ODVA 2012
Industry Conference
and 15th Annual Meeting

Advances in Robust, Easy to Install Fiber Cabling Systems to Support EtherNet/IP

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Technical Track

Fiber Cabling Systems for EtherNet/IP

Outline Agenda

- Historical Perspective
  - Fiber Media & Connectivity
- SFF Electronics & MDI (Media Device Interface)
  - LC FOCIS-10 Connectors
  - SFF PMD Capabilities
- New Fiber Media Variant
  - What is GI-PCF? Cable styles?
  - Media Value Proposition
  - New GI-PCF connector system
- Reference Architectures/Use Cases
- Solution & Channel Validation of GI-PCF

Historical Perspective
Fiber Use Issues

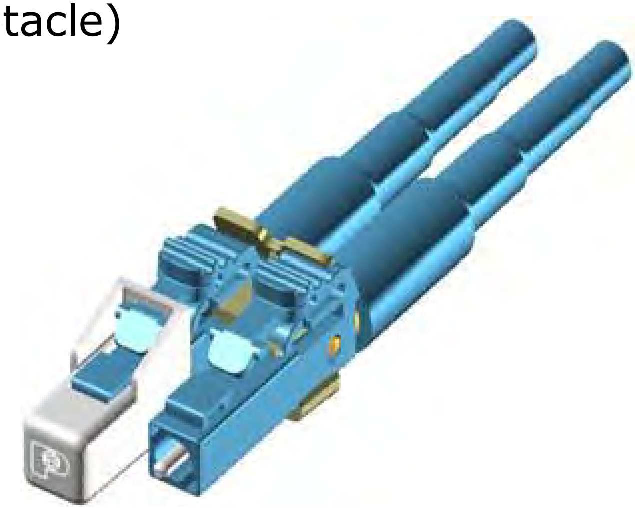
- For many fiber EtherNet/IP applications, the use of enterprise cabling systems present issues of robustness, and deployment ease by factory personnel
- Challenges tend to inhibit fiber use and increase Total Cost of Ownership (TCO)
- At the control level, current need simple, robust fiber solutions that support 100Mb/s
- Need for 1Gb/s uplinks with fiber on switches for resiliency/performance

SFF (Small Form Factor)
Electronics & MDI

- Historically, in industrial automation, several lower density fiber interfaces have been deployed such as Straight Tip (ST), Sub Miniature Assembly (SMA), Subscriber Connector (SC) and ‘proprietary’ non-MSA (Multi-Source Agreement) interfaces such as TosLink or Versatile Link
- Industrial Automation equipment vendors are now offering SFP modular transceivers on their switch lines for Gb/s Ethernet Uplinks and switch ports

SFF Electronics & MDI

MDI – Media Device Interface
(LC Duplex Receptacle)



1GBASE-SX SFP
Modular Transceiver

FOCIS-10 LC Connector

SFF Electronics & MDI

- Optical receptacle on the SFP for Ethernet is defined as an LC interface. Most major transceiver vendors, including early proponents of "MT-RJ-only" transceivers, now sell SFPs with the LC interface only
- The LC is the clear market leader in SFF connectors
- To support the trend of readily available SFP transceivers in industrial networks, it is imperative that we provide a practical LC field-connection solution

SFF Electronics & MDI
IEEE 802.3u - 100BASE-FX

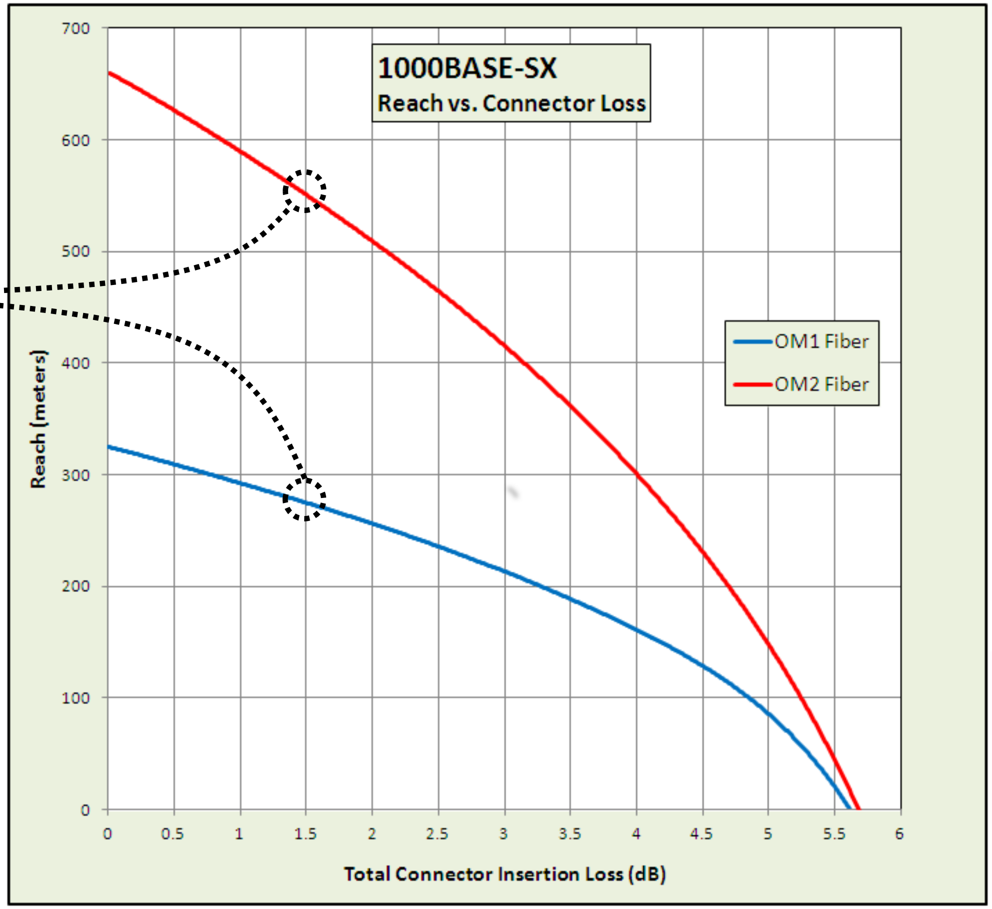
- The Fast Ethernet over Fiber-Optic at 100 Mb/s application (100BASE-FX - 12.5MB/s with auto-negotiation) is a version of Fast Ethernet over optical fiber
- Uses 1300 nm wavelength transmitted via two strands of optical fiber, one for receive (Rx) and the other for transmit (Tx)
- The standard specifies a max. distance of 2 km (6,600 ft) for full-duplex over FDDI-grade (Fiber Distributed Data Interface) MM optical fiber (large power budget!)

SFF Electronics & MDI
IEEE 802.3z - 1000BASE-SX

- Gb/s Ethernet over Fiber-Optic at 1 Gb/s (1000BASE-SX - 125 MB/s) is a gigabit Ethernet standard for operation over MMF
- Standard calls for light operating wavelength at approximately 850 nm
- The standard specifies a distance capability between 220 meters (62.5/125µm with low modal bandwidth) and 550 meters (50/125µm with high modal bandwidth)
- Have to be careful with power budget!

SFF Electronics & MDI
IEEE 802.3z - 1000BASE-SX

- Channel designed around connector Insertion Loss of 1.5dB max (2 connectors of 1.5dB each max.)
- Possible to have higher levels of IL in the 1000BASE-SX channel
- May desire higher #s of connectors in channel or allow for simpler (and higher loss) connectors to be used

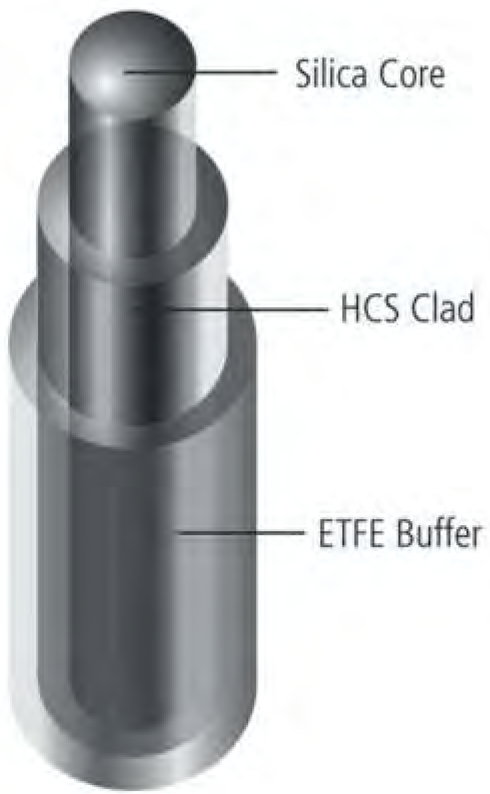


New Fiber Solution

Graded Index Polymer Clad Multimode Fiber

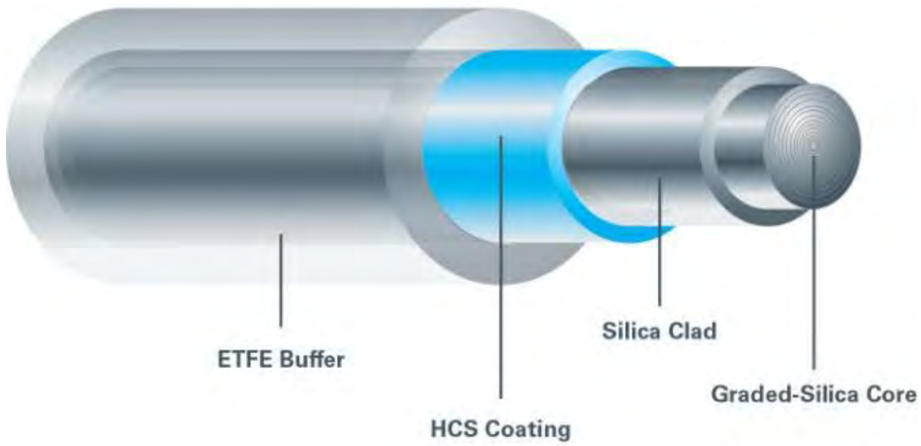
- Recently introduced Polymer Clad Fiber (PCF) fibers with improved bandwidth
- Environmentally/mechanically robust fiber
- Rapid connector field termination (simple tools/short learning curve
- ODVA recognizes the LC (sealed/unsealed) and transceiver OEMs have standardized the SFF LC as the MDI for 1Gb/s+
- Solution useful for 10/100Mb/s and 1Gb/s EtherNet/IP applications

New Fiber Media Variant
Graded Index Polymer Clad Multimode Fiber



'Traditional'
200/230 PCF

62.5/200/230
Graded-index PCF Fiber



New Fiber Media Variant

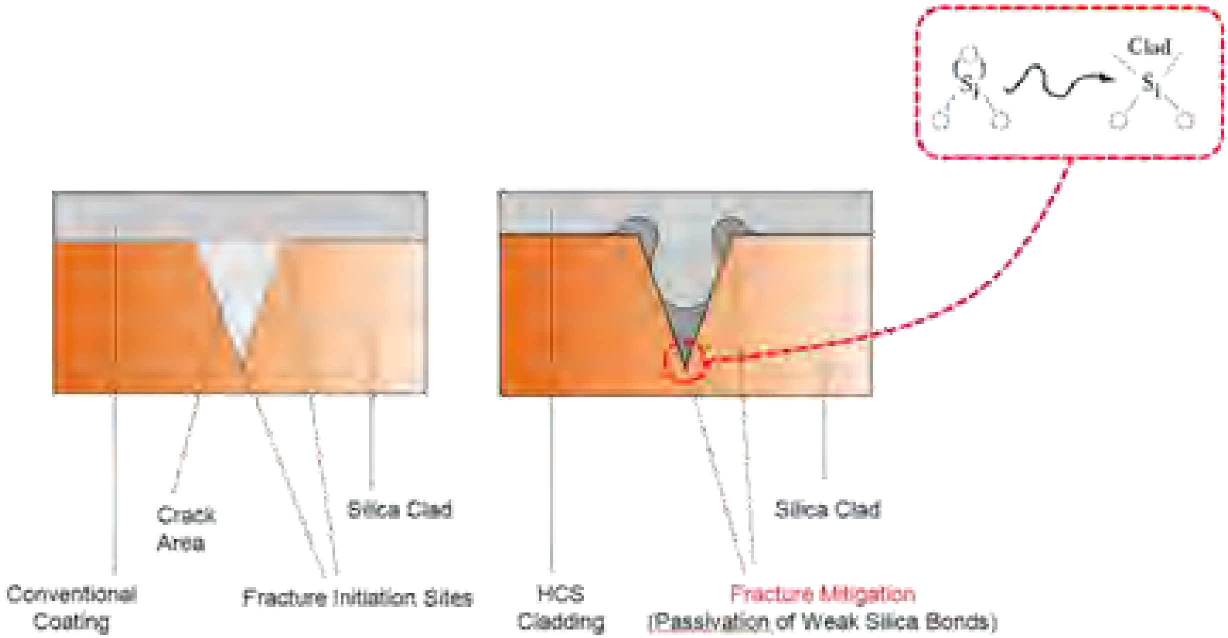
Graded Index Polymer Clad Multimode Fiber

- Designed for applications and harsh environments that require high mechanical reliability at the fiber level
- Hard coating, makes possible the vision of "electrician friendly" field terminations
- Silica is a 'brittle' material - strength depends on surface flaw severity, not basic material strength
- Under bending/tensile load, surface flaws act as stress concentrators and grow in size resulting in catastrophic fiber failure

New Fiber Media Variant

Graded Index Polymer Clad Multimode Fiber

- Polymer clad (applied during draw) creates chemical bonds to silica, significantly improving fiber reliability
- “Bridge bonds” formed healing small flaws on the fiber surface, making it impermeable to moisture ingress
- Fiber strength enhanced, static fatigue reduced



New Fiber Media Variant

Graded Index Polymer Clad Multimode Fiber

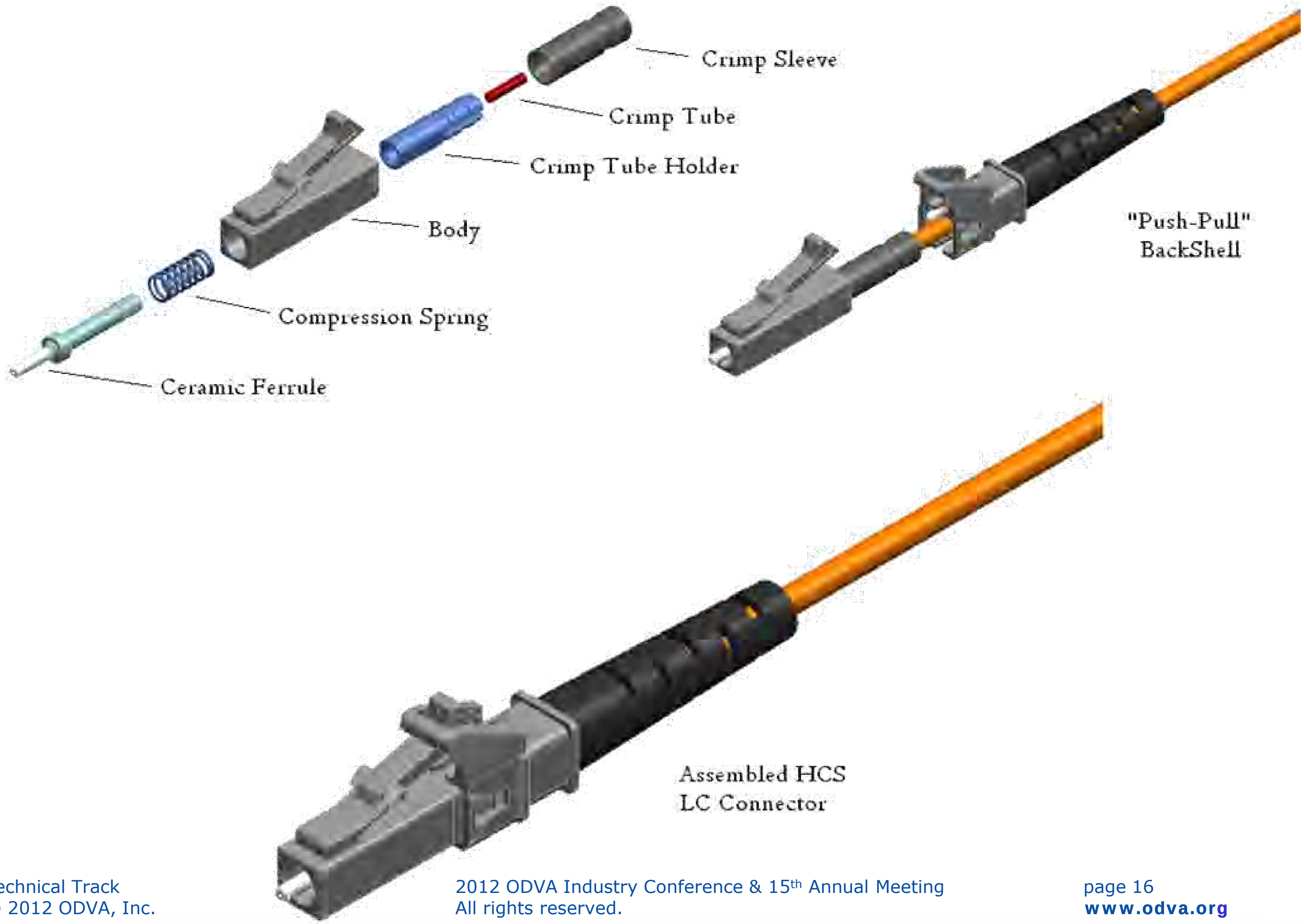
- Strength degrades vs time (*static fatigue*)
- $H_2$0 acts as catalyst for crack growth
- Hard poly coating chemically bonds to fiber
- Significant improvement to mechanical properties - coating moisture impermeable
- Fiber strength greatly enhanced and static fatigue is significantly retarded
- Managing static fatigue with PCF enables tight, long-term bends, often found in the confined spaces of industrial installations

SFF Electronics & MDI

GI-PCF Field Terminable LC Design Goals

- Termination OM1 & OM2-compatible PCF fiber in the field
- Terminate like a CATV 'F' connector - less than a minute termination
- Short learning curve
- Ability to perform connector end-face finishing operation in seconds
- Support for aramid yarn-less cable constructions (Zip & Break-out)
- "Push-Pull" functionality

SFF Electronics & MDI
GI-PCF Field Terminable LC Design



SFF Electronics & MDI

GI-PCF LC Field Termination Process

1 Load Connector into Crimper

2 Prepare Cable Subunit

3 Insert Fiber

4 Crimp Fiber

5 Cleave Fiber

6 Mount Backshell/Boot

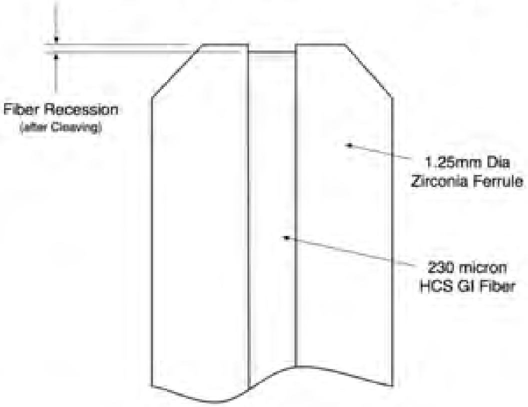
SFF Electronics & MDI
GI-PCF LC Field Termination Process

- Cleaving Tool (right) – performs fiber end finishing in one action
- Tool applies known strain to fiber exiting connector
- Diamond blade indexed on ceramic ferrule nose that scores fiber, producing mirror finish
- Fiber will slightly recess into the nose of the ferrule (typically about 10 microns)

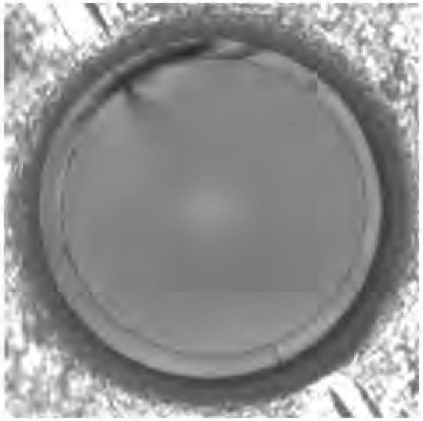
SFF Electronics & MDI
GI-PCF LC Field Termination Process

LC Connector Ferrule after Cleaving

Fiber Recession after Cleaving



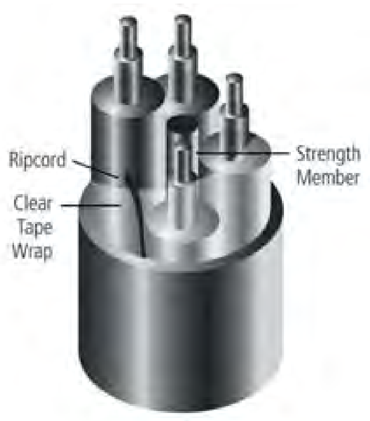
Fiber Endface Detail after Cleaving



- Typical cleaved GI-PCF looking into ferrule
- Note cleave 'vestige' & mirror surface
- Fiber is approx. 13 microns recessed

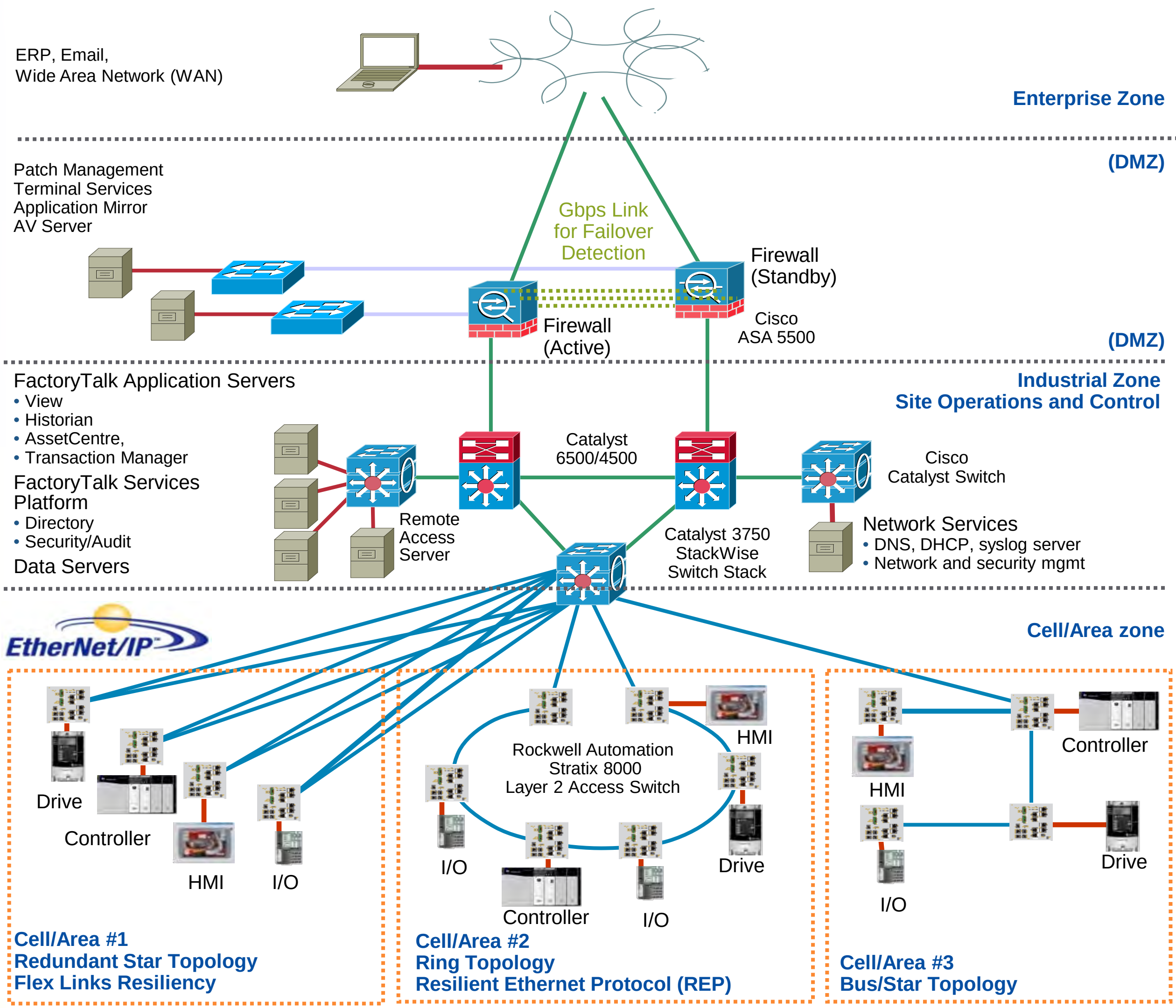
PCF Cabling Systems

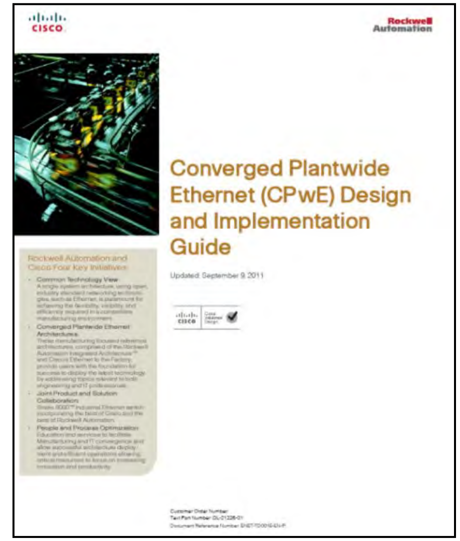
- 1Gb/s networks require either OM1 or OM2
- Duplex zip cord & 2/4 fiber breakout cable
- Elimination of aramid yarn (simplifies termination)
- Intended for open pathway and zone/control panel builds
- Dual rated LSZH and Riser
- Cables use PCF fiber as crimp substrate and strength member

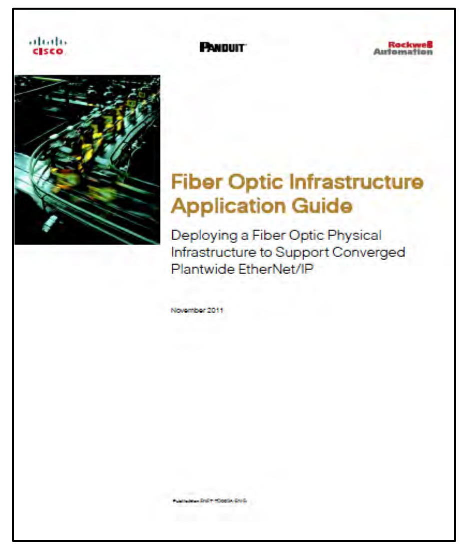


Ref. Architectures / Use Cases

Architecture



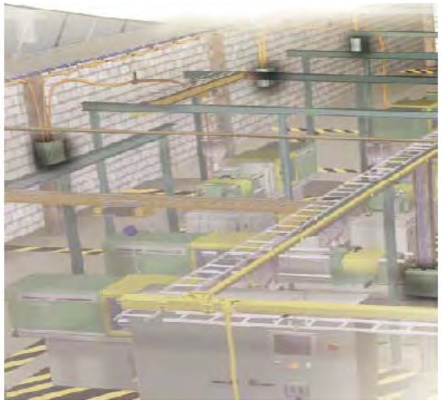




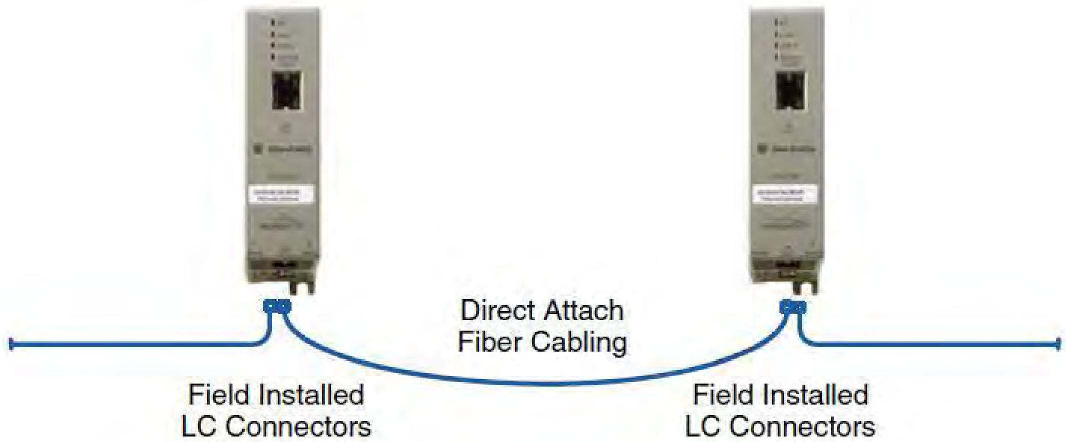
Physical Infrastructure Reference
Architecture Levels and Fiber Strategy

Physical Level		Fiber Strategy
Cell / Area Zone Levels 0-1 End device and Controller	 	▶ Noise-Immunity ▶ High-Performance ▶ Linking Devices ▶ Ring or Linear Topologies
Cell / Area Zone Levels 0-2 Control Panel		▶ Secure ▶ Testable ▶ High Performance ▶ Uplinks for panel-mounted switches

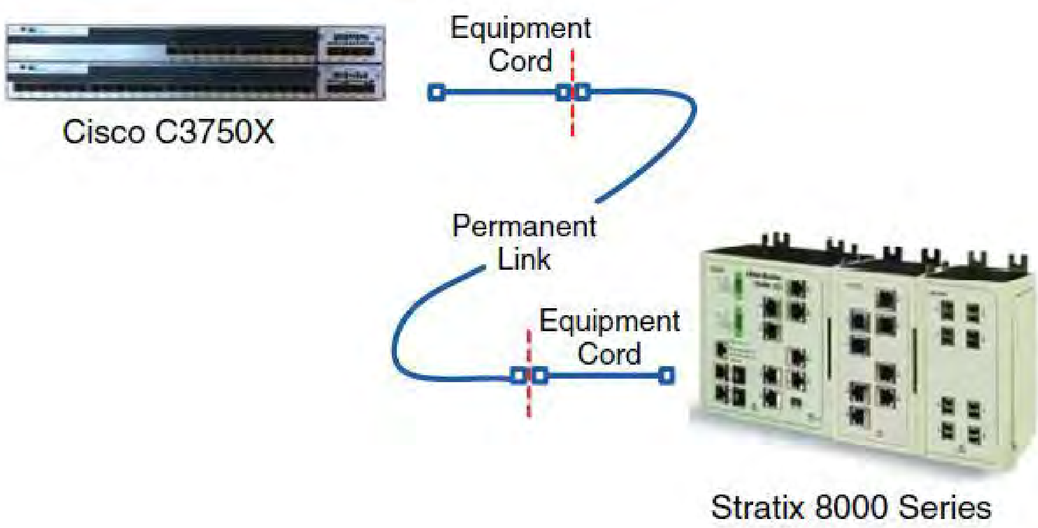
Physical Infrastructure Reference
Architecture Levels and Fiber Strategy

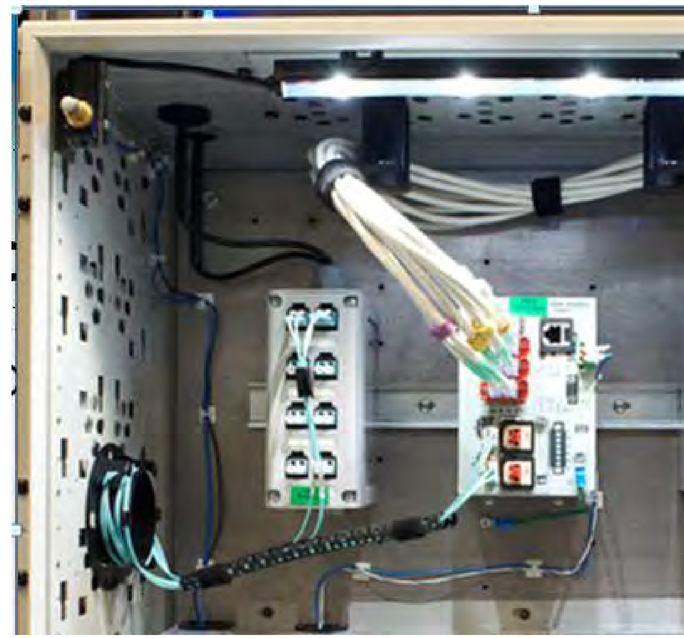
Physical Level		Fiber Strategy
Manufacturing Zone Levels 0-2 Network Zone Cabling		▶ Robust ▶ Cost Effective ▶ Safe Zone Architecture ▶ Distributing Fiber Connectivity across the Plant Floor
Manufacturing Zone Levels 3 Micro Data Center (core to distribution, distribution access)		▶ Secure ▶ High Performance Connections ▶ Plant Floor Fiber Networks to Higher Level Switches and Servers

Ref. Architectures / Use Cases
Direct Attach Model



Ref. Architectures / Use Cases
Structured Cabling Model





Ref. Architectures / Use Cases
Structured Cabling Model - Cost Analysis

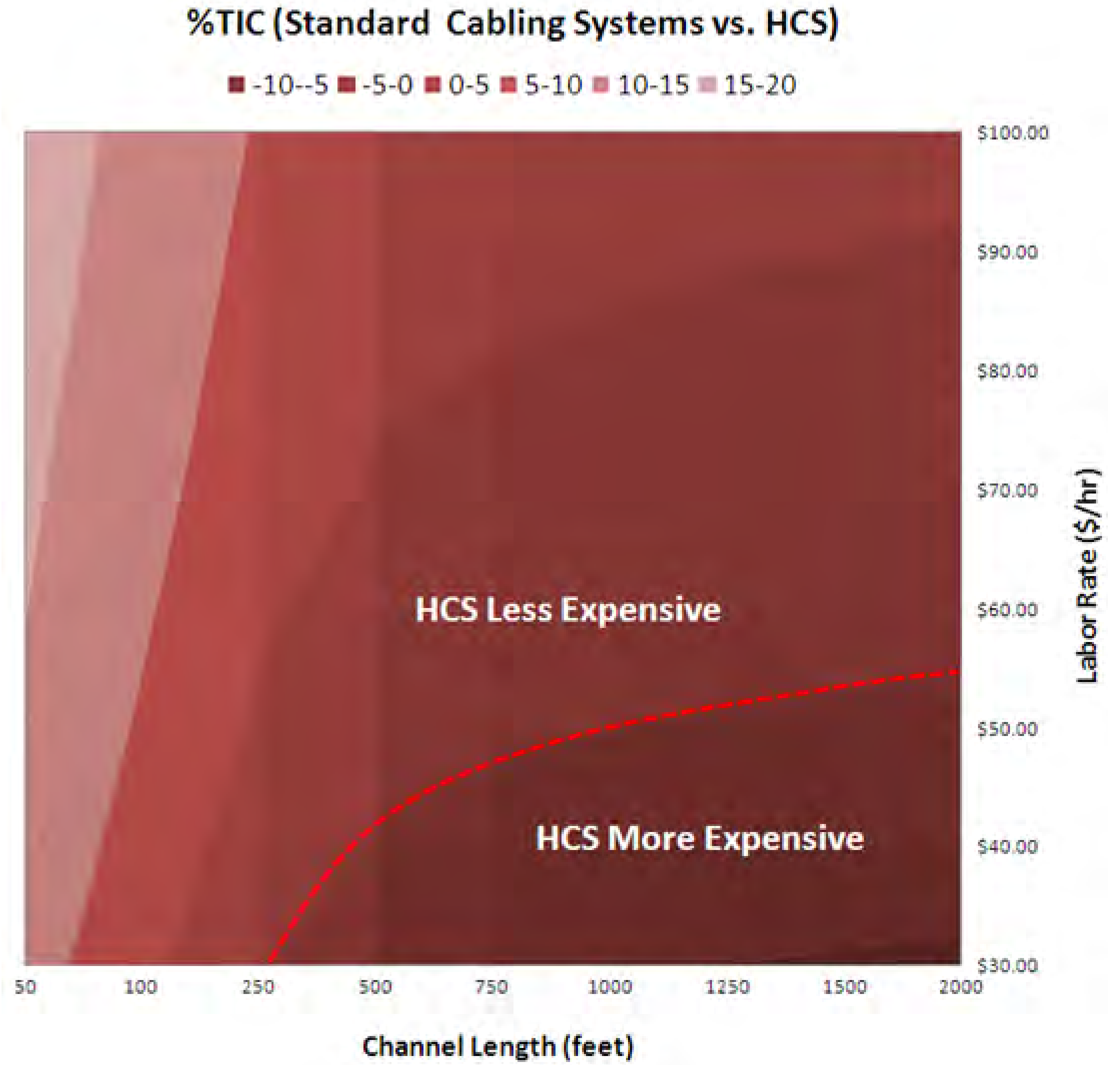
- For most applications, PCF breakout cables don't require closed pathway (conduit)
- Deployment of PCF breakout cables in open pathway system such as J-Hooks
- Cost saving compared to standard non-PCF cables pulled into conduit and terminated with Cam-style or field polish connectors

Ref. Architectures / Use Cases
SCS Model - Cost Analysis Assumptions

- Conventional cabling is 4 fiber dist. cable in 1.5” dia., 1/8” wall HDPE conduit
- PCF cabling is 4 fiber, ‘tactical’ style cable
- Both are OM1
- Both cables installed on J-Hook system and penetrate enclosures on each end (terminated inside each enclosure)
- Cam-style connectors installed on the conventional cabling system - PCF LC system is installed on PCF cabling

Ref. Architectures / Use Cases

SCS Model - Cost Analysis



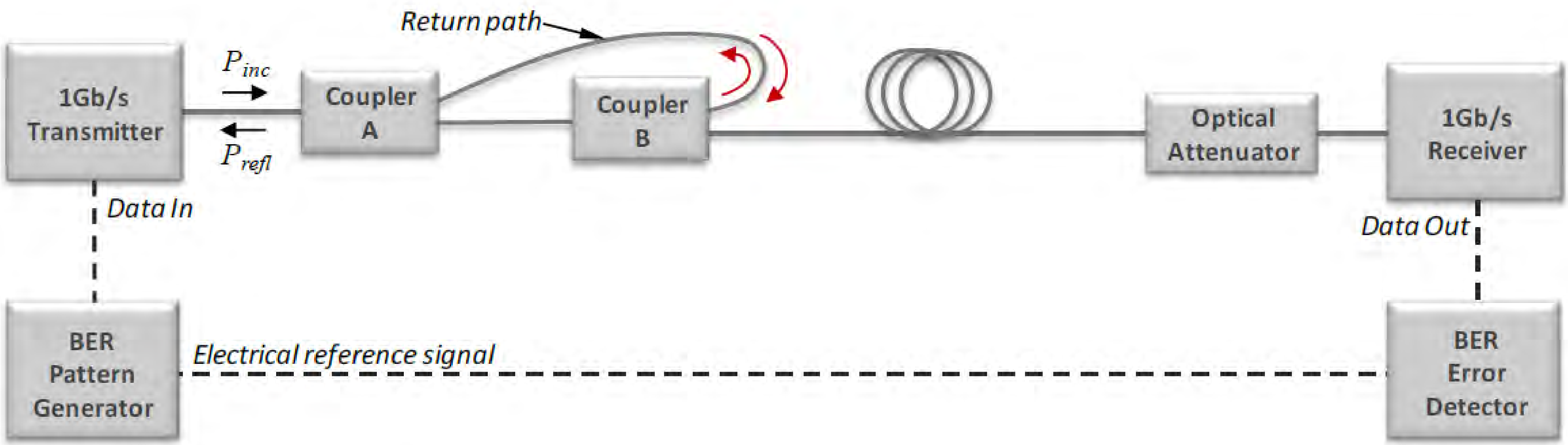
Channel Validation w/GI-PCF

Channel Impairments

- Mated fibers not in physical contact (air gap between fibers causes a small insertion loss penalty)
- No physical contact produces reflection (added loss)
- Effects create incremental loss in connectors compared to std LC connectors with conventional fiber
- Increased impairments when using PCF connectors in 1000BASE-SX (de-rated reach per 802.3u)
- High reflections can interfere with the transmitted signal causing amplitude noise (degrading performance)
- Adding connectors incrementally increases reflections
- No limit to max. # of connectors deployed; practical implementations typically limit max. to two mated pairs

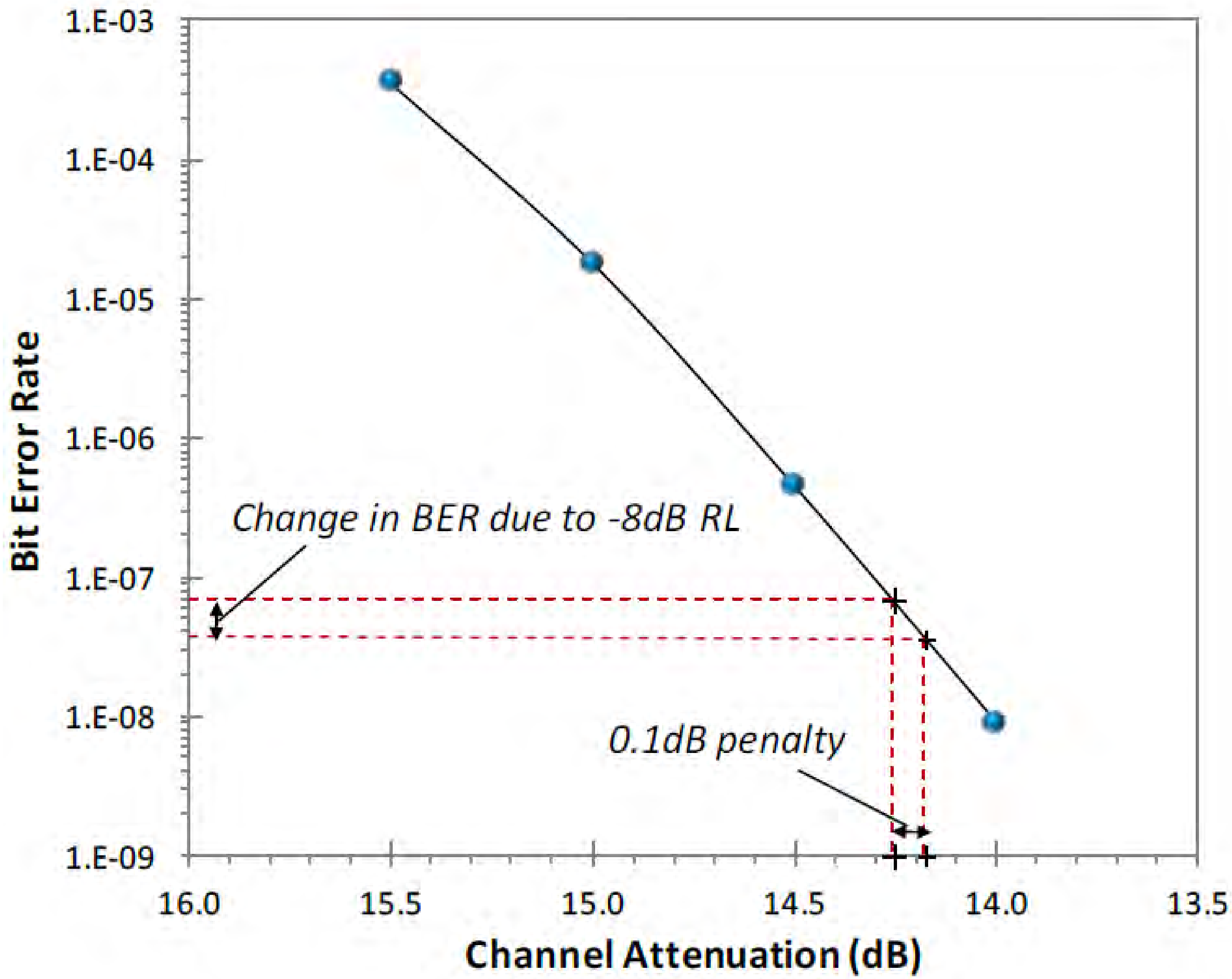
Channel Validation w/GI-PCF

Channel Testing with BERT



- Effect of RL on 1Gbps channel - channel configured using std's compliant Ethernet SPF+ transceiver and a MMF optical attenuator
- Signal return path connecting output ports of the couplers was repeatedly disconnected and reconnected to simulate a high/low channel RL

Channel Validation w/GI-PCF
BERT Channel Results



Solution Validation w/GI-PCF

Mechanical, Optical & Environmental Testing

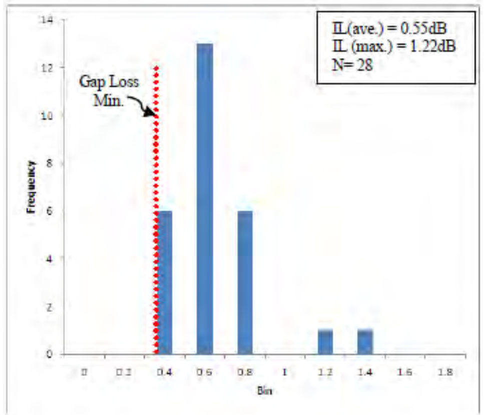
- PCF LC tested to TIA/EIA-568-C for MM performance
- Cable retention target for industrial app's in static environment (zone box perm. link or direct attach) is >0.5lbs (4-8 lbs target)
- Higher value (11.2 lbs) based on use case of duplex jumpers that see a high # of MACs

TEST	REQUIREMENT	METHOD	RESULT
Insertion Loss	Maximum IL: 0.75dB.	EIA/TIA-455-171 (FOTP-171); Method D	See IL distribution (below)
Return Loss	Minimum RL: 20dB (MM)	EIA/TIA-455-107 (FOTP-107)	NA
Cable Retention*	> 11.24 pounds for each jacketed cable channel > 0.5 lbs. for each buffered fiber	EIA/TIA-455-6B (FOTP-6)	See data (below)
Low Temperature	0°C temperature for 4 days (mated connector pair)	EIA/TIA-455-188 (FOTP-188)	Complies
Temperature Life	60°C for 4 days (mated connector pair)	EIA/TIA-455-4 (FOTP-4)	Complies
Impact Test	Drop of 1.8 meters (mated connector pair)	EIA/TIA-455-2 (FOTP-2)	Complies
Cable Flexing	Flex cycles (90 to -90 degrees for 100 cycles) Mated connectors weighted with: a) 1.1 pounds for jacketed cable b) 0.5 lbs. for buffered fiber	EIA/TIA-455-1 (FOTP-1)	Exceeds Requirement
Coupling Strength	7.4 lbs of force at a 0°angle applied at a rate of 1 inch/minute; must remain mated for 5 seconds (mated connector pair)	EIA/TIA-455-185 (FOTP-185)	Complies
Durability	500 mating cycles	EIA/TIA-455-21 (FOTP-21)	Exceeds Requirement >1000 cycles
Humidity	4 days at 90-95% humidity at 40°C. (mated connector pair)	EIA/TIA-455-5 (FOTP-5)	Complies
Jacket Cable Twist	5 twist rotations in both clockwise and counterclockwise directions for 10 cycles: a) 3.5 lbs. for jacketed cable b) 5 lbs. for buffered fiber (mated pair)	EIA/TIA-455-36 (FOTP-36)	Exceeds Requirement

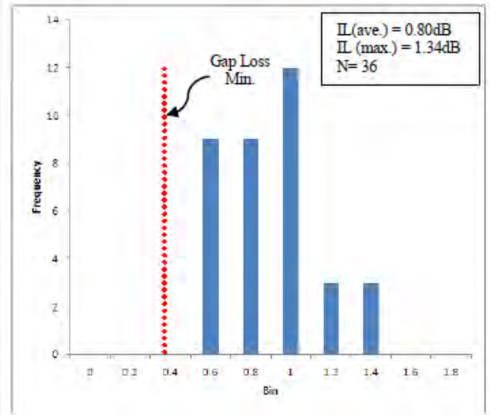
Solution Validation w/GI-PCF

Mechanical, Optical & Environmental Testing

Insertion Loss Statistics (OM1 @ 850nm)



Insertion Loss Statistics (OM2 @ 850nm)



Failure Load Statistics (lb's to failure)

Cable Failure Load @ Optical Failure (lbF)
Defined as the load at which there is a inflection point in the optical loss (the point at which the optical loss is unrecoverable).

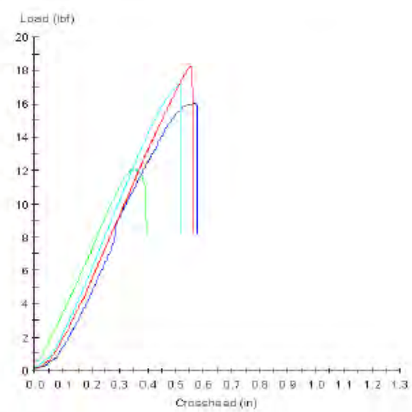
- Average = 9.6 lbs
- Min = 5.1 lbs

Cable Failure Load to Mechanical Failure (lbF)
(See traces at right) - Linear limit of fiber extension under stress (the point at which the fiber/crimp insert become detached from the connector body).

- Average = 15.9 lbs
- Min = 12.1 lbs

Note: Results based on simplex HCS® fiber cable

Failure Load to Mechanical Failure (lbF)



GI-PCF Solution for Ethernet/IP
Summary

- PCF proven reliable in many applications (Military, Oil/Gas, utility, factory automation and Medical applications)
- New GI-PCF fiber variant provides MM graded-index, high bandwidth, long reach fiber core in the same large diameter footprint as traditional PCF solutions
- Benefits of PCF LC connectivity and fiber media in EtherNet/IP architectures for both Structured and Direct Attach cabling

GI-PCF Solution for Ethernet/IP

Summary

- Use of GI-PCF fiber media and PCF LC connector systems into 1000BASE-SX SCS-based cable plant (with limited restrictions)
- Enables widespread field installation of fiber EtherNet/IP - termination similar to POF (but longer reach, higher bandwidth)
- Opens door to high bandwidth applications at all levels of industrial networks
- Provides immediate benefit for 10/100M EtherNet/IP "direct attach" networks