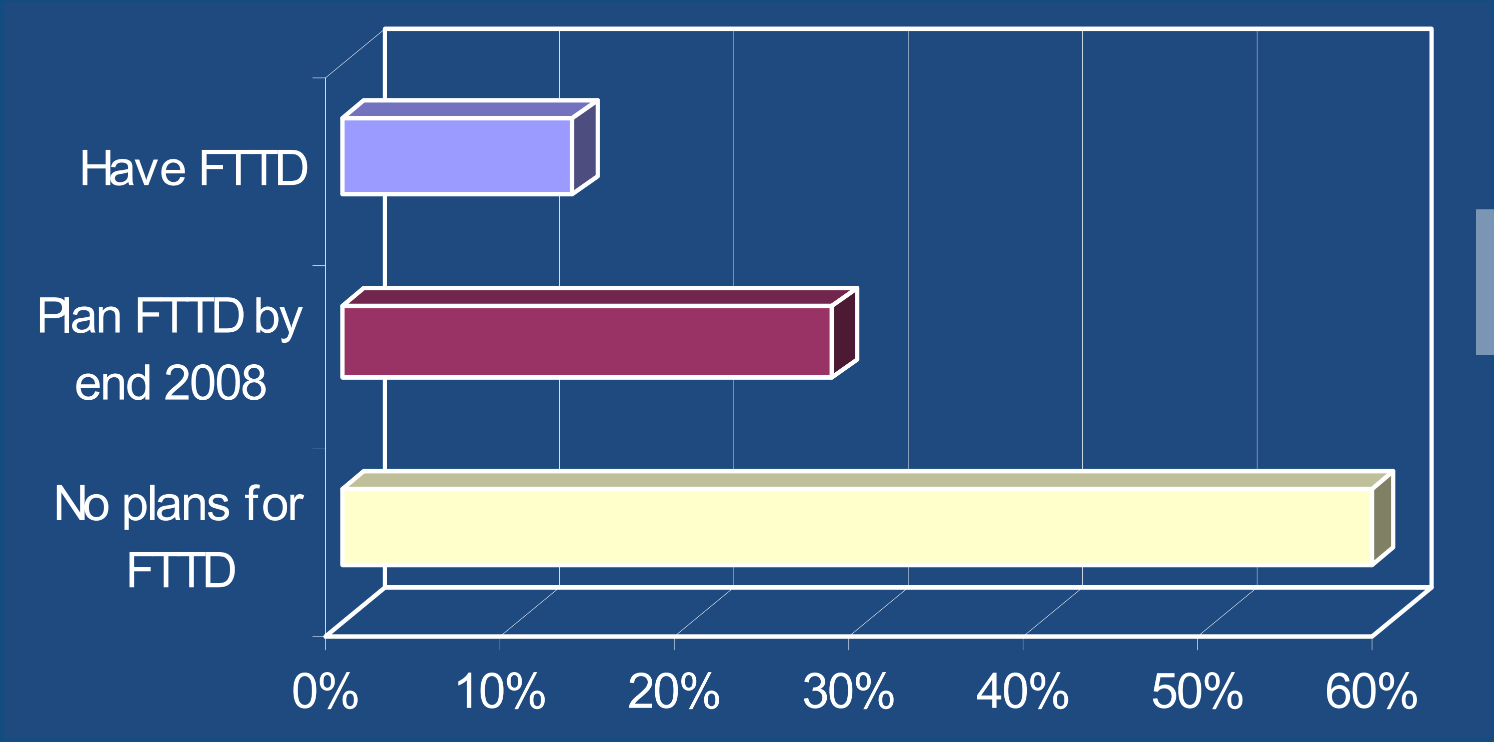
Network Cabling: 2006 vs. 2008



Fiber to the Desk: 2006 vs. 2008



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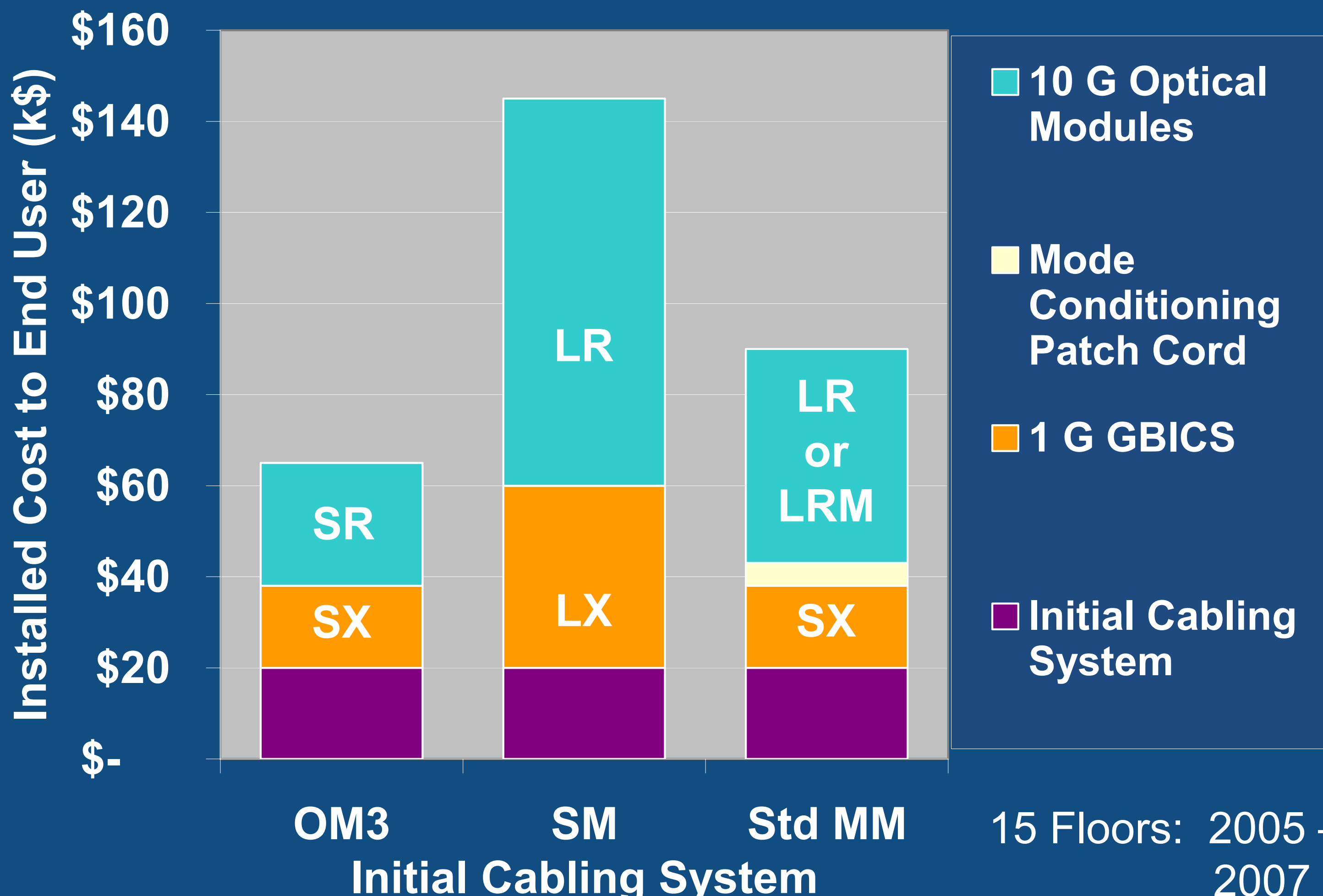
10GbE Market Forecast

- 10G Optical Ports
  - $570M in 2005
  - $1.8B in 2006
  - $3.3B by 2009, dominated by 10 GBE (source CIR, Dell’Oro)
- 10GbE Drivers
  - Data center consolidation
  - LAN switches continue to take more functions, i.e. anti-virus, anti-spam, VoIP, TVIP and related features
  - Significant 1Gb/s deployments to desktops and data center servers with cheap NIC’s requiring 10Gb/s backbones
  - The emergence and deployment of 10G NIC’s for servers/storage requiring data center backbones installed 4-5 years ago to be upgraded to 10Gb/s
  - Sarbanes-Oxley Compliance

Cost of Migrating to 10 GBE



15 Floors: 2005 – 1 Gb/s
2007 – 10 Gb/s

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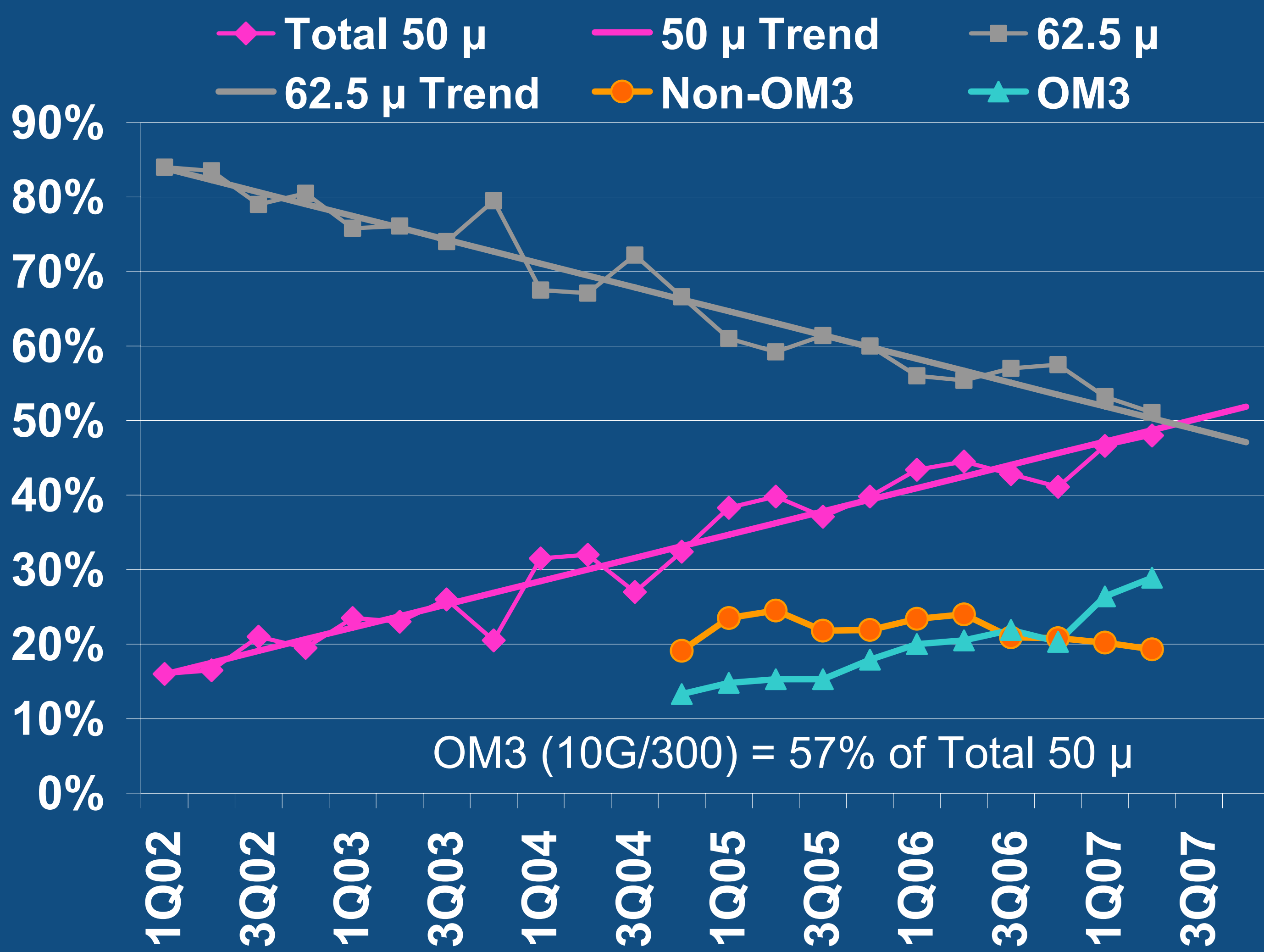
Market Shift to 50 µ



Source: Burroughs

Security: Wireless, Copper and Fiber

- Wi-Fi
  - WEP – Wire Equivalent Privacy
  - Failed in ~20 seconds on busy 802.11g network and ~80 seconds on 802.11b using Aircrack-PTW algorithm
  - Wi-Fi Protected Access: WPA & WPA2
- Copper
  - Data encryption helps to secure network
  - Tapping still possible, even if shielded
- Fiber
  - Most difficult media to tap
  - Bend Insensitive SMF < MC SMF < 62.5/50μ

Trends in Applications & Standards

Application	Light Source	λ (nm)	62.5 µm Fiber: Max Channel Length (m)	62.5 µm Fiber: Max Channel Attenuation (dB)	50 µm Fiber: Max Channel Length (m)	50 µm Fiber: Max Channel Attenuation (dB)
10BASE-FL	LED	850	2000	12.5	2000	7.8
100BASE-FX	LED	850	2000	11	2000	6.3
1000BASE-SX	Laser	850	220-275	2.38	500-550	3.56
1000BASE-LX	Laser	1300	550	2.35	550	2.35
10GBASE-S	Laser	850	26	2.6	82	2.3
10GBASE-S	Laser	850			300*	2.6

*Laser Optimized 50µm fiber

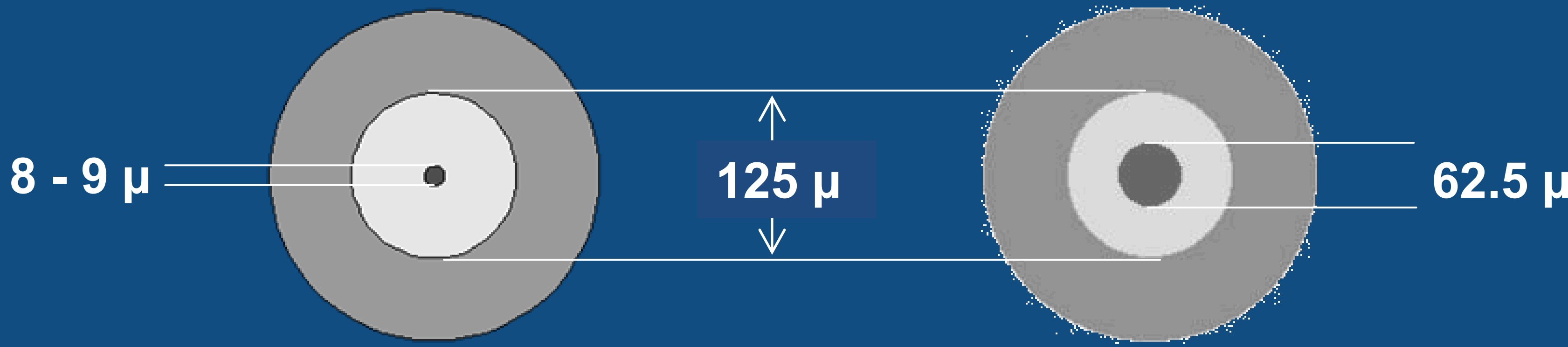
Market Update and Trends

Questions?

Optical Fiber Glass & Cable

- Fiber Options
  - Single Mode vs. Multimode
  - Manufacturing & Performance
- Cable Options
  - Cable Types
  - Applications

Optical Fiber Type Comparison



Single Mode

- Lower Cost
  - ➢ Inexpensive Cable
- Very small core
  - ➢ Expensive Splicing
- Lower Attenuation
  - ➢ Longer Distance
- Higher Bandwidth
  - ➢ High Capacity

Multi-mode

- Higher Cost
  - ➢ Expensive Cable
- Very Large Core
  - ➢ Inexpensive Splicing
- Higher Attenuation
  - ➢ Shorter Distance
- Lower Bandwidth
  - ➢ Lower Capacity

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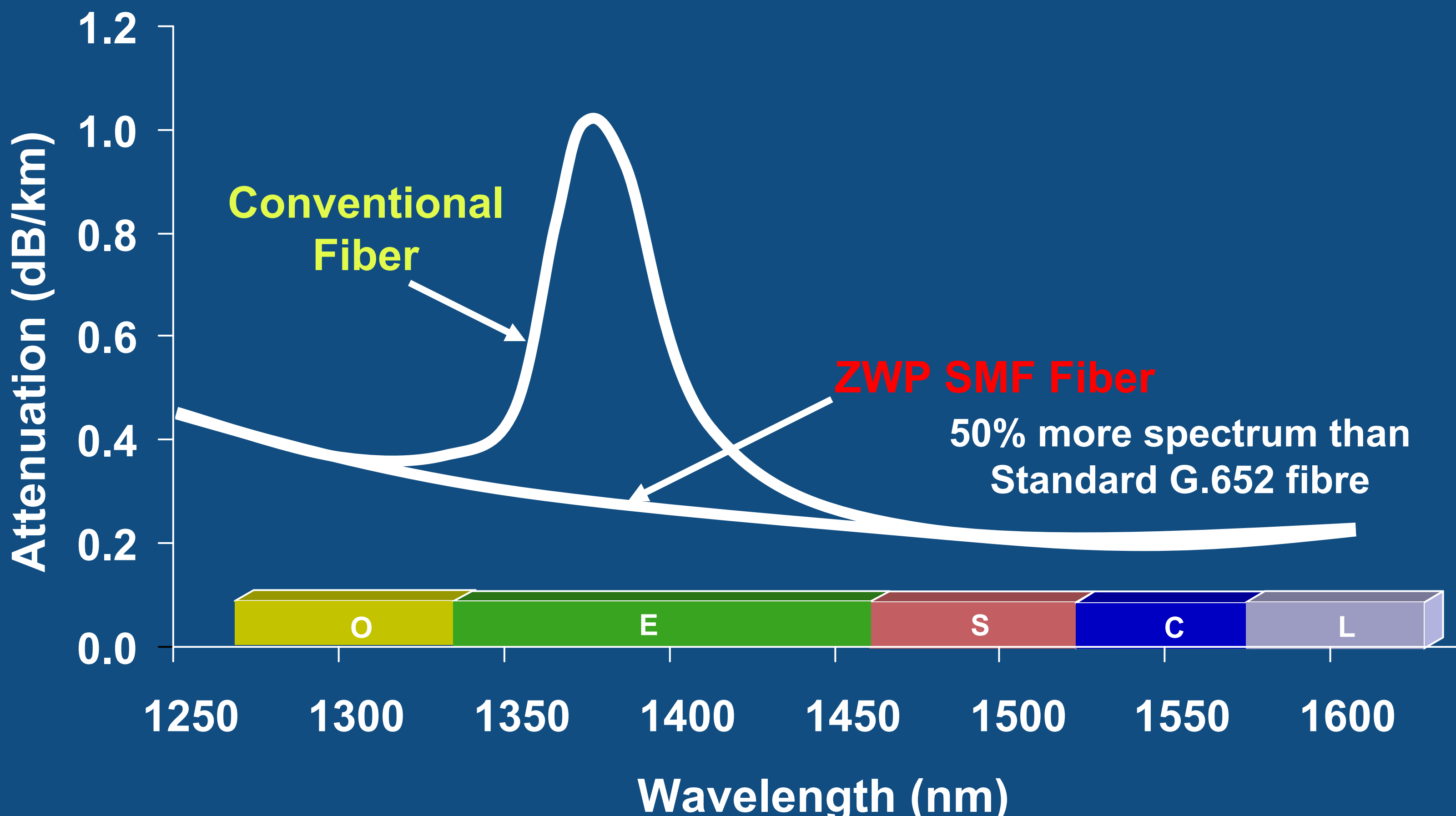
Single Mode Fiber

- Standard Single Mode Fiber
  - Designed for use at 1310 and 1550 nm.
  - Effective for Dense Wave Division Multiplexing (DWDM) in the 1550 nm wavelength region
  - Standards
    - ITU-T G.652
    - TIA/EIA-492CAAA
    - IEC 60793-2
    - GR-20-CORE
- Low or Zero Water Peak Single Mode Fiber
  - Standard: ITU-T G.652 A,B,C,D.
  - Fully compatible with standard Single Mode
  - CWDM through “E” Band
- Macrobend Resistant SMF – ITU-T G.657

ZWP SMF Fiber Characteristics



Which Multimode Fiber?

- Standard 62.5 µm multimode fiber
  - Optimized for LED legacy systems
  - Good support from 10 Mb/s to 1 GB
  - IEEE 802.3aq to support 10 GB @1300 nm using EDC
- Standard 50 µm multimode fiber
  - Equivalent support at 100Mb/s
  - 550 meter support for 1 GB
  - 82 meter maximum support for 10 GB
- Laser optimized 50 µm multimode fiber (OM-3)
  - Longest useful lifecycle
  - Maximum 600M (1968 ft) distance support for 10GbE
  - Broad support for legacy applications 10 MB and above

Multimode Performance Comparison at 850 nm

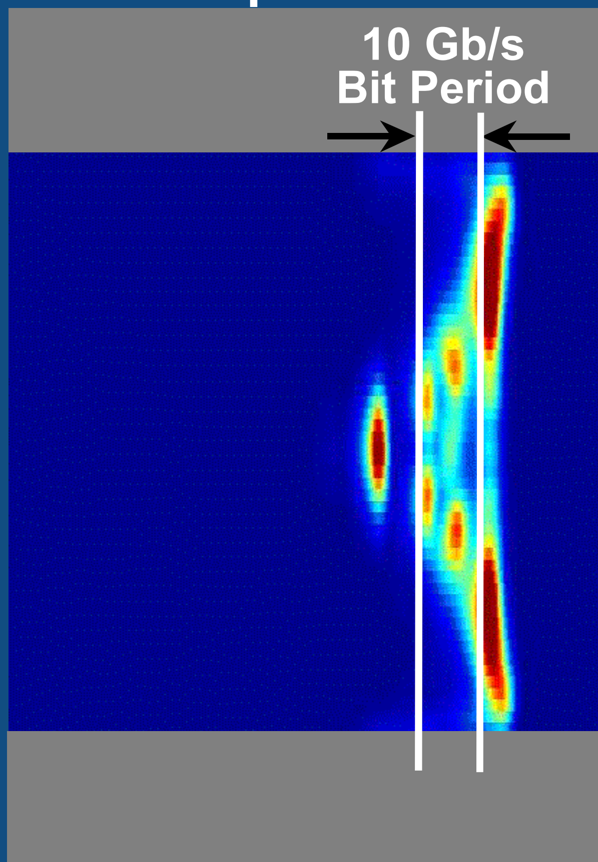
Fiber Type	Bandwidth (MHz-km @ 850 nm)	1 Gb/s Link Length (@850 nm)	Performance Advantage	10 Gb/s Link Length (@850 nm)	Performance Advantage
62.5 µ	220	300 m	---	26 m	---
50 µ	500	550 m	127%	82 m	215%
10G/150	700 (950)*	750 m	241%	150 m	477%
10G/300 (OM3)	1500 (2000)*	1000 m	373%	300 m	1053%
10G/550	3500 (4700)*	1040 m	636%	550 m	2015%

*** EMB Bandwidth**

Differential Modal Dispersion

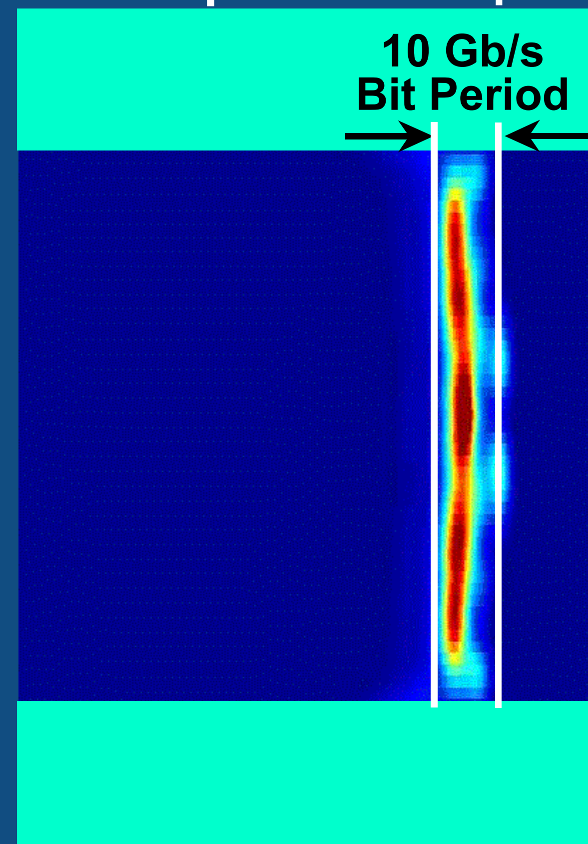
Standard 62.5 μ vs. Laser Optimized 50 μ Fiber:
Received pulse at 10 Gb/s over 300 meters

62.5 μ fiber



Fiber Core Center

Laser Optimized 50μ Fiber



Are all Multimode Fibers Created Equal?

- Method of Making Preform Critical
  - OVD and VAD great for SM
  - MCVD and PCVD great for MM
- Optical Fiber Coating
  - Must resist microbending
  - Must have low moisture absorption
- Bandwidth
  - Over-Filled Launch (OFL)
  - Effective Modal Bandwidth (EMB)
  - Differential Modal Dispersion (DMD)

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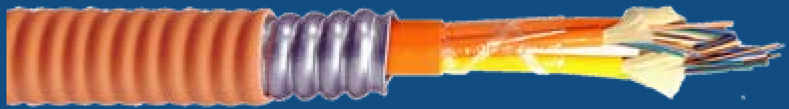
Premises Cable Constructions

- Interconnect, simplex & duplex
  - 900 µm tight buffered fiber + Aramid yarn + Jacket
- Breakout Cable
  - Assembly of simplex interconnect cables
- Distribution
  - Assembly of 900 µm tight buffered fibers + aramid + jacket with higher tensile rating than interconnect
- Indoor/Outdoor
  - Tight Buffer Distribution Design
  - Central Tube & Stranded Loose Designs
- Composite Cables
  - Contains both fiber and copper
  - Jacketed or “Speed Wrapped”

Premises Interconnect Products

- Applications
  - “In Front of the Shelf” Applications
  - Patch cords for communications closets and central office, FTTD
- Features and Benefits
  - Small flexible construction compliant with industry standard connectors
  - Aramid is crimped onto connector
- Physical Characteristics
  - 3 mm & 2 mm
  - 1 to 4 fibers, 900µm tight buffer, OFNR and OFNP ratings
  - Simplex, Zip cord, Duplex and Quad Constructions
  - Fiber availability: singlemode, 62.5/125, 50/125

Premises Distribution Products



- Applications
  - “Behind the Shelf” Applications: 900 μ fiber connected directly to connector
  - Backbone vertical and horizontal runs between communications closets
  - Interbuilding installations in conduit
- Features and Benefits
  - Installer friendly dry core construction compliant with industry standards
- Physical Characteristics
  - 4 to 144 fibers, 900μm tight buffer
  - OFNR/OFCP and OFNP/OFCP ratings
  - Single unit construction 4 - 24 fibers
  - Multiple unit construction for 18 - 144 fibers
  - Fiber availability: singlemode, 62.5/125, 50/125, hybrids

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Indoor/Outdoor Tight Buffer Optical Fiber Products

- Applications
  - Interbuilding/Intrabuilding direct buried, aerial or conduit backbone installations
- Features and Benefits
  - Tight Buffer Construction
  - Water blocked dry core design reduces installation time
  - Cable can be run from outdoor direct buried or aerial installation to indoor communications closet without a costly transition point
  - Can attach directly to connector; no transition piece
- Physical Characteristics
  - 4 to 144 fibers, 250µm fiber/900µm tight buffer, OFNR/FT4 rating (UL1666) and OFNP/FT6 (NFPA 262)
  - Fiber availability: Single Mode, 62.5 µm, 50 µm, hybrid

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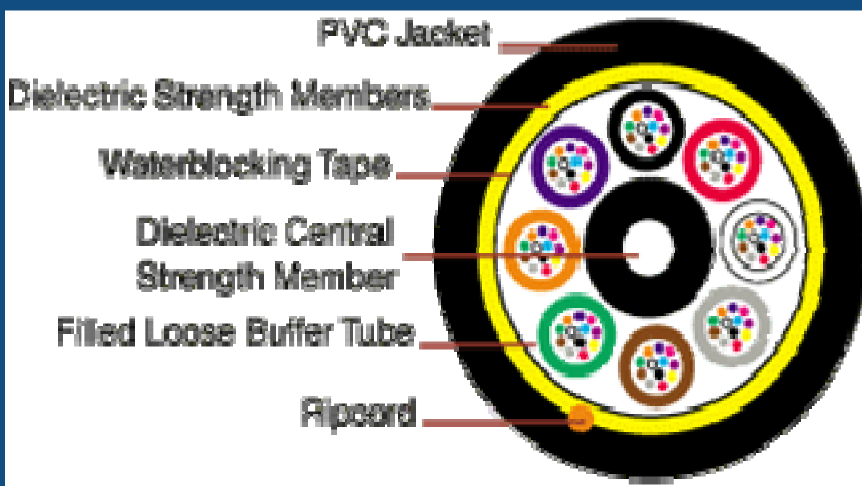
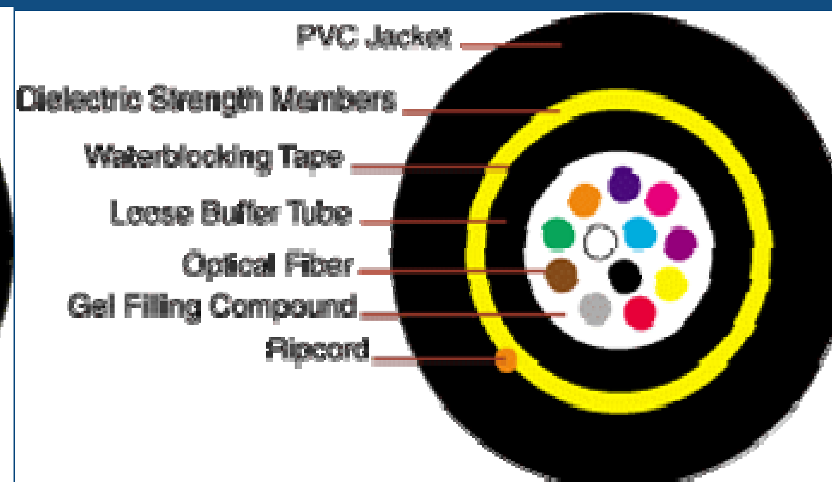
Outdoor/Indoor Loose Tube Riser Cables

Stranded Loose Tube Riser

Central Core Loose Tube Riser





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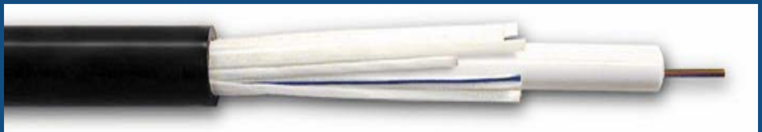
O/I Loose Tube Cables

- Applications
  - Interbuilding/Intrabuilding direct buried, aerial or conduit backbone installations
- Features and Benefits
  - Water blocked dry core design reduces installation time
  - Highest density indoor/outdoor cable design available today
  - Cable can be run from outdoor direct buried or aerial installation to indoor communications closet without a costly transition point
- Physical Characteristics
  - 4 to 216 fibers, 250µm fiber/loose tube, OFNR rating (UL1666)
  - Telcordia GR-2961-CORE
  - Fiber availability: singlemode, 62.5/125, 50/125, hybrids

O/I Central Tube Cables

- Applications
  - Interbuilding/Intrabuilding direct buried, aerial or conduit backbone installations
- Features and Benefits
  - Small diameter provides for maximum conduit fill and cable flexibility
  - Cable can be run from outdoor direct buried or aerial installation to indoor communications closet without a costly transition point
- Physical Characteristics
  - 4 to 96 fibers, 250µm fiber/loose tube, OFNR rating (UL1666)
  - Telcordia GR-2961-CORE
  - Fiber availability: singlemode, 62.5/125, 50/125, hybrids



Composite Cables

- Applications
  - Interbuilding, Backbone and Horizontal
- Features
  - Nearly any combination of OSP or Premises Copper cables with OSP or Premises Fiber cables.
- Benefits
  - Copper Now – Fiber when more bandwidth required
  - Single Runs for Lower Installation Costs
  - Power over Ethernet (over Twisted Pairs)
- Physical Characteristics
  - Copper – Category Cables & Coax
  - Loose Tube or Tight Buffer
  - SM, 62.5 μ, 50 μ, Hybrid
  - Jacketed or “Speed Wrapped”

Choosing Between Tight Buffer & Loose Tube

- Existing Infrastructure
- Tight Buffer – 900 µ Jacketed 250 µ Fiber
  - Easily used with mechanical connectors without additional material
  - If cable size is not an issue
- Loose Tube – 250 µ
  - Typical Fusion spliced
  - Can be used with mechanical connectors with transition kits
  - If cable size is an issue

Connectivity & Termination

- Mechanical vs. Fusion
- Connectors – Mechanical vs. Adhesive
- Legacy vs. Small Form Factor
- Array Connectors
  - MPO/MPT
  - Cassettes
  - Impact of TIA 942

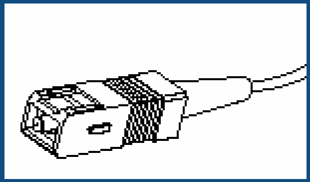
Connectivity: Fiber Splices

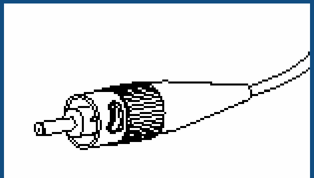
- Mechanical Splice
  - Little specialized equipment required
  - New techniques and splice connectors have improved the loss per splice (some < 0.1 dB)
  - Good for emergency field repairs, low volumes
- Fusion Splices
  - Requires special, expensive equipment
  - Hard to do under adverse conditions
  - Low loss (can be < 0.05 dB)

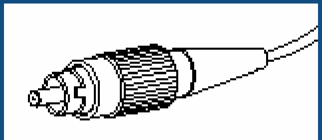
Fiber Connectors

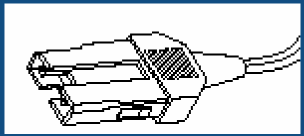
- Mechanical Style
  - Fast termination, good for emergency field repairs
  - Typically does not require access to power or use of harmful or flammable chemicals
  - Loss: can be >0.5 dB
- Adhesive Style
  - Most permanent method for connectorization
  - Loss typically < 0.2 dB
  - Often requires flammable chemicals and curing ovens that require power
  - Often requires more skilled installers

Styles Of Legacy Connectors

SC  Rectangular, push-push lock

ST  Very popular, bayonet lock, keyed

FC  Screw-on lock, keyed

MIC  Designed for FDDI, dual fiber

Other: SMA, D4, ESCON, & more

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Small Form Factor Fiber Connectors

MT-RJ  Polarized, pinned & unpinned

LC  Non-polarized, 1.25 mm ferrules

VF-45  Polarized, v-groove connections

FJ  Non-polarized, 2.5 mm ferrules

Other: MU & more

Two fibers are connected by each Small Form Factor (SFF) connector

Bicsi

Multi-Fiber Connectors (MTP/MPO)

12 Fiber – For plug and play cassettes in datacom environment

16 Fiber – For SAN market, where switch & director blades come in increments eight fiber increments

24 Fiber – High density for the data center server side

MPO/MTP Fiber Cassette: 24 Fiber 10 GB LC Implementation

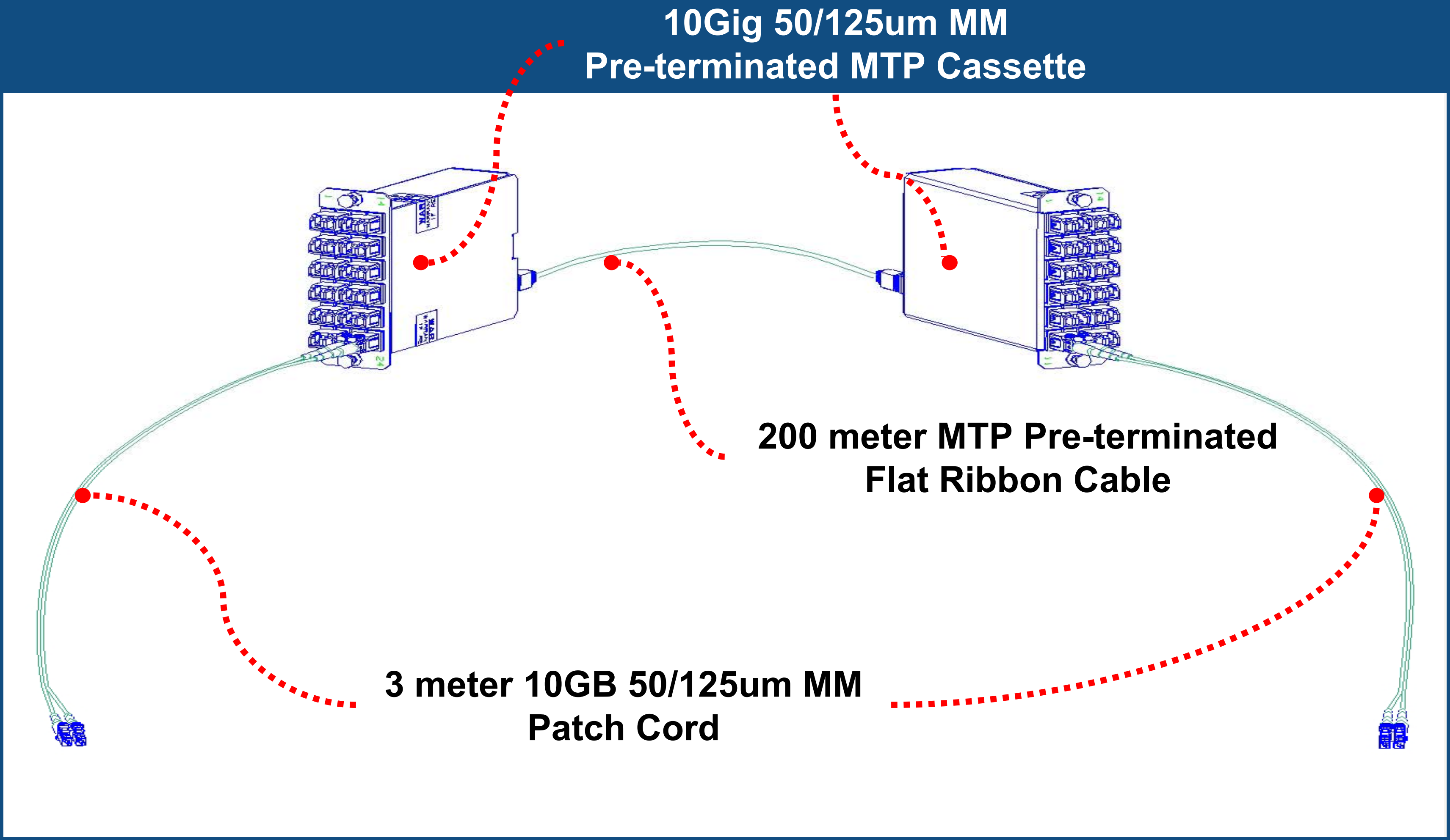
- Contain a short "breakout" cable to change to single fiber connectors
- Considered part of the permanent link
- Have 'male' MPO/MTP connectors (pins)
- Three different wiring methods specified in the standards

Typical cassette
20dB Return Loss
40dB RL Typical
1.0dB Insertion Loss
0.75dB IL Typical

Premium cassette
>20dB Return Loss
40dB RL Typical
0.5dB Insertion Loss
0.35dB IL Typical

BICSI

Fiber Cassette-Based Channel



Specifying Cabling Infrastructure per EIA/TIA 942

- “Plug & Play” cabling not the same as legacy trunk cables and patch panels
- MPO cassette configurations (see table)
- Issues with Cassettes:
  - High return loss
  - Difference between channels
  - Dirt on one fiber creates air gap (high reflectance) for all fibers in the connector!
- All must be properly installed and tested

	Output Fiber		
Input Fiber	Type - A	Type - B	Type - C
1	1	12	2
2	2	11	1
3	3	10	4
4	4	9	3
5	5	8	6
6	6	7	5
7	7	6	8
8	8	5	7
9	9	4	10
10	10	3	9
11	11	2	12
12	12	1	11

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Optical Fibers:
Glass, Cable & Connectivity Options

Questions?

Field Testing & Troubleshooting Fiber Optic Links in a Gigabit Environment

Applications & Standards

Application	Light Source	λ (nm)	62.5 µm Fiber		50 µm Fiber	
			Max Channel Length (m)	Max Channel Attenuation (dB)	Max Channel Length (m)	Max Channel Attenuation (dB)
10BASE-FL	LED	850	2000	12.5	2000	7.8
100BASE-FX	LED	850	2000	11	2000	6.3
1000BASE-SX	Laser	850	220-275	2.38	500-550	3.56
1000BASE-LX	Laser	1300	550	2.35	550	2.35
10GBASE-S	Laser	850	26	2.6	82	2.3
10GBASE-S	Laser	850			300*	2.6

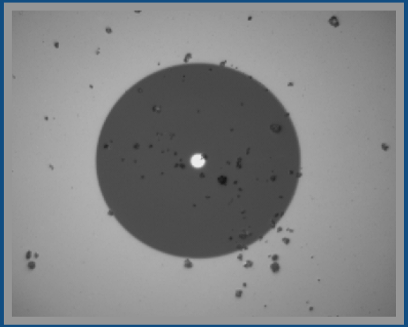
*Laser Optimized 50um fiber

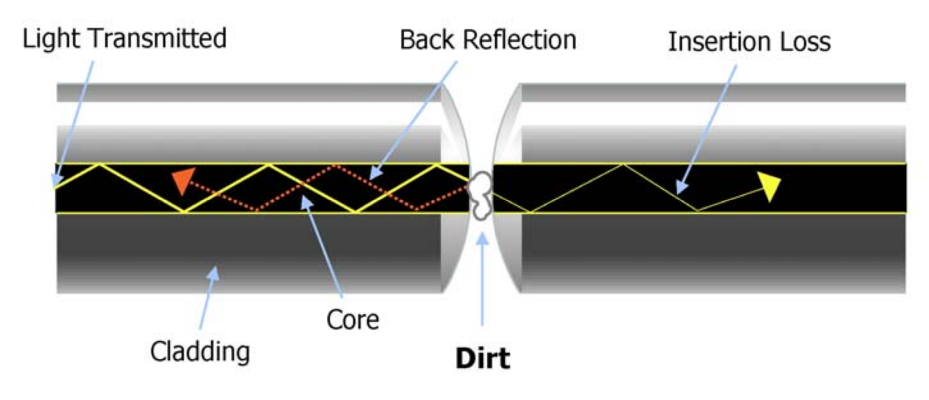
Smart Testing & Troubleshooting

- Know your loss budget and design accordingly
- Use verification tools to ensure best termination and installation practices
- Certify to both tier one and two testing per TSB140
- If using “plug and play” cassettes, make sure that the solution meets loss budgets and is interoperable

#1 Problem: Dirt

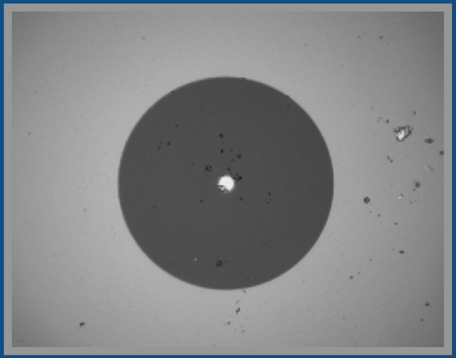
- Contaminated connector end-faces: Leading cause of fiber link failures
- Particles of dust and debris trapped between fiber end faces cause signal loss, back reflection, and damaged equipment
- Many Sources of contamination:
  - Equipment rooms & Telecommunication rooms in filthy environments
  - Improper or insufficient cleaning tools, materials, procedures
  - Debris and corrosion from poor quality adapter sleeves
  - Hands of technicians
  - Airborne

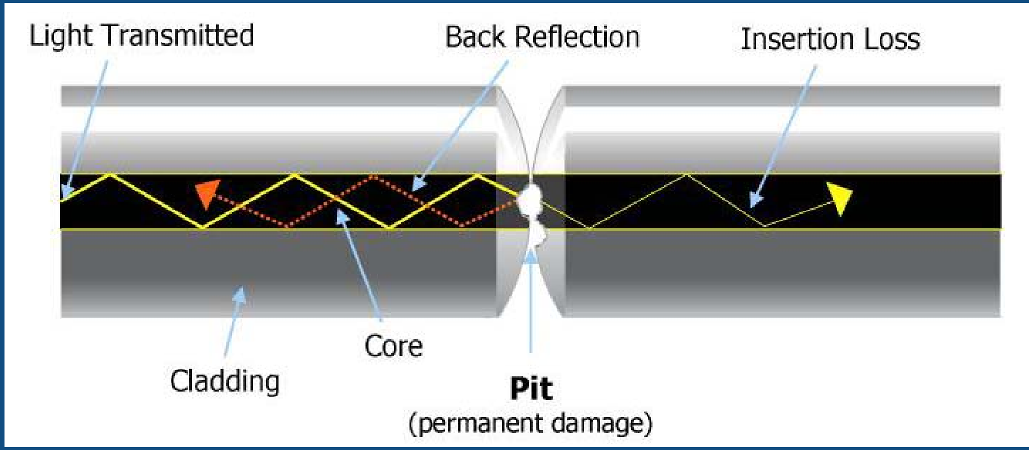




Why Bother Inspecting End Faces?

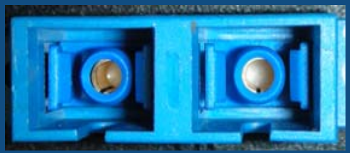
- To Prevent Damage
  - Debris will embed in glass when contaminated connectors are mated
  - When embedded debris is removed, pit remains in glass as permanent damage
  - Pits cause signal loss and back reflection
- Debris can also cause other types of damage such as chips and scratches





Fiber End-Face Cleaning

- Inspect end-face
- If clean, then insert
- If dirty, apply minimal solvent to cleaning pad or swab
  - For patch cables, hold ferrule perpendicular, wipe from wet to dry
  - For ports/adaptors, using gently pressure, twist damp swab on end-face followed by dry swab
- Inspect end-face
  - If clean, then insert
  - If not, clean again



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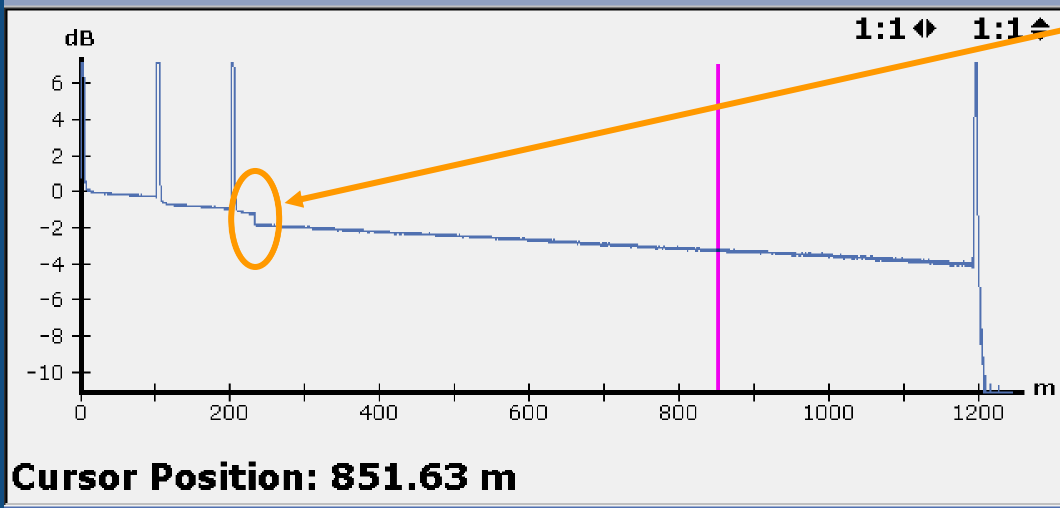
Problem #2: Poor Termination

- Choose the right connector for the job
  - Compatible with Cable (dist or breakout)
  - Standard Compliant (FOCIS)
  - Appropriate for environmental conditions
  - Insertion Loss Connector Dependent (i.e. tunable LC)
- Following manufacturer's termination instructions
- Proper consumables & tools
- Cleanliness
- End-Face Inspection
- Polarity (Tx to Rx)

Problem #3: Unplanned Loss Events

OTDR TRACE 850 nm:End 1

OTDR-JUL29D 09/14/2004 10:54:30 a.m.



Non-reflective event
Splice or severe bend

EVENT TABLE OFTM-5612

OTDR-JUL29D 09/14/2004 10:55:27 a.m.

LOCATION (m)	dB@850nm	dB@1300nm	EVENT TYPE	STATUS
101.2	0.39	0.43	REFLECTION	PASS
202.1	0.19	0.11	REFLECTION	PASS
230.6	0.64	0.76	LOSS	FAIL
1194.5	N/A	N/A	END	

Two-Tier Testing per TSB-140

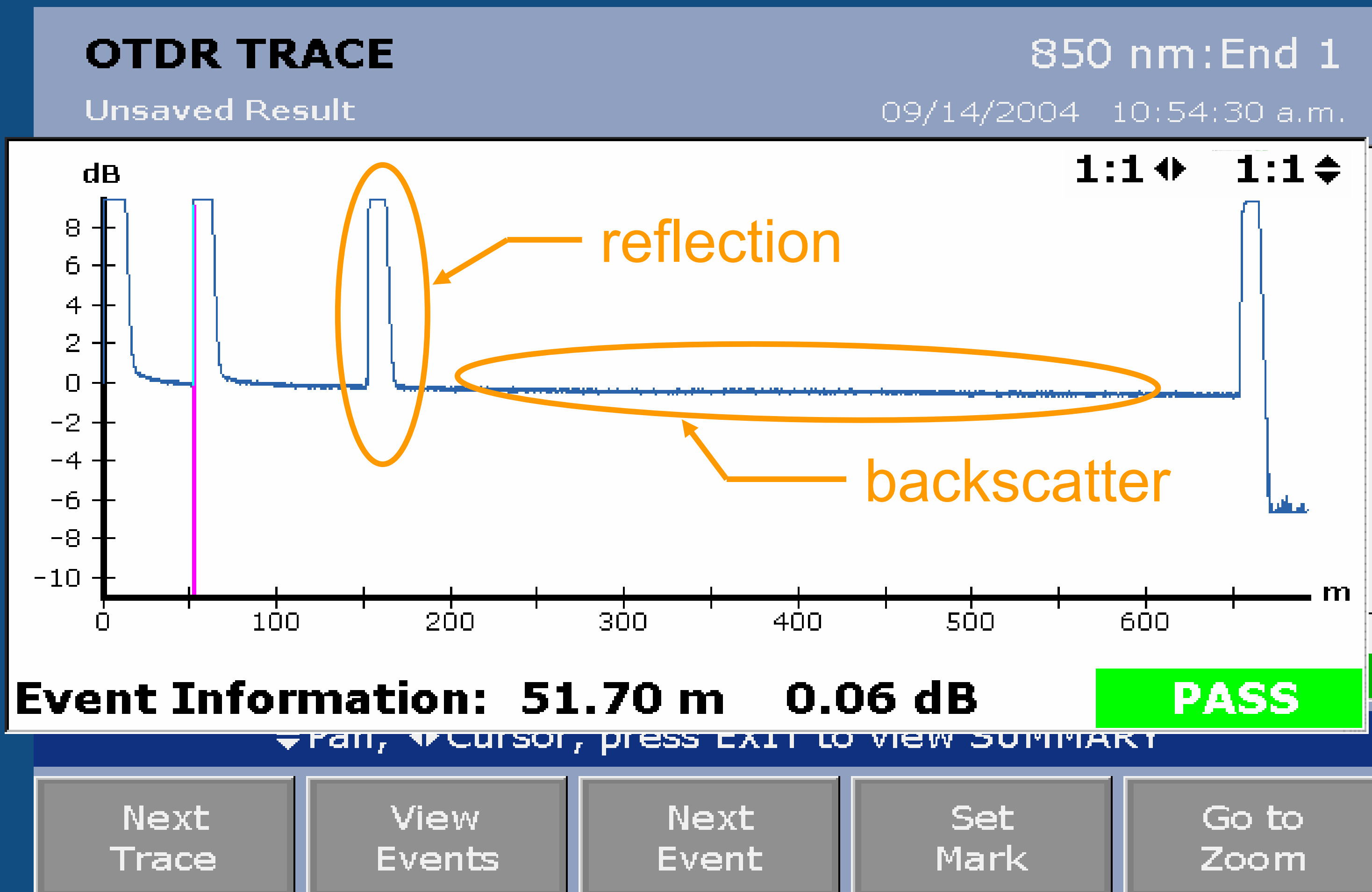
- Tier 1: OLTS (Optical Loss Test Set)
  - Conforms to TIA-526-14A and TIA-526-7
  - Most closely simulates system
  - Measures the total loss of a fiber channel
  - Verify polarity using OLTS or VFL
- Tier 2: OTDR Trace
  - Can show segment lengths, connector locations & losses, and losses not at a connector
  - Provides evidence that cable is installed without degrading events (e.g., bends, connection, splice)
  - Can do single-ended testing

Why Use An OTDR For Enterprise Fibers?

- Basic (Tier 1) Fiber Certification
  - PMLS test is always required.
  - Ensures that the link meets an industry standard in order to run the planned application

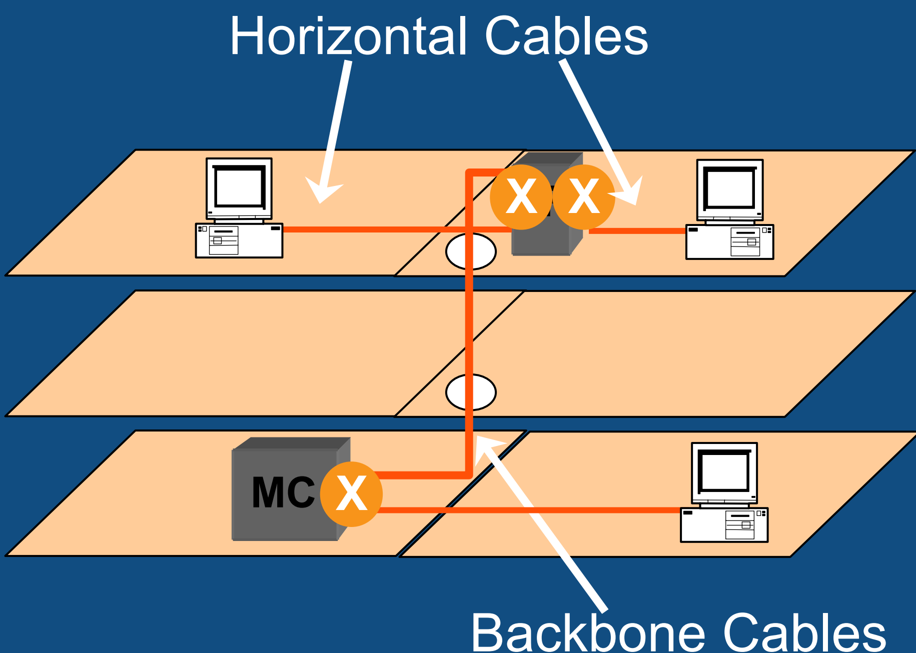
- Extended (Tier 2) Fiber Certification
  - An OTDR trace characterizes a fiber link and helps increase the quality of fiber link.
  - Certify that the fiber link meets installation specifications
    - Shows loss and reflectance for each component in the channel
    - Provides more complete documentation
  - Certify that the fiber link meets expectations for current and future applications
  - Efficient Single-ended Troubleshooting.

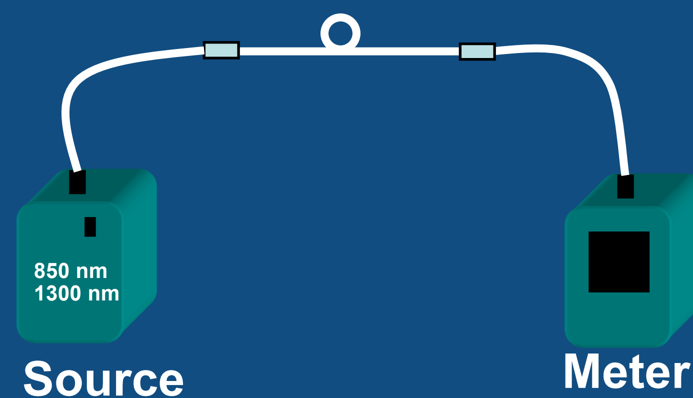
A Typical OTDR Trace



Test Example: Tier 1 (OLTS)

50/125 µm OM3 Channel:
130 m backbone cable
7 m patch cord
80 m to the wall outlet

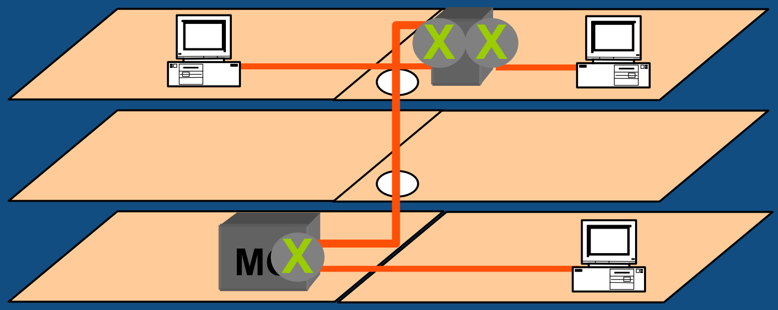




2.15 dB

2.6 dB max attenuation
300m max distance

Test Example: Tier 2



Event Table from OTDR

Location (m)	850nm (dB)	Event	Pass/Fail
0	.18	Reflect	Pass
130	.14	Reflect	Pass
137	.88	Reflect	Fail
217	.19	Reflect	Pass

1.39 + 0.76 (for cable) = <u>2.15 dB</u>

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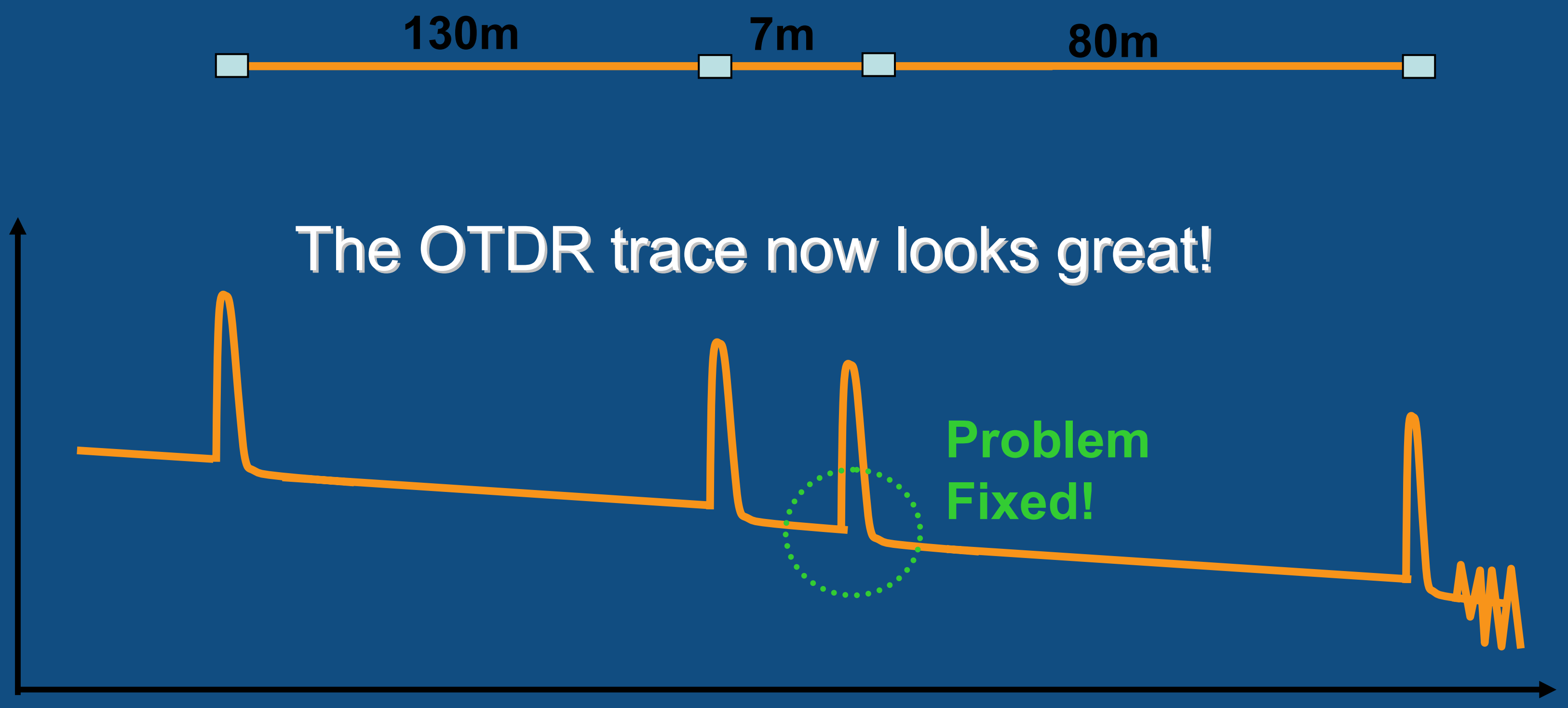
Fix The Problem And Retest



The lower insertion loss results in a higher quality installation!

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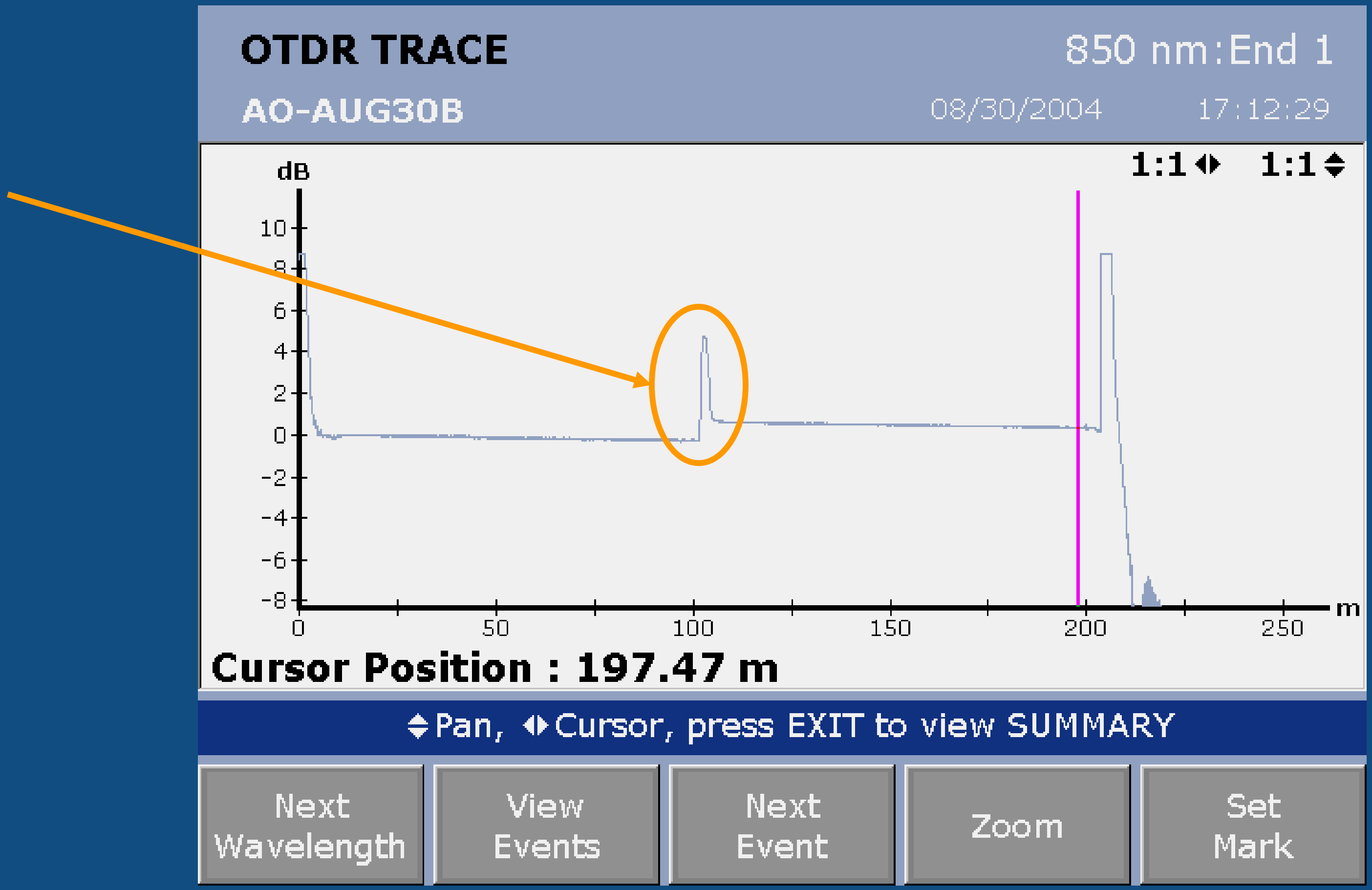
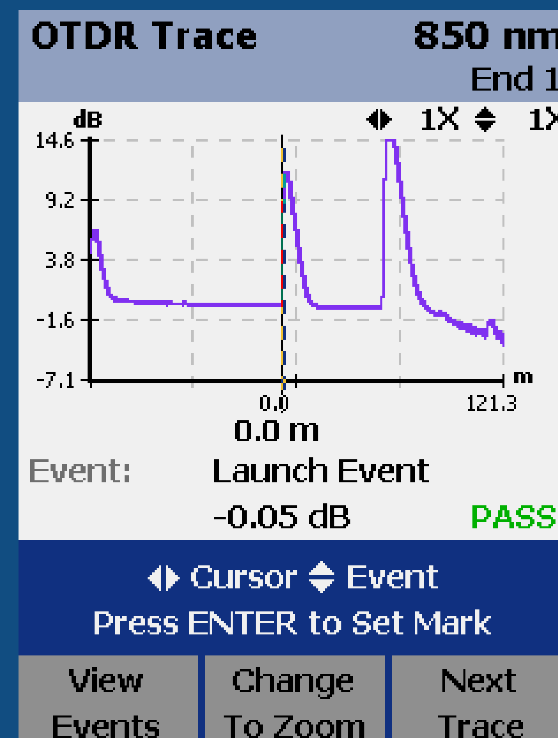
Gainer Event



50 micron fiber connected to a 62.5 micron fiber

OTDR Test Results



Testing Links with Fiber Cassettes

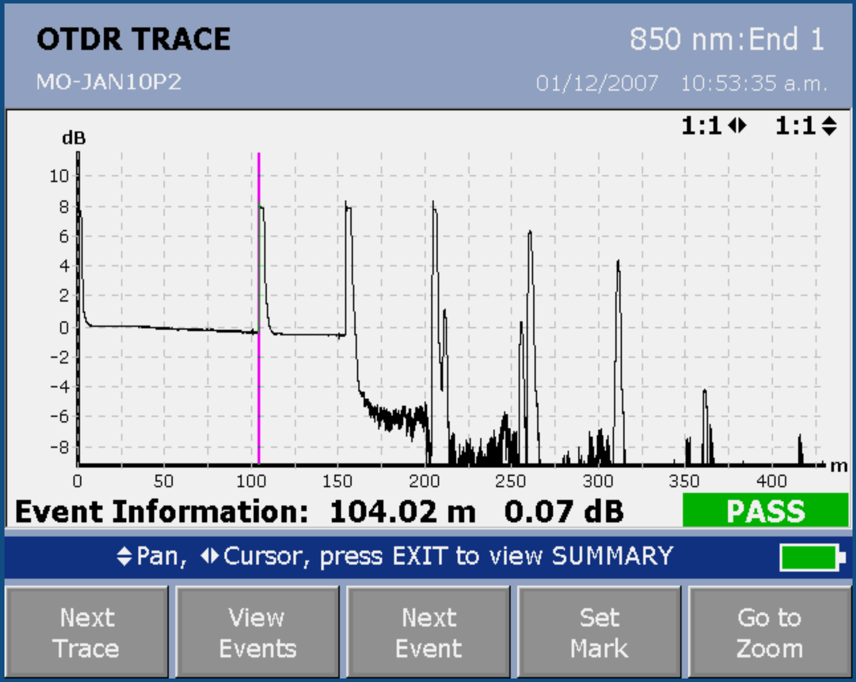
1. First Clean end-faces.
2. Test the link with a power meter and source to get the overall loss of the link.
   – Yields overall loss of the link.
   – Cannot find out where problems are
   – Cannot measure the reflectance of the connections

So, How Do You Test OTDR Links That Have Fiber Cassettes?

3. Test the link with an OTDR.
   - An OTDR shows the quality of each piece of the link.
   - If you can't get a trace, the link has problems.
   - An OTDR can help find the location of link problems.

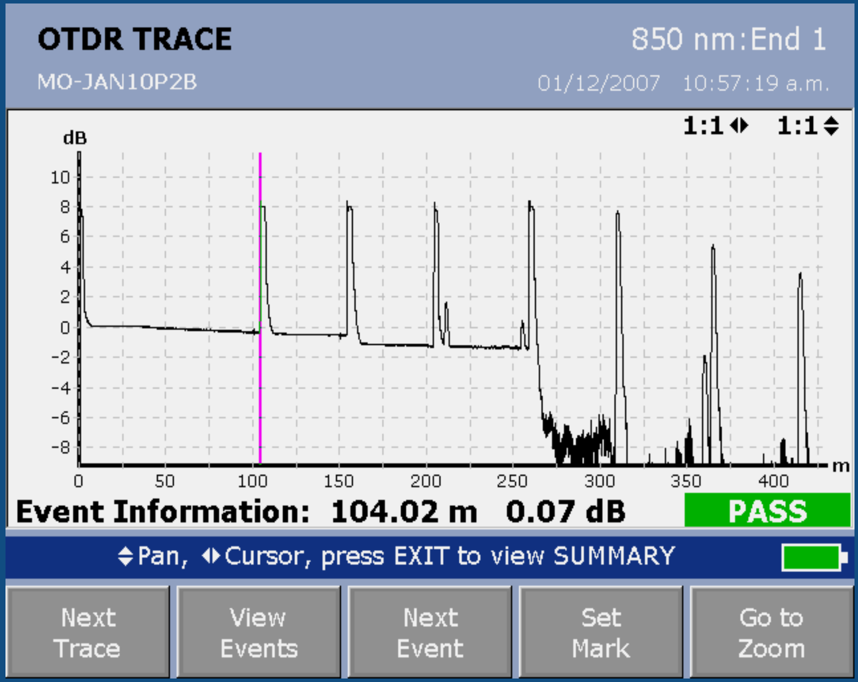
OTDR Traces With Fiber Cassettes

- Here is how an OTDR can help find the location of problems:
- The connector at 154 m did not get seated correctly and shows a big loss.
- With a power meter, you would know there was too much loss, but would not know where the problem was.



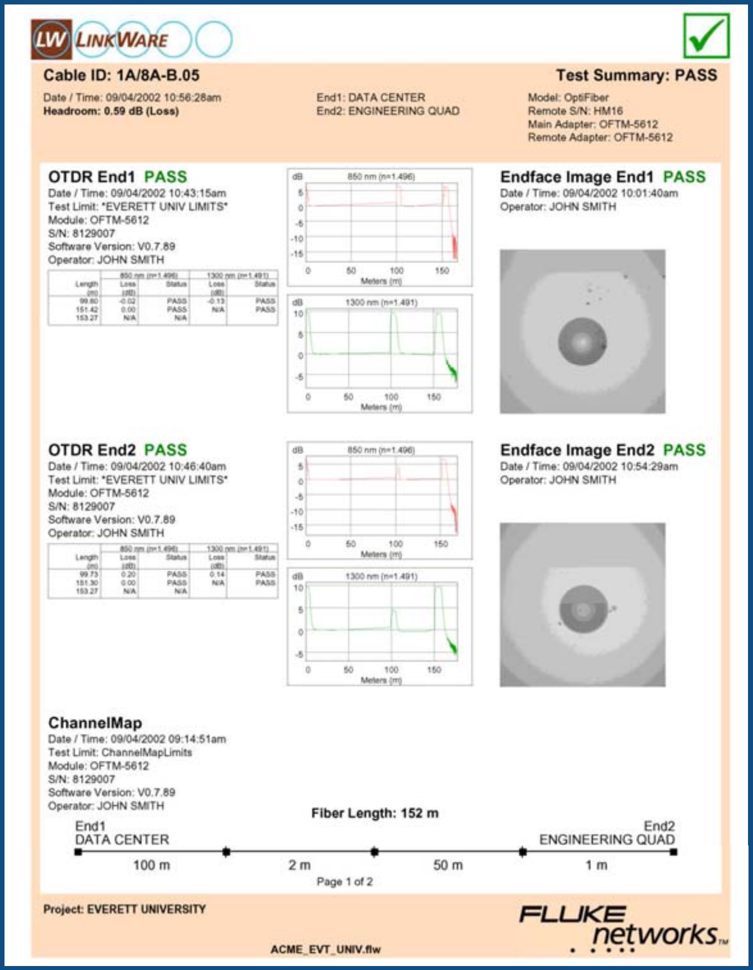
OTDR Traces With Fiber Cassettes

- After the connector was properly seated, the loss at the second connector is fine.



OTDR Testing and Troubleshooting: Competitive Advantage in GB Environment

- Designers
  - Robust "real world" specifications
  - Minimize exposure to liability (perceived or real)
  - Build and maintain long relationships with customers
- Installers/Contractors
  - Minimize installation and troubleshooting time
  - Eliminate costly call backs
  - Documentation for Warranted Systems
- Network Owners
  - Fewer surprises from outsourced work
  - Decrease network downtime
  - Minimize recurring network upgrades


LinkWare

Cable ID: 1A/8A-B.05 **Test Summary: PASS**

Date / Time: 09/04/2002 10:56:28am
Headroom: 0.59 dB (Loss)

End1: DATA CENTER
End2: ENGINEERING QUAD

Model: OptiFiber
Remote S/N: HM16
Main Adapter: OFTM-5612
Remote Adapter: OFTM-5612

OTDR End1 PASS
Date / Time: 09/04/2002 10:43:15am
Test Limit: *EVERETT UNIV LIMITS*
Module: OFTM-5612
S/N: 8129007
Software Version: V0.7.89
Operator: JOHN SMITH

	850 nm (n=1.496)		1300 nm (n=1.491)	
Length (m)	Loss (dB)	Status	Loss (dB)	Status
99.80	-0.02	PASS	-0.13	PASS
151.42	0.00	PASS	N/A	PASS
153.27	N/A	N/A		

Endface Image End1 PASS
Date / Time: 09/04/2002 10:01:40am
Operator: JOHN SMITH

OTDR End2 PASS
Date / Time: 09/04/2002 10:46:40am
Test Limit: *EVERETT UNIV LIMITS*
Module: OFTM-5612
S/N: 8129007
Software Version: V0.7.89
Operator: JOHN SMITH

	850 nm (n=1.496)		1300 nm (n=1.491)	
Length (m)	Loss (dB)	Status	Loss (dB)	Status
99.73	0.20	PASS	0.14	PASS
151.30	0.00	PASS	N/A	PASS
153.27	N/A	N/A		

Endface Image End2 PASS
Date / Time: 09/04/2002 10:54:29am
Operator: JOHN SMITH

ChannelMap
Date / Time: 09/04/2002 09:14:51am
Test Limit: ChannelMapLimits
Module: OFTM-5612
S/N: 8129007
Software Version: V0.7.89
Operator: JOHN SMITH

Fiber Length: 152 m

End1 DATA CENTER — End2 ENGINEERING QUAD

100 m · 2 m · 50 m · 1 m

Page 1 of 2

Project: EVERETT UNIVERSITY

ACME_EVT_UNIV.flw

FLUKE networks

Summary

- Choose a Technology Partner that will grow with you and has a full range of service, product and/or testing solutions
- Focus on the Future
  - Design & install the fiber and cable system that will not only meet existing applications but that will grow with your customers increasing need for bandwidth
  - Certify your installation for warranty compliance by fully characterizing your network

QUESTIONS?

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